ERA-NET Bioenergy

Future Bio Tec

Concepts for the design and application of particle precipitators for residential biomass combustion

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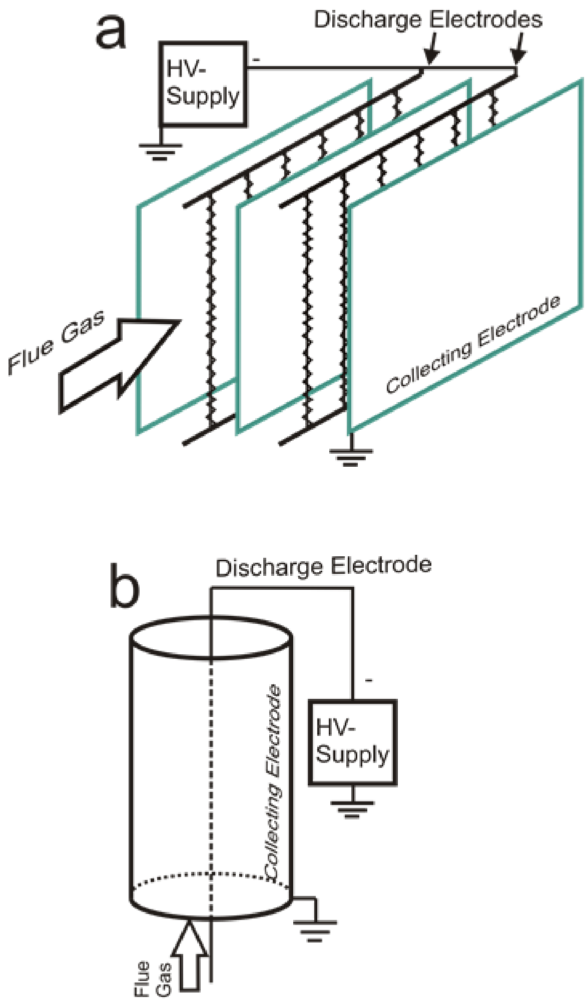
Objectives

- Residential firing of biomass is a major source of $PM_{2.5}$ in ambient air
  - Other sources are traffic and industry
- $PM_{2.5}$ constitutes a potential health risk
- Particle emissions from residential firing can be limited by
  1. Favourable combustion conditions (modern technologies)
  2. Flue gas cleaning devices
- There are several flue gas precipitator devices under development, some already on market
  - Mostly Electro Static Precipitators (ESPs)
- This work summarizes experiences from residential ESPs tested within the Future BioTec project group

Basic definitions of an ESP

The main parts of an ESP are:

- **Discharge electrodes**
  - charge the particles in the ESP
- **Collecting electrodes**
  - Attract and collects charged particles
- **High-voltage power supply**



Efficiency

- **To meet future emission requirements the collecting efficiency of an ESP should be at least 75 % during normal operation**

- **Under ideal conditions (turbulent flow, perfect mixing and immediate charging), the collecting efficiency is determined by:**

$$\eta = 1 - e^{-De}$$

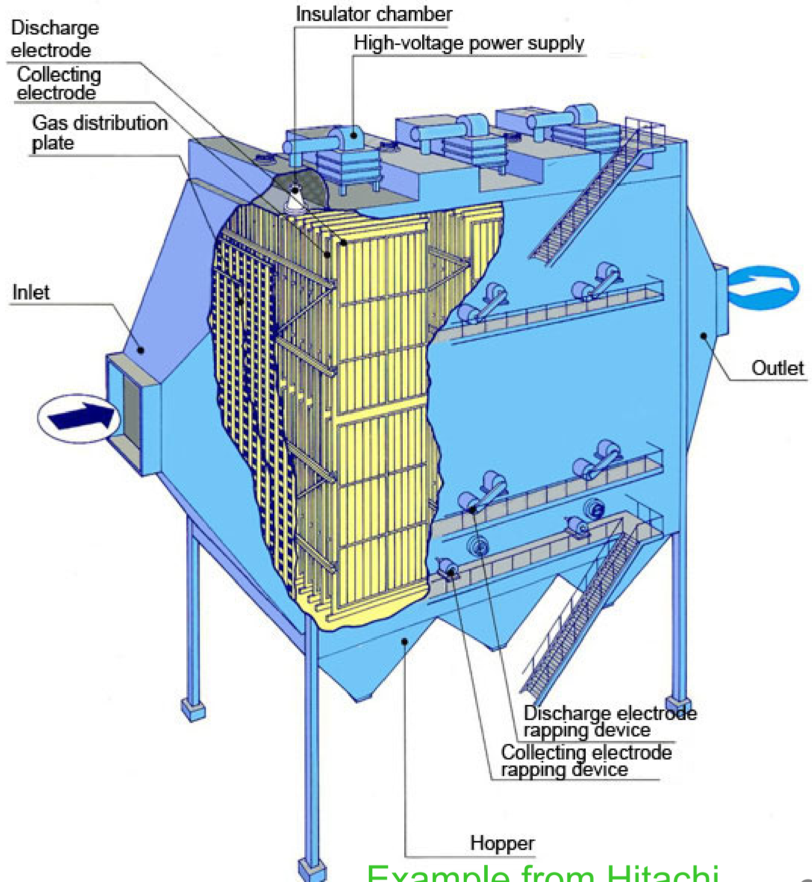
in which *De* is the Deutsch number:

$$De = \omega \frac{A}{Q}$$

Large scale example

Large-scale ESPs

- Used in industrial processes for decades
- Large gas volumes:
    - Large cross-section (gas velocity)
    - Parallel plate design
    - Typical voltage 50-80 kV
- Individually controlled systems
- Rapping of electrodes
    - Dust collected in hoppers
- High collecting efficiency possible
- Robust design, low pressure drop



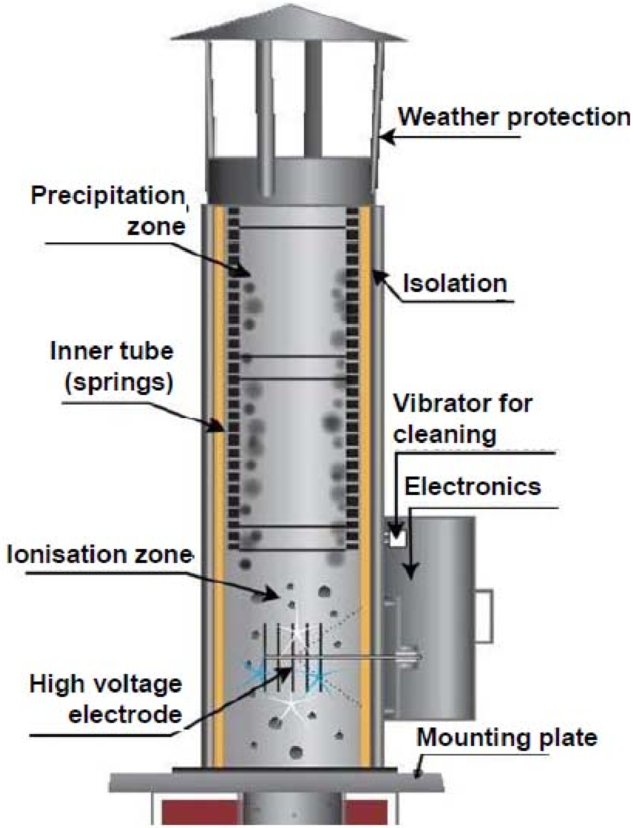
Example from Hitachi

Residential ESP compared to industrial units

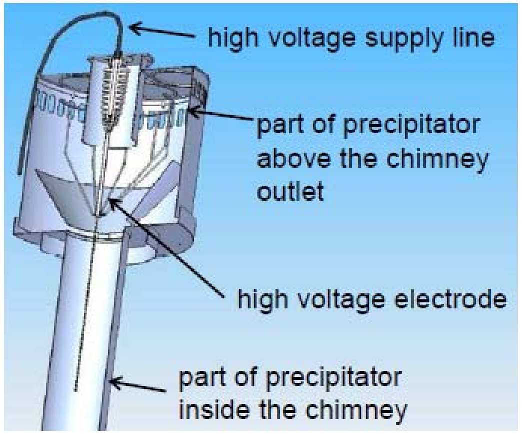
- **A precipitator for residential use differs from traditional industrial designs:**
  - **Lesser gas volumes**
    - Smaller units, usually of cylindrical design
  - **Non professional users**
    - User friendly control interface
    - Robust
    - Safety
  - **Residential installation**
    - Size and design an issue
    - Cost
    - Noise

Residential ESP examples - Rooftop

Two examples of rooftop designs



RuFF-Kat (Germany)



ResidentialESP/APP (Norway)

- Space for installation
- Cooler flue gas
- Inspection
- Weather conditions

Residential ESP examples - Indoors

Combustion devices

- Stove
  - In living space
- Boiler
  - Separate room

ESP location

- Next to boiler/stove
- In chimney/gas duct

Considerations

- Limited space
- Maintenance
- Noise
- Design (appearance)

SF20/Spanner (Germany)

Airbox/Spartherm (Switzerland)

Design criteria 1

- **Installation**
  - Correct installation crucial for the function
  - Should be performed by a professional
  - Well written installation manual should be available

- **Pressure drop**
  - Low pressure drop important, especially for natural draft systems

- **Control system**
  - For automated boilers/stoves – an interface between boiler and ESP control systems can manage start and stop procedures
  - Otherwise, a temperature sensor may be used
  - Operation of cleaning system for electrodes

Design criteria 2

High voltage and electrodes

- Power supply (in range of 15- 30 kV)
- Thin discharge electrodes, preferably with sharp surfaces, to achieve high charging efficiency (corona)

- Some observed causes for frequent sparkovers:
  - Too flexible electrodes (vibrates during operation)
  - Poorly aligned electrodes
  - ESP below moisture dew point (condensation)
  - Ash deposits and condensation of tars on insulators

Design criteria 3

Maintenance and availability

- **Available a whole heating season without maintenance**
  - Except cleaning by chimney sweeper, if required
  - Availability ensured by robust and well-proven technical solutions

- **Simple, safe and quick access for cleaning and inspection**

- **Influence on ESP operation from condensable and sticky particles formed under poor combustion conditions (for example during start up)?**

- **Internal logging of ESP operation?**

Design criteria 4

- **Applicability of ESP for different combustion devices specified**
  - Old systems (perhaps high amounts of tars and soot)
  - Stoves
  - Boilers
- **Cleaning, the dust collected have to be removed**
  - Automatic cleaning system (vibration, brush or water spray)
  - Manual cleaning by chimney sweeper or user
- **Safety**
  - Closed system (prevent leakage indoors)
  - High voltage
  - Fire safety
  - Safety instructions

Quality assurance

- **ESP function verified by independent testing laboratory**
  - **Efficiency**
  - **Availability**

- **No test-standard yet available for residential ESP:s**

- **General aspects regarding measurements at ESP units:**
  - **Losses of charged particles in sampling lines not fully understood**
  - **Hard to determine collecting efficiency of rooftop filters in the field**
  - **Considerations at test stand tests, some examples:**
    - Position of ESP comparable to foreseen installation
    - Flue gas temperature comparable to field conditions
    - Simultaneous dust measurements before and after filter recommended
    - Preferably, tests are performed after filter been in use

Performance testing

- **Two different evaluation criteria:**
  - **The collecting efficiency of the ESP**
    - ✓ Calculated from PM concentrations at ESP inlet and outlet
    - ✓ This criterion is of interest from a technical viewpoint
  - **PM emission in the flue gas at ESP outlet**
    - ✓ Measured in diluted flue gas (diluted to below 50°C)
    - ✓ PM will include condensable organic compounds that still are in gas phase at the ESP outlet
    - ✓ This provides a more relevant value from an environmental viewpoint

- **A standard test method is being elaborated in Germany (VDI Guideline 33999)**

Conclusions

- Electrostatic precipitation (ESP) of fly ash is a well-established technique for flue gas cleaning in industrial processes.
- Smaller EPS:s, to suit residential furnaces, are under development.
- In order to become widely used, such ESPs have to meet some criteria regarding efficiency, cost, and availability. Furthermore, aspects of safety, noise and convenient installation have to be considered.
- There is a lack of commonly accepted methods for testing the efficiency of residential ESPs. The set-up and sampling methods used may considerably affect the test results. Thus, caution should be applied when comparing results from ESPs tested under different conditions.

Thank you for your attention

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