Deutsche Bundesstiftung Umwelt

Institut für angewandte Bau- und Reststoff-Forschung

Karlsruher Institut für Technologie

MHKW Mannheim Nord

Increasing of the Energy Efficiency of Power Plants by Optimization of the Heat Transfer in the Boiler

KIT, 23.03.2011

DBU-PROJECT

Sponsored by:

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Project Management:

IBR Institut für angewandte Bau- und Reststoff-Forschung

Dr.-Ing. Jürgen Reichelt

Partners:

KIT Karlsruher Institut für Technologie

ITC/TAB:
Prof. Dr.-Ing Helmut Seifert
Dr. Gudrun Pfrang-Stotz
(project manager)
Dr. Britta Bergfeldt

MVV Umwelt

MHKW Mannheim Nord

Dipl.-Ing Peter Knapp

STRUCTURE

- Problem and objective
- Principles: Formation of deposits on heat exchangers
- Research results from MSWI power plants
- Practical implementation
  - classification of deposits
  - valuation of different boiler systems
  - influence of reconstruction measures and waste input
- Comparison of deposits of different power plants
- Research results from biomass power plants
- Summary

PROBLEM AND OBJECTIVE

problem:

- encreased formation of deposits on heat exchangers
- formation of large deposits which are difficult to remove
- reduced heat transfer from the flue gas to the heat exchangers

objective:

- reduction of the velocity of the formation process
- formation of uncritical deposits
- longer cleaning intervals
- improvement of the heat transfer to the heat exchangers
- increase of energy efficiency

PROBLEM AND OBJECTIVE: procedure

investigation of the fouling behaviour of 3 different boilers of the MSWI power plant Mannheim:
different boilers show different process technologies, flue gas temperatures and fouling rates

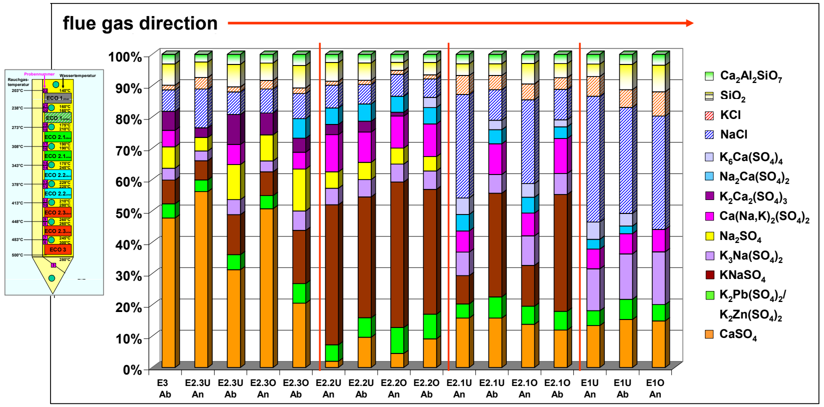
boiler 2

boiler 4

boiler 5

high flue gas temperatures

high formation of deposits



low flue gas temperatures

low formation of deposits

1. zone | 2. zone | 3. zone | 4. zone

temperatures:

500 – 413°C

413 – 343°C

343 – 273°C

273 – 206°C

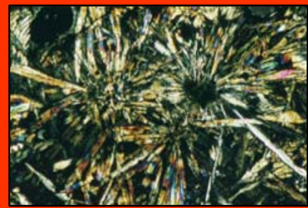
PROBLEM AND OBJECTIVE: extent of the investigations

boilers of different process technology

mineralogical-chemical characterization of the deposits

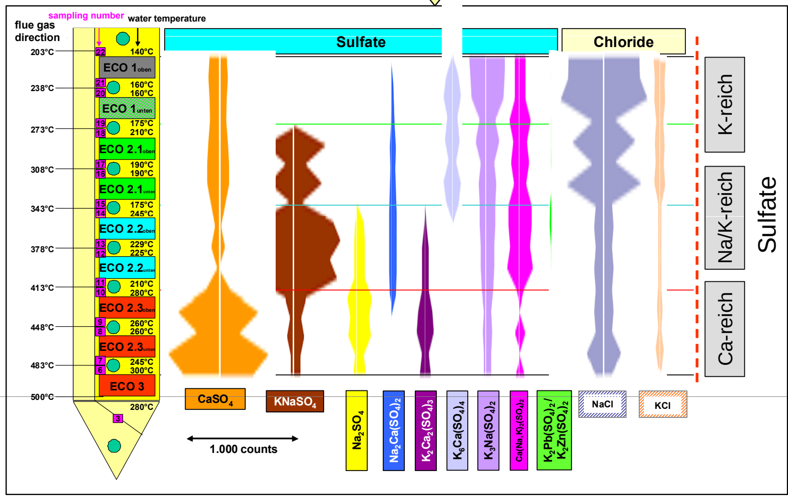
mineralogical-chemical characterization of flue gas particles

correlation: test results and macroscopic appearance

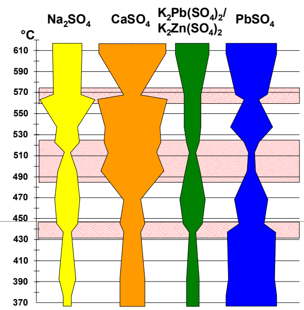


heating tests on deposits in laboratory scale

mineralogical boiler profile



formation of deposits on heat exchangers

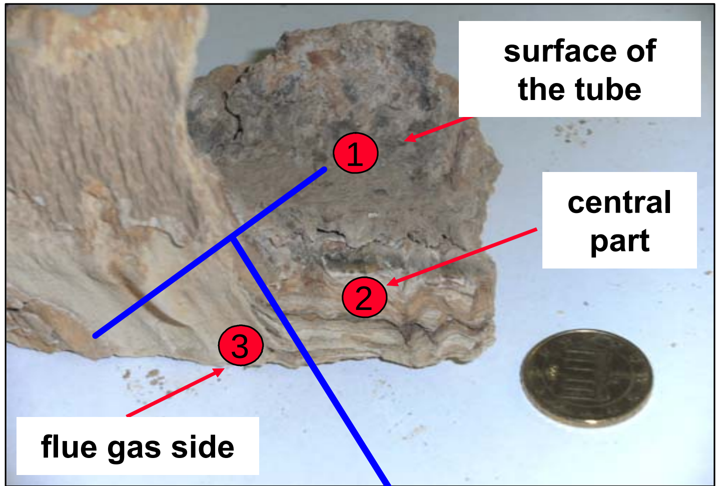


fundamental diagram

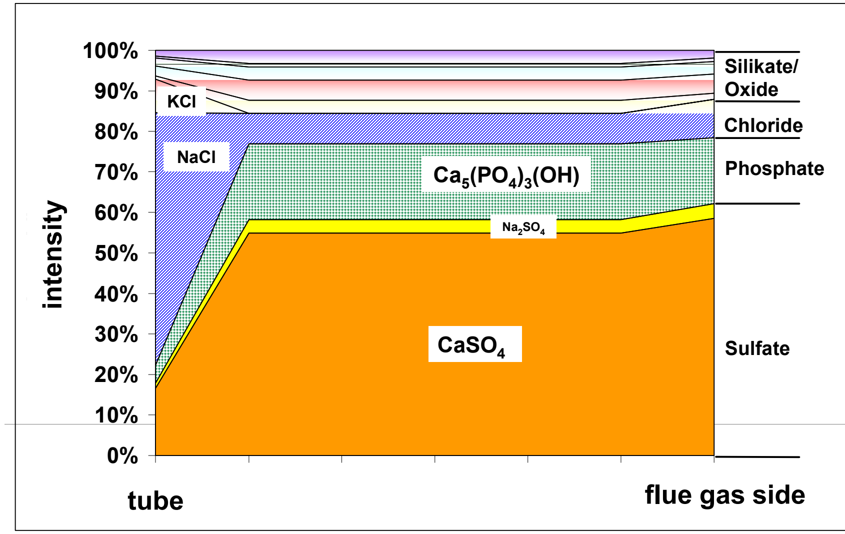
PRINCIPLES: appearance of deposits in power plants

PRINCIPLES: preparation of the deposits

division of the sample in different layers



different informations about the mineralogical and chemical composition of the deposit and the formation process



mineralogical cross section

sample

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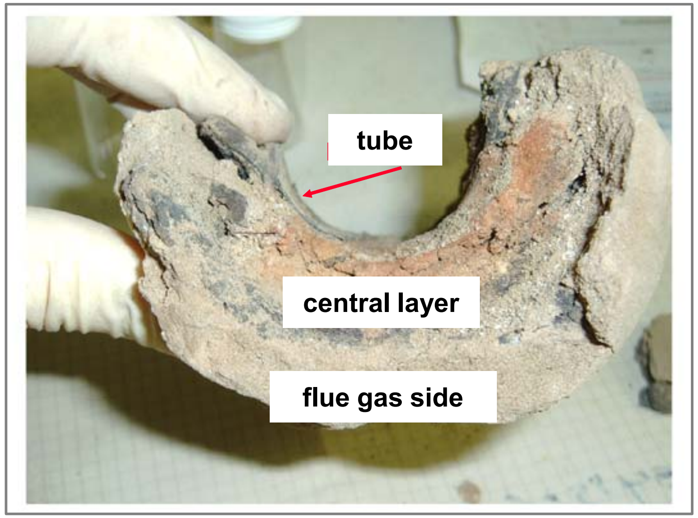
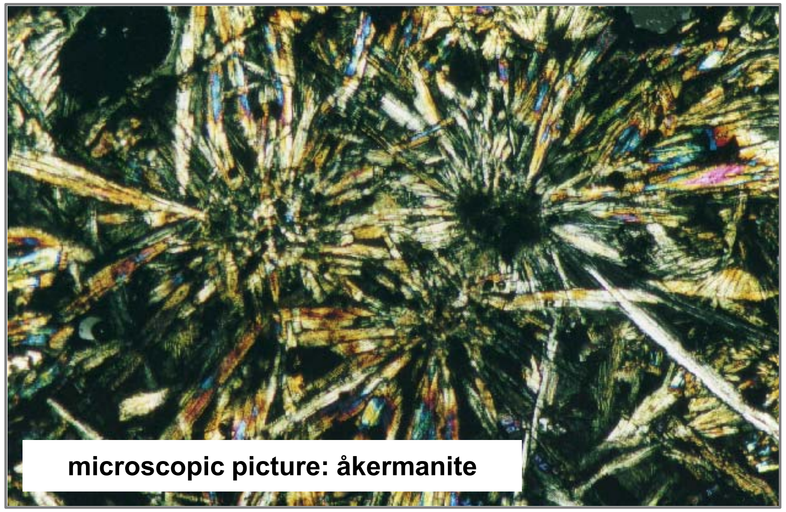
PRINCIPLES: mineralogical investigations



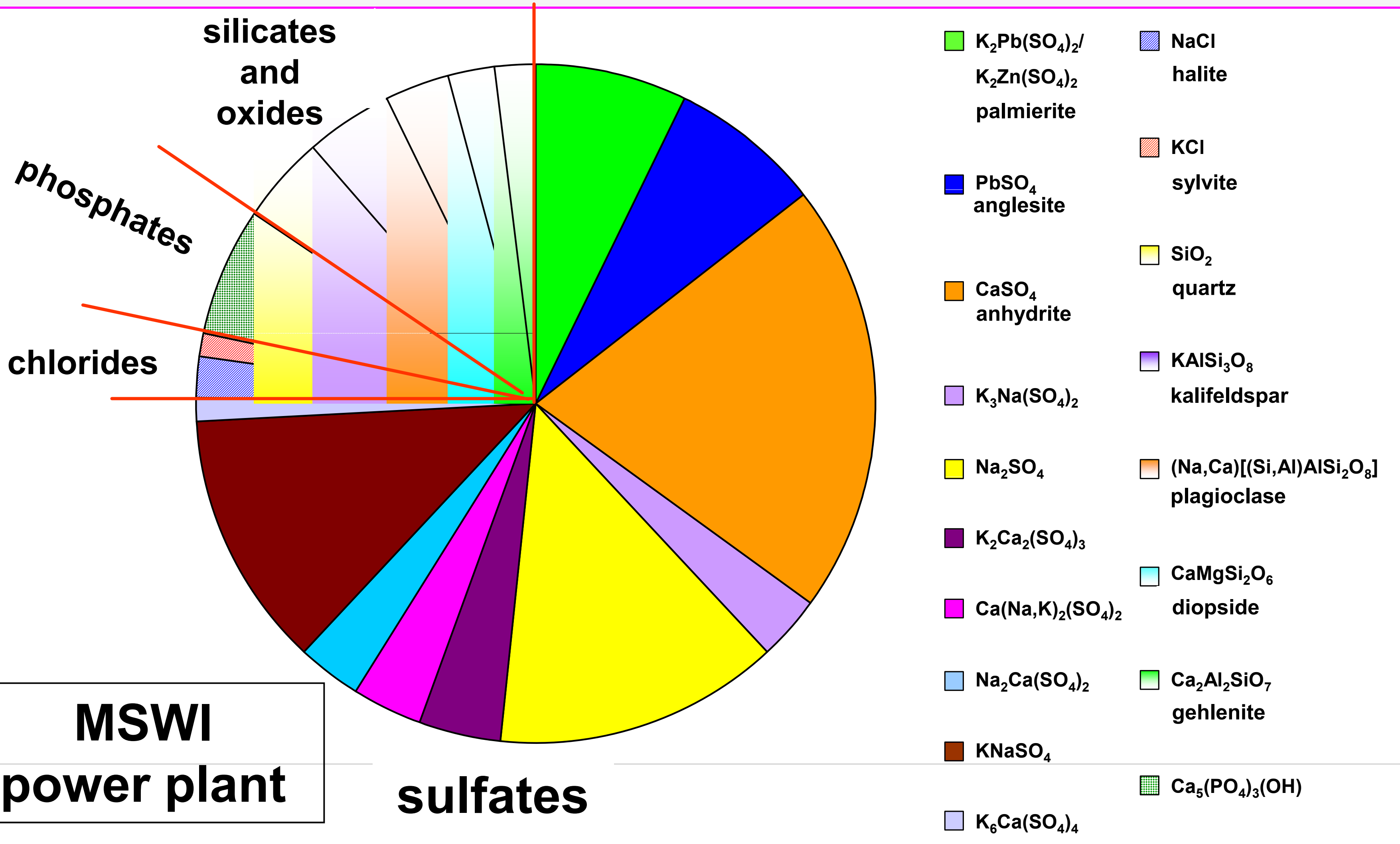


mineral phases

chemical properties | **physical properties**

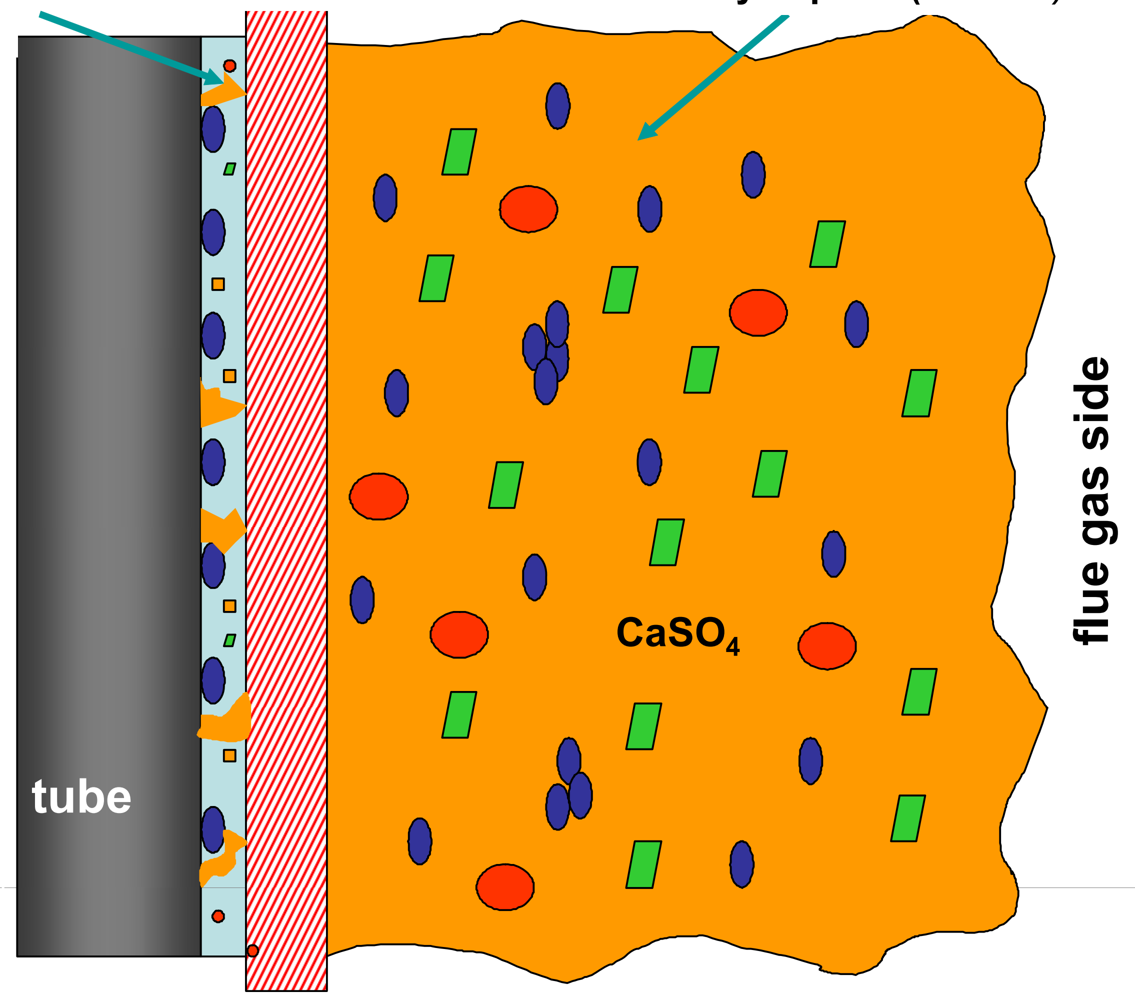
- formation conditions
- hardness
- melting points
- corrosion effects

PRINCIPLES: mineral phases of the deposits

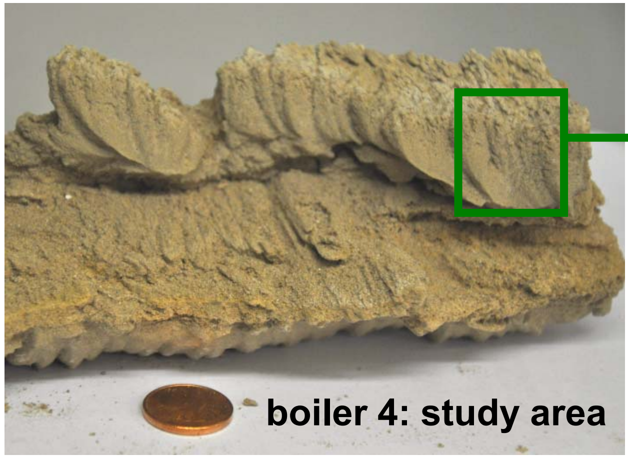


MSWI power plant

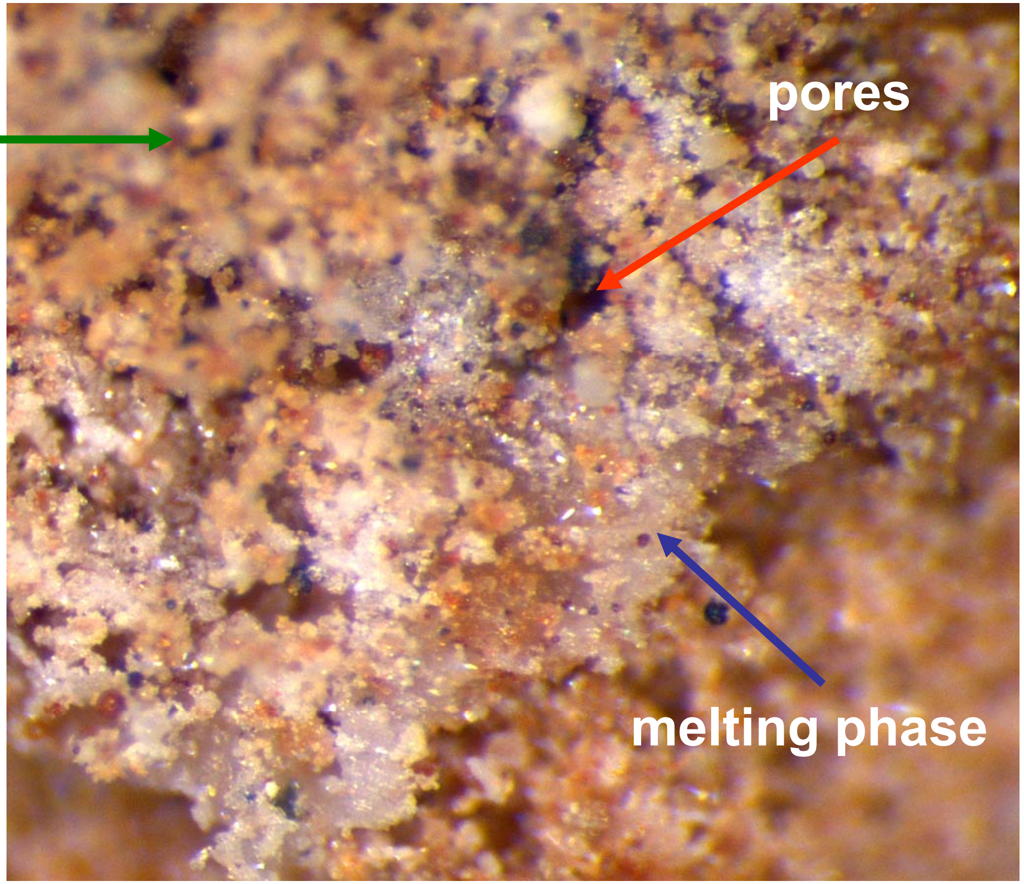
PRINCIPLES: structural and mineralogical composition



PRINCIPLES: structural and mineralogical composition

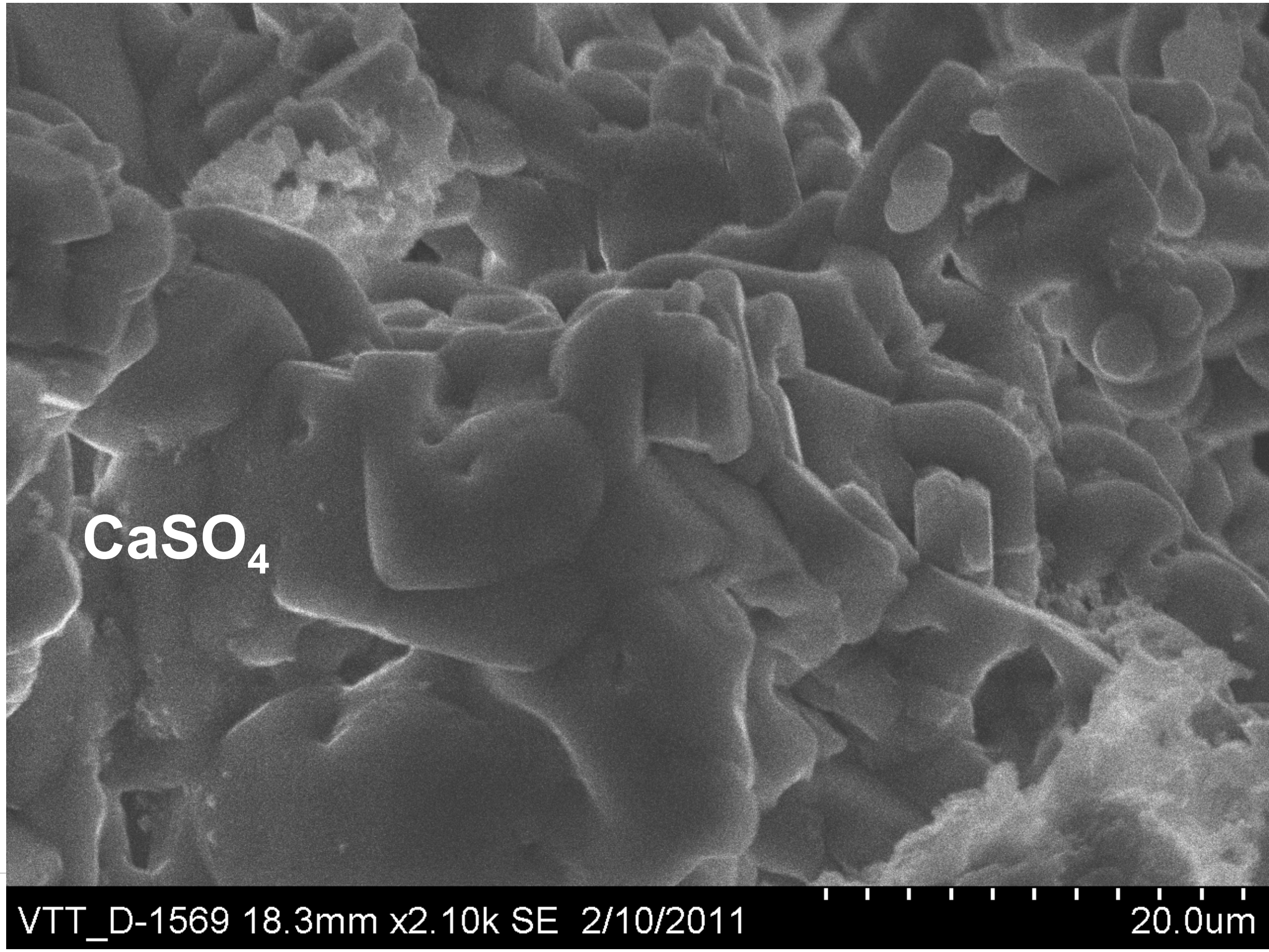


Deposits:
- mineral phases (crystals)
- melting phase
- pores

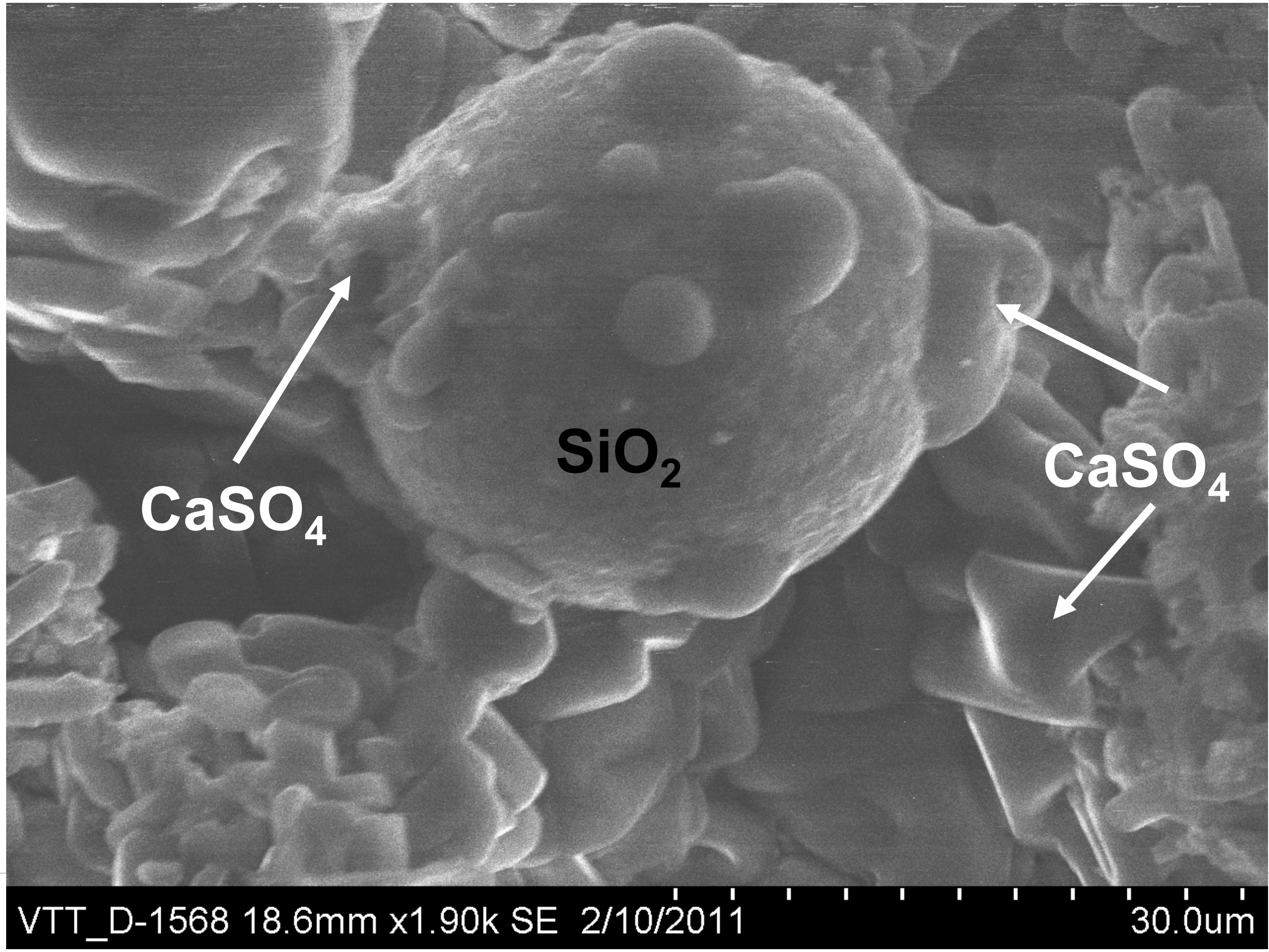


microscopic picture of a deposit

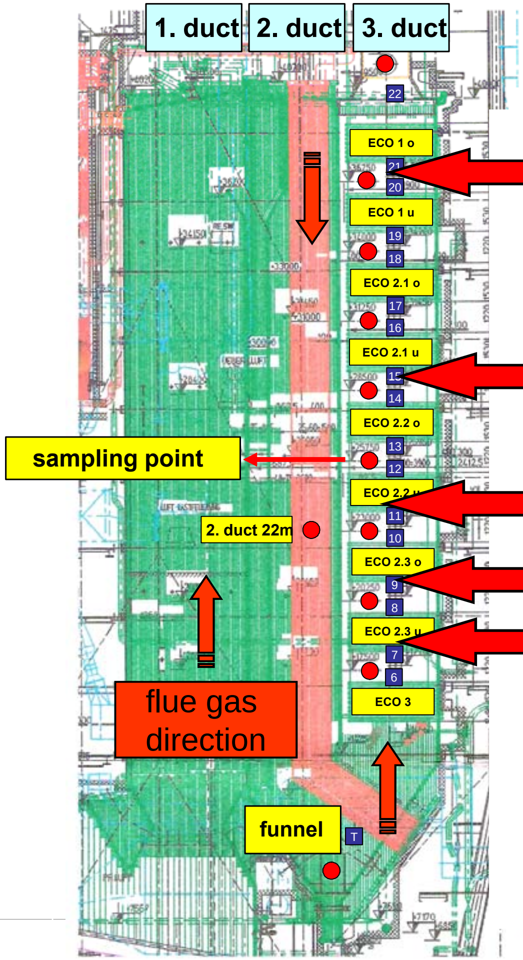
PRINCIPLES: structural and mineralogical composition



PRINCIPLES: structural and mineralogical composition



RESULTS: MSWI power plant: MVV, boiler 4



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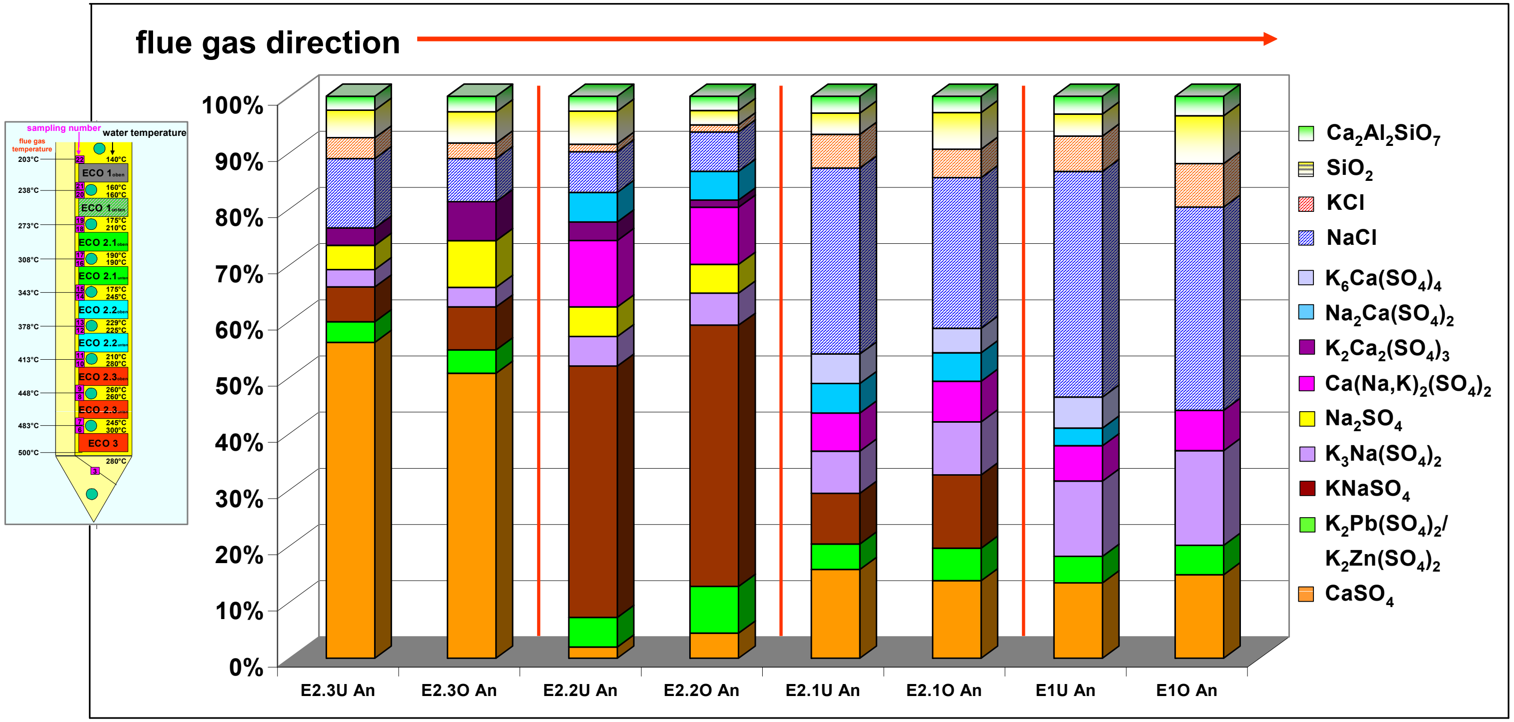
RESULTS: mineralogical composition: MVV, boiler 4



1. zone · 2. zone · 3. zone · 4. zone

temperatures:

- 500 – 413°C
- 413 – 343°C
- 343 – 273°C
- 273 – 206°C

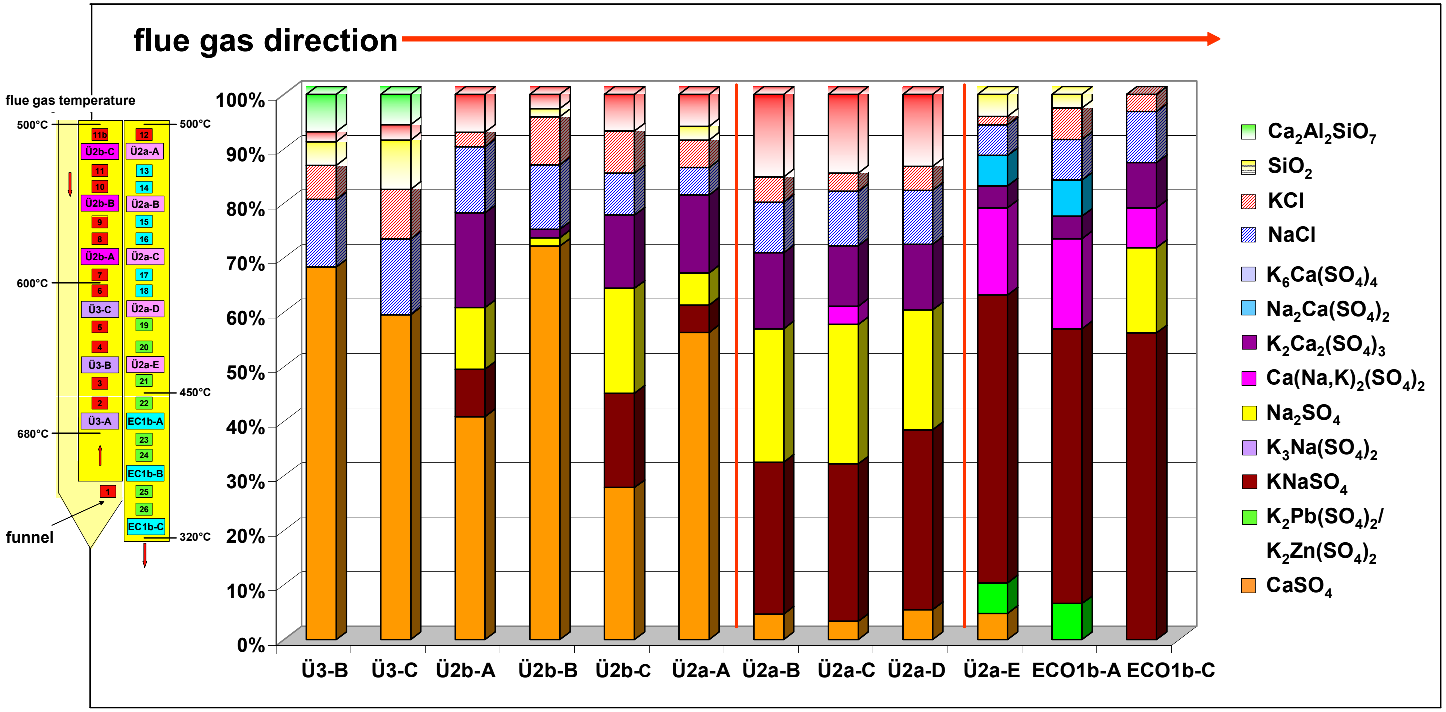
very hard / hard

breakable

easily breakable

dusty

RESULTS: mineralogical composition: MVV, boiler 2



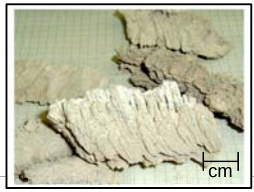
temperatures:

680 – 500°C

500 – 470°C

470– 320°C

1. zone



very hard / hard

2. zone

breakable

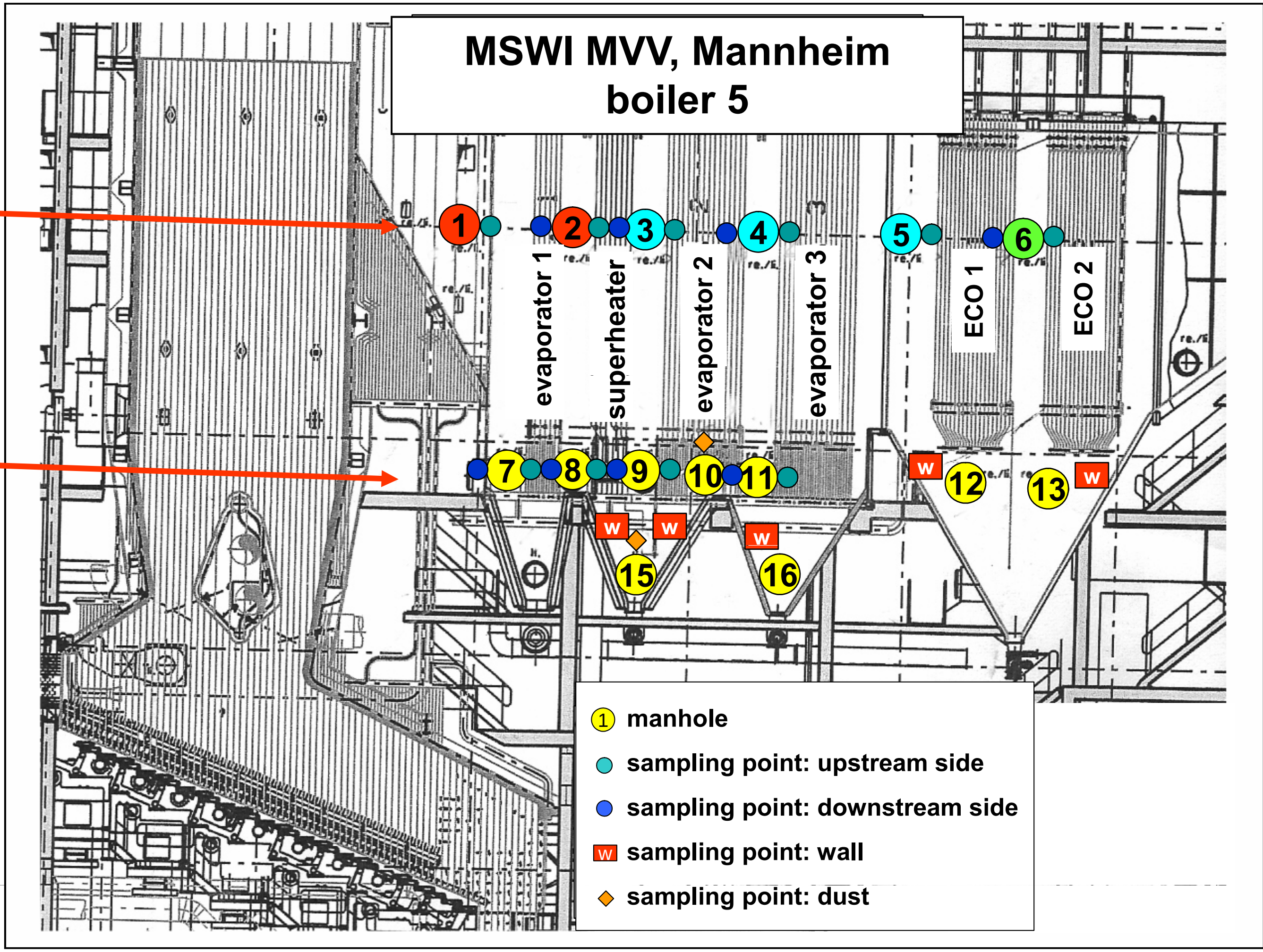
3. zone

easily breakable

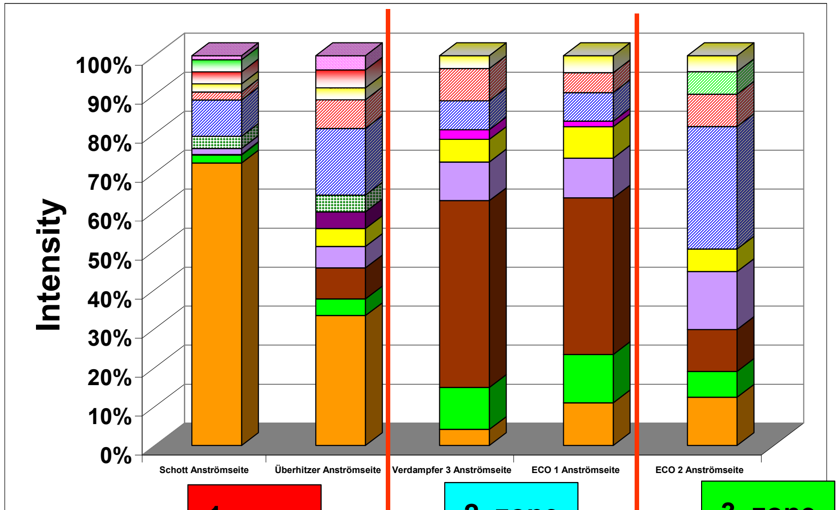
RESULTS: MSWI power plant: MVV, boiler 5

upper sampling level

lower sampling level



RESULTS: mineralogical composition: MVV, boiler 5



1. zone | 2. zone | 3. zone

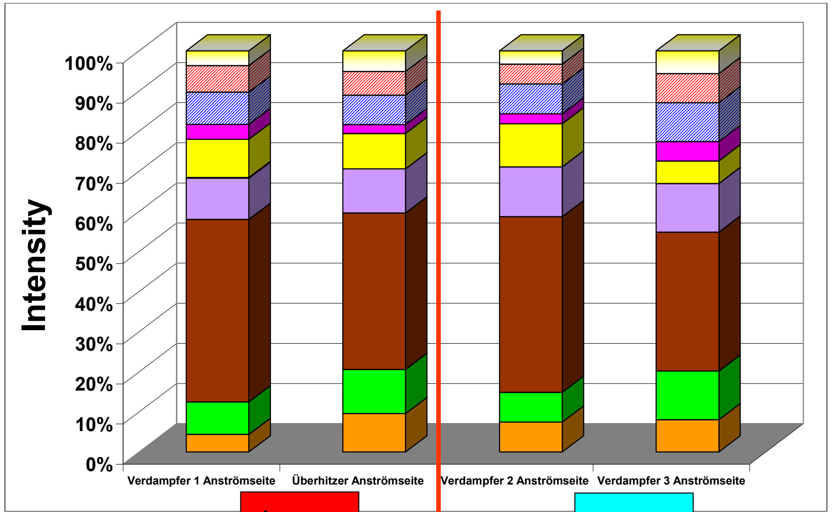
temperatures:

700 – 595°C

595 – 355°C

355 – 260°C

breakable | easily breakable | dusty



1. zone | 2. zone

temperatures:

700 – 595°C

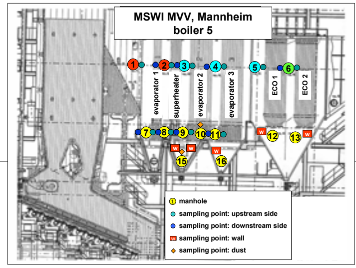
595 – 355°C

easily breakable | easily breakable

upper sampling level

„physical“ + „mineralogical“ forming of deposits

⇨ harder deposits at the inlet area



lower sampling level

„mineralogical“ forming of deposits

⇨ weak deposits at the inlet area

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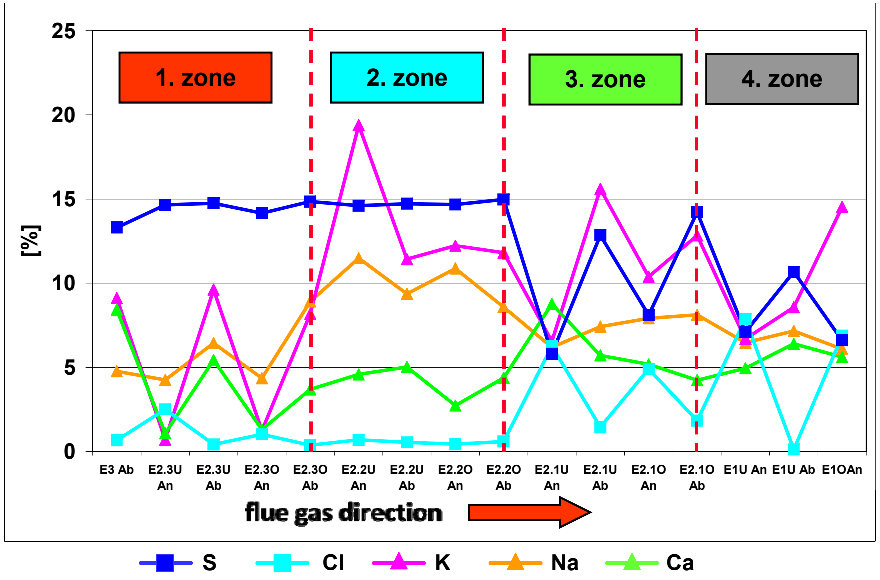
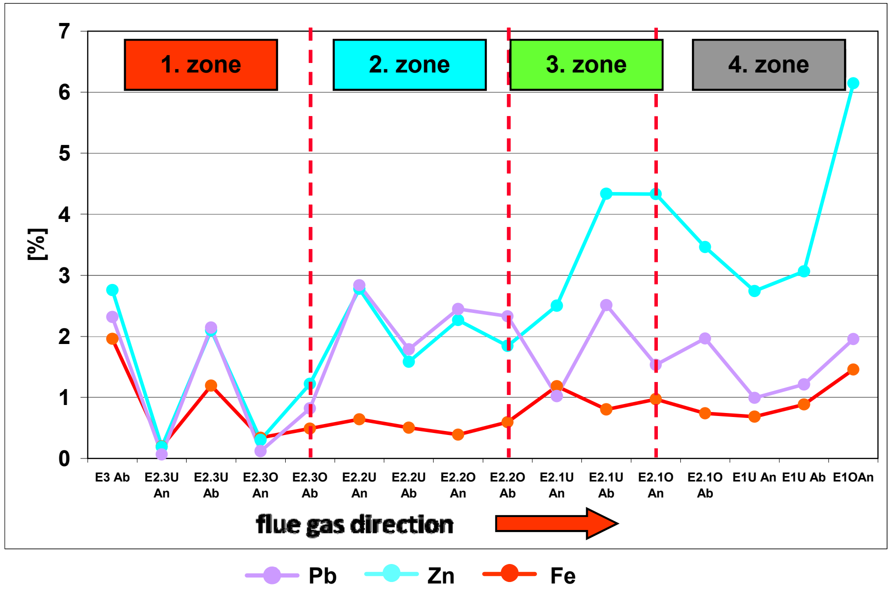
RESULTS: chemical test results: MVV, boiler 4

chemical investigations

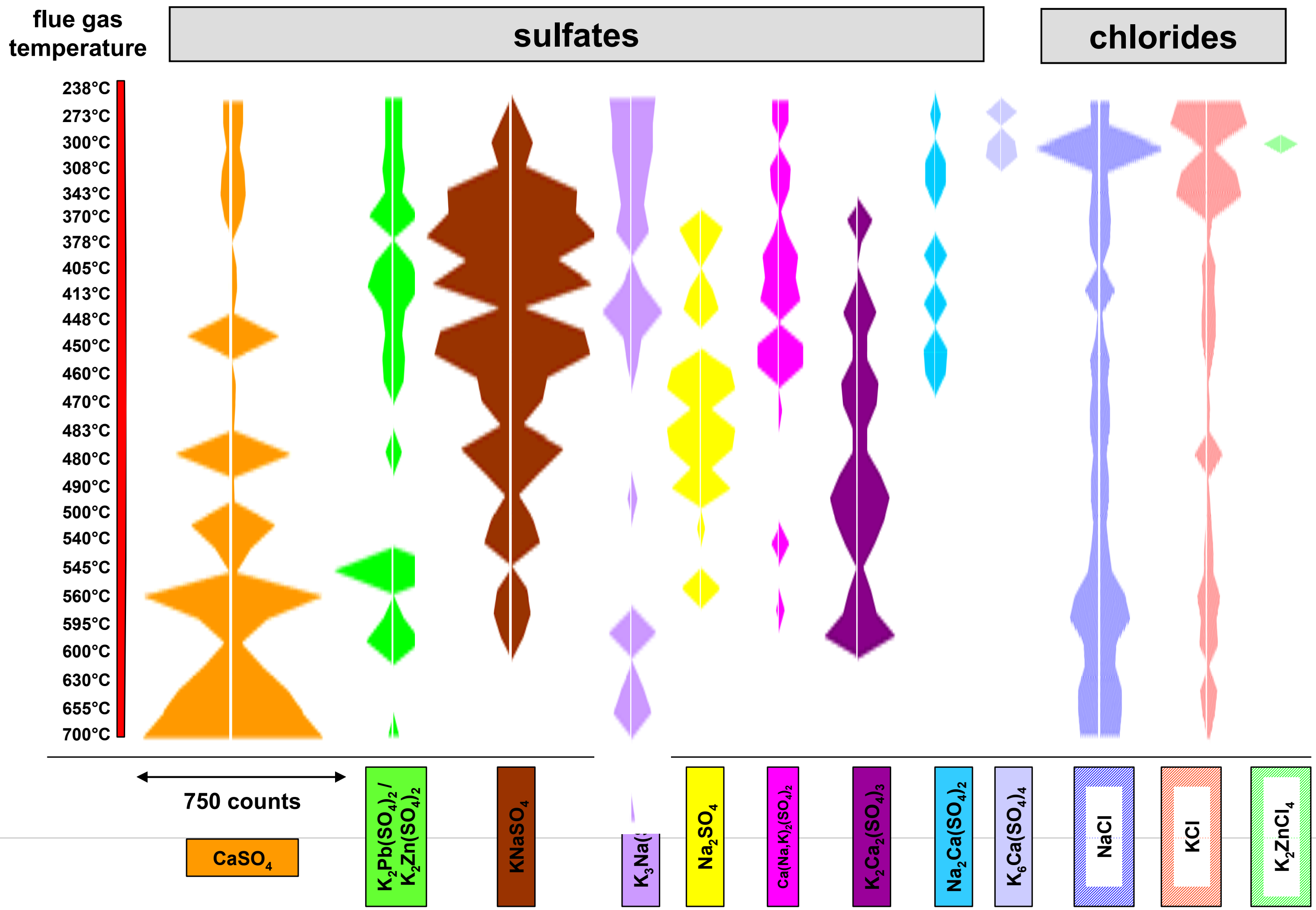
main elements



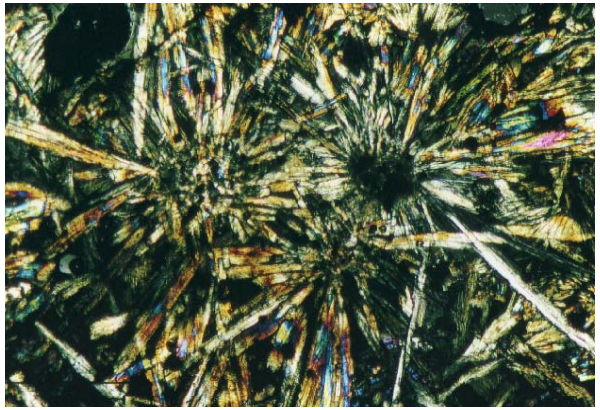
heavy metals / metals:



RESULTS: mineralogical temperature profile of boilers 2, 4 and 5



PRACTICAL IMPLEMENTATION



mineralogy
process technology

very critical ⇦ **classification of deposits** ⇨ uncritical

evaluation of the deposits

specific technical measures to reduce the forming of critical deposits

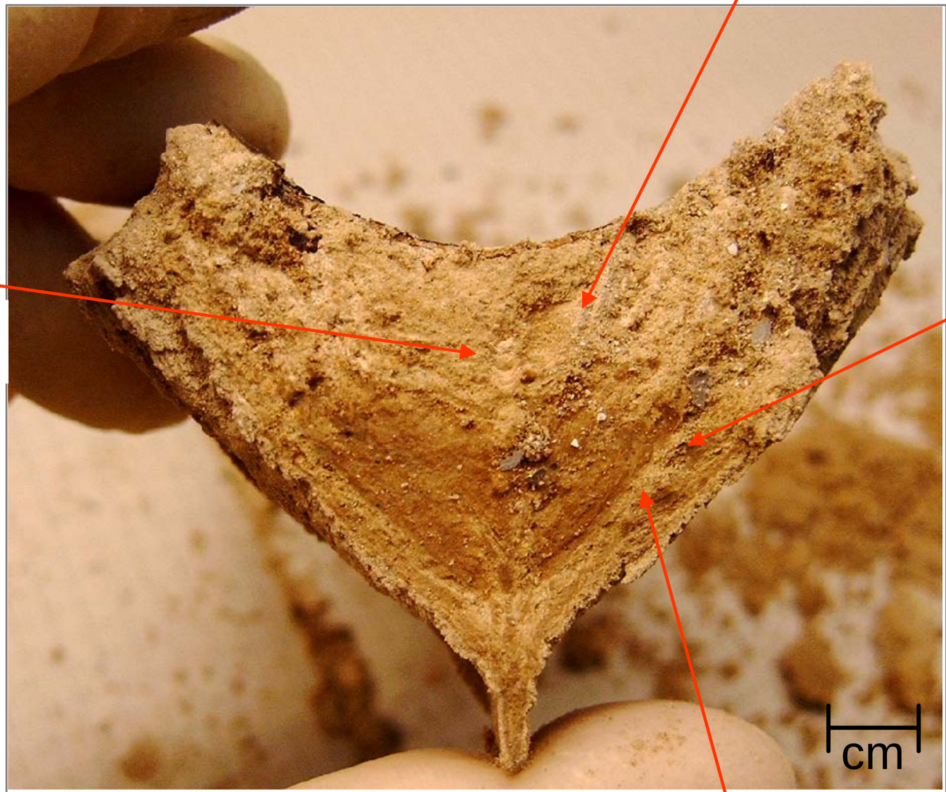
PRACTICAL IMPLEMENTATION: basis of valuation

4 parameters:

macroscopic appearance

hardness

thickness



mineralogical composition

PRACTICAL IMPLEMENTATION: classification of deposits (refer to heat transfer / cleaning)

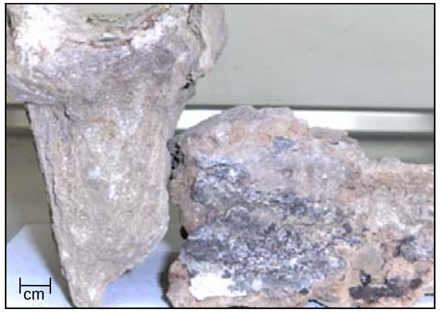
reduced heat transfer

voluminous, hardness

fast growing, difficult to clean

good heat transfer

class 1 very critical



class 2 critical

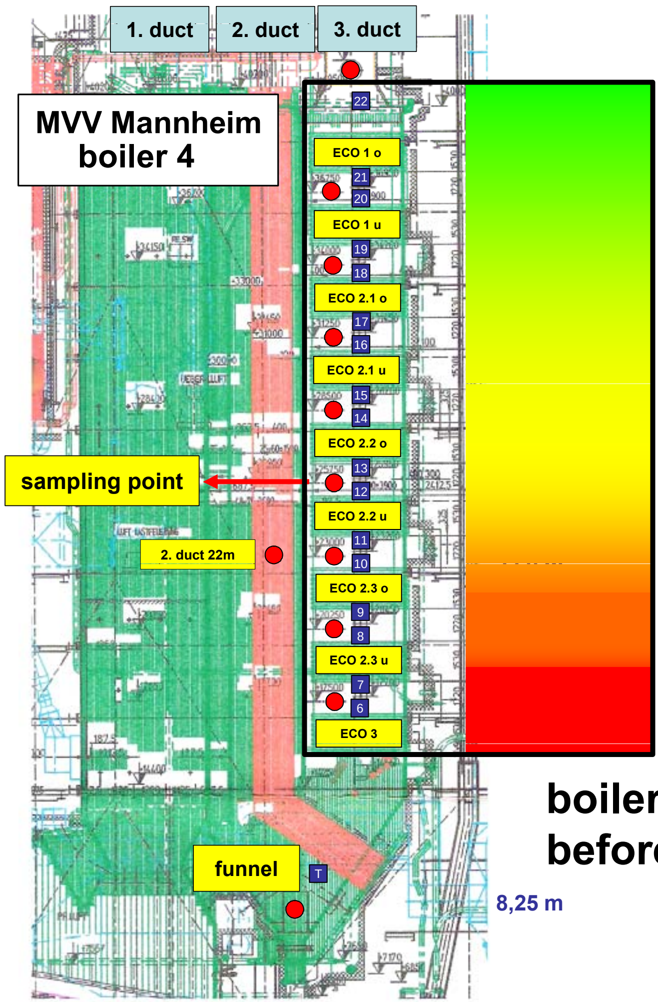
class 3a acceptable

class 3b acceptable

class 4a uncritical

class 4b uncritical

PRACTICAL IMPLEMENTATION: valuation

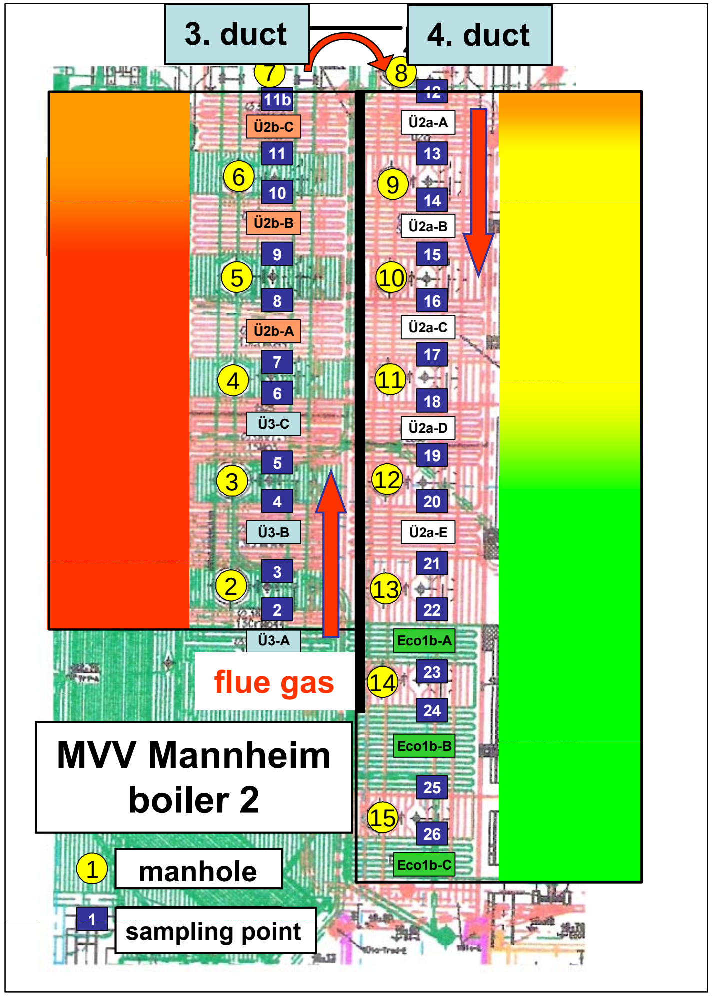


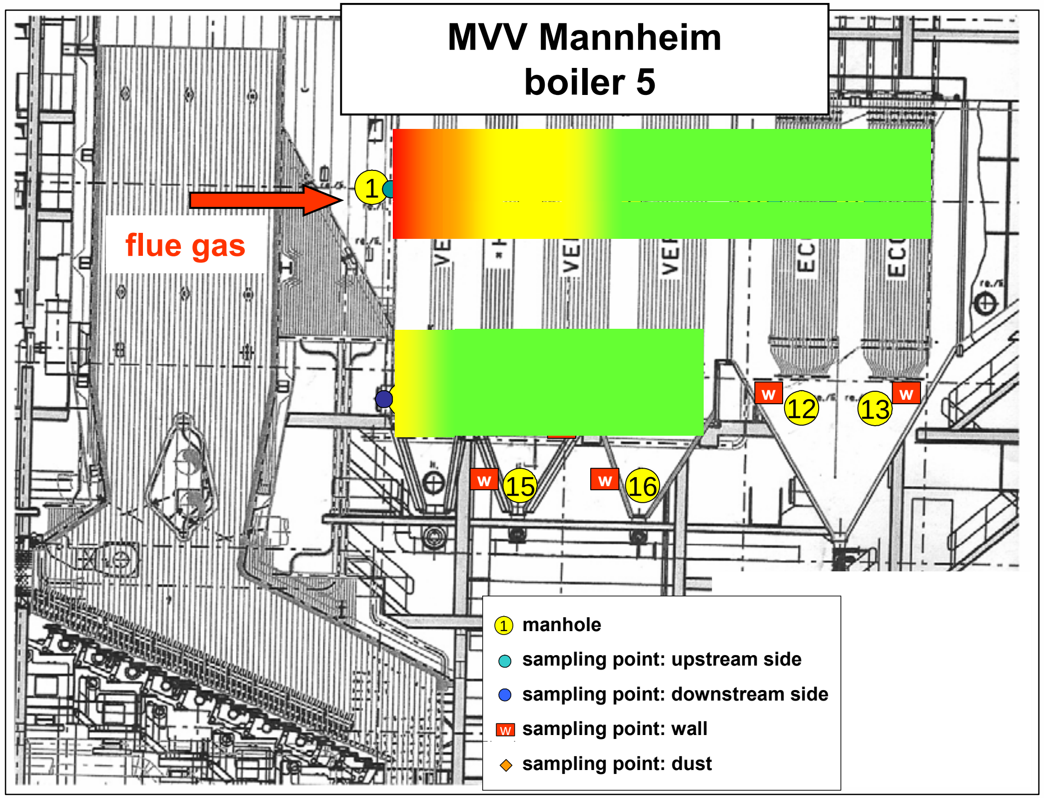
influence of the process technology (boiler 4)

classification	
1	very critical
2	critical
3	acceptable
4	uncritical

boiler profile before reconstruction

PRACTICAL IMPLEMENTATION: valuation



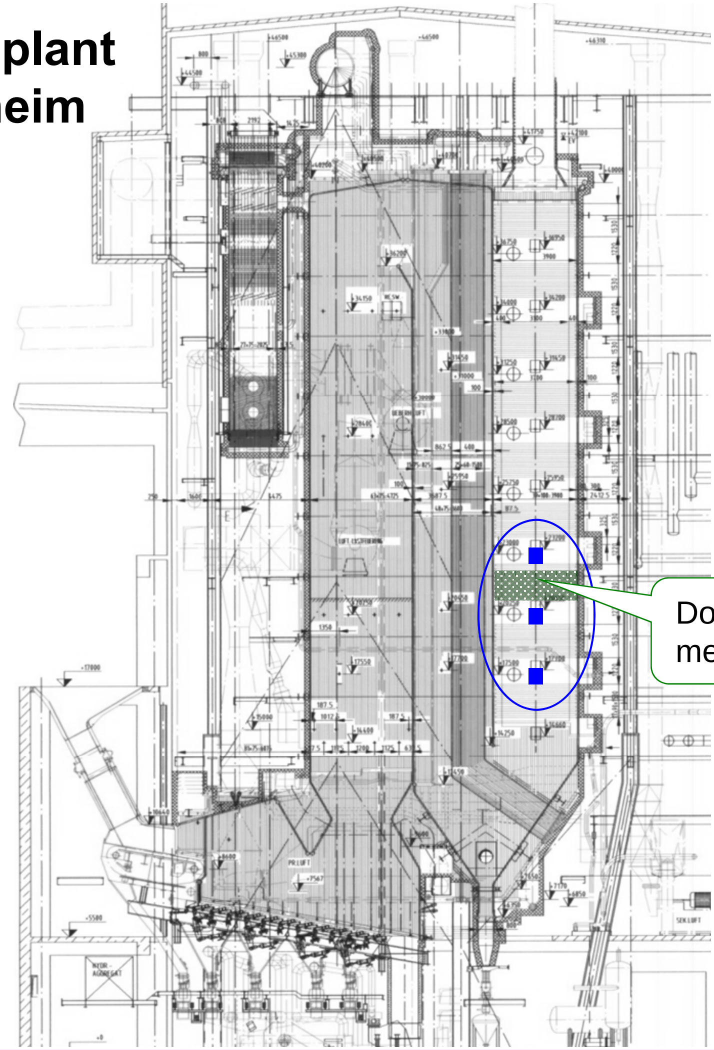


influence of the process technology (boiler 2 / 5)

classification	
1	very critical
2	critical
3	acceptable
4	uncritical

PRACTICAL IMPLEMENTATION: reconstruction

MSWI power plant MVV Mannheim boiler 4

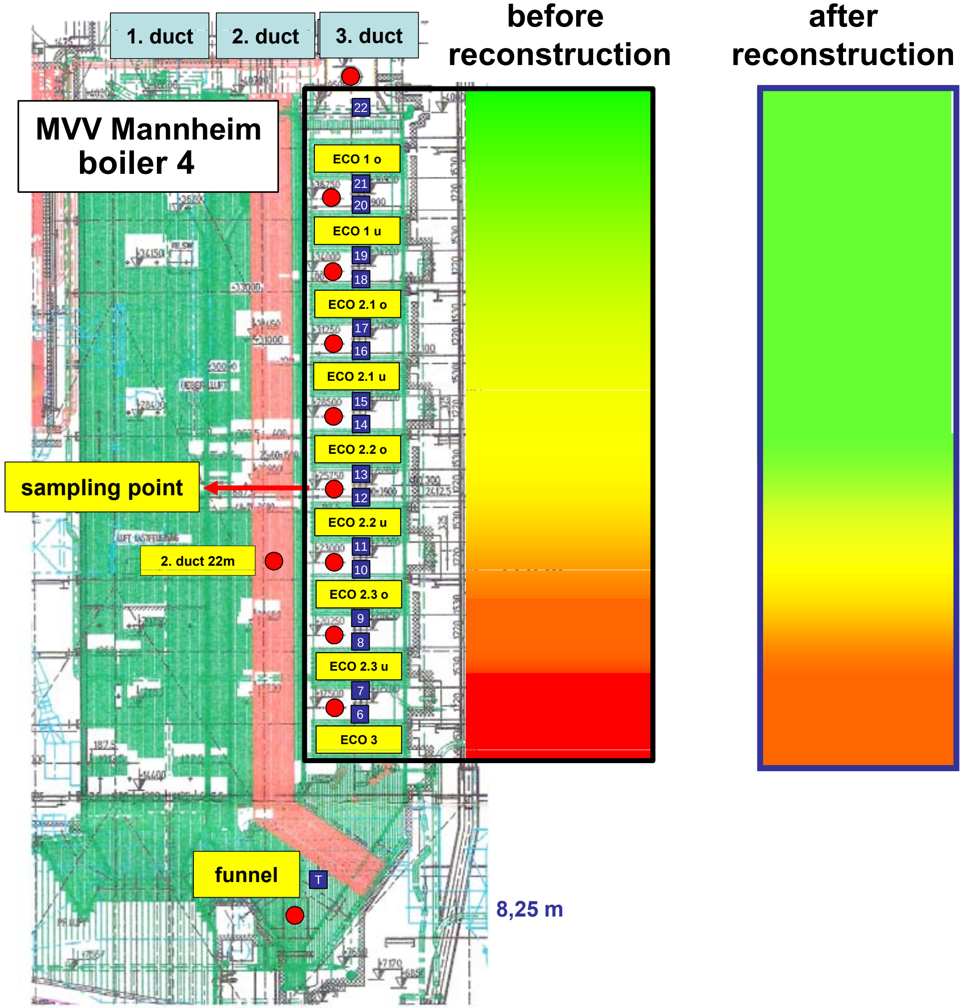


measure leads to

- **extension of the running time**
- **reduction of the costs (about 27 %)**

Double division of the critical heat exchanger + mechanical cleaning system

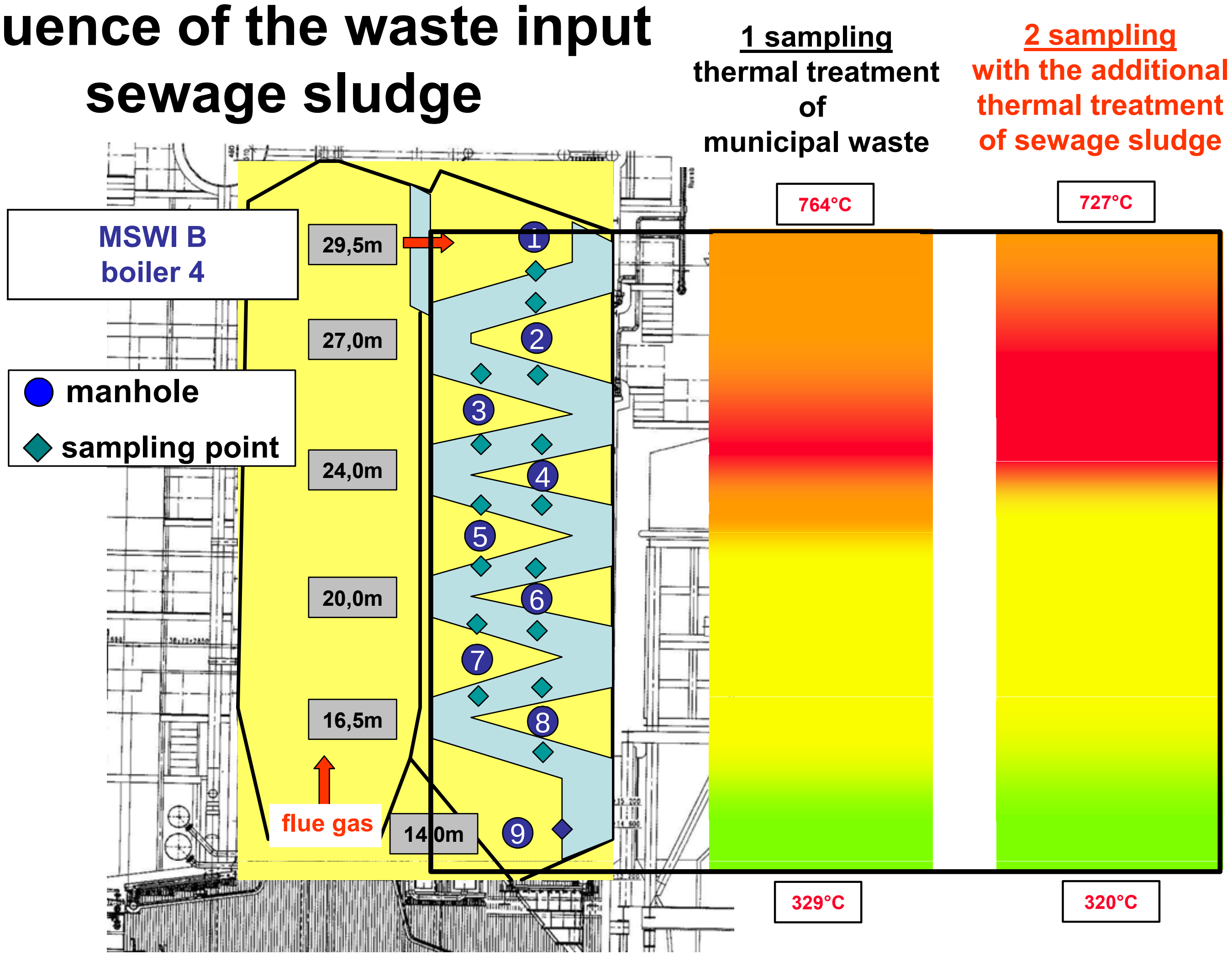
PRACTICAL IMPLEMENTATION: reconstruction



classification	
1	very critical
2	critical
3	acceptable
4	uncritical

PRACTICAL IMPLEMENTATION: waste input

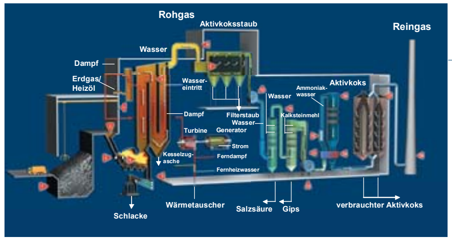
influence of the waste input sewage sludge

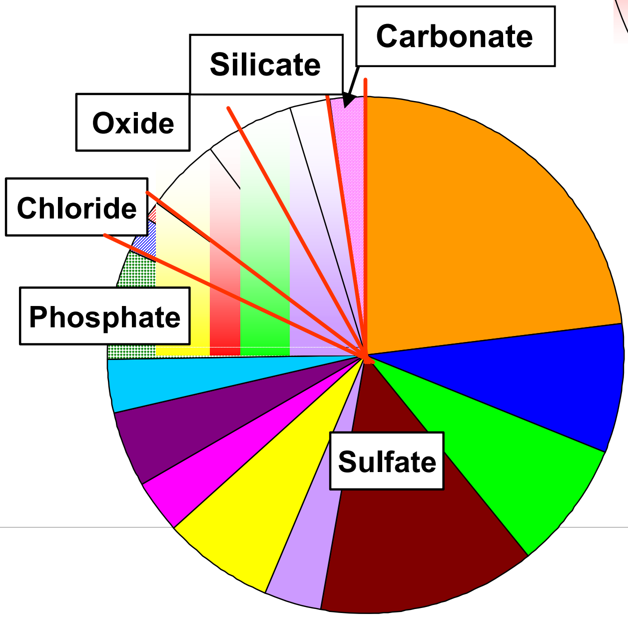


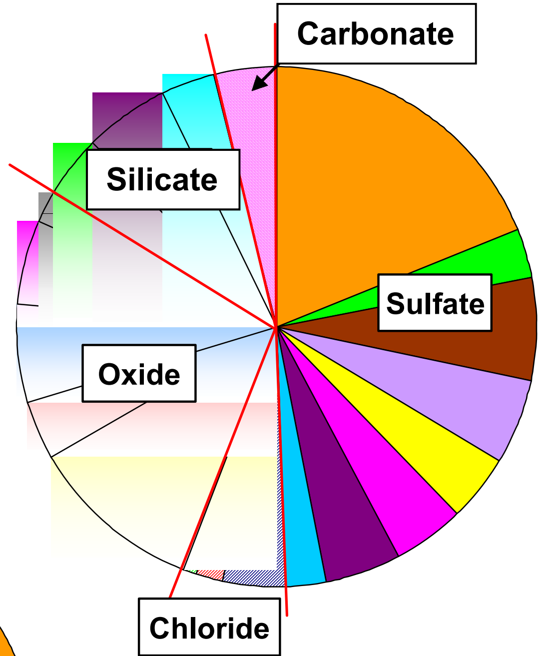
classification	
1	very critical
2	critical
3	acceptable
4	uncritical

COMPARISON OF DEPOSITS OF DIFFERENT POWER PLANTS

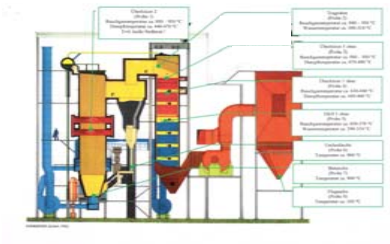
MSWI power plant

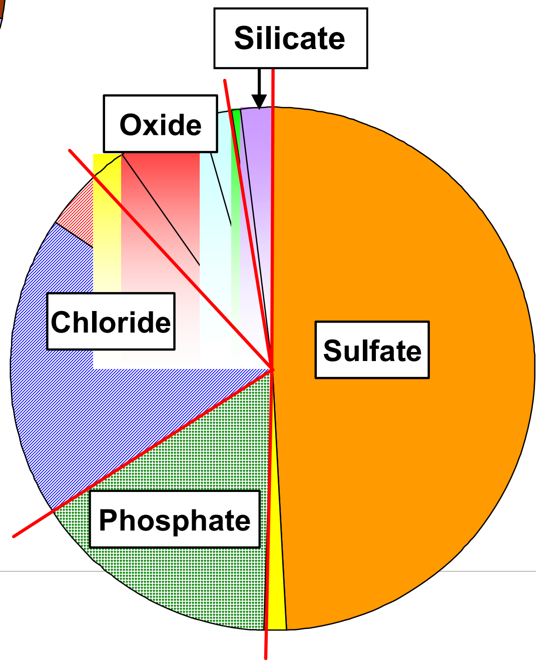






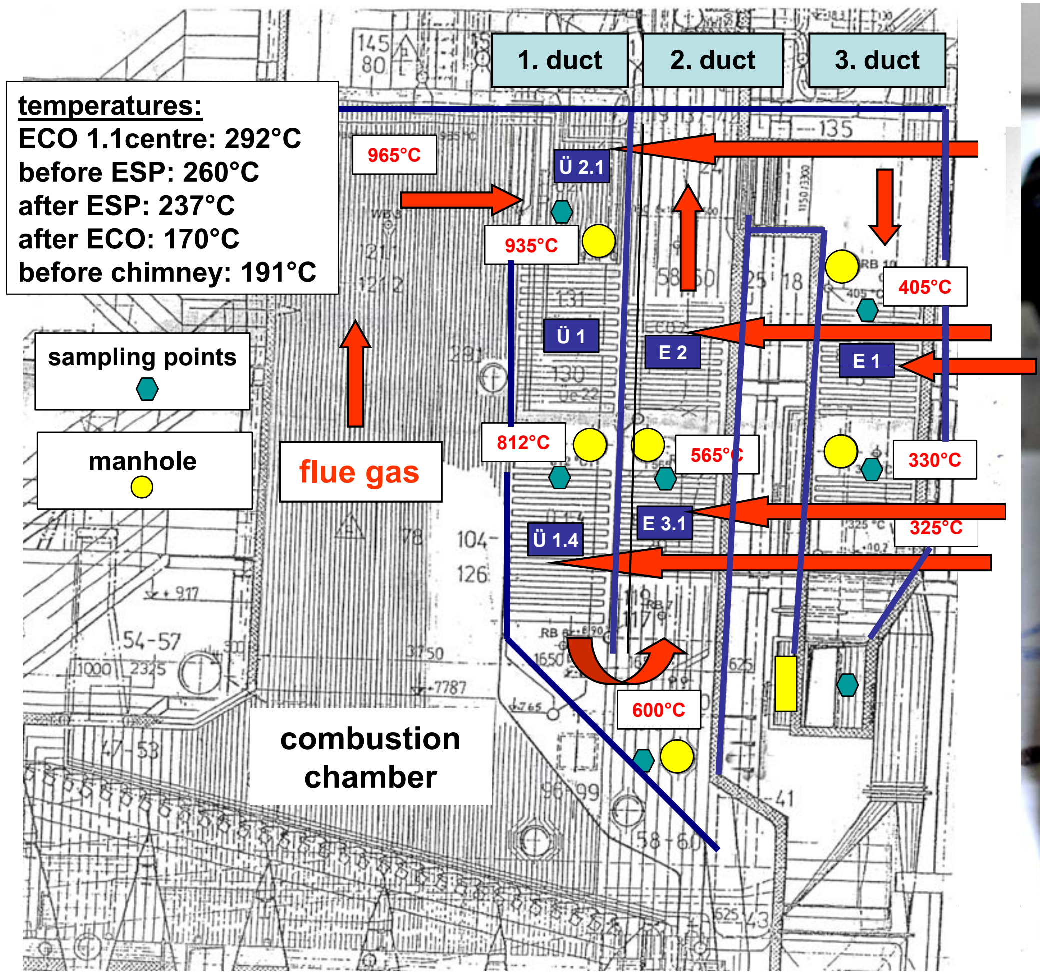
RDF power plant





Biomass power plant

BIOMASS POWER PLANT



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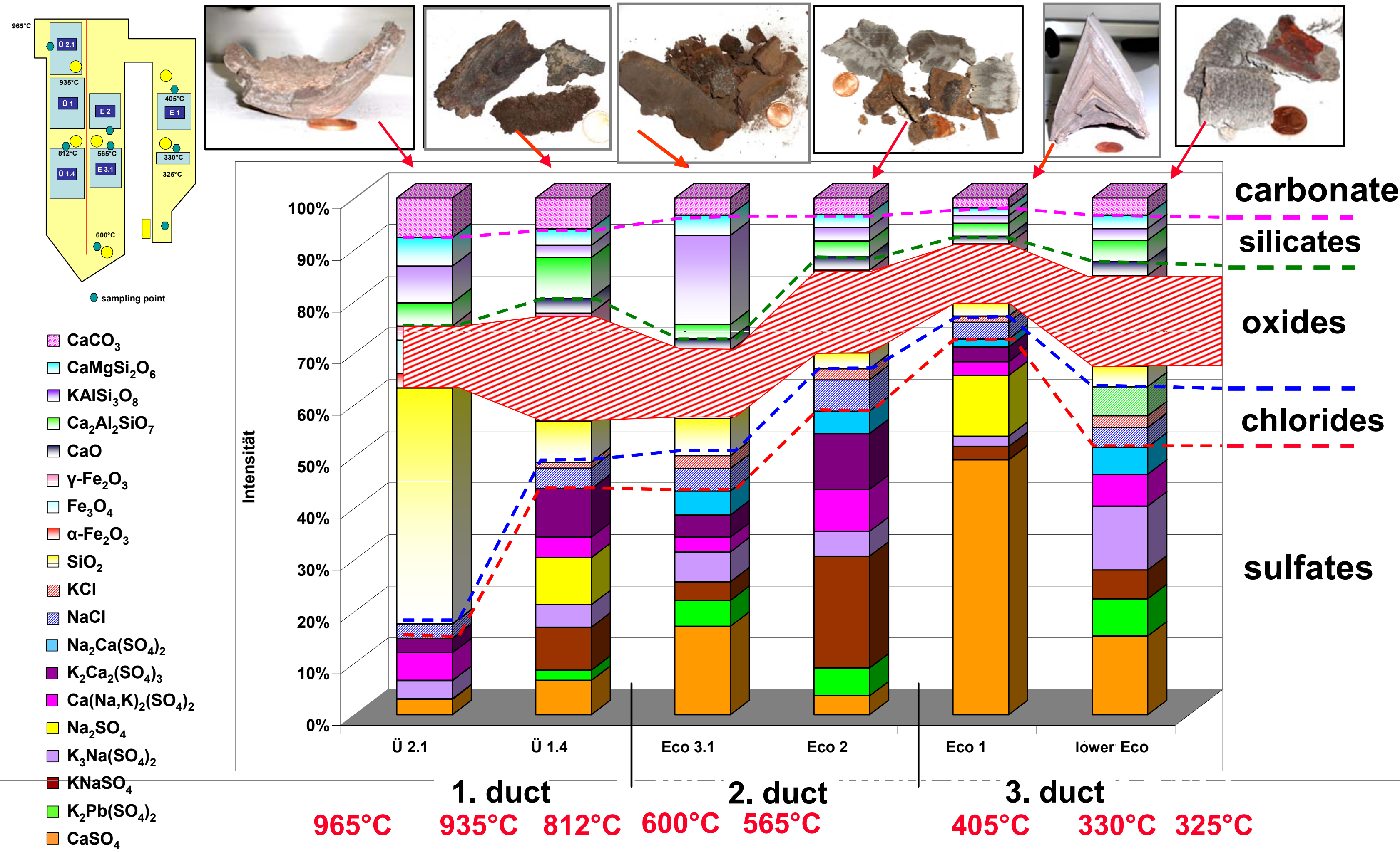
RESULTS: mineralogical composition



RESULTS: mineralogical composition and heat transfer

superheater 2.1: 965 – 935°C

- **compact material**
- **oxides and silicates**
- **extremly difficult to clean**
- **reduced heat transfer**

economizer 1: 405°C

- **thin layered deposits**
- **sulfates and oxides/silicates**
- **difficult to clean**

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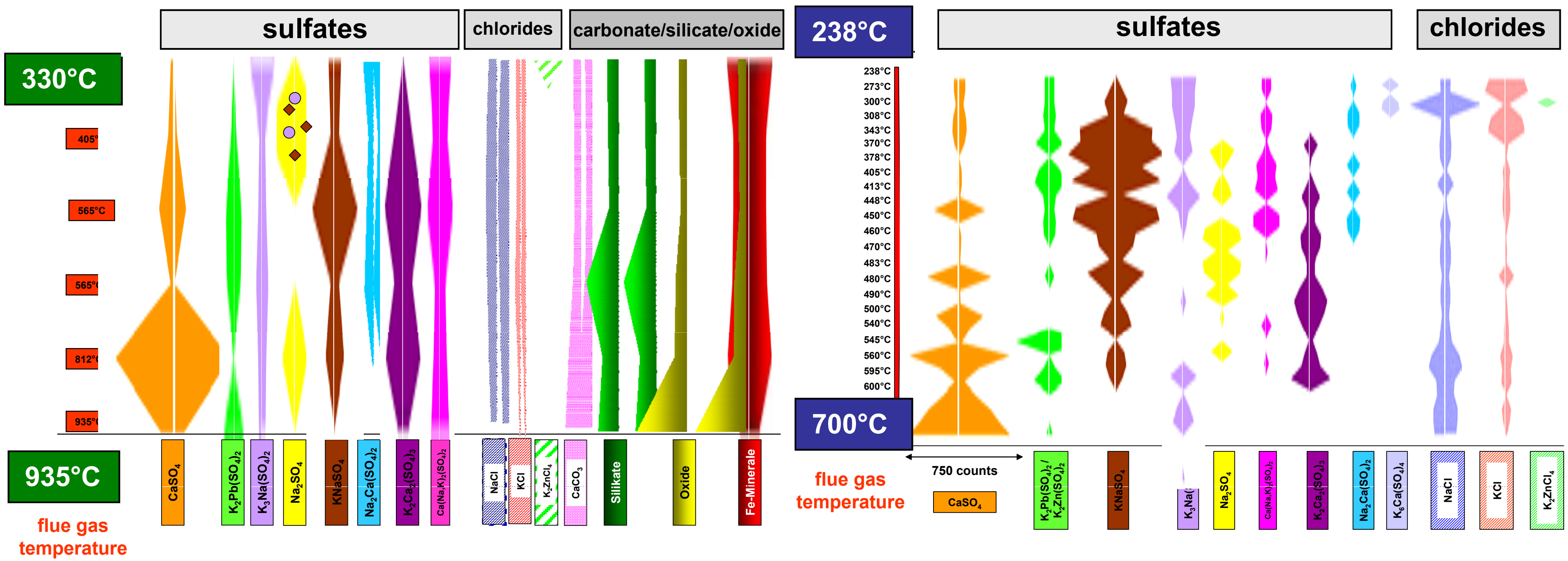
RESULTS: temperature profile

biomass power plant

MSWI power plant



SUMMARY

- **investigated power plants:**
  - MSWI power plant Mannheim boilers 2, 4, 5, 6 / MSWI power plant TREA Leuna
  - biomass power plant Zapfendorf / biomass power plant Mannheim
  - RDF plant Osnabrück: residues of paper production

- **mineralogical and chemical characterization of deposits: sulfates, chlorides, silicates, oxides**

- **development of temperature profiles of boilers**

- **development of a classification model for deposits**

- **relevance for practice:**
  - **optimization of existing plants**
  - **optimization the planning of new plants**
  - **determination of the influence of different waste inputs**

- **succesful measures**
  - **modification of boiler 4 of MSWI power plant Mannheim**
  - **construction of boiler 6 of MSWI power plant Mannheim**
  - **planning of new boilers of the energy company MVV**