Content of the presentation

- Introduction
- Co-combustion and additives
- The strategy of Vattenfall
- IACM (In-situ alkali chloride monitor)
- The ChlorOut concept
- Examples from full-scale boilers
Most bio-fuels fuels have a high content of alkali metals (mainly K) and chlorine, and very little sulphur. K released during combustion can condense as chlorides (KCl) or sulphates (K$_2$SO$_4$). KCl in deposits may cause accelerated corrosion.
Additives and co-combustion

- Superheater corrosion and deposit formation can be reduced by co-combustion (peat, coal) or by additives.
- Additives can either prevent the release of gaseous KCl or react with KCl in the gas phase and form less corrosive components.
- The additives can be added with the fuel or to the flue gases.
Additives and co-combustion

- Reaction with K resulting in K-alumino silicates and consequently decrease the levels of KCl (g) in the flue gas. The main constituents of them are Al₂O₃ and SiO₂.
- Kaolin, sludge, peat, coal ash.
- Sulphation of gaseous alkali chlorides to less corrosive alkali sulphates.
- Elemental sulphur, or other sulphur containing additives.
The strategy of Vattenfall

- On-line control of the in-coming fuel-mix by measuring KCl
- Reduction of alkali chlorides by a sulphur containing additive
- Measurements by means of deposit and corrosion probes, characterisation of the flue gas environment at the super heaters
- Reduced of deposit formation and super heater corrosion
The strategy of Vattenfall

- Vattenfall has developed and patented:
  - a sulphate containing additive called **ChlorOut** (normally ammonium sulphate);
  - an instrument that measures KCl(g) on-line called **IACM** (in-situ alkali chloride monitor);
- This presentation will describe some aspects on IACM and the ChlorOut concept.
- Results from a research campaign in a typical application of the concept.
IACM

- In-situ Alkali Chloride Monitor
- Measures KCl, NaCl and SO$_2$ on-line at 600-1500 °C
- 3 - 15 m measuring length
- 5 sec measurement time
- ~1 ppm detection limit
Conversion of a PF burner from co-combustion of coal to 100% bio-fuel
Munksund – Previous results

Inblandning av wellrejekt - KCl mot last

![Graph showing KCl concentration (ppm) against outgoing steam (ton/h)]
**The ChlorOut concept**

- ChlorOut (ammonia sulphate) is sprayed into the flue gases and converts chlorides to sulphates, which reduces corrosion and fouling. It also reduces NOx and CO.

- **Main chemical reactions:**
  
  \[
  (\text{NH}_4)_2\text{SO}_4 \rightarrow 2 \text{NH}_3 + \text{SO}_3 + \text{H}_2\text{O}
  \]
  
  \[
  \text{SO}_3 + \text{H}_2\text{O} + 2\text{KCl} \rightarrow 2\text{HCl} + \text{K}_2\text{SO}_4
  \]
Idbäcken CHP ~ 100 MWtot BFB

Fuel: Wood chips, demolition wood,

Steam data: 540°C 140 bar

Combustion zone

ChlorOut Spray

Superheater 2

Condensate

On-line KCl monitor

ChlorOut Soln.
Lövholmen – Reduction of NOx and CO

16 MW grate. Biofuel from a saw mill

Miljödator Lövholmen, 25 mars
Ugnstemp 900 - 950 C, O2 5%
Ugnstemp ~ 925 C, O2 7%
Ugnstemp ~ 900 C, O2 7%

NOx, mg/MJ
CO, mg/MJ

Ugnstemp 900 - 950 C, O2 5% 10:00 11:00 12:00 13:00 14:00 15:00
Ugnstemp ~ 925 C, O2 7%
Ugnstemp ~ 900 C, O2 7%
The research campaign in Munksund

98 MWth CFB boiler
Fuel: Mainly bark > 80%, sawdust, wood chips, 6% plastic waste (comes from cardboard recycling)

Steam data: 420°C after SH2
480°C 60 bar after an Intrex.

Two separate cyclones, the flue gases mix again prior to SH2
The research campaign in Munksund

- A short term-measurement campaign: Normal fuel mix, Normal + ChlorOut, 20% Peat + Normal, IACM, deposit probes, DLPI impactor, FTIR
- Right side injection of ChlorOut: Normal fuel mix, Normal + ChlorOut, IACM, deposit and corrosion probes,
- Long-term measurements: IACM, ChlorOut, Corrosion probes, data recording from the plant including stack emissions
The Munksund boiler

IACM

ChlorOut

Corrosion/ deposit probes

FTIR
Short-term – Reduction of alkali chlorides

![Graph showing the reduction of alkali chlorides over time.](image-url)
Short-term – Reduction of alkali chlorides

![Graph showing the reduction of KCl and SO2 with different treatments: Peat, Normal, and ChlorOut.](image-url)
Short-term – Deposit growth

Deposit growth

Weight increase (g/m²*h)

Ring temperature

- Peat
- Normal
- ChlorOut
Short-term – Wet chemistry, 500°C

Wet chemical analysis

<table>
<thead>
<tr>
<th>Element</th>
<th>Content (weight %)</th>
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<tbody>
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<td>Na+K</td>
<td>Normal</td>
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<tr>
<td>S</td>
<td>ChlorOut</td>
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<tr>
<td>Cl</td>
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Right sided injection – Deposit growth

Deposit growth - right sided injection of ChlorOut

- Weight increase (g/m²*h)
- Ring temperature

- Normal
- ChlorOut

Graph showing weight increase with different ring temperatures for Normal and ChlorOut conditions.
Right sided injection – wet chemistry, 500°C

Wet chemical analysis - right sided injection

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- Normal
- ChlorOut
Right sided injection – the corrosion probe

- A corrosion probe exposed during 4 weeks
- Left side: Normal fuel mix
- Right side: Normal fuel mix + ChlorOut
Long-term measurements – KCl vs load
Long-term measurements – NOx vs load
Conclusions – the research campaign

- It was possible to measure KCl (g) on-line with IACM. It was also possible to distinguish between normal fuel-mix with and without an additive.
- The deposit growth decreased during ChlorOut.
- The deposits content of Cl decreased during both ChlorOut and co-combustion with peat.
- NOx was significantly reduced during ChlorOut.