Corrosion/Fouling Environment Evaluation in WTE and Biomass Fired Boilers

Wolfgang Spiegel, Marie Kaiser

CheMin GmbH (Germany)

What we would like to present

Tool for mitigation of corrosion/fouling

Corrosion/Fouling Environment Evaluation

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Corrosion Environment Evaluation (CEE)

Content

1. Environment
    - 1-a) Thermal Environment
    - 1-b) Mechanical Environment
    - 1-c) Chemical Environment
2. Technology for Evaluation
    - 2-a) online technology
    - 2-b) offline technology
3. Conclusions

This presentation will focus primarily on the corrosion topic.

1) Environment

General condition

A given firing system and a given fuel interact to create the corrosion environment of a boiler.

It is characterized by:

- **Thermal environment**
- **Mechanical environment**
- **Chemical environment**

Typically, all conditions are not constant. They are fluctuating due to process impact and evolution of boundary conditions during an operational period.

1) Environment

General condition

Thermal environment

- Level of temperature and heat transfer
- Rapid changes (i.e. impact of online cleaning)

Mechanical environment

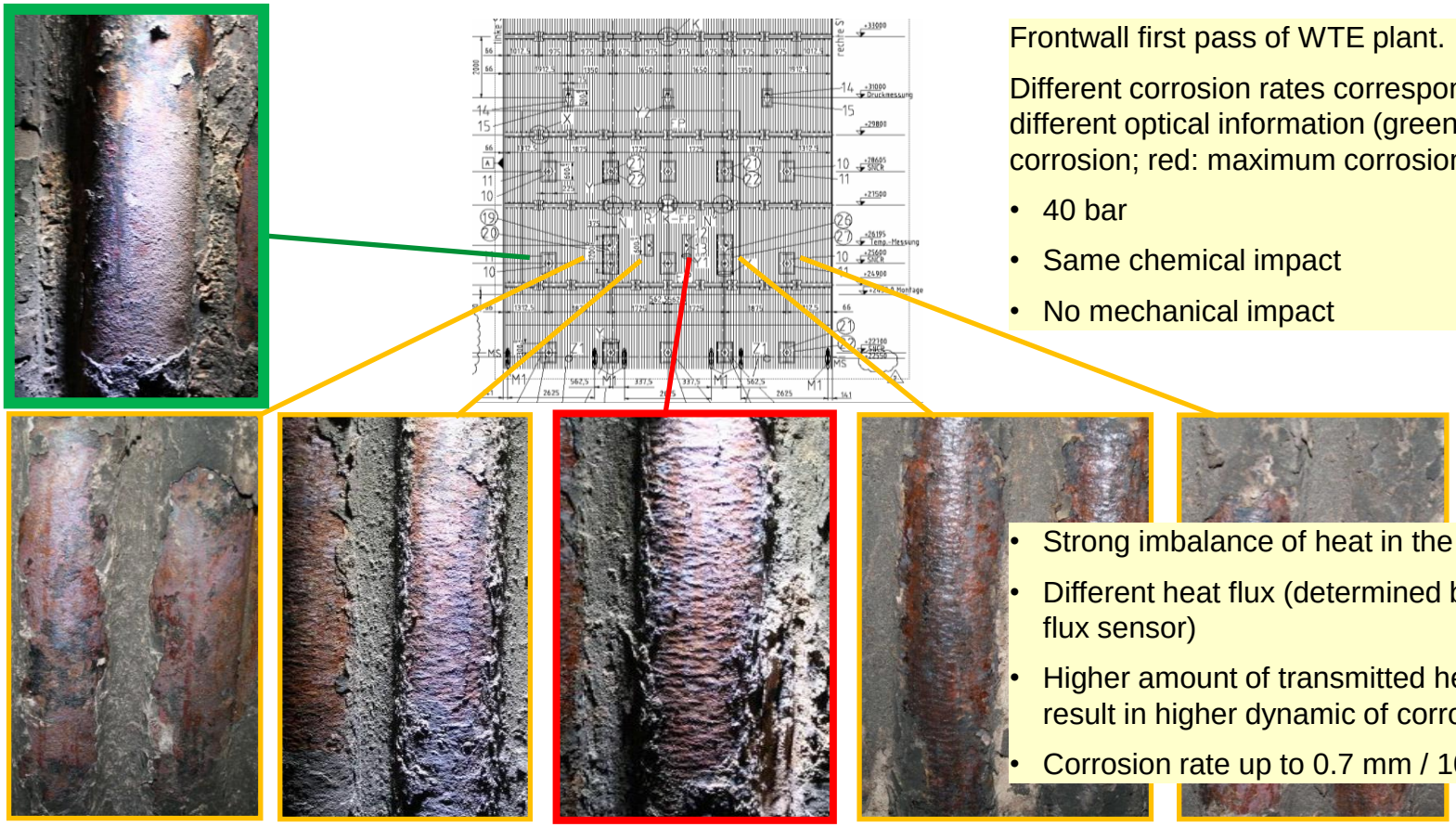
- Erosion by particle-load / -shape / -hardness
- Erosion by flue gas velocity
- Impact of online cleaning

Chemical environment

- Chemical compounds in the flue gas (most important: salts)
- Their load
- Proportions to each other
- Thermodynamic properties in relation to cooling

1-a) Thermal Environment

Example: Importance of heat transfer



Frontwall first pass of WTE plant.

Different corrosion rates correspond to different optical information (green: no corrosion; red: maximum corrosion).

- 40 bar
- Same chemical impact
- No mechanical impact

- Strong imbalance of heat in the flue gas
- Different heat flux (determined by heat flux sensor)
- Higher amount of transmitted heat result in higher dynamic of corrosion
- Corrosion rate up to 0.7 mm / 1000 h

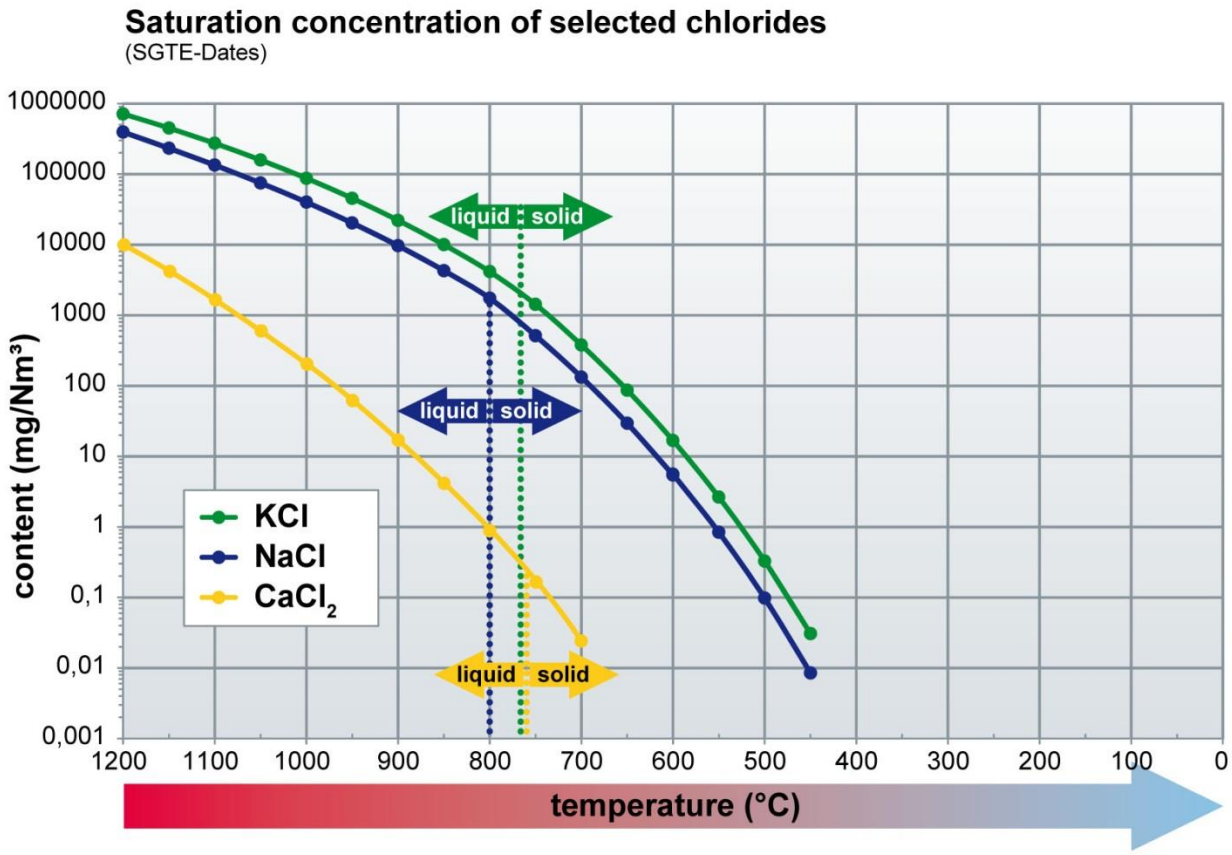
1-b) Mechanical Environment

Example: Impact of online cleaning (destruction of protective layers)

Influence of soot blower

1-c) Chemical Environment

Example: Importance of saturation of gaseous salts



Typical content of a gaseous salt after firing zone in WTE and biomass plants in the range below 1000 mg/Nm3

Saturation temperature:

- Calcium chloride at about 1000°C (= first pass)
- Potassium chloride and sodium chloride at about 700°C (= end of radiative part)

CaCl2: liquid particles

KCl/NaCl: solid particles

1-c) Chemical Environment

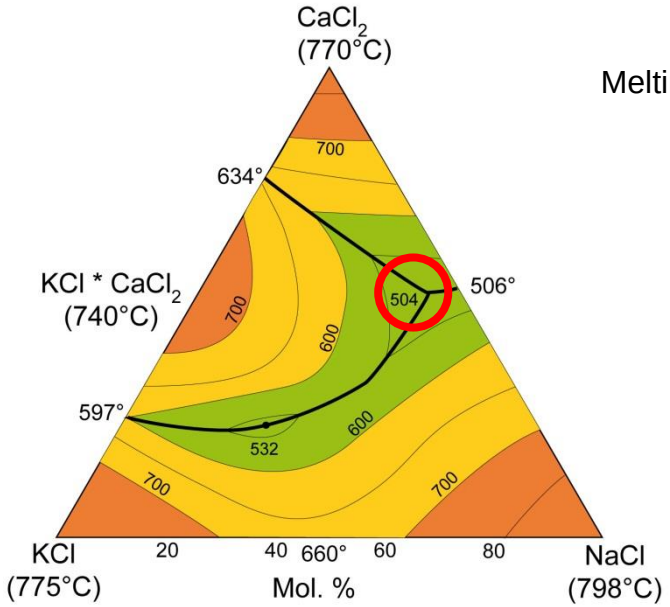
Example: **Importance of eutectic salt melts** (inside fouling)

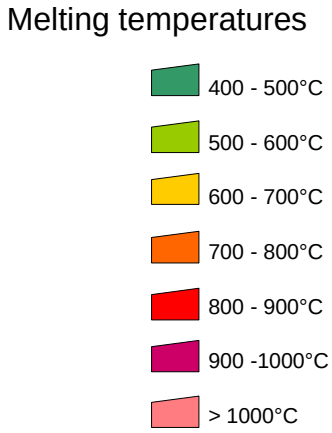
Chlorides form solid solutions.

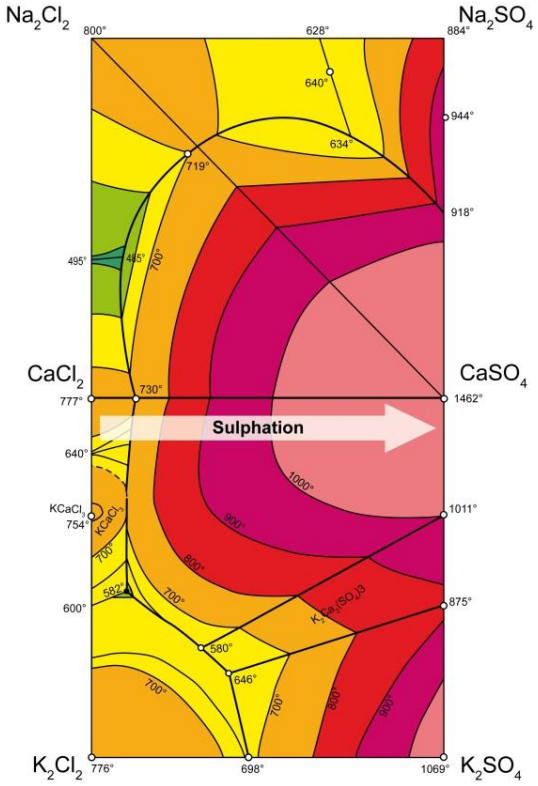
Chlorides and sulphates form solid solutions.

Inside fouling such solid-solid reactions between salts are possible.

Eutectic salt melts can be formed locally.







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Environment Evaluation

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Environment **Evaluation**

2) Technology for Evaluation

Online

Gathering of information by

- Probes
- Collectors
- Sensors

Offline (during maintenance, including scaffolding)

Inspection of non-cleaned boiler:
Gathering of information about fouling

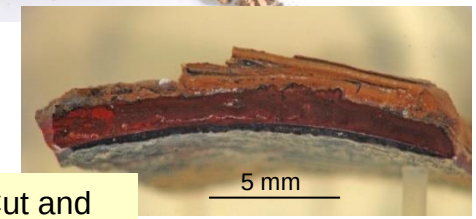
Inspection of cleaned boiler:
Gathering of information about tube wear

2-a) Online technology

Online probe (tube type) for multi-target issues

- Temperature-Range-Probe
- Cooled by pressurized air
- Temperature control and data logger

After removal



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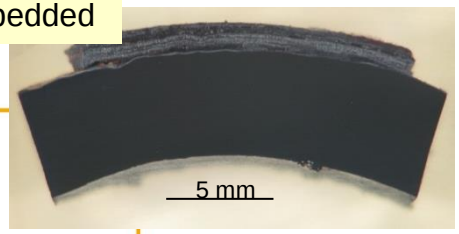

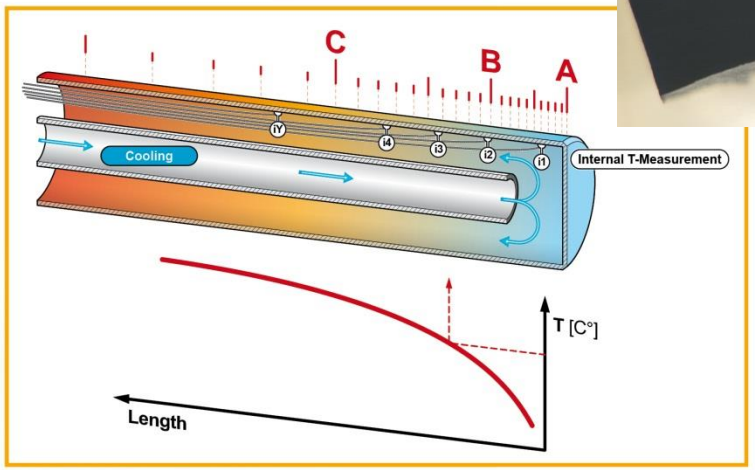

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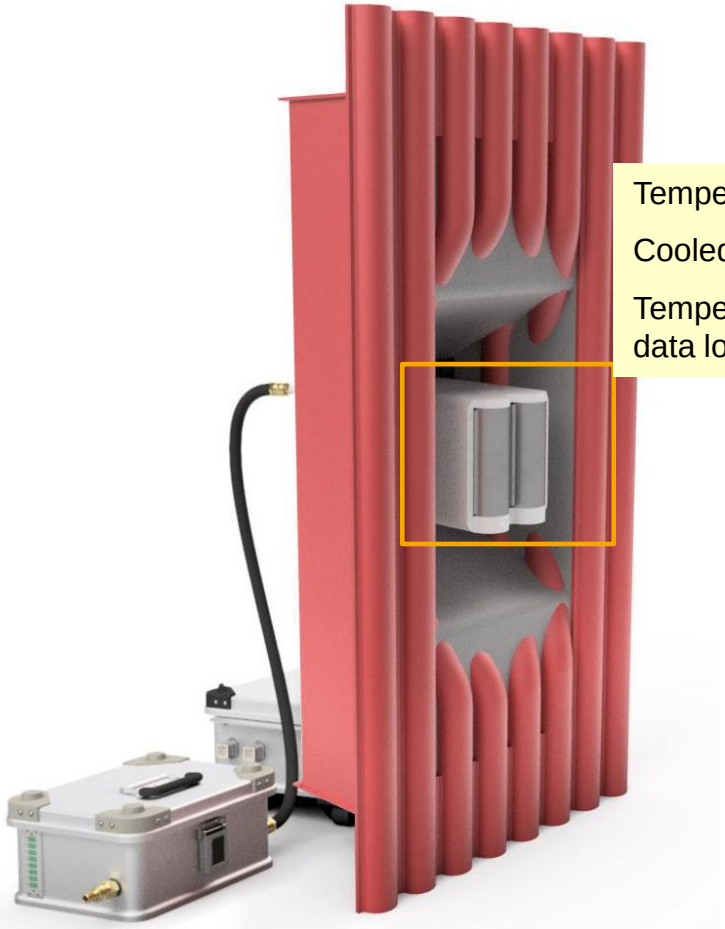
2-a) Online technology

Online probe (tube-wall type) for multi-target issues

After removal

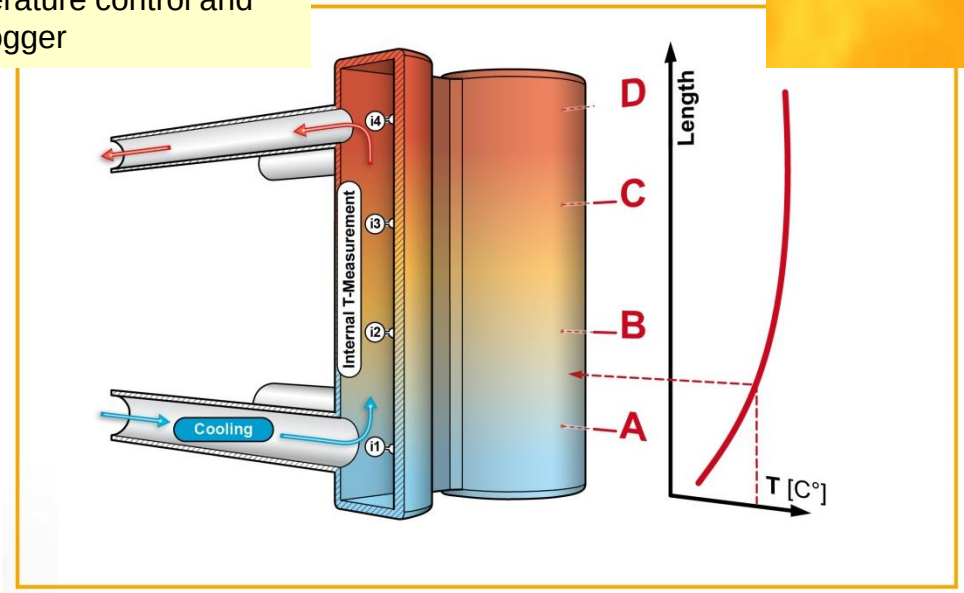
Installed probe



Temperature-Range-Probe

Cooled by pressurized air

Temperature control and data logger



2-a) Online technology

whole environment

Online-probes for multi-target issues have these functions and features:

- One-time probe for robust, quick and frequent use
- High variability of size (length, diameter), materials and positions inside the boiler
- Simulation of heat exchanging components
  - in the radiative part of the boiler
  - in the conductive part of the boiler
  - at the end of the boiler and ducts along flue gas cleaning
- Simultaneous identification of cause(s) of corrosion, mechanism of corrosion, corrosion rates, properties of the selected material (protective oxide layer) and fouling characteristics
- Free selectable level and range of material temperature
- Determination of dew point temperature and cause of dew point corrosion

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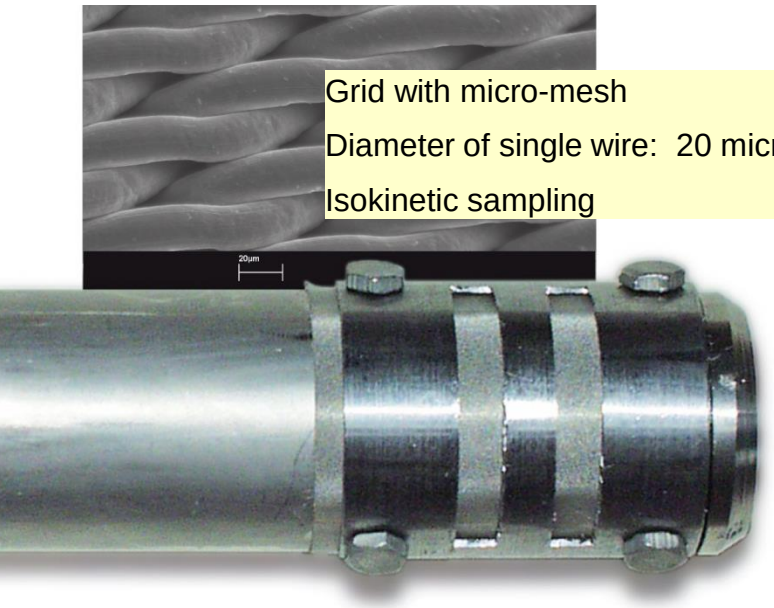
2-a) Online technology

chemical environment

Desublimation collector

Relevant information:

- Species of desublimating salts
- Species of solid particles
- Shape and size of solid particles

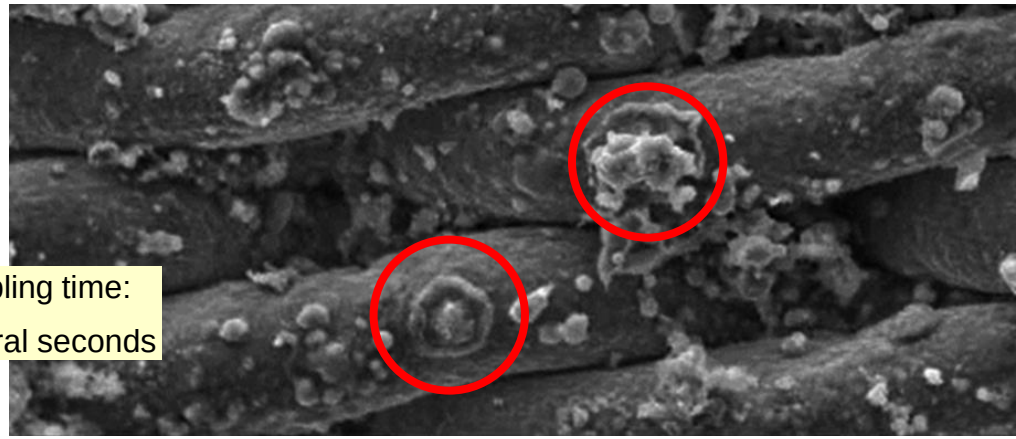


Grid with micro-mesh

Diameter of single wire: 20 micron

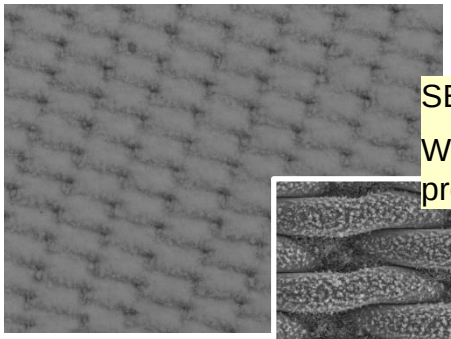
Isokinetic sampling

Example: Impact of particle into a layer of „mud“ of desublimated salts (WTE, superheater area)



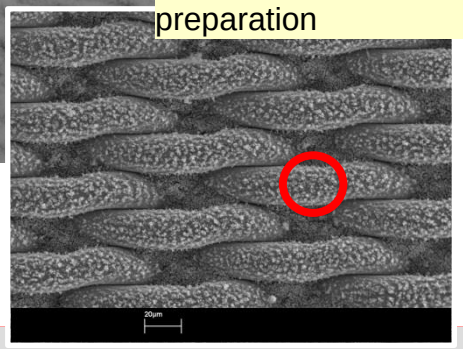
Sampling time:

Several seconds



SEM-EDX

Without further steps of preparation



Examples of different load of desublimated particles (WTE, superheater area)

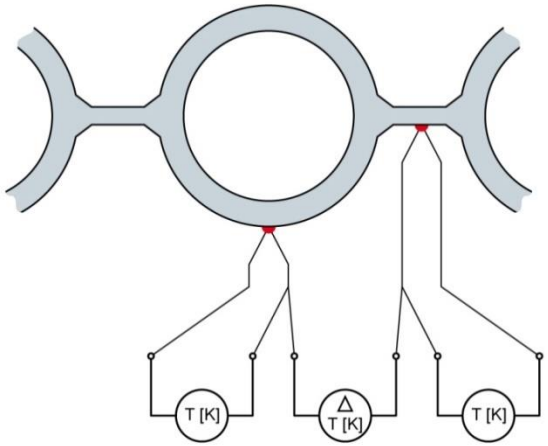
2-a) Online technology

thermal environment

Heat flux sensor

Relevant information:

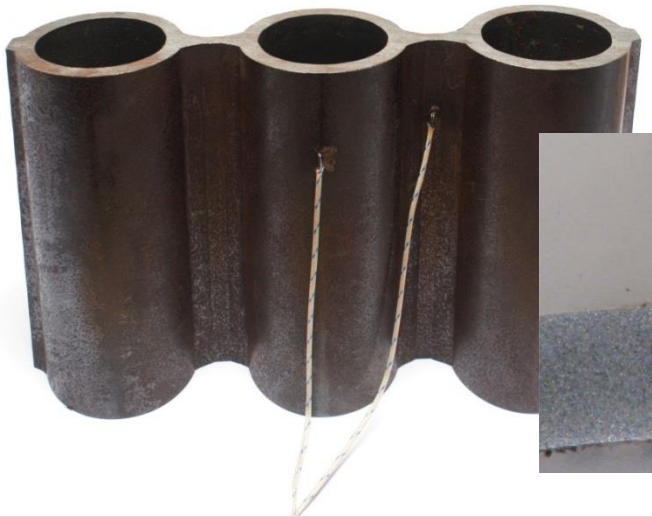
- Transparency of heat distribution
- Information about fouling (online cleaning)
- Information about imbalances
- Information about refractory damage
- Information for SNCR

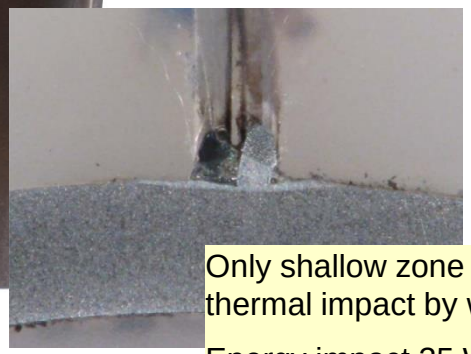


Two thermocouples are one sensor (one at fin position and one at crown of tube)

Attachment at the outside of the membrane wall

Several 10 of sensors along the flue gas path are a sensor system





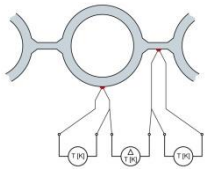
Only shallow zone of thermal impact by welding

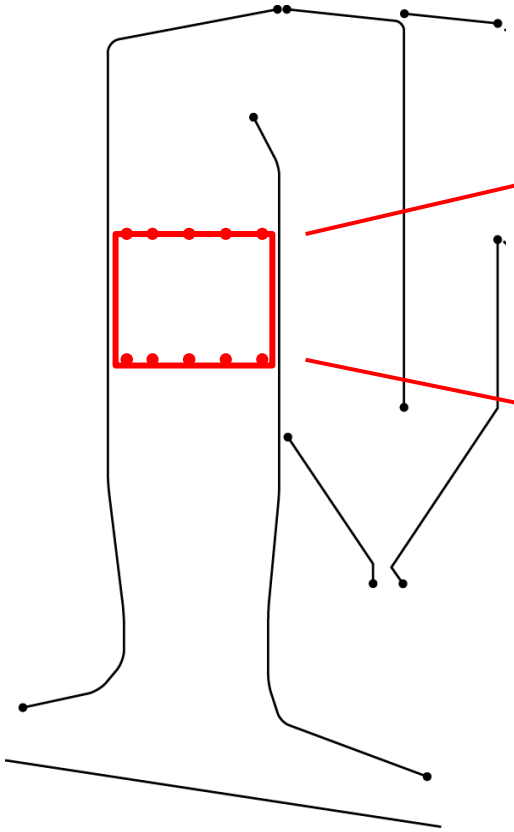
Energy impact 35 Ws

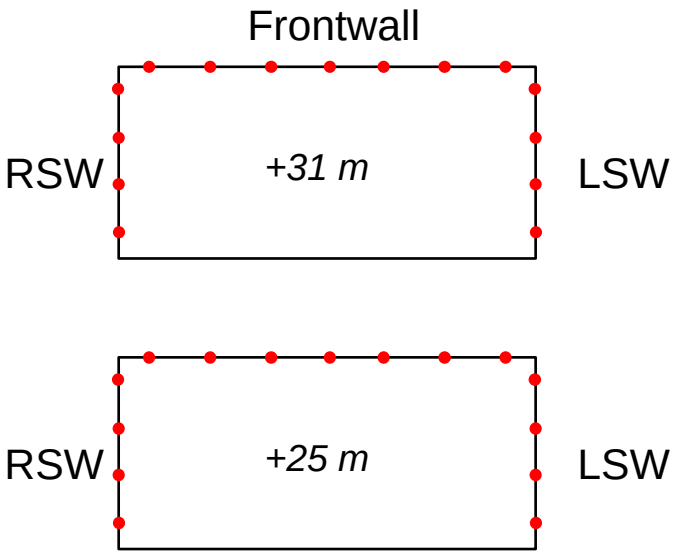
Data collection and storage near boiler

2-a) Online technology

Heat flux sensor system







Example:

Two levels of 15 sensors each in the first pass of a WTE plant at +25m and +31m

To detect imbalances of heat distribution.

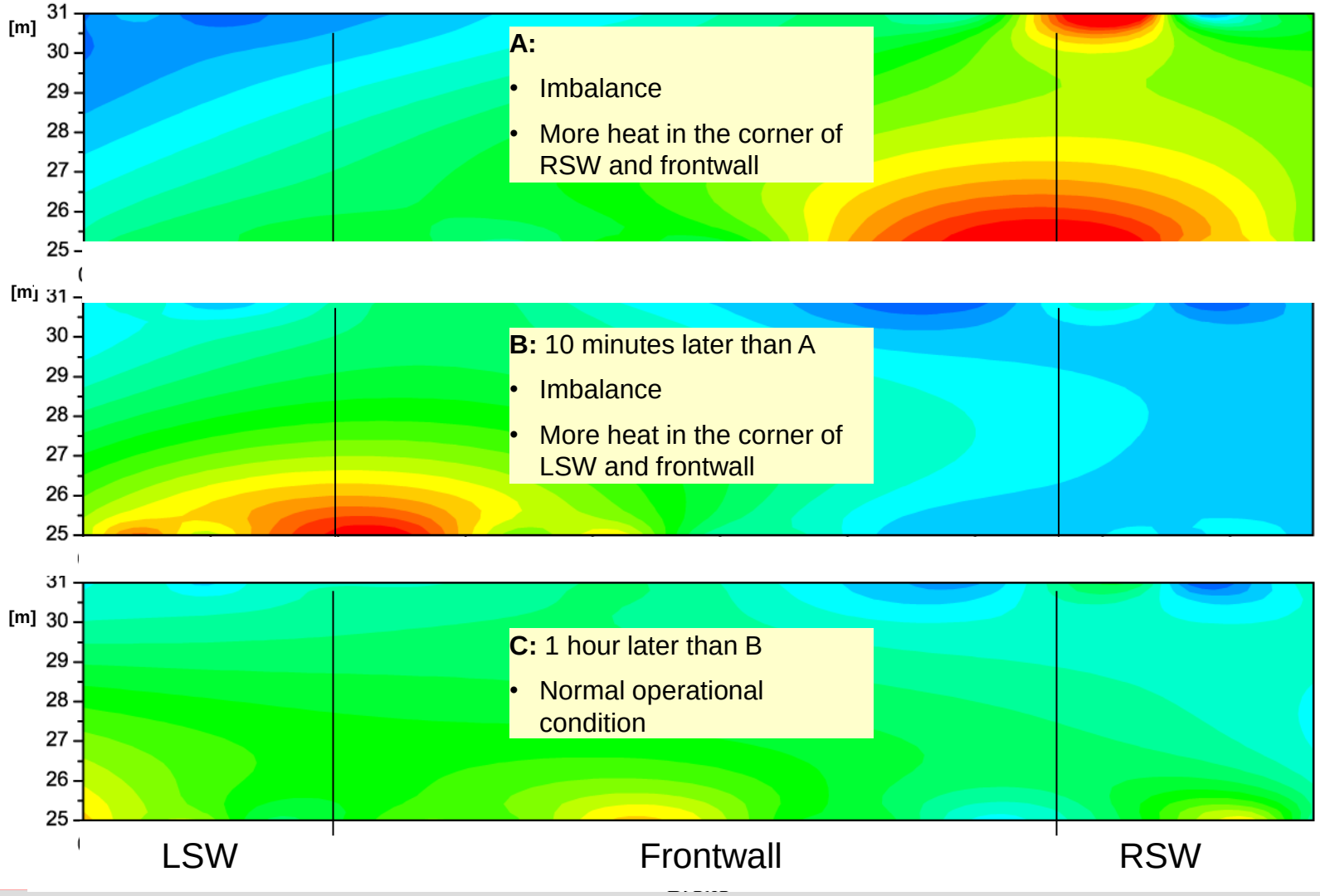
Data from these 30 thermocouples can be processed to visualize heat distribution between +25 and +31 m to support operator.

Monitoring of online signal.

Examples see next slide.

2-a) Online technology

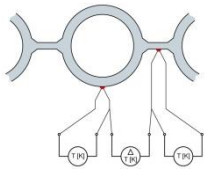
thermal environment



2-a) Online technology

thermal environment

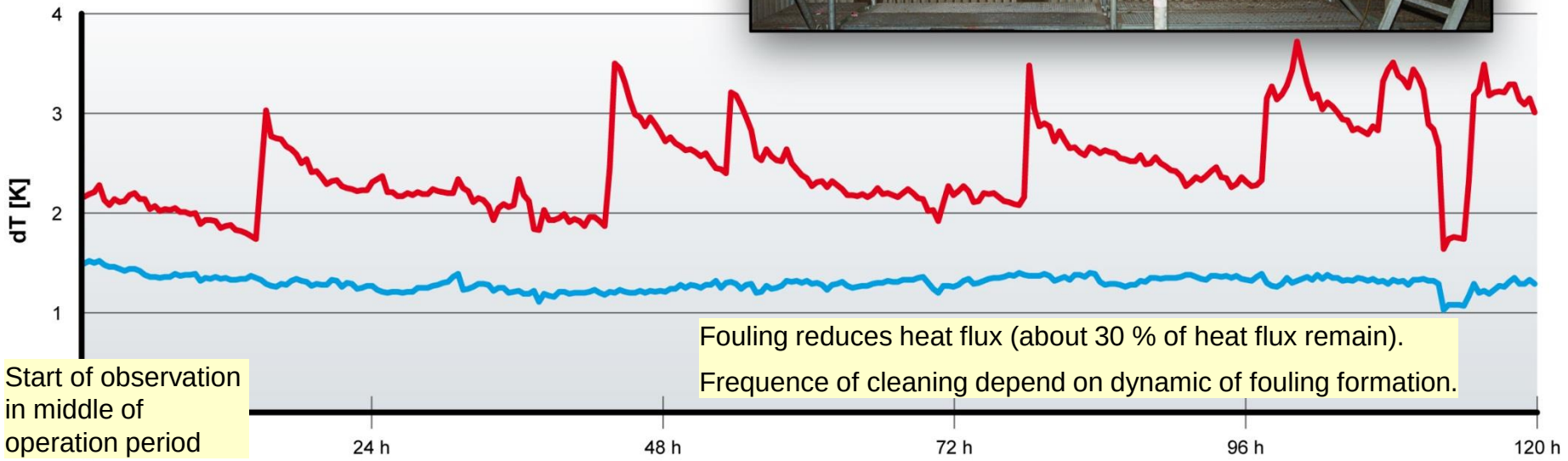
Heat flux sensor



To evaluate cleaning effectivness and optimum frequence of water canon cleaning in the first pass (example from biomass plant)

Position of heat flux sensor (outside)

View during outage



Start of observation in middle of operation period

Fouling reduces heat flux (about 30 % of heat flux remain).

Frequence of cleaning depend on dynamic of fouling formation.

2-b) Offline technology

Inspection during outage gives complementary information to online technology:

- Eyes of corrosion experts scan the boiler
- Uncover strong corrosion impact (mitigate unexpected outages)
- Evaluation of fouling (including sampling)
- Distribution of corrosion phenomena (local, systematic, general)
- Kind of corrosion effects and relation to materials
- Impact of online cleaning on boiler tubes

3) Conclusions

Targets supported by CEE

Integral measure for economic and ecologic targets, like:

- lower maintenance expenses
- higher availability of operation
- longer service life / operation period
- higher energy efficiency

Such targets typically are implemented by adaption processes, like:

- Optimization of the given operational situation
- Readjustment of changes in fuel and/or firing
- Shift of boiler parameters
- Use of corrosion/fouling mitigating additives

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Environment Evaluation