Co-Firing of REF and Biofuels in a CFB With Advanced Steam Parameters and a High Plant Efficiency in Igelsta Plant, Sweden

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ABSTRACT


The boiler is designed to fire a fuel mixture comprising of maximum 25% REF pellets and 75% biofuels, mainly wood residues. The boiler is also designed to fire up to 70% demolition wood together with 30% biofuels. Major challenge for the plant has been high steam pressure / temperature combined with possibility to use fuel with high chlorine content. For this high corrosion/erosion/fouling challenge FW has developed several technical features.

To handle the challenge the boiler concept is utilizing features from Waste To Energy boiler; from both German demolition wood, Italian RDF burning boilers as well as earlier Swedish co-firing experiences.

Injection of sulphur, as a mean to neutralize the chlorine, was also applied.

The main objective of the project has been to enable firing of waste type of material with a high efficiency using relatively high steam data.

This paper will discuss the special features of this multi fuel biomass CFB boiler and report the result of how these measures have worked in actual operation.
1 INTRODUCTION

Söderenergi AB is an energy company, supplying district heat (DH), owned by the three municipalities Södertälje, Botkyrka and Huddinge, some 50 km south of Stockholm. The jointly owned company was founded in 1990, but the district-heating network used for supplying energy to customers in the region south of Stockholm is from the early 60s. Söderenergi supplies heat to around 70,000 households, industrial plants and offices. The company generates heat for Södertälje, Botkyrka, Huddinge and Salem. In addition, heat cooperation has been established with Fortum AB, under the terms of which Söderenergi supplies heat to parts of South-western Stockholm during certain parts of the year and vice versa. Steam to a nearby pharmaceutical plant (Astra Zeneca AB) is also produced.

During the 1990s, Söderenergi switched from coal and oil to firing mainly with biofuels and fuels derived from recovered waste materials/1/. The main production units are situated in Igelsta, close to Södertälje, where also this new Combined Heat and Power Plant will be built. /1/

The basis for making the investment in a new CHP, called IKV (Igelsta Kraft Värme), was to produce electricity and to assure the long-term competitiveness of district heat – and to do this in a way that was both economically feasible and environmentally responsible. The new CHP will operate as a base load boiler and together with existing units the availability of the production capacity will increase and the expected life time of older units will increase as they will be changed from base load to top- and intermediate load units. /2/

In the pre-study of the investment, two main alternatives were studied. A boiler with high steam parameters (140 bar, 540-560 °C) fired with “clean” biomass fuels was compared to a boiler with

Figure 1. Present DH production.
reduced steam parameters (90 bar, 520-540 °C) and fired with recovered fuels together with “clean” biofuels. Both alternatives included a flue gas condenser with humidification of combustion air for increasing of the plant heat output. The fuel basis for the co-fired boiler is to decrease the amount of more difficult fuels to optimize steam parameters.

The pre-study showed that a more flexible boiler with limited steam parameters was preferred due to the higher fuel flexibility making firing of less expensive fuels possible. Generally, the continuously increasing firing capacity of “clean” biomass in Sweden is lowering the availability of “clean” biomass and increasing the price of such fuels, which was a factor that was influencing the final decision.

The fuel mix will be based on availability, price, and transportation-related issues.

- Main biomass fuel is wood residues, but also wood chips, bark, saw dust and stub chips can be fired.
- Recovered fuels will be pelletized REF (source selected industrial waste) and/or demolition wood.
- Despite the positive properties of peat regarding high temperature corrosion and fouling, the use of peat will be minimized, as it is subject of CO₂ emission trade.
- Coal was not considered in the selection of the combustion concept, although clearly the basic design will accommodate the firing of coal. If coal becomes attractive in the future, modifications to auxiliary equipment can be done.

The fuel will be transported to the site by boat or by truck and is expected to be both domestic and imported. The fuel will be stored in three storage silos at the yard, of which one will be used for REF pellets and the two others will be used for a mixture of demolition wood and biomass fuels. The two main fuel streams, REF pellets and biomass/demolition wood will be mixed before being fed to the fuel day silos.

The main requirement of the selected firing concept was therefore high fuel flexibility with low emissions and high steam parameters. In addition, the selected concept needed to incorporate waste-classed fuels, thereby fulfilling of the requirements in the EU directive for co-combustion i.e. combustion temperature of 850 °C during 2 s.
Figure 2. DH production with the new CHP, IKV, in operation.

Figure 3. Igelsta plant areas sketch, including IKV.

2 PLANT CONCEPT

The plant concept was developed in cooperation between Foster Wheeler and Söderenergi. Foster Wheeler provided input primarily in the areas of the firing concept selection, the feed water
temperature and the steam parameters in relation to various combinations of difficult-to-burn fuels. Söderenergi has a long experience in the main fuels expected to be fired in IKV, making a mutual understanding of the complexity of the concept selection possible. Unpelletized REF is fired in a grate-fired block and REF pellets and demolition wood in a Bubbling fluidized bed boiler (BFB), a Foster Wheeler retrofit of a grate-fired boiler from 1995. However, both these boilers are hot water boilers.

2.1 Fuel

Three types of fuel combinations were considered in the design:

1. Biomass fuel and REF pellets, which is considered to be the most challenging fuel mixture regarding high temperature corrosion, due to high chlorine content in REF.
2. Biomass fuel and demolition wood, a combination giving the driest fuel mixture with the highest amount of unfluidizable material due to the demolition wood’s metal and glass content.
3. 100% biomass fuel which is the wettest fuel mix giving the highest flue gas flow and therefore dimensions the boiler cross sections.

Other fuel combinations and corresponding firing ranges are described further in Section 3.2.2.2.

Table 1. IKV fuels

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Branches and tops</th>
<th>Stump chips</th>
<th>Wood chips</th>
<th>Saw dust</th>
<th>Bark</th>
<th>REF pellets</th>
<th>Demolition wood</th>
<th>Peat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LHV MJ/kg</td>
<td>6 - 13</td>
<td>11,8 – 14</td>
<td>6 - 13</td>
<td>6-12</td>
<td>4-11</td>
<td>17-21</td>
<td>10-18</td>
</tr>
<tr>
<td>Moisture</td>
<td>%</td>
<td>30 - 60</td>
<td>25 – 35</td>
<td>30 - 60</td>
<td>35-60</td>
<td>50-70</td>
<td>3-12</td>
<td>5-40</td>
</tr>
<tr>
<td>Ash</td>
<td>% dry</td>
<td>2-12</td>
<td>1-6</td>
<td>1-6</td>
<td>&lt;1</td>
<td>2-10</td>
<td>10-20</td>
<td>2-20</td>
</tr>
</tbody>
</table>

Table 2. IKV main fuel mixes

<table>
<thead>
<tr>
<th>Main fuel mixes</th>
<th>Mix 1</th>
<th>Mix 2</th>
<th>Mix 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Branches and tops</td>
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<td>75</td>
<td>30</td>
</tr>
<tr>
<td>REF pellets</td>
<td>% - LHV</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Demolition wood</td>
<td>% - LHV</td>
<td>0</td>
<td>70</td>
</tr>
<tr>
<td>H₂O</td>
<td>%</td>
<td>44,3</td>
<td>35,6</td>
</tr>
<tr>
<td>LHV</td>
<td>MJ/kg</td>
<td>9,7</td>
<td>11,0</td>
</tr>
<tr>
<td>Ash</td>
<td>% vått</td>
<td>3,6</td>
<td>3,0</td>
</tr>
<tr>
<td>S</td>
<td>% vått</td>
<td>0,05</td>
<td>0,05</td>
</tr>
<tr>
<td>N</td>
<td>% i TS</td>
<td>0,6</td>
<td>0,8</td>
</tr>
</tbody>
</table>
2.2 **Boiler with auxiliary equipment**

A CFB unit was selected as it gives maximum fuel flexibility and minimized risk of high temperature corrosion by using superheaters (Intrex™) as the final superheaters. To give a better understanding of the boiler concept, the overall plant and the boiler auxiliary equipment will first be described.

2.3 **Emission control**

The emissions are controlled primarily utilizing the high combustion efficiency provided by the CFB. Due to the strong turbulence in the furnace and the separators, effective mixing of oxygen and flue gases is secured. Together with a long residence time, CO, TOC and unburned carbon (UBC) are minimized. Secondarily, SNCR and a bag filter are utilized.

2.4 **SNCR**

The base NO\(_X\) in a CFB is low, because of the low combustion temperature and a staged combustion. In Sweden however there is an emission trade program aiming at minimizing the total domestic NO\(_X\) emissions. As a result, there is an economic incentive to reduce the NO\(_X\) even further than the outcome of primary means.

Because of that, and environmental permit requirements, SNCR is used to reduce NO\(_X\) emissions. Ammonium (NH\(_3\)), water solution, is fed to the solids separators where the flue gas temperature is optimal and the mixing of ammonium and the flue gas is at its best. The amount of ammonium is controlled to minimize NO\(_X\), without causing an NH\(_3\) slip exceeding the environmental permit level.

2.5 **Bag filter**

The flue gas is cleaned from dust, HCl, HF, SO\(_2\), heavy metals and dioxins in a dry bag filter. Because the flue gas temperature reaches an operation maximum of 175 °C, an unconventional additive dosing concept was adopted:

CaOH\(_2\) will be used to capture SO\(_2\), HCl and HF. The reduction of SO\(_2\) with CaOH\(_2\) is however depending on a series of process parameters; a lower flue gas temperature and higher HCl level as well as moisture content is favorable for SO\(_2\) reduction with CaOH\(_2\).
Due to high flue gas temperatures, sodium bicarbonate (NaHCO₃) will be used because it is known to react better with SO₂ at such conditions.

This concept was selected to secure the SO₂ emission below permit levels and to minimize the cost of additives, as sodium bicarbonate is a more expensive additive than CaOH₂.

As both additives have individual silos and feeding equipment, the choice of additive, or a combination of additives, will be an online optimization based on the operating parameters described above.

Active carbon is fed from a separate silo to reduce dioxins and mercury.

### 2.6 IKV emission levels

Based on the design selections described above, the plant shall fulfill the following emission levels:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Particles</strong></td>
<td>10 mg/nm³</td>
<td><strong>HCl</strong></td>
</tr>
<tr>
<td><strong>SO₂</strong></td>
<td>75 mg/nm³</td>
<td><strong>HF</strong></td>
</tr>
<tr>
<td><strong>NOₓ</strong></td>
<td>35 mg/MJ</td>
<td><strong>Cd + Tl</strong></td>
</tr>
<tr>
<td><strong>CO</strong></td>
<td>50 mg/nm³</td>
<td><strong>Hg</strong></td>
</tr>
<tr>
<td><strong>NH₃</strong></td>
<td>10 ppm</td>
<td><strong>Heavy metals</strong></td>
</tr>
</tbody>
</table>

### 2.7 Flue gas condensing (FGC) plant

Downstream the ID fan there is a flue gas condensation plant including a combustion air humidifier. The purpose is to recover the flue gas’s low-grade energy, in the form of water vapor, when firing wet fuels.

In the condenser, the flue gas is cooled, by using return DH water. The water vapor condensate and the energy is transferred to the DH water. The waste part of the energy to DH water comes from the condensation.

The saturated flue gas exiting the condenser is being even further cooled with combustion air in a rotating air humidifier of “Ljungström” type. In the humidifier, energy is transferred to the combustion air including the condensate from the flue gas, which is evaporated on the airside of the humidifier. The humid combustion air gives higher water content in the flue gas, which in the end will give a higher
heat output in the DH condenser, and additionally the possibility to operate the FGC plant with drier fuels through the higher dew point in the flue gas.

The up side using a FGC plant comes from the higher DH output with a given firing capacity, the down side is a decreased electric output given a certain DH demand as well as a higher combustion air temperature giving lower boiler efficiency in return.

Therefore the flue gas condenser will be operated in high load conditions to produce DH with high overall plant efficiency and on partial load only if the electric price is low versus the DH price. Firing dryer fuels will also limit the output of the condenser when the dew point of the flue gas is lower.

For operation without FGC plant the flue gas ducting is equipped with a by-pass of the FGC plant. The humidifier is also possible to operate at reduced loads by varying the speed of rotation and also by reducing the condensate being evaporated in the combustion air.

The increased heat output to the DH-net gives an efficiency of the total plant that is higher than 100% based on LHV (Lower Heating, Value), as the LHV does not consider the energy from condensation the water vapor from the combustion gas, (the latent heat).

### 2.8 Turbine and balance of plant

The turbine plant consists of a 84 MW$_{el}$ turbine. The turbine has a two-stage DH condenser, one LP pre-heater and one HP pre-heater. In case the turbine is out of operation, DH deliveries can continue via a direct condenser with 100% MCR capacity.

The feed water temperature after the HP pre-heater is at MCR load 200 °C. A higher feed water temperature with acceptable investment cost and a reasonable flue gas temperature was not feasible when the humidification of the combustion air increases the combustion air temperature and the (flue gas / steam) and (flue gas / feed water) mass flow ratios.

### 2.9 Overall plant output

The overall plant output, when firing the most expected fuel combination of 25% REF pellets and 75% wood residues at 100% MCR equaling 240 MW thermal heat output, is summarized as follows:

- Net electric output, considering auxiliary consumption: 73 MW
- District heating from turbine condensers: 151 MW
- District heating from FGC plant with humidifier in operation: 58 MW
- Totally 282 MW plant energy output.

The high useful energy output is possible through the utilization of the flue gas condenser and the combustion air humidifier.

The energy output is even further maximized by recovering heat from cooling of blow down, bottom ash and water/steam sampling to the return DH water.

Based on fuel LHV input the plant efficiency in combined power and heat generation (calculated in accordance with the traditional manner) reaches approximately 110%, as has been described above. Based on HHV, the plant efficiency is over 90%.

Figure 4. IKV, CHP process flow sheet.
3 BOILER CONCEPT

Foster Wheeler has previously built two REF fired plants; Viken Energinett’s hot water CFB (35 MWth, 16 bar, 205 °C, 2001), close to Oslo in Norway; and one in Högdalen (91 MWth, 60 bar, 480°C, 2000), close to Stockholm in Sweden.

In Italy, Foster Wheeler has two references; Lomellina I (87 t/h steam, 63 bar, 443°C, 2000), close to Milan, and Lomellina II (76 MWth, 63 bar, 443°C, 2007), at the same site, both firing RDF (fuel derived from municipal solids waste in a waste treatment plant).

The Högdalen and Lomellina plants are CFB boilers equipped with Intrex™ superheating as the final stage.

In the design of IKV these experiences have been utilized together with experiences of around 300 CFB units of which 30 units co-fire some type of waste and even more units fire biomass fuels. Typical maximum steam parameters in CFB boilers firing biomass fuels with only a small portion of difficult fuels are 140-170 bar and ~540 °C. A typical boiler reference that has been used as a basis for the design, mentioned here, is Mälarenergi P5 (157 MWth, 171 bar, 540°C, 2001), in Västerås, Sweden.

IKV design utilizes also experiences from the German demolition wood market, where Foster Wheeler has around 10 references, all firing up to 100% demolition wood. One of the latest Foster Wheeler
boilers in that market is the Prokon Nord, Borsigstrasse (63 MWth, 90 bar, 500°C, 2006), in Hamburg, Germany.

### 3.2 IKV boiler concept

In the tables below are listed the main parameters from each example of boiler concept categories being utilized in IKV, as well as IKV’s corresponding parameters.

**Table 3. comparison of key fuel parameters between reference boilers**

<table>
<thead>
<tr>
<th>Category</th>
<th>RDF</th>
<th>Demolition wood</th>
<th>Biofuel with small portion of waste</th>
<th>Biofuel with larger portion of REF and/or demolition wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel analysis</td>
<td>Lomellina II</td>
<td>Prokon Nord</td>
<td>Mälar Energi (Forest residues:))</td>
<td>IKV</td>
</tr>
<tr>
<td>LHV (MJ/kg)</td>
<td>10,5-16,7</td>
<td>10-15,5</td>
<td>9,8</td>
<td>6,0-16,1</td>
</tr>
<tr>
<td>Design Cl content (in d.s.)</td>
<td>0,6</td>
<td>0,1</td>
<td>&lt;0,05</td>
<td>0,12</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>20-35%</td>
<td>10-40</td>
<td>45</td>
<td>14-60</td>
</tr>
<tr>
<td>Ash</td>
<td>3,7-17,3</td>
<td>0,6-9</td>
<td>3</td>
<td>&lt;17,5</td>
</tr>
<tr>
<td>Steam temperature (°C)</td>
<td>443</td>
<td>500</td>
<td>540</td>
<td>540</td>
</tr>
<tr>
<td>Steam pressure (bar)</td>
<td>63</td>
<td>90</td>
<td>171</td>
<td>90</td>
</tr>
</tbody>
</table>

### 3.3 Utilized reference boilers concepts

Experiences from each boiler concept category have been taken into consideration when designing the IKV concept. The target was to find a concept in between conventional CFB and waste firing CFB concepts to be suitable for firing the actual fuel mix.

### 3.4 RDF firing experience

Lomellina II is the heavy-duty version of CFB, which specific features have been carefully used in the design of IKV to keep the cost level down, but still making a large portion of waste classed fuels to be co-fired.

Important items that have been selected are the empty pass with water canons. The empty pass, which is being cleaned with water cannons, will be able to keep the flue gas temperature during the whole firing season by effective water cannon cleaning of the walls.
In Lomellina II the flue gas temperature reduction in the empty pass is down to 600 °C, where it in IKV is lowered to 700°C. The hanging superheaters placed in a separate horizontal pass, with individual hoppers below makes removal of fouling particles efficient without having the risk of blocking down stream super heaters. The pass design and the boiler house area around the pass are made such that exchanging of the superheaters from above shall be fast and cost effective.

![Diagram of IKV empty pass and convective super heater pass](image)

**Figure 7. IKV empty pass and convective super heater pass**

An even fuel distribution in the furnace is essential for maximum combustion efficiency. Like in Lomellina II, IKV will be equipped with drop chutes for the fuel to the furnace. In the drop chute the fuel is transported into the furnace using combustion air.
3.5 Demolition wood CFB experience

Experiences from the German markets reference boilers firing 100% demolition wood has shown that the quality of demolition wood varies a lot depending of the origin and the effectiveness of the preparation of the fuel. Generally demolition wood is expected to contain high amounts of unfluidizable items such as metal pieces, wires, stones and glass. These items need to be removed from the grid. The step grid with ash sieving and fine fraction circulation capability has proven to be an effective technology without an excessive need of make up sand.

Demolition wood contains high amounts of harmful substances such as chlorine and heavy metals, mainly lead and zinc. The experience with 90 bar steam pressure shows that this is an acceptable level firing 100% demolition wood, without having a risk of fouling and corrosion on the furnace walls, whose temperature corresponds to the saturation temperature of the drum pressure.
The convective superheater steam temperature, 400 °C, has also proved to be acceptable where some boilers are equipped with austenitic superheaters and others with ferritic. In IKV the corresponding level is set to around 425 °C using austenitic superheaters, allowed by the fact of having an empty pass reducing the flue gas temperature to around 700 °C before the convective superheaters.

To secure a high availability, in IKV, the soot blowers situated in the superheater pass, will be of full stroke type.

Experiences from the demolition wood boilers, and from other recovered fuel boilers, show that the fuel quality is varying heavily and the need of proper fuel quality management systems has been recognized. The use of such systems has in several cases improved the quality of the fuel and accordingly the problems with corrosion and fouling has decreased. In addition to a proper boiler design selection, this is the most important issue to prevent these problems from occurring. This issue has been emphasized in the development of IKV and Söderenergi’s long experience of fuel quality management, firing difficult fuels, will naturally be utilized to its full extent.

3.6 Biofuel CFB experience

The main feature from biofuel fired CFB’s taken into consideration in IKV is the experiences firing wet fuels in combination with air humidifiers known to cause an increased rate of corrosion, both hot and cold. Therefore IKV will be equipped with austenitic cold end flue gas air preheater package to avoid fouling and corrosion caused by Ca Cl₂. A design feature quite normal in biofuel boilers is also a hot air preheater, when firing wet fuels and given a relatively high feed water temperature (limiting the economizer power). A hot air preheater is necessary to secure a low flue gas exit temperature, and accordingly high boiler efficiency.
Figure 10, IKV economizer- and air pre heater pass

The final superheating temperature after Intrex SH, 540°C, is selected based on experiences from these references. The higher level of harmful substances in the fuel used in IKV will not have an abnormal impact on the lifetime of the Intrex tube bundles.
SPECIAL FEATURES IN IKV BOILER CONCEPT

4.1 Sulphur feeding to furnace

To assure a minimum risk of corrosion, one extra effort has been made to complement the above-described corrosion minimizing key items. In Sweden, high temperature corrosion when firing alkali- and Cl rich fuels has been a problem for a long time (co-combustion of biomass fuels and demolition wood).

This kind of corrosion problem was not experienced to the same degree in previous applications that used high levels of peat. The reason is known to be related to the peat ash characteristics and to the high sulphur content in peat. When peat has become subject to CO₂ trade, other additives have been tested in a variety of forms, such as elementary sulphur, ammonium sulphate and kaolin.
In IKV sulphur granulate was selected based on its tested positive impact reducing high-temperature corrosion and fouling.

The corrosion rate is reduced by the reaction of sulphur and alkalis (potassium and sodium), preventing these substances from forming alkali chlorides, which are known to be the major substances increasing the hot corrosion in convective superheaters. The chlorine will therefore pass the convective superheaters in the form of HCl, which is a gaseous substance, all through the boiler passes, and it will therefore not have an impact on the corrosion process.

Substances including sulphur also have the tendency of forming ash compositions on the heat surfaces, which are elevating the melting temperature of the deposits. This elevated melting temperature prevents the ash deposits from being sticky, causing additional deposits. This will give less fouling, which has been concluded in several test programs where sulphur granulates has been fed to the boiler.

There are also indications from a reference boiler that sulphur granulates feeding to the bed may reduce the risk of agglomerations. This behaviour has been carefully studied in the project.

4.1.1.1 Firing range

One of the most challenging design parameters in IKV is the wide fuel range, from 6 MJ/kg to 16 MJ/kg (LHV, wet). The boiler needs not only to be able to operate in the given range, but also to fulfil the co-combustion requirement of 850°C during 2 seconds in the waste part of the fuel range.

In addition to the fuel range, the use of a combustion air humidifier (described in chapter 2.7) gives a higher airflow and cooling of the combustion when it is in operation, and the opposite when not in operation.

Firing wet fuels, when the humidifier is in operation, will give the highest combustion and flue gas flow, and firing driest fuels will give a maximum demand of recirculation gas. A high need of recirculation gas has given the need of feeding the gas both to the grid, together with primary air, and to additional recirculation gas nozzles above the grid.

This has led to a very high requirement of high turn down ratio for air fans, rec fans as well as for flue gas (I.D.) fan. To be able to operate the boiler with modest need of recirculation gas and reasonable fan efficiency, the boiler is even equipped with two recirculation-gas fans

<table>
<thead>
<tr>
<th>Load limitations</th>
<th>Driest fuel with 100%</th>
<th>Driest fuel with load limitations</th>
<th>Wettest fuel with 100%</th>
<th>Wettest fuel with load limitations</th>
</tr>
</thead>
</table>

Table 4. Fuel combinations and firing range
<table>
<thead>
<tr>
<th></th>
<th></th>
<th>MCR</th>
<th>MCR</th>
<th>MCR</th>
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<tbody>
<tr>
<td>Boiler load</td>
<td>% av MCR</td>
<td>32 -100</td>
<td>32 - 70</td>
<td>32 - 100</td>
</tr>
<tr>
<td>LHV</td>
<td>MJ/kg, a.f</td>
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<td>16.1</td>
<td>8.3</td>
</tr>
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<td>H2O</td>
<td>%</td>
<td>35.6</td>
<td>14.3</td>
<td>50.0</td>
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<td>Air humidity</td>
<td>g/kg, tl</td>
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<td>≤76&lt;sup&gt;1)&lt;/sup&gt;</td>
<td>5</td>
</tr>
<tr>
<td><strong>Fuel mixture content</strong></td>
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<td></td>
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<td>Forest residues</td>
<td>% - LHV</td>
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<td>0-100</td>
<td>0-100</td>
</tr>
<tr>
<td>(Branches and tops)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood chips</td>
<td>% - LHV</td>
<td>0-100</td>
<td>0-100</td>
<td>0-100</td>
</tr>
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<td>Stump chips</td>
<td>% - LHV</td>
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<td>0-30</td>
<td>0-30</td>
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<td>Saw dust</td>
<td>% - LHV</td>
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<td>0-30</td>
<td>0-30</td>
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<td>Bark</td>
<td>% - LHV</td>
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<td>0-100</td>
<td>0-100</td>
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<td>REF pellets</td>
<td>% - LHV</td>
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<td>0-25</td>
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<td>Demolition wood</td>
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<td>0-70</td>
</tr>
<tr>
<td>Peat&lt;sup&gt;2)&lt;/sup&gt;</td>
<td>% - LHV</td>
<td>0-100</td>
<td>0-100</td>
<td>0-100</td>
</tr>
</tbody>
</table>

<sup>1</sup> Combustion air humidifier in operation

<sup>2</sup> Firing of Peat over 50% of MCR requires an addition of limestone feeding silo and equipment (limestone feeding to the furnace) to handle the increased SO₂ emissions from peat sulphur content.
Figure 12. Firing diagram, with and without combustion air humidifier.
5 INITIAL OPERATION EXPERIENCE

Initial operation experience of the CFB boiler in Igelsta has been fully satisfactory. As a combined heat and power producing unit the plant has been operated mainly at full output ever since the commissioning. Basic process parameters are shown on following table.

Table 5 Process parameters on different load levels
with fuel mixture of Forest Residue and pelletized REF (combustion air humidified)

<table>
<thead>
<tr>
<th></th>
<th>50 %MCR</th>
<th>75 %MCR</th>
<th>100 %MCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler output</td>
<td>MW</td>
<td>120</td>
<td>180</td>
</tr>
<tr>
<td>Main steam flow</td>
<td>kg/s</td>
<td>45,6</td>
<td>67,0</td>
</tr>
<tr>
<td>Main steam pressure</td>
<td>bar</td>
<td>89,9</td>
<td>90,2</td>
</tr>
<tr>
<td>Main steam temperature</td>
<td>°C</td>
<td>505</td>
<td>536</td>
</tr>
<tr>
<td>Bed temperature</td>
<td>°C</td>
<td>815</td>
<td>815</td>
</tr>
<tr>
<td>Furnace outlet temperature</td>
<td>°C</td>
<td>729</td>
<td>814</td>
</tr>
<tr>
<td>Flue gas exit temperaturef1</td>
<td>°C</td>
<td>135</td>
<td>148</td>
</tr>
<tr>
<td>Flue gas O₂f1</td>
<td>vol-%, dry</td>
<td>5,4</td>
<td>4,5</td>
</tr>
<tr>
<td>SO₂f2</td>
<td>mg/m³n</td>
<td>15</td>
<td>&lt;1</td>
</tr>
<tr>
<td>HClf2</td>
<td>mg/m³n</td>
<td>2,9</td>
<td>3,2</td>
</tr>
<tr>
<td>NOx*</td>
<td>mg/m³n</td>
<td>68</td>
<td>31</td>
</tr>
<tr>
<td>NH₃f1</td>
<td>ppm</td>
<td>6,1</td>
<td>7,9</td>
</tr>
<tr>
<td>N₂Of4</td>
<td>mg/m³n</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>COf3</td>
<td>mg/m³n</td>
<td>34</td>
<td>8</td>
</tr>
<tr>
<td>Particulatesf2</td>
<td>mg/m³n</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

1): fluegas composition after boiler
2): fluegas composition after baghouse
3): fluegas composition in stack
Process behavior
Fuel flexibility, high combustion efficiency and low emissions are well known advantages of CFB boilers. The boiler process with the selected construction layout featured by empty pass and convection superheaters with low temperature as well as INTREX® final superheaters has shown excellent performance. Slagging and corrosion has been minimal. Furnace operation is in designed temperature window in the whole load range.

Ammonia feeding both into the separator and into different feeding locations in the furnace enable low emission levels of nitrogen oxides and ammonia slip also towards boiler lower load range.

Flue gas emissions have been met

Mechanical scale up
The boiler’s general layout was based on the conventional in-line arrangement that has been adopted for larger boiler sizes years before. The boiler design utilizes constructional features from other waste fired units. One of the features is the Empty Pass arrangement where superheaters have been placed into Horizontal Pass area after the Empty Pass. INTREX® superheaters are used as final superheaters. The boiler is functioning according to design parameters without problems after the Taking Over.

Auxiliary equipment operation
The Operation of auxiliary equipments has been according to design parameters throughout the whole guaranteed boiler load range. The subsystems in question are:

- Combustion air system,
- Fuel feeding system,
- feed water system,
- makeup system,
- sand Feeding system,
- boiler water/Steam circuit chemistry.

Sulphur feeding system was adopted to control the distribution of chlorines from fuel to flue gases and ash. When the amount of sulphur has been optimized the portion of chlorines in fuel has been distributed from flue gas to ashes. Lower amount of Chlorines in flue gas is essential for protecting the superheaters from corrosive impact of chlorines. The chlorine granulate as designed shall be used to
ensure reliable operation of the system. If there are too many fine particles in the bulk sulphur it may cause deposition of pneumatic conveying system.

Flue gases are treated with Bag Filter including the back pulse cleaning. The efficiency of the filter has been good and sulphur, chlorine and heavy metal contents are being according or significantly lower than designed. Additives being used are active carbon and lime. The injection point for additives is located upstream of the filter. Bicarbonate feeding equipment has been installed to be used in case of high flue gas temperature or high sulphur oxide contents.

Empty Pass membrane walls are cleaned with water cannon system. The high water pressure injection cleans accumulated particles from the membrane wall surfaces.

6 SUMMARY

IKV design is a new CFB compact boiler concept based on technological features from biomass, demolition wood and RDF fired CFB’s. Igelsta Boiler is suitable for challenging fuels, while still having a high steam temperature output of 540°C.

Basis for Boiler Design:

- high steam temperature,
- high chlorine contents
- humidification of the combustion air.

These features, individually and in combination with each other, shall increase corrosion. In Igelsta Design there is an empty pass before convective superheaters, a hopper after the empty pass, water cannons in the empty pass, sulphur feeding system, 100% austenitic superheaters and INTREX® superheaters to reduce impacts.

The sulphur granulate feeding system to the furnace was installed to the plant. The sulphur granulates react with the alkali in the fuel preventing it from forming alkali chlorides, which cause high temperature corrosion.

Experiences from firing recovered fuels show that the use of an efficient fuel quality management system is essential when firing fuels with great variations. In IKV, such a system will be one of the corner stones in the concept of assuring high plant availability.
The use of air humidification increases the overall plant efficiency; however in combination with a wide fuel moisture range, it makes the boiler auxiliary equipment design challenging. There is a possibility to burn wide range of fuels and this is why the design incorporates two recirculation gas fans and additional recirculation-gas nozzles in the lower furnace.

Regarding emissions, the CFB will once again prove its outstanding performance by primary emission control in the furnace (CO, TOC, UBC and base NOx), together with SNCR (NOx) and a bag filter (SO2, HCl, HF, particles, heavy metals and dioxins).

The plant Take Over took place in end of 2009.

REFERENCES

/1/ www.soderenergi.se / Facts about Söderenergi 2006
/2/ IKV Request For Quotation / Administrativa föreskrifter 2006-05-23