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New Ways in Nanoparticle Reduction in Combustion Processes

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Ökozentrum Langenbruck

and its

Laboratories for Sustainable Energy Systems

are subsidiaries of the

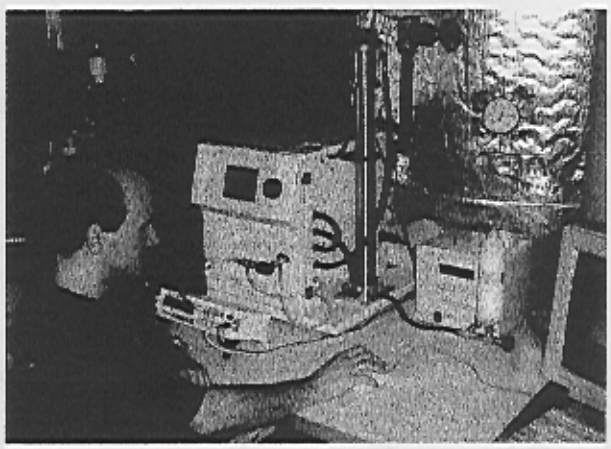
Foundation of Appropriate Technology and Social Ecology (FATSE)
CH-4438 Langenbruck, Switzerland

The *Ökozentrum Langenbruck* is partner in two Joint-European Projects of the European Commission (EC):

- *Development of newly designed wood burning systems with low emissions and high efficiency* (Jan. 96 – Dec. 98)
- *Increased combustion stability in modulating biomass boilers for district heating systems* (Jul. 98 – Jun. 01)

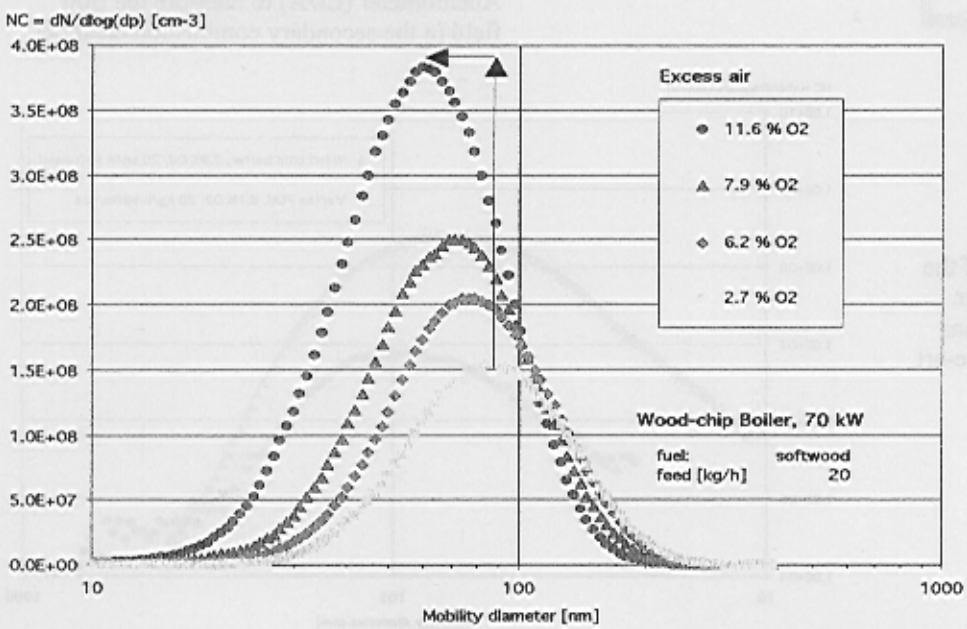
In contrast to fossil fuel burner systems, which are easily to switch on and off, biomass burner systems need substantial time to achieve steady state operation in their combustion process. Modulating power output of biomass burner helps to avoid stop and go operation with the increased emission of hazardous emissions. To main goal of the research and technical development (R&D) activities at the Ökozentrum Langenbruck is increased combustion stability over a wide range of power output. Particularly the reduction of particulate matter (PM) is a major issue in the R&D activities.

Thanks to the contact to Prof. C. Siegmann and his team of the Laboratory of Solid State Physics at the Federal Institute of Technology (ETH), Zürich, we were able to establish nanoparticle analysis. A student established end of 1996 in his PhD a sampling technique for nanoparticle analysis specifically in flue gas of biomass burners.

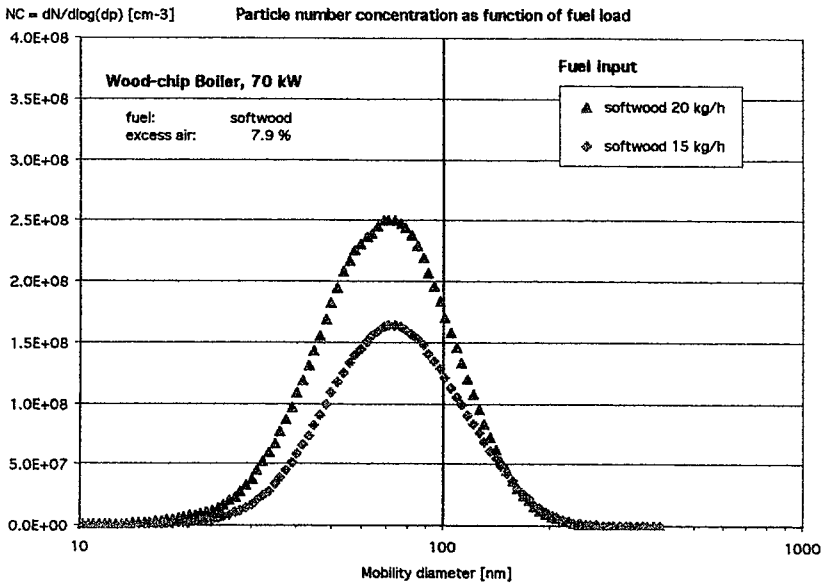


For our R&TD activities we apply SMPS equipment of latest measuring technique. The equipment is commonly used with the Laboratory of Solid State Physics and the Abgasprüfstelle of the *Fachhochschule Bern* at Biel.

Particle Analysis in Biomass Combustion



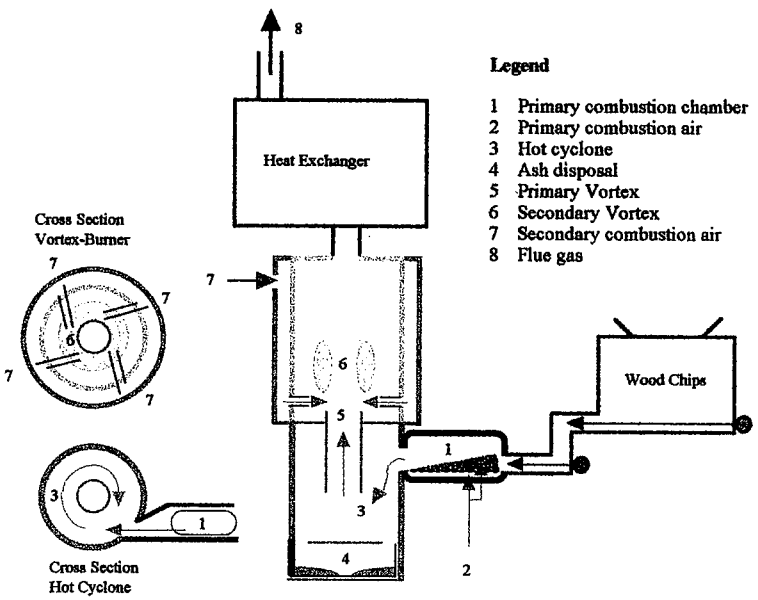
Looking at nanoparticle emission of a state-of-the-art wood chip burner there is a clear correlation of excess combustion air and Number Concentration (NC), but only little on the most frequent diameter.



The increase of feed rate at constant excess air condition also raises the NC. The particulate formation is rather caused by combustion process than by entrained ash particles in the combustion air.

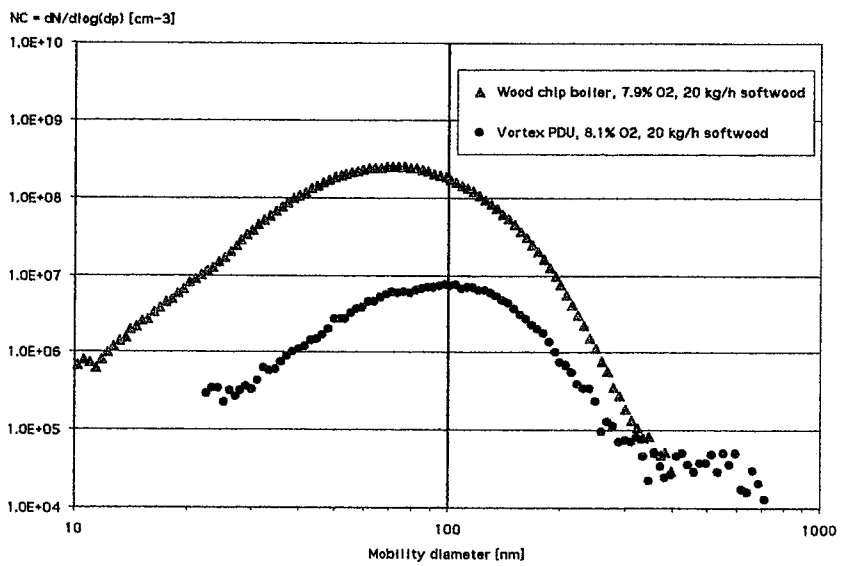
Based on the knowledge obtained of the state-of-the-art burners, we designed a new biomass burner system with air staging and a combustion chamber creating vortex flow patterns. The R&T was part of the Joint-European project "*Development of newly designed wood burning systems with low emissions and high efficiency*".

Basic Design of a Vortex Biomass Burner System with Air Staging

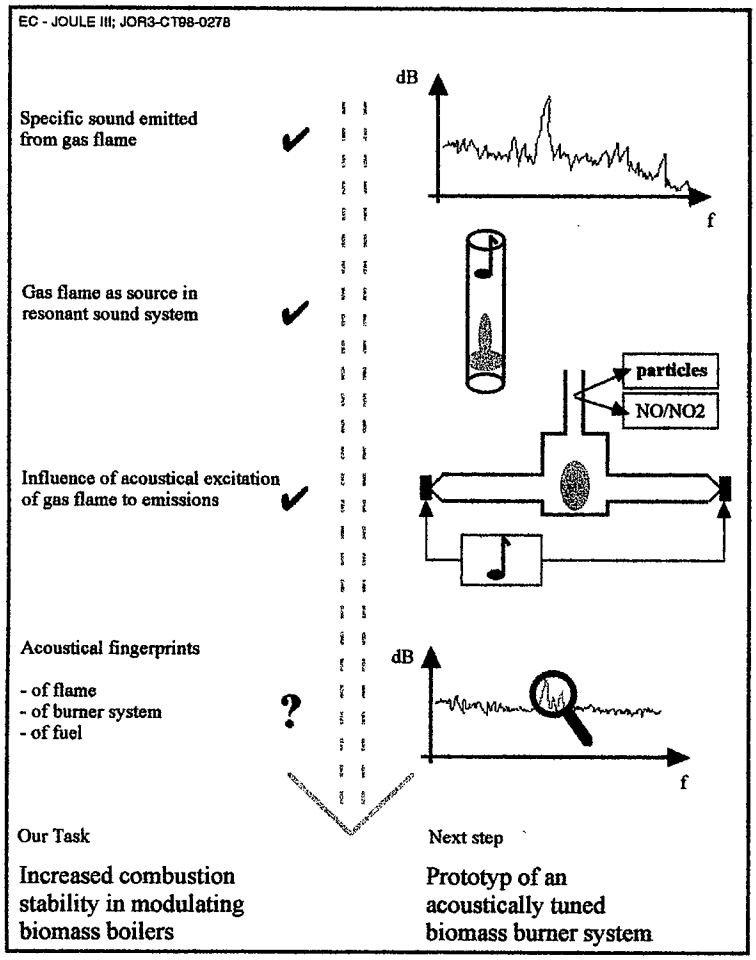


In a primary combustion chamber we burn wood chips with a fuel rich flame at understoechiometric conditions. This primary flame is led into a cyclone, where ash and coarse particles are separated. The flame leaves the cyclone to the secondary combustion chamber where preheated secondary air is tangentially blown to the fuel rich flame. This process leads to vortex flow patterns in the secondary combustion chamber. The vortex forms a virtual burning chamber according to the mass flow with good mixing of all combustion reaction partners. Together with the Institute for Process Engineering and Power Plant Technology (IVD) of the University of Stuttgart we applied Laser Doppler Anemometer (LDA) to measure the flow field in the secondary combustion chamber.

Particle analysis in the flue gas of the new burner system showed a clear decrease of Number Concentrations (NC), compared to the state-of-the-art wood chips burner.

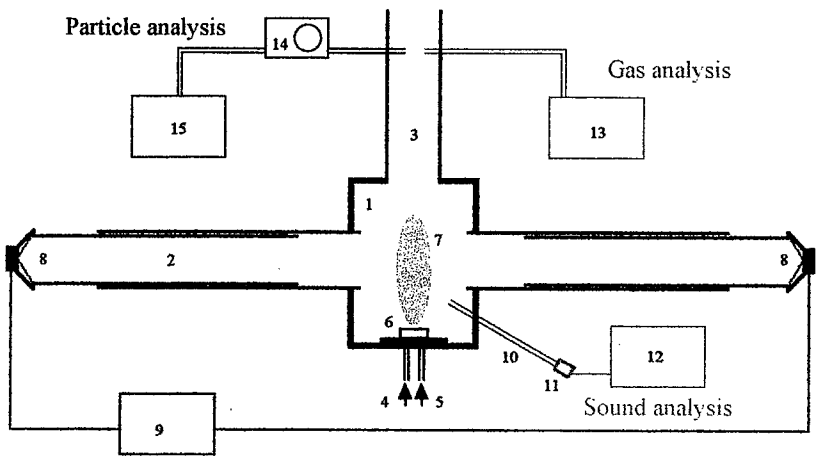


Thermo-Acoustic Effects and Combustion Vortices



In the ongoing R&D project *Increased combustion stability in modulating biomass boilers for district heating systems* we investigate in addition to the vortex flow patterns thermo-acoustic effects on particulate formation in modulating biomass boilers.

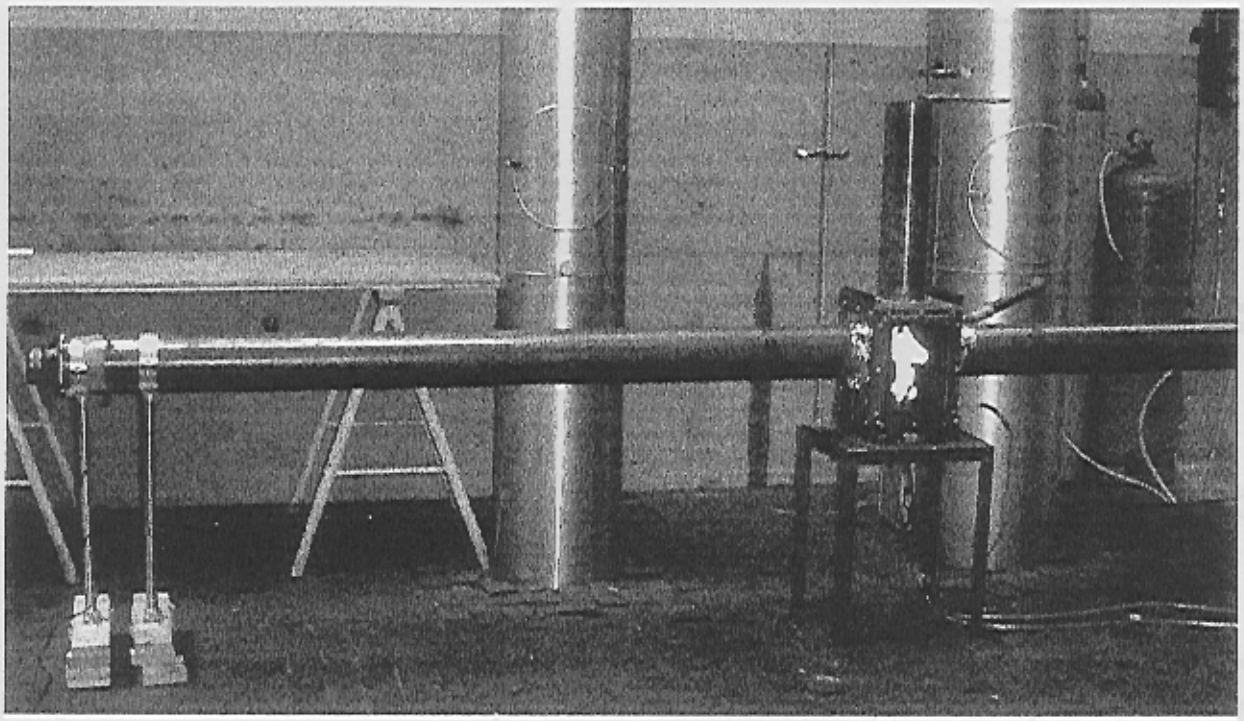
We tested acoustic effects in premixed and diffusion flames.



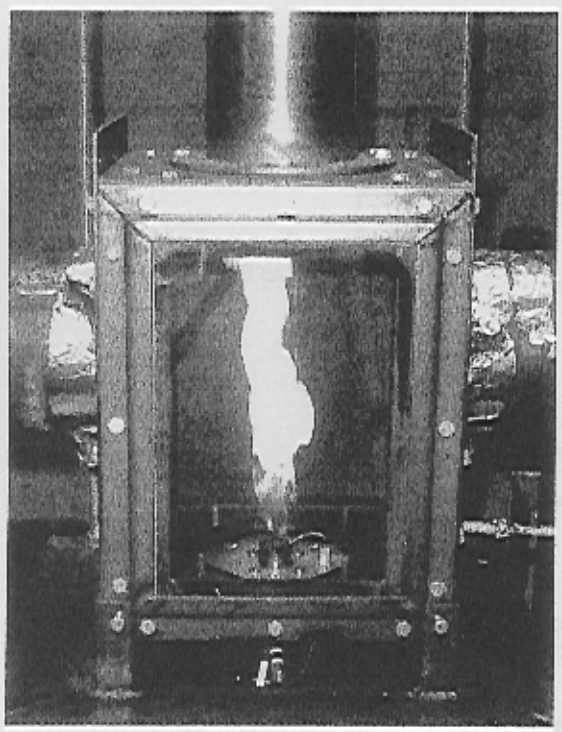
Test rig for excitation of gas flames with sound

Legend:

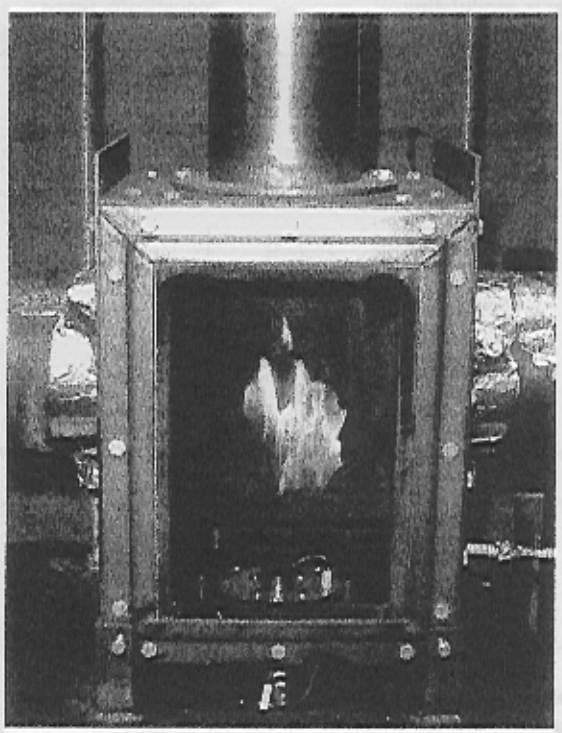
1 Small combustion chamber	6 Burner module	11 Microphone
2 Telescopic tube	7 Flame	12 Sound analysing system
3 Short flue duct	8 Speakers	13 Fluegas analysing systems
4 Fuel	9 Sound generator/amplifier	14 Particle dilution unit
5 Combustion air	10 Ceramic tube	15 Particle analysing systems



Test rig for active excitation of flames with sound. In a small combustion chamber we put a gas burner system with controlled fuel and combustion air. Setting the combustion air to a fuel rich flame led to products of incomplete combustion (PIC) such as PM.

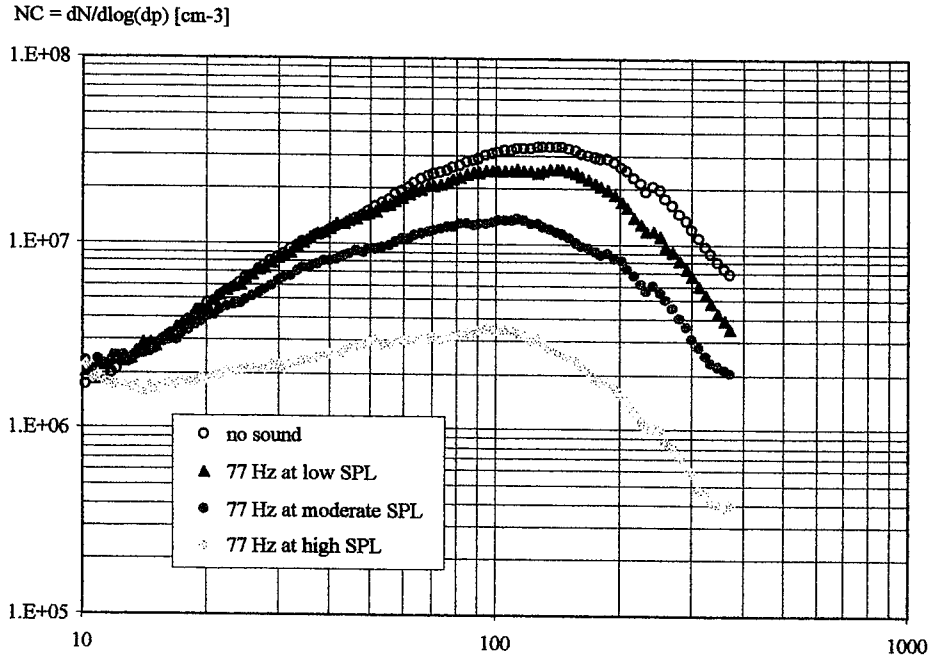


Without applied sound the flame reached the top of the combustion chamber.



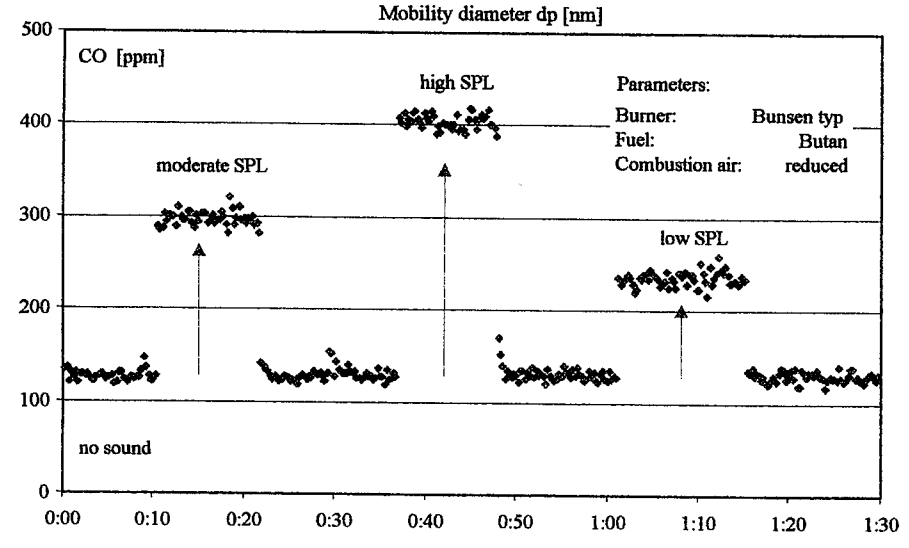
Treated from both sides with sound of 77 Hz at moderate sound pressure level, the flame was shortened and consisted of many little tips, which indicated a better mixture of fuel gas and combustion air.

Effects of Sound Pressure Level

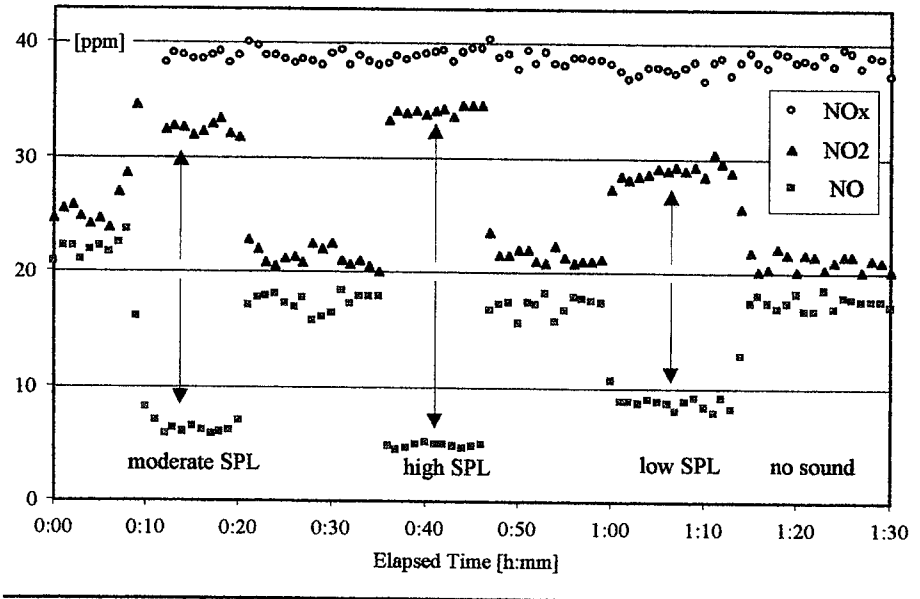


Particle formation:

Sound pressure level strongly influences particle formation. High levels of SPL decrease formation of particles in the range of mode diameter.



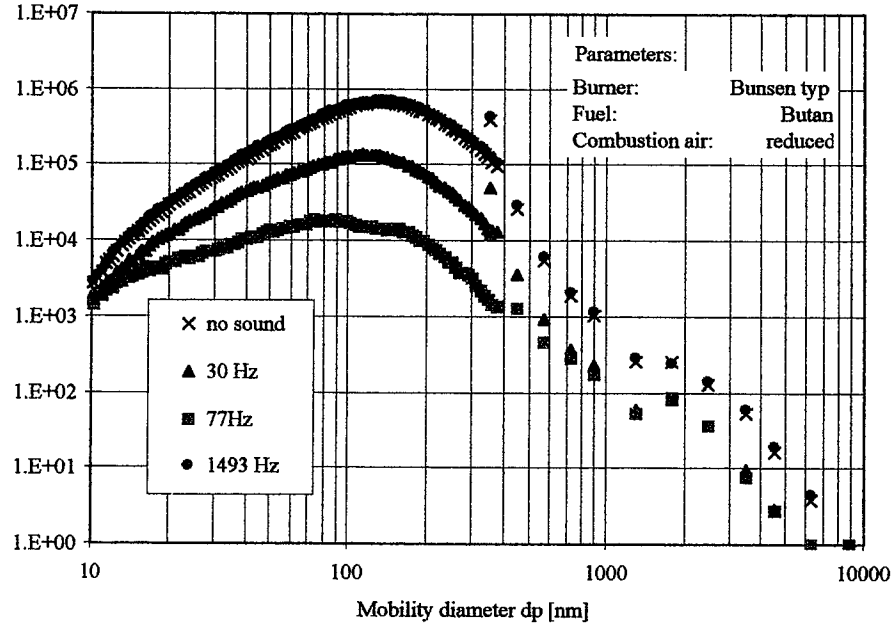
CO formation as function of sound pressure level



NO/NO2 formation as function of sound pressure level

Effects of Frequency

NC = dN/dlog(dp) [cm-3]

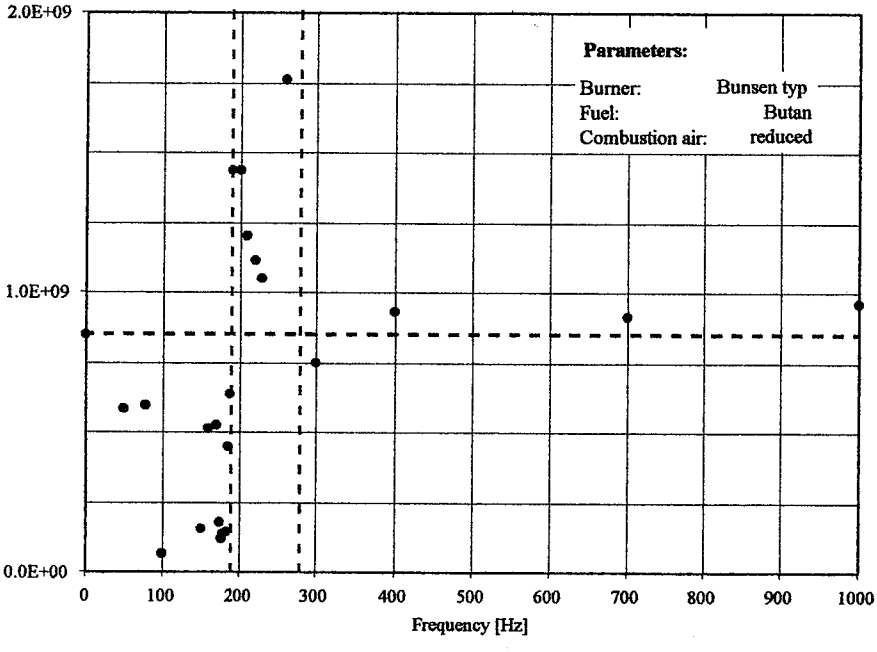


Particle formation:

Frequency has also an impact on particle formation.

Particles below 400 nm were measured with SMPS, whereas particles in the range of 300 nm to 10 µm were counted with a Mini Laser-Aerosol-Monitor *Grimm Dustcheck Type 1.108.*

Total Number Concentration (TNC) [cm-3]



Low frequencies reduced and increased particle formation.

Frequencies between 50 and 180 Hz reduced Total Number Concentration (TNC). In the range of 200 to 300 there was a increase observed. At frequencies above about 400 Hz we recognised almost no effect of sound treatment on particle formation.

Particle Reduction in Modulating Biomass Boilers

Study of two different test rigs for active acoustical treatment of biomass flames.

EC - JOULE III; JOR3-CT98-0278

Our subjects:

Thermo-acoustic effects and combustion vortices

Next steps:

Construction of a Pellet-biomass Vortex burner system with acoustical excitation of flame

Comparison with a Rijeke-like tube burner system (Test rig of VTT, Finnland)

Our focus:

Particle formation

CO and NOx in flue gas

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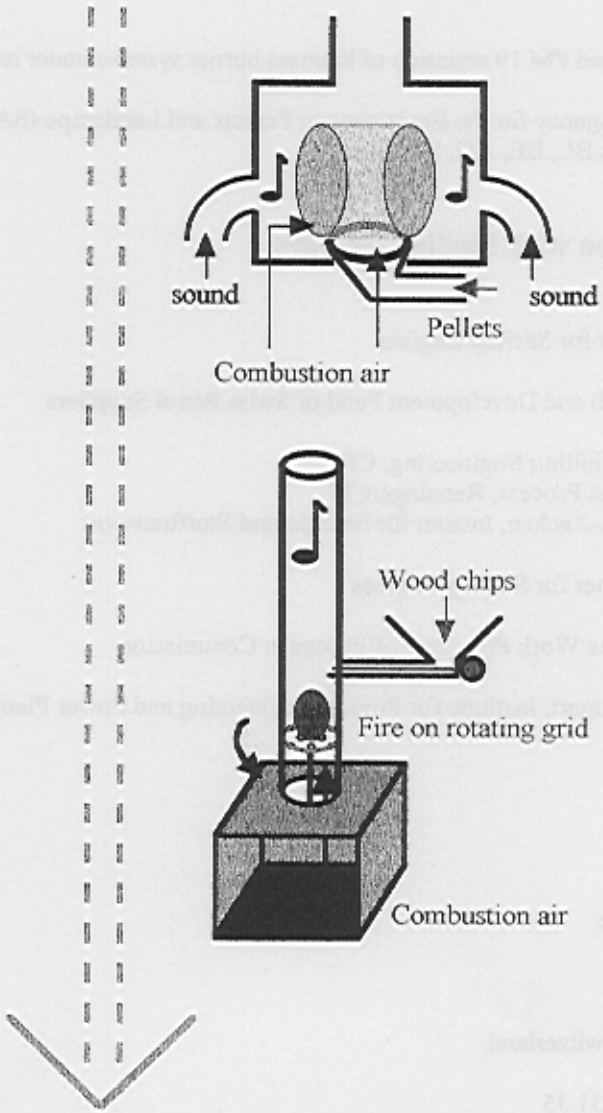

Prototyp of an acoustically tuned biomass burner system

Further Projects in Nanoparticle Measurement

Particle Emission of Biomass Burners

In situ measurement of particle emission and particle size distribution of typical wood burning systems

Definition of

Emission factors and PM 10 emission of biomass burner systems under real world conditions

Funded: Swiss Agency for the Environment, Forests and Landscape (SAEFL),
Cantons BL, BE, AG, SO, LU

Micro-Co-Generation with Stirling Engines

1. Diesel Fuel Burner for Stirling Engines

   Funded: Research and Development Fund of Swiss Petrol Suppliers

   Partners: S.W. Schilling Engineering, CH
   WS-Heat Process, Renningen, D
   RW-TH-Aachen, Institut für Energie und Stofftransport

2. Biomass Fuel Burner for Stirling Engines

   Applied: 5th Frame Work Programe of European Commission

   Partner: TU-Stuttgart, Institute for Process Engineering and Power Plant Technology

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