Ash related challenges from a boiler manufacturer’s point of view

FPK II course 2016
Sonja Enestam
Contents

• Valmet Technologies

• Fuels
  – Trends
  – Challenges

• Ash related challenges
  – Fouling and slagging
  – Bed agglomeration
  – Corrosion

• The significance of corrosion

• How do we tackle issues of corrosion?
  - Questions and solutions

• Case Naantali
Valmet
Leading global developer and supplier of process technologies, automation and services for the pulp, paper and energy industries
Converting renewable resources into sustainable results

End-products

- Biogas
- Biofuels
- Biochemicals
- Biomaterials
- New paper grades
- Heat
- Electricity
- Diss pulp
- Chem pulp
- Mech pulp
- Paper
- Board
- Tissue

Services

- Energy
- Pulp
- Paper

Automation

Technologies

Raw materials

- Waste
- Agro
- Wood
- Recycled paper

Customer industries

- Energy production
- Biofuel refining
- Pulp
- Paper
Valmet’s Road to Becoming a Global Market Leader

1942 Rauma-Raahe
1951-1995 Several M&As
1999 Metso created through merger of Valmet and Rauma
End of 2013 Demerger to Valmet and Metso

1797 Tamfelt
1856 Tampella
1858 Beloit
1860 KMW
1868 Sunds
1886 Defibrator
1887 Wärtsilä paper finishing machinery
1986 KMW
1992 Tampella Papertech
2000 Beloit Technology
2006 Kvaerner Pulping
2009 Tamfelt
2009 Kvaerner Power
Unique offering covers process technology, automation and services

Paper
- Recycled fiber lines
- Tailor-made board and paper machines
- Modularized board and paper machines
- Tissue production lines
- Modernizations and grade conversions
- Standalone products

Pulp and Energy
- Complete pulp mills
- Sections and solutions for pulp production
- Multifuel boilers
- Biomass and waste gasification
- Emission control systems
- Biotechnology solutions e.g. for producing bio fuels

Services
- Spare parts and consumables
- Paper machine clothing and filter fabrics
- Rolls and workshop services
- Mill and plant improvements
- Maintenance outsourcing
- Services energy and environmental solutions

Automation
- Distributed control systems
- Quality control systems
- Analyzers and measurements
- Performance solutions
- Process simulators
- Safety solutions
- Industrial Internet solutions

Focus in customer benefits
Key figures 2015

Orders received
EUR 2,878 million

Net sales
EUR 2,928 million

EBITA before NRI1
EUR 182 million

EBITA margin (before NRI1)
6.2%

Employees
12,306

Market position
#1-2 Services
#1-3 Pulp & paper automation
#1-2 Pulp
#1-3 Energy
#1 Paper, board, tissue

1) NRI = non-recurring items
Stable business = Services and Automation business lines
Capital business = Pulp and Energy, and Paper business lines
Strong global presence close to our customers

140 locations in 33 countries
Our pulp and energy technology offering

- Wood handling systems
- Cooking systems
- Complete fiber lines
- Pulp drying systems

- Evaporation systems
- Recovery islands

- Circulating fluidized bed boilers (CYMIC)
- Bubbling fluidized bed boilers (HYBEX)
- Biomass and waste gasification
- Oil and gas boilers
- Waste heat recovery
- Air pollution control systems

- Pyrolysis solutions for bio-oil production
- LignoBoost for lignin extraction
- Steam treated pellets production lines
- Biomass prehydrolysis for further refining to fuels or chemicals

300 complete fiber lines and 350 recovery islands delivered

400 boilers and environmental protection systems delivered
Fuel use in electricity and heat production in Finland 2012–2013

Source: Statistics on production of electricity and heat, Statistics Finland and Electricity statistics, Finnish Energy Industries
Bio-energy technologies are in transition

- Combustion
  - heat
  - steam
  - electricity

- New bio products:
  - Bio gas
  - Bio oil
  - Bio coal
  - Lignin
  - Ethanol

Fuel handling and pre-processing:
- Gasification
- Pyrolysis
- Torrefaction
- LignoBoost
- Chemical or biochemical

Inputs:
- agro
- waste
- wood
- peat
- fossil
The trend: From coal and peat to biofuels and recycled fuels
Parameters steering the fuel choice
Balancing economy and sustainability

Environmental regulations
- CO₂ trade
- green energy benefits

Ethical aspects

Fuel availability

Price

Fuel quality and combustibility
- emissions
- corrosion
- ash quality
- bed sintering
The fuel dilemma

Fuel price [€/MWh] vs. Level of challenge

- **Fossil**
  - Hard coal

- **Wood biomass**
  - Northern wood
  - Pulp&Paper sludges
  - Wood pellets

- **Fast growing wood**
  - Willow
  - Eucalyptus

- **Agro biomass**
  - Straw
  - Sunflowerhulls
  - Corn Stover
  - Miscanthus

- **Recycled fuels**
  - Packaging waste
  - Recycled wood
Fuel properties

- Heating value
- Moisture
- Physical characteristics
- Ash content
- Ash composition
  - Cl, S, Ca, K, Na, Pb, Zn, P...

- Furnace dimensions
- Air / fuel ratio
- Use of flue gas recirculation

- Fuel feeding
- HSE

- Fouling and slagging propensity
- Ash handling

- Fouling propensity
- Corrosivity
- Bed agglomeration
- Emissions
- Ash quality
Fuel related challenges

- Fuel feeding
- Agglomeration
- Slagging & Fouling
- Corrosion
- Ash quality
- Emissions
The influence of fuel composition on the combustibility

Corrosive environment
Low melting ash

Corrosion
Fouling
Slagging
Bed sintering

Ca
S
Zn^{2+}
Pb^{2+}
Cl^{-}
K^{+}
Na^{+}
Typical analyses of different types of fuels
minimum – average – maximum

<table>
<thead>
<tr>
<th></th>
<th>Peat</th>
<th>Wood chips</th>
<th>Bark</th>
<th>Demolition wood</th>
<th>SRF</th>
<th>AGRO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash (815°C) [wt-% of ds]</td>
<td>2 – 6 – 18</td>
<td>0.2 – 1.5 – 4</td>
<td>0.1 – 4.0 – 13</td>
<td>1 – 3.5 – 13</td>
<td>10 – 18 – 26</td>
<td>4 – 6.5 – 12</td>
</tr>
<tr>
<td>S [wt-% of ds]</td>
<td>0.1 – 0.2 – 0.8</td>
<td>0.01 – 0.04 – 0.09</td>
<td>0.01 – 0.05 – 0.2</td>
<td>0.01 – 0.07 – 0.15</td>
<td>0.1 – 0.5 – 0.7</td>
<td>&lt;0.08 – 0.08 – 0.2</td>
</tr>
<tr>
<td>Cl [wt-% of ds]</td>
<td>0.02 – 0.04 – 0.25</td>
<td>&lt;0.01 – 0.01 – 0.01</td>
<td>&lt;0.01 – 0.07 – 0.32</td>
<td>0.01 – 0.07 – 0.26</td>
<td>0.2 – 0.7 – 1.6</td>
<td>0.15 – 0.3 – 1</td>
</tr>
</tbody>
</table>
Fuel related challenges

- Fuel feeding
- Agglomeration
- Slagging & Fouling
- Corrosion
- Ash quality
- Emissions
Agglomeration mechanism

- Fuel
- Ash
- Sand
Agglomeration mechanism

- Bed particle (B)
- Sticky material (A) consists mostly of K, Ca, Si, Na
- The melting temperature of the sticky material is < 800 °C
Bed Agglomeration -> solutions

- Inert bed material: AggloStop
- Bed temperature: < 750 °C
- Bed material removal
- Additives

Refer. Piotrowska, Åbo Akademi
Bed Agglomeration

Solution

- Bed temperature: < 750 °C
# AggloStop

Diabase as an alternative bed material

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Diabase B (wt-%)</th>
<th>Natural sand A (wt-%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz (SiO$_2$)</td>
<td>&lt; 0.1</td>
<td>40</td>
</tr>
<tr>
<td>Feldspar (KAIS$_3$O$_8$)</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Feldspar (NaAlSi$_3$O$_8$ + CaAl$_2$Si$_2$O$_8$)</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>Pyrokseeni (XYSi$_2$O$_6$)</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>Biotite (K(Mg,Fe)$<em>3$(AlSiO$</em>{10}$)(OH)$_2$)</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Olivine (Mg,Fe)$_2$SiO$_4$)</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>Magnetite (Fe$_3$O$_4$)</td>
<td>4</td>
<td>-</td>
</tr>
</tbody>
</table>
Fouling & slagging
Influence of fuel composition and process conditions

- Amount of ash in the fuel and composition of the ash
  - Ash melting behavior => stickiness of the ash
  - Condensable matter

- Increased temperature => increased slagging and fouling, often caused by increased load

- Often leads to a ”snow ball” effect progressing with the flue gas flow in the boiler

- Swirls caused by the air feeding system can cause areas with high slagging in the furnace
  - CFD modelling

- The fuel feeding system in combination with the air feeding can move the combustion too high up in the furnace
  - Both systems can be optimized with CFD modelling
Effects of fouling

- Reduced heat transfer => Decreased efficiency of the boiler
- Increased need for sootblowing (steam consumption)
- Increased corrosion risk
  - Without deposits usually no corrosion
  - All deposits are not corrosive
- Plugging of the boiler
  - Unavailability
- Partial plugging leads to increased flow velocity which in turn leads to erosion
  - Tube leakages
  - Unavailability
Avoiding slagging and fouling

• Correct boiler design based on the fuel properties
  – Empty pass in waste boilers
  – Correct placement on heat exchangers
  – Tube spacing of heat exchangers

• Understanding of fuel ash properties
  – Avoiding difficult fuel mixtures at high loads
  – Avoiding certain fuel fuels

• Limiting the furnace temperature
  – By recirculating flue gas

• Furnace cleaning
  – Avoiding the snow ball effect

• Optimization of sootblowing
  – Sufficient amount of superheaters
  – Right type of superheaters
  – Sufficient soot blowing, 1/d -> 1/ shift

• Boiler cleaning at annual shut down
Corrosion
The influence of corrosion on boiler technology and plant efficiency

- Final steam temperature and pressure → Efficiency
- Change of material → Price
- Fuel mixture Boiler availability → Economy
- Superheater placement → Design
Different corrosion types – BFB boilers

- Alkali chloride induced corrosion
- Heavy metal induced corrosion
- Erosion-corrosion
- Dew point corrosion
Different corrosion types – CFB boilers

- Erosion-corrosion
- Alkali chloride induced corrosion
- Heavy metal chloride induced corrosion
- Dew point corrosion
- Alkali chloride induced corrosion
Corrosion types – Recovery boilers

- Alkali chloride induced corrosion
- Sulphidation
- Acidic sulphates
Corrosion mechanisms
Protectiveness of the oxide layer

Compact steel-oxide layer
- protects from further oxidation
- requires the presence of oxygen

Does not work if
- the steel-oxide layer breaks
- oxygen is absent
- the steel-oxide layer is porous
The oxide formed on FeCr steel consists of a corundum-type solid solution, 
(Cr, Fe)$_2$O$_3$. The Cr/Fe ratio determines whether it is protective (as 
Cr$_2$O$_3$) or poorly protective (as Fe$_2$O$_3$).

Reactions that convert protective chromium-rich oxide to non-protective 
iron-rich oxide play a key part in high temperature corrosion…

Ref.: HTC, Chalmers
Corrosion mechanisms

- Gas phase corrosion
- Solid phase corrosion
- Molten phase corrosion
Corrosion mechanisms

- Solid particles
- Molten particles
- Gaseous particles
Gas phase corrosion

- Gas molecules reacting directly with the tube material
- No condensation due to
  - tube temperature
  - concentration in the gas
- HCl, H₂S, Cl₂, KCl, NaCl, PbCl₂, ZnCl₂

<table>
<thead>
<tr>
<th>Corrosion rate, ipy</th>
<th>Temperature, °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.240&quot;</td>
<td>480</td>
</tr>
<tr>
<td>0.180&quot;</td>
<td>570</td>
</tr>
<tr>
<td>0.120&quot;</td>
<td>660</td>
</tr>
<tr>
<td>0.060&quot;</td>
<td>750</td>
</tr>
<tr>
<td>0.060&quot;</td>
<td>840</td>
</tr>
<tr>
<td>0.060&quot;</td>
<td>930</td>
</tr>
</tbody>
</table>

H₂S induced corrosion
Molten phase corrosion

- Molten deposit on the tube surface
- Better contact with tube surface
- Faster reaction
- Catastrophic corrosion rates
- Occurs when $T_{\text{mat}} > T_0$ of the deposit
- Rule of thumb: $T_{\text{mat}} < T_0$
The influence of melt formation in the deposit

Steel: T91
Time: 168 h

The thickness of the oxide, μm

Ash 10, T₀ = 522°C
Ash 9, T₀ = 621°C
Ash 8, T₀ = 526°C
Ash 7, T₀ = 625°C
Ash 6, T₀ = 834°C
Ash 5, T₀ = 884°C
No Ash

Method
The influence of deposit composition on ash melting behaviour

Alkali salt (Na,K,SO$_4$,Cl)
Alkali salt + PbCl$_2$
Alkali salt + ZnCl$_2$
Solid phase corrosion

- Solid deposit reacting with the tube material
  - Condensed material
  - Impacted material
  - KCl, NaCl, PbCl$_2$, ZnCl$_2$, sulphates, sulphides, carbonates
Solid phase corrosion

The thickness of the oxide, μm

Temperature, °C

15: KCl $T_0 = 771^\circ$C
17: NaCl $T_0 = 801^\circ$C

Steel: T91
Corrosion mechanisms – alkali chloride induced corrosion

\[
\text{Fe}_2\text{O}_3
\]

\[
\text{Cr}_2\text{O}_3
\]

\[
\begin{align*}
\text{KOH} & \rightarrow \text{KCl} & \text{HCl} & \rightarrow \text{Fe}_2\text{O}_3 \\
\text{Fe}_2\text{O}_3 & \rightarrow \text{Cl}^- & \text{MeCl}_2 & \rightarrow \text{Me}_2\text{O}_3 \\
\text{Me} = \text{Cr}, \text{Fe} & \\
\end{align*}
\]
304L exposed in the presence of KCl and H$_2$O at 600°C for 1hr

Corrosivity of alkali chlorides on two steels

S. Enestam

NaCl and KCl equally corrosive on the tube surface.

Cr₂O₃ more protective than Fe₂O₃.
# Steel composition

<table>
<thead>
<tr>
<th>Grade</th>
<th>Category</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>Others</th>
<th>Relative price&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Typical use (boiler part)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10CrMo9-10</td>
<td>Low alloy</td>
<td>2.25</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2.3</td>
<td>Superheaters</td>
</tr>
<tr>
<td>AISI 347</td>
<td>Standard stainless steel</td>
<td>19</td>
<td>-</td>
<td>10</td>
<td>Nb</td>
<td>6.7</td>
<td>Superheaters</td>
</tr>
</tbody>
</table>

<sup>a</sup> May 2011
Corrosion test: Low alloy steel 10CrMo9-10
The influence of Pb and Zn

Corrosion product layer [µm]
Different corrosion types – CFB boilers

- Erosion-corrosion
- Alkali chloride induced corrosion
- Heavy metal chloride induced corrosion
- Dew point corrosion
Dewpoint corrosion

Dewpoint of acidic gases

Concentration (ppm)

Dewpoint temperature (°C)

HNO₃
HCl
H₂SO₄
Dewpoint corrosion

• Dewpoint corrosion is usually caused by *sulfuric acid* (H₂SO₄), since it has the highest dewpoint of all the acid gases in the flue gases
  – Dewpoint between 120 - 180 °C with normal fuels
  – Other acids condense only at temperatures below 80 °C

• The *concentration* of condensing sulfuric acid depends on the temperature and moisture content
  – Concentration typically between 65% and 75%
  – Temperature close to *boiling point*

• Sulfuric acid condensed at dewpoint is very corrosive

• Alternative corrosion mechanism: corrosion caused by hygroscopic salts such as CaCl₂, ZnCl₂, NH₄Cl
The corrosion rate is influenced by

- Flue gas composition
- Flue gas temperature
- Solid and/or molten fly ash
- Deposit composition

Steel grade

Material temperature

The corrosivity of the environment

\[ T_{\text{mat}} \]

\[ T_{\text{flue gas}} \]
Technical solutions
Corrosion -> solutions

1. Superheater material and temperature
   - Price v.s. life time v.s. efficiency and profitability
   - Coatings, overlay weld. E.g. Ni based coatings in waste combustion
2. Tube shields – most corrosive locations
3. Superheater location
4. Superheater design
5. Fuel mixture: Co-firing or additives
6. Gasification
Superheaters
Water-steam cycle, preassure vessel weight aprox. 600tn, 100km tubing
HYBEX boiler
Bubbling Fluidized Bed (BFB) technology

Kymin Voima,
Kuusankoski,
Finland

Steam
269 MW\textsubscript{th}
107 kg/s
114 bar
541 °C

Fuels
Bark, forest residue,
sludge, peat, gas, oil

Start-up 2002
HYBEX boiler
Bubbling Fluidized Bed (BFB) technology

Furnace:
- Width 12 m
- Depth 11 m
- Height 36 m

Furnace membrane tubes 26 km
Superheater tubes 35 km
Economizer tubes 15 km
Connection tubes 2 km
Weight of pressure parts 1600 ton
## Typical boiler materials

<table>
<thead>
<tr>
<th>Grade</th>
<th>Category</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>Others</th>
<th>Relative price</th>
<th>Typical use (boiler part)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P265GH</td>
<td>Non-alloy</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
<td>Eco, furnace, boiler bank</td>
</tr>
<tr>
<td>16Mo3</td>
<td>Low alloy</td>
<td>-</td>
<td>0.3</td>
<td>-</td>
<td>-</td>
<td>1.1</td>
<td>Furnace, boiler bank</td>
</tr>
<tr>
<td>13CrMo44</td>
<td>Low alloy</td>
<td>1</td>
<td>0.5</td>
<td>-</td>
<td>-</td>
<td>1.8</td>
<td>Superheaters</td>
</tr>
<tr>
<td>10CrMo9-10</td>
<td>Low alloy</td>
<td>2.25</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2.3</td>
<td>Superheaters</td>
</tr>
<tr>
<td>X10CrMoVNb9-1</td>
<td>High alloy ferritic</td>
<td>9</td>
<td>1</td>
<td>-</td>
<td>V, Nb</td>
<td>5.4</td>
<td>Superheaters</td>
</tr>
<tr>
<td>AISI 347</td>
<td>Standard stainless steel</td>
<td>19</td>
<td>-</td>
<td>10</td>
<td>Nb</td>
<td>6.7</td>
<td>Superheaters</td>
</tr>
<tr>
<td>AISI 310 (Modc)</td>
<td>High Cr stainless steel</td>
<td>25</td>
<td>-</td>
<td>21</td>
<td>N, Nb</td>
<td>10.0</td>
<td>Superheaters</td>
</tr>
</tbody>
</table>

*May 2011    c Modified with Nb*
The influence of $T_{fg}$, $T_{mat}$ and material on corrosion

$T_{fg} \approx 1100 \, ^\circ C$

$T_{fg} \approx 775 \, ^\circ C$

Probe 1

Probe 2

Removable clad

Test materials

 Probe body

Air in

Air out
The influence of $T_{fg}$, $T_{mat}$ and material on corrosion

Probe 1 (WIND) Stainless steel
0, no corrosion
0, no corrosion
1, slight corrosion

Probe 1 (WIND) Low alloy steel
$T_{fg} \approx 1100 \, ^\circ C$

Probe 2 (WIND) Stainless steel
$T_{fg} \approx 775 \, ^\circ C$

Probe 2 (WIND) Low alloy steel
$T_{fg} \approx 1100 \, ^\circ C$

4, severe corrosion
4, severe corrosion

4, severe corrosion
2, moderate corrosion
4, severe corrosion
Calculation of the corrosivity of the environment

Empirical data

Material selection based on fuel composition

Valmet
Calculation of the corrosivity of the environment

Empirical data

- Reference follow-up
- Laboratory tests
- Probe tests
SteaMax

Plant and fuel specific corrosion prediction

**Use**
- Selection of superheater materials
- Optimization of steam temperature
- Optimization of fuel mixtures and fuel limits
- Evaluation of the corrosivity of fuels and fuel mixtures
- Estimation of corrosion rate and superheater life length
- Trouble shooting

**Based on**
- Composition of fuels and fuel mixtures
- Boiler design and superheater placement
- Valmet in-house tool for estimating corrosivity
- Empirical data from more than 1300 laboratory corrosion tests and more than 45 full scale plants
Furnace wall corrosion and overlay welding

Typical problem in boilers burning waste and waste wood

=> Low alloy base material overlay welded with Ni-based alloy
Corrosion -> solutions

1. Superheater material and temperature
   - Price v.s. life time v.s. efficiency and profitability
   - Coatings, overlay weld. E.g. Ni based coatings in waste combustion

2. Tube shields – most corrosive locations

3. Superheater location

4. Superheater design

5. Fuel mixture: Co-firing or additives

6. Gasification
Tube shields
Most corrosive locations
Superheater location

Reduced concentration of gaseous, corrosive chloride in the vicinity of tube surfaces
Superheater design
Reduce probability of contact between tube surface and corrosive chlorides
Double tube superheater design
=> Reduced condensation of corrosive compounds

Target surface temperature is determined by the environment (fuels, flue gas temperature, steam temperature,...)

Surface temperature is achieved by controlling the tube heat transfer characteristics with additional, coaxial layers

Steam
Pressure bearing tube

Single tube design
Life length < 1 year

Double tube design
Life length > 3 years
Comparison of deposit compositions (XRF)
E.ON Norrköping EfW Plant

Steam: 75 MW / 6,5 MPa / 470 C
Fuels: MSW, industrial waste, demolition wood, sewage sludge, TDF

Norrköping Händelö site

<table>
<thead>
<tr>
<th>#</th>
<th>Type</th>
<th>Fuel</th>
<th>MW&lt;sub&gt;th&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>P11</td>
<td>Grate</td>
<td>Demolition wood</td>
<td>117</td>
</tr>
<tr>
<td>P12</td>
<td>Grate</td>
<td>Coal, TDF</td>
<td>125</td>
</tr>
<tr>
<td>P13</td>
<td>CFB</td>
<td>Bio, TDF</td>
<td>125</td>
</tr>
<tr>
<td>P14</td>
<td>CFB</td>
<td>Waste</td>
<td>75</td>
</tr>
</tbody>
</table>
Ways to minimize corrosion
Modification of the combustion environment

• Additives
  - Sulphur
  - Aluminium sulfate $\text{Al}_2(\text{SO}_4)_3$
  - Ferric sulfate $\text{Fe}_2(\text{SO}_4)_3$
  - Ammonium sulfate $(\text{NH}_4)_2\text{SO}_4$

• Co-combustion
  - Peat
  - Coal
  - Sludge
Corrosion management by sulphur addition

CorroStop Additives

- The sulphate eliminates alkali chlorides in the gas phase and attaches to superheater surfaces forming a protective coat and neutralize the effects of alkalichloride in the process.

- Sulfate decomposes at high temperature:
  \[
  \text{Fe}_2(\text{SO}_4)_3 \rightarrow 2 \text{Fe}^{3+} + 3 \text{SO}_4^{2-}
  \]

- Alkali chloride reacts with sulfur trioxide or dioxide
  \[
  2\text{MCl}(g,c) + \text{SO}_3(g) + \text{H}_2\text{O}(g) \rightarrow \text{M}_2\text{SO}_4(g,c) + 2 \text{HCl}(g)
  \]
  \[
  2\text{MCl}(g,c) + \text{SO}_2(g) + \frac{1}{2} \text{O}_2(g) + \text{H}_2\text{O}(g) \rightarrow \text{M}_2\text{SO}_4(g,c) + 2 \text{HCl}(g)
  \]

  where M is Na or K.
Fuel mixture - additive

Valmet corrosion management

Corrored Analyzer

• On-line sampling and analysis of the corrosivity of the flue gas
• Provides information for fuel blend and additive control

CorroStop Additives

• CorroStop™ – liquid solution
  Aluminiumsulfate $\text{Al}_2(\text{SO}_4)_3$ or Ferric sulfate $\text{Fe}_2(\text{SO}_4)_3$
  15-30 % liquid solutions
  Spraying through nozzles before superheaters

• CorroStop+™ – elementary sulphur
  Sulphur content > 95 %
  0.5 – 3.2 mm granulates
  Addition to fuel feeding screws
The influence of fuel mixture on corrosion

Corrosive bio fuel mixture requires stainless steel in the hottest superheaters

Adding sulphur rich fuel (e.g. peat) or S-additive enables the use of low alloy superheater material
Gasification
Recycled waste gasification plant for Lahti Energia Oy

- Metso delivery: waste gasification process, gas boiler, flue gas cleaning system with auxiliary and automation systems
- 2 gasification lines: 50 MW of electricity and 90 MW of district heat
- High-efficiency (gas boiler 121 bar, 540 C) conversion of recycled waste to energy and reduction of fossil fuels
- Waste is turned into combustible gas, which is cooled, cleaned and combusted in a high-efficiency gas boiler to produce steam for a steam turbine
Corrosion related plant optimization

- Efficiency
  - Maximize steam $T$ and $p$

- Availability
  - Minimize shut-downs due to corrosion, fouling or bed sintering

- Maintenance costs
  - Minimize the need for tube replacement (=minimize corrosion)

- Investment costs
  - Optimize material choice (Good enough material but not too good)
Corrosion control is a piece of a big puzzle of economics
Turun Seudun Energiantuotanto CYMIC boiler
Turun Seudun Energiantuotanto, Naantali, Finland

- Turun Seudun Energiantuotanto (TSE) is a utility company owned by local municipalities and Fortum.
- TSE provides district heating for the owner municipalities and electricity.
Turun Seudun Energiantuotanto, Naantali
CYMIC -kattila
Circulating Fluidized Bed (CFB) technology
Turun Seudun Energiantuotanto, Naantali, Finland

CYMIC boiler
CYMIC boiler - Circulating Fluidized Bed (CFB) technology

- Steam: 144 / 130 kg/s
- Pressure: 164 / 44 bar
- Temperature: 555 / 555 °C
- Thermal Power: 390 MW

Fuels: Wood biomass, agro biomass, peat, coal, SRF

Start-up: 2017