



Tempus158989-Tempus-1-2009-1-BE-Tempus-JPHES  
Creation of university-enterprise cooperation networks for education on  
sustainable technologies

# Retraining and updating of PC universities staff in AT

14 – 20 November 2010.



**Tempus158989-Tempus-1-2009-1-BE-Tempus-JPHES  
Creation of university-enterprise cooperation networks  
for education on sustainable technologies**

**Retraining and updating of PC universities staff in AT  
14<sup>th</sup> - 20<sup>th</sup> November 2010.**

**List of participants from WB PC**

**Serbia**

University of Novi Sad, Faculty of Technology  
Novi Sad

1. Zoltan Zavargo
2. Mile Klašnja
3. Slobodan Sokolović
4. Dunja Sokolović

University of Niš, Faculty of Technology  
Leskovac

5. Milorad Cakić
6. Goran Nikolić

**Bosnia and Herzegovina**

University of East Sarajevo  
Faculty of Technology  
Zvornik

7. Radoslav Grujić
8. Mitar Perušić

Tuzla University  
Faculty of Technology

Tuzla

9. Zoran Iličković
10. Husejin Keran

**The former Yugoslav Republic of Macedonia**

University Ss Cyril and Methodius  
Faculty of Technology and Metallurgy  
Skopje

11. Emilija Fidancevska
12. Sveto Cvetkovski

University Goce Delcev  
Faculty of Technology

Štip

13. Vineta Srebrenkoska
14. Sanja Spasova

**MINUTES OF THE MEETING**

**Sunday 14<sup>th</sup> November 2010.**

Arrival of participants in Vienna

**Monday 15<sup>th</sup> November 2010.**

University of Technology  
Institute of Chemical Engineering

**The Meeting was attended by**

Institute of Chemical Engineering

Wilhelm Höflinger

Gerd Mauschwitz

14 participants from WB PC

1. Welcome by the Head of the Institute of Chemical Engineering  
Wilhelm Höflinger

2. **Presentation of the Institute of Chemical Engineering and the Vienna University of Technology**  
Wilhelm Höflinger
3. **Presentation of the programmed**  
Wilhelm Höflinger
4. **Individual grant holder reports**  
Zoltan Zavargo

#### Lunch

##### *Institute of Chemical Engineering*

5. **Environmental Protection**  
**Dust separation from air and gases**  
Wilhelm Höflinger  
The presentation was focused on the definitions and European regulations. The differences of dust (100µm) and aerosol (10µm) as well as the definition of aerodynamic diameter were defined. EU- Council Directive 1999/30 EC, PM10 and EU - Council Directive 2008/50EC, PM2.5 were briefly explained as environment regulations for Imission. Also, dust regulation for working place EN 481, ISO 778 was summarized. Imission and emission sampling was described in the frame of dust sampling and measuring methods. The following often used measurement techniques were explained during the presentation:
  - high volume sampler-(PM10, PM2.5 PM1) with discontinuous filter sampling, particle mass;
  - 1 stage impactor with beta radiation-(PM10, PM2.5 PM1) with continuous filter sampling, particle mass;
  - cascade impactor-particle size distribution 0.1 to 20µm, discontinuous, particle mass;
  - scattered light sensor-particle size distribution 0.25 to 40µm, continuous particle number;
  - scanning mobility sizer (SMPS)- particle size distribution 0.02 to 1µm, continuous, particle number.

#### Coffee break

6. **Environmental Protection**  
**Separation of gaseous pollutants from air and gases**  
Gerd Mauschitz  
The presentation was focused on dust separators. The attention was paid on the explanation of different kinds of dust separators like: settling chamber, cyclone, bag house filter, wet scrubber and electrostatic precipitator. The scientific approach for filter mediums relating to the pore depth distribution and surface porosity was discussed. USA ASTM, German VDI3926 Type I, German VDI 3926 Type II, German VDI3926 Type III and JIS Z 8909-1 Japan were mentioned as different national standard test regulations.

#### Dinner

##### *Restaurant Heurigen*

**Tuesday 16<sup>th</sup> November 2010.**

**University of Technology  
Institute of Chemical Engineering**

**The Meeting was attended by**

**Institute of Chemical Engineering**

*Wilhelm Höflinger*

*Gerd Mauschitz*

*Tobias Pröll*

14 participants from WB PC

1. **Zero energy emission technologies**  
**Chemical Looping Combustion for CO<sub>2</sub> Ready Steam Generation**  
Tobias Pröll

As a part of retraining seminar in Vienna Mr. Tobias Pröll from Vienna University of technology presented his lecture "Chemical looping combustion for CO<sub>2</sub> ready steam generation". First of all Mr. Tobias Pröll introduced us with organization scheme of Vienna university of technology and its department for Future energy technology. This department is divided in three parts; zero emission technologies, biomass gasification and gas cleaning and second generation biofuels. In each group they approximately have ten people. One of their basic research activities now is chemical looping combustion (CLC). Carbon capture and storage was recognized as a one of main field of research where EU prepared a lot of funds for projects and research activities.

Chemical looping combustion for carbon capture is one of the basic research activities at Vienna University of Technology, group for zero emission technologies. In his presentation Mr. Tobias Pröll gave us basic facts about carbon capture and storage, then about chemical looping combustion for carbon storage and oxygen carrier materials, too. He also presented to us basic facts about the pilot plant unit at Vienna university of technology and results what they got from that pilot plant and at the end of his presentation he introduced us with their main conclusions. By the way, Chemical looping combustion (CLC) typically employs a dual fluidized bed system (circulating fluidized bed process) where a metal oxide is employed as a bed material providing the oxygen for combustion in the fuel reactor. The reduced metal is then transferred to the second bed (air reactor) and re-oxidized before being reintroduced back to the fuel reactor completing the loop.

Isolation of the fuel from air simplifies the number of chemical reactions in combustion. Employing oxygen without nitrogen and the traces of gases found in air eliminates the primary source for the formation of nitrogen oxide (NO<sub>x</sub>), producing a flue gas composed primarily of carbon dioxide and water vapor; other trace pollutants depend on the fuel selected.

As we have recently mentioned, interest has been shown in CLC as a carbon capture technique. Carbon capture is facilitated by CLC because the two redox reaction can be made to occur in separate vessels. This gives CLC clear benefits when compared with competing carbon capture technologies, as the latter generally involve a significant energy penalty associated with either post combustion scrubbing systems or the work input required for air separation plants. This has led to CLC being proposed as an energy efficient carbon capture technology. Briefly, CLC can achieve both an increase in power station efficiency simultaneously with low energy penalty carbon capture.

**2. Advanced energy conversion, Biomass gasification and Chemical Looping**  
**Short Power point introduction and**  
**Lab-tour at the Institute of Chemical Engineering**  
Tobias Pröll

After the presentation about chemical looping combustion capture storage colleague from Vienna University of Technology gave us a short presentation about biomass gasification, where they sideline basic information about this process.

After the short presentation the Lab-tour was organized at the Institute of Chemical Engineering where we had opportunity to see pilot plants for CLC and biomass gasification and some other equipment too.

**Lunch**  
*Institute of Chemical Engineering*

## **Company visits**

**The Visit were attended by**  
**Institute of Chemical Engineering**  
Gerd Mauschitz  
Thomas Laminger

14 participants from WB PC

**1. Waste water treatment plant EBS Vienna**

Visit to the Entsorgungsbetriebe Simmering GmbH (EbS company) in Vienna was realized on Tuesday 16/Nov/2010, from 14 to 18 hours, according to programme. The presentation was made by the company's general manager, Mr Gerd Mauschitz.

Entsorgungsbetriebe Simmering GmbH (EbS) was founded in 1976. The city of Vienna is the sole proprietor of EbS, the *Simmering Waste Disposal Facilities*. Vienna's main wastewater treatment plant and the city's animal disposal plant have formed part of EbS since 2000. Since then the company has also invested in several water technology companies. Top-quality standards and continuously enhanced services have made EbS an environmental competence centre as well as one of the main pillars in the provision of public services. About 160 employees take care of the smooth operation of the EbS facilities and therefore contribute to the top quality of life in Vienna.



Environmental protection, occupational health and safety, and the quality of work play an important role for the EbS. Therefore, the general management decided to develop an Integrated Management System (IMS) for the documentation and continuous improvement of these factors. The IMS combines the demands of quality, environmental protection and occupational health and safety to an integrated system. The IMS was accredited by an independent institution according to the relevant standards of environment (EMAS, ISO 14001:2004), quality (ISO 9001:2000) and occupational health and safety (OHSAS 18001:1999).

In Simmering, at Vienna's lowest point, where the Danube Canal meets the Danube, lies Vienna's main wastewater treatment plant. Here around 98 % of Vienna's wastewaters are purified. On dry-weather days this is more than 500,000 cubic meters, which corresponds to a flow of a medium-size river. It takes about twenty hours for the wastewater to pass through the mechanical and the two biological purification stages before it is purified and discharged into the Danube Canal. The expansion of Vienna's main wastewater treatment plant was realized from the years 2000 to 2005. The expansion included the construction of a second biological purification stage for nitrogen elimination (nitrification and denitrification). The second biological stage is added in the first biological stage which is in operation since 1980. The application of latest technologies with a significantly increased purification capacity will contribute considerably to Vienna's waste water management and justify its reputation as a model city with high standards in environmental protection.



The wastewater generated by households, trade and industry remains in the main wastewater treatment plant for 20 hours. During this time it is treated mechanically and biologically. By means of this process, more than 80% of the nitrogen, over 90% of the phosphates, and more than 95% of the organic pollutants of the wastewater are eliminated. About 30% of all pollutants are already removed by mechanical purification. Each day, about 100,000 kg of carbon, 30,000 kg of nitrogen and 5,000 kg of phosphates are removed from the wastewater. In the biological purification stage, trillions of micro-organisms are continuously purifying Vienna's wastewater.

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## 2. Incineration Plant MVA Pfaffenau in Vienna

A multimedia informative presentation was presented to the Tempus participants. In the presentation the participants were informed about how waste collection is carried out in Vienna, the processes involved in efficient partial separation, recycling and incineration of waste, and, in particular, the high-tech Pfaffenau waste incineration / combined heat and power electricity generating and district heating plant. Afterwards, the visitors were given a guided tour through the Pfaffenau plant - one of the most modern in Europe.

The "MVA Pfaffenau" plant was built to the highest technological, emission control and environmental impact standards achievable at the time of its construction. The quality of emission control well exceeds the quality required under current regulations.

For a project of this size, the two and a half year construction time was relatively short and the project was completed in the autumn of 2008. Now about 50 people take care

of the running of the plant. Consuming 250,000 tons of residential waste per year, MVA Pfaffenau produces 65 GWh of electricity and 410 GWh of district heating per year.

The residential waste is collected by the municipal refuse collection service and brought directly to the plant. About 200 trucks per day empty their loads into the refuse bunker which has the capacity of approximately 18,000 cubic meters.

The refuse bunker is equipped with two grab cranes which are used to mix the waste and deliver it to the inlet hoppers of the two fluidized bed incinerators which, combined, incinerate 32 tons of waste per hour at a furnace temperature of 850°C.

At the back end of the combustion grates, slag and other residue is discharged for wet purging. A magnetic separator removes any ferrous metal for recycling and the slag is fed into the slag collection bunker.

The waste heat boilers of the incinerators absorb the heat from the incinerator flue gas to produce steam, at 40 bars and 400°C, which is fed through a steam turbine coupled to a generator, producing electricity. The exhaust steam from the turbine is then passed through the heat exchangers of the district heating installation. Here the steam is condensed and fed back into the water circuit of the waste heat boilers. Meanwhile, the residual heat absorbed by the district heating heat exchangers is piped away to heat up to 50,000 households connected to the district heating network of Vienna.

The exhaust gases from the boilers are cleaned to a very high environmental standard using a series of precipitators, scrubbers, filters and a deNOx unit.

**Wednesday 17<sup>th</sup> November 2010.**

## **Company visit**

### **1. Sugar factory Tulln**

Sugar factory in Tulln, in Austria, belongs to food company AGRANA; which has three sectors, and Sugar factory Tulln, with other Sugar factory in Leopoldsdorf, is part of company sector for sugar production (AGRANA Zucker GmbH). Sugar factory Tulln (in further text: Factory) is a large plant, in last campaign it processed about 1.5 million tons of sugar beet, and produced about 400 000 tons of sugar. Factory is founded in the year 1937; and the major improvement was installing a plant for obtaining sugar and betaine from molasses, which is in operation since 2002. About half of sugar beet, 47% is received directly from farmers (from distances shorter than 40 km), and another half, 53% from longer distances, is transported to the Factory by railroad. For continuity in production process, in a Factory there is the daily stock with capacity of 10 000 tons sugar beet.

Production process scheme in one sugar factory, as in Factory in Tulln, is complex; with many unit processes: mechanical (slicing, filtration, centrifugation, packaging), physical (concentration, crystallization, drying), as well as chemical (extraction, purification). The main process steps are: (i) sugar beet extraction (obtaining of sugar, as a raw sugar juice, from washed and sliced sugar beet with hot water); (ii) sugar juice purification (treatment of raw juice with milk of lime and carbon dioxide, which is prepared in separate equipment - limestone furnace); and (iii) evaporation and crystallization (purified juice is concentrated by evaporation to produce a thick juice, which is filtered and transferred to vacuum pans when the liquor is slightly supersaturated, the pan is seeded with fine icing sugar to initiate crystallization; the mixture is centrifugally separated to extract crystalline sugar, which is dried, conditioned for packaging or bulk loading). About 20% of produced sugar is for household consumption (only one sugar packaging plant for a whole Austria is in Factory Tulln, and there is a stock with capacity of 8000 tons of sugar), and about 80% of produced sugar is for industry, which is delivered by special trucks.

For the purposes of our Tempus program, the most important were energy and environmental aspects of sugar production. During our visit to Factory, we obtained following data: (i) consumption of ~ 1100 kWh energy per ton of sugar; (ii) energy from natural gas: consumption of 10 000 m<sup>3</sup> natural gas per hour; (iii) cogeneration (combined heat and power): boiler: 140 tones of steam on 40 bar steam turbine, 15 MW of electricity; (iv) type and amount of wastes and by-product from sugar beet processing (annually): 80 000 tons of beet soil, 60 000 tons of beet pulp, 60 000 - 70 000 tons of molasses (obtaining of ~ 25 000 tons of sugar from molasses, 10-15% of sugar remains in molasses); (v) two-steps biological treatment of wastewater from lagoons: ~ 5000 m<sup>3</sup>/day of treated wastewater into Danube.

## Lunch

### *Sugar Factory Tulin*

## 2. Visit of the Bioethanol plant in Tulln

The Sugar factory Tulin (Zuckerforschung Tulln Ges.m.b.H.) is also active in the preparation, processing and application of agricultural products, not only in the foodstuffs area, but also in the area of renewable fuels.

The bioethanol plant annually processes up to 620,000 tons of cereals to produce up to 240,000m<sup>3</sup> or 190,000 tons of bioethanol as well as up to 190,000 tons of the high-quality, GMO-free, protein-rich animal feed Actiprot.

During the production of bioethanol, some of the carbon dioxide stored in the renewable raw materials (primarily wheat and corn) is released. The planned plant will recover, clean and liquefy over 100,000 tons of the biogenic carbon dioxide released from these renewable raw materials. This liquefied CO<sub>2</sub> will be available for use in various industrial applications, particularly for carbonated beverages.

In Austria, 5% bioethanol by volume is currently added to petrol in line with the mandatory admixture legislation. The bioethanol is also used in the new and environmentally sensitive fuel SuperEthanol E85, which consists of up to 85% bioethanol, the remainder being petrol.

During a recent research and development project concerning bioethanol production Sugar factory Tulin has found that the process can be significantly enhanced through the incorporation of commercially available cellulose enzymes to the fermentation process. Up to 55% of the cellulose fraction within the fermentation substrate can be converted to produce an approximate 2.5% additional increase in BioEtOH per kg of raw material.

## Thursday 18<sup>th</sup> November 2010

University of Technology  
Institute of Chemical Engineering

### The Meeting was attended by

Institute of Chemical Engineering  
Wilhelm Höflinger  
Jörg Faschingleitner  
Thomas Laminger

### Scheuch Company Austria

Dominik Steiner

14 participants from WB PC

## 1. Fugitive dust emissions

Jörg Faschingleitner

Fugitive dust emissions, (by Jörg Faschingleitner) gave us a clear presentation on danger of long-term exposure to fugitive dust, dust definitions and kinds, EU guidelines as well as methods of dust minimization.

Dangers for long-term exposure to fugitive dust are:

- chronic injury of the lung;
- decreased lung function in children and adults
- shortened life expectancy, primarily due to heart/lung diseases and probably also because of cancer.

Further information on the consequences of particulate matter for human health can be obtained from all websites of the environmental agencies within the European Union.

### Dust definitions

EPA: PM 10 = Particulate matter with an aerodynamical diameter smaller than 10µm

Guideline 1999/30/EG: PM10 are particles which pass a size selective air inlet which performs for particles with an aerodynamical diameter of 10µm a separation efficiency of 50%. The PM10 restrictions in the EU are based on the 1999/30/EG

### Further specified classification of dust:

TSP: "Total Suspended Particulate", emittable dust particles with an aerodynamical diameter < 57 µm

- SP: "Suspended Particulate", is considered as "PM-30" .  
IP: "Inhalable Particulate", particulates with an aerodynamical diameter < 15 µm, als "PM-15"  
FP: "Fine Particulate", particulates with an aerodynamical diameter < 2.5µm, als "PM-2.5"

### **Fugitive dust emission**

There are two kinds of dust emission: point dust source and fugitive dust source. Fugitive dust emission

- arising from non conducted sources;
- Diffuse dust sources can be **assigned by geometry**: point source line source, area source or volume source;
- Dust sources which create **fugitive dust are created for example** by exposure of :
  - open faces (construction, mining or agricultural sites),
  - roads or parking areas,
  - stock piles or
  - bulk solid processing

At dust minimization in the encasing there are 2 effects, which are acting in series:

1. Moistening effect and
2. **Dust separation by water droplets**

With experiments it was proven that the fugitive dust suppression could get divided in two effects. This primary and secondary dust suppression effects were quantified and compared with a model usually used for two separators which are acting in series.

Wherefrom the primary dust suppression measure is four times more efficient than the secondary dust suppression measure.

For both effects calculation methods were derived so that the proposed dust reduction of each measure can get calculated.

The total dust suppression efficiency could get calculated by an adoption of a depth filtration model. This model was improved by an equation to calculate the evaporation effect. As a result, all separation efficiencies (total-, primary- and secondary dust suppression efficiency) could get referred to an effective water flux which actually performs dust suppression.

## 2. **Metalworking mist separation**

Thomas Laminger

### **Introduction**

Metalworking fluids play very important role in different field of application like:

- Cutting processes such as drilling, turning, milling, broaching, honing, grinding
- Shaping processes such as rolling, deep drawing, pressing
- Machine tools, machining centers and transfer systems for cutting processes
- Rolling mills for sheet metal and steel, light alloys and heavy non-ferrous metals
- Presses for molding and deep drawing parts made of steel, light alloys or non-ferrous metals.

But, metalworking fluids (MWFs) have been clearly documented as causing severe health problems due to workers coming in contact with these metalworking fluids such as contaminated toxic solvents, oil mists, coolant mists and oil containing smoke. These industrial solutions and airborne mists and aerosols enter the body through direct skin contact or through inhalation from breathing. Millions of workers who are employed in the manufacture of automobiles, farm equipment, aircraft, heavy machinery, and other hardware are exposed to machining fluid mists and smoke on a constant basis.

### **Purpose of the presentation**

The basic idea of performed presentation was to explain the development of a standardized test procedure for metal working fluid mist separators (filtering separators) with emulsion as test substance. For MWF-mist separators no standards or norms exist, as they are available for cleanable dust filters or particulate air filters.

Different separators can be distinguished by their filtration mechanism: Filtering separators, Electrostatic precipitators, Centrifugal collectors and Combinations.

Analogies to norms and standards for dust filter

Basic norms:

EN 1822-2:2009 high efficiency air filters (EPA, HEPA and ULPA) - Part 2: Aerosol production, measuring equipment, particle counting statistics;



## European Standard for Coarse and Fine Filters

In 2002, the European Committee for Standardization, Technical Committee 195, Work Group 1 (CEN/TC195-WG1) established a new standard for general ventilation filters. The introduction of this standard is under document name EN779:2002

VDI-Guideline 3926 "Testing of Filter Media for Cleanable Filters"

### Proposal of a standardized test procedure

**Institute for Chemical Engineering, Mechanical Process Engineering and Clean Air Technology, TU Vienna**

For this procedure, FILTER TEST RIG was used as equipment. It consists of: Aerosol generator (generation of a test aerosol), Ageing nozzle and Filter holder. Obtained, measured and calculated values important for this procedure are: Pressure drop, Drainage flow, Oil concentration of the drainage flow and the emulsion tank, Raw gas and clean gas concentration, Total holdup (stored emulsion inside the filter), Oil holdup (stored oil inside the filter), Separation efficiency. For measurement is used CYCL-FID-Measurement device for online detection of vapor and droplet concentration. The performed, accelerated filter ageing procedure was tested using six different filters.

### The OUTLOOK of this presentation is:

Development of a classification procedure using e.g. the stationary fractional separation efficiency in several particle size ranges.

Implementation of a filter test norm or standard (e.g. ÖNORM).

### 3. Dust separation on bio mass combustion plants

Dominik Steiner

The presentation: Dust separation at biomass combustion plants was presented by Dominik Steiner from the company "Scheuch" during the retraining session in Vienna, Austria. He presented about innovative technologies and processes for clean air in the company "Scheuch". The company have developed own product line-up, which includes centrifugal separators, fabric filters, wet and dry electrostatic precipitators, biological exhaust gas scrubbers, a variety of cooling and heat extraction systems, as well as fans, rotary valves, discharge devices, valves and control systems or control devices. All components were completely compatible with each other and were optimized for the respective application. The company „Scheuch“ has five main business segments: wood processing industry, wood based panel industry, metals industry, industrial minerals and energy industry. The main attention was paid on energy industry - which included a range of innovative systems for dedusting, reduction of pollutants, heat recovery and for the cleaning of exhaust gases generated by biomass - fired heating and combined heating and power plants, as well as plants used to recover energy from fossil fuels, scrap wood, residual materials and waste. The presentation was oriented to these three main technologies:

1. Effective dust separation - for the separation of particles and centrifugal separators for pre-separation and dry electrostatic precipitators for final cleaning were presented.

2. The ERCS process (Energy-Recovery & Cleaning-System) which were developed and patented by "Scheuch" and offers dust and particle separation and highly efficient heat recovery and energy-optimized plume removal.

3. Efficient removal of pollutants - the bag filters were presented. They showed that the fabric filter plants are extremely well suited for filtering fine dust and for use in combination with sorptive processes to reduce pollutants.

Particular attention was paid on lab-tour at the Institute where particle size measurement techniques and dust filter test equipment were presented. They have showed us the test equipment for measurement of clean gas concentration which consisted of two filters: membrane and polyamide filter. They have worked according standards. By using white xenon they could note the particles size and count the number of particles which cross trough the xenon light and they could make a short flash. The good filter should be cleaned after 20 minutes of work. The membrane filter was very thin and the clean gas concentration was about 0.5 mg on cubic meter. Since this filter was very thin the problem could occur if there was a mechanical damage, so all the particles in that case would go through the filter.

By using the contemporary laboratory equipment they could classify the load of particles by using electrostatic field. They have produced special voltage of the electrostatic field so called monodispersion which means that all the particles will have the same particle size. With this method they have got information about the particle size and their number concentration, so they could calculate the particle size distribution. Particle size distribution has been very low starting with 4 or 5 nm up to 1000 nm. They could get the information in the time of 2 - 3 minutes. The scanning process was very quick.

## Coffee break

4. **Lab - tour at the Institute  
Dust separation research**  
Jörg Faschingleitner  
Thomas Laminger

During lab-tour we had possibility to see laboratory filter test equipment with the following main components:

- Aerosol generator;
- Ageing nozzle;
- Filter holder and CYCLE-FID measurement device.

This lab apparatus give possibility to measure: pressure drop, drainage flow, oil concentration, raw gas and clean gas concentration, stored emulsion and oil inside the filter as well as separation efficiency. It was presented that balancing of liquid mass flows of a filter medium allows the calculation of the total holdup, water holdup and oil holdup by Mr. Laminger.

## Dinner

*Restaurant Salm Bräu in Vienna*  
**Friday 19<sup>th</sup> November 2010.**  
University of Technology  
Institute of Chemical Engineering

**The Meeting was attended by**  
Institute of Chemical Engineering  
Wilhelm Höflinger  
Gerd Mauschitz

14 participants from WB PC

1. **Lab - tour at the Institute  
Dust separation research**  
Gerd Mauschitz
2. Concluding remarks

**Saturday 20<sup>th</sup> November 2010.**  
Departure