New developments in small scale ESP technology

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• Introduction

• Current developments of small ESP's for wood combustion and results from tests

• Outlook on filter test project by TFZ

• Test procedure

• Conclusions
German emission directive
– Proposed future limitations for room heaters/stoves

Requirements for type tests according to 1.BImSchV-amendment, emissions given at 13 % O₂-conc.
(here: no inspection by chimney sweep shall be required!)

<table>
<thead>
<tr>
<th>Furnace type</th>
<th>Step 1: erected after regulation date</th>
<th>Step 2: erected after 31.12.2014</th>
<th>erected after regulation date</th>
<th>minimum efficiency [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO [g/m³]</td>
<td>Dust [g/m³]</td>
<td>CO [g/m³]</td>
<td>Dust [g/m³]</td>
</tr>
<tr>
<td>Room heaters with flat furnace</td>
<td>2,0</td>
<td>0,10</td>
<td>1,25</td>
<td>0,04</td>
</tr>
<tr>
<td>Room heaters with filling furnace</td>
<td>2,5</td>
<td>0,10</td>
<td>1,25</td>
<td>0,04</td>
</tr>
<tr>
<td>Heat storage stoves</td>
<td>2,0</td>
<td>0,10</td>
<td>1,25</td>
<td>0,04</td>
</tr>
<tr>
<td>Closed fireplaces</td>
<td>2,0</td>
<td>0,10</td>
<td>1,25</td>
<td>0,04</td>
</tr>
<tr>
<td>Tiled stoves (flat furnace)</td>
<td>2,0</td>
<td>0,10</td>
<td>1,25</td>
<td>0,04</td>
</tr>
<tr>
<td>Tiled stoves (filling furnace)</td>
<td>2,5</td>
<td>0,10</td>
<td>1,25</td>
<td>0,04</td>
</tr>
<tr>
<td>Cooking stoves</td>
<td>3,0</td>
<td>0,10</td>
<td>1,50</td>
<td>0,04</td>
</tr>
<tr>
<td>Central heating&amp;cooking stoves</td>
<td>3,5</td>
<td>0,10</td>
<td>1,50</td>
<td>0,04</td>
</tr>
<tr>
<td>Pellet stoves without water jacket</td>
<td>0,40</td>
<td>0,05</td>
<td>0,25</td>
<td>0,03</td>
</tr>
<tr>
<td>Pellet stoves with water jacket</td>
<td>0,40</td>
<td>0,03</td>
<td>0,25</td>
<td>0,02</td>
</tr>
</tbody>
</table>
State-of-the-art wood furnaces in Germany – Recent measurements from practice oriented trials. Here: total dust and particle sizes

Average of 10 to 12 measurements (per furnace) using hard and soft wood in the usual moisture range

Source: TFZ, unpublished
Spanner ESP-type (Germany): SFF 20, SFF 50 and SFF 100
Electrostatic precipitator for small scale application

- Manufacturer: Spanner Re², Neufahrn, Germany
- Power of boiler: <30 kW, <85 kW and <150 kW
- Voltage: 15 kV (50 W transformer)
- Pressure drop: 40 Pa
- PM-emission: <10 mg/Nm³
- Automatic cleaning system by vibration (daily)
- State: field testing of prototypes
- Prospected price: around 1000,-/1500,- €
Spanner ESP-type: Large filter version (SFF 50)

- Filter entrance (top)
- Filter outlet (bottom)
Test results with Spanner ESP-type (SFF 20):
Particle removal from log wood boiler exhaust fumes

PM emissions and removal efficiency measured with 30 kW log wood boiler at the TFZ test stand with different wood fuels (unpublished data by TFZ)

- Birch, mc=18%
- Beech, mc=14%
- Spruce, mc=23%
- Normal logs
- Spruce, mc=13%
- Unsplit
- Spruce, mc=13%
- Large logs

The chart shows the PM emissions and removal efficiency in mg/Nm³ (13 % O₂) and % removal efficiency, respectively, for different wood fuels.
Test results with Spanner ESP-type (SFF20):
Particle size distribution
Ruegg- / K&W-type ESP (Switzerland/Germany):
Electrostatic precipitator for small scale application

- Mainly for wood stoves
- Min. 1,5 m metal exhaust pipe required
- Voltage: 20 kV
- Cleaning by hand
- Electr. consumption: 12/3,6 W (on/standby)
- State: series (Switzerland), field testing (Germany)
- Price: around 1300,- €
Ruegg- / K&W-type ESP: Examples of applications

**Application in living rooms**
- Filter insert
  - Electrode
  - Thermostat
- Feed pipe
  - Purge air
  - High voltage
- Control module
  - Control unit
  - Ventilator
  - Electr. supply 230V

**Application in chimneys**

Source: Ruegg, Switzerland
Test results with Ruegg- / K&W- type ESP

**Further conclusion:**
- Particle reduction by mass is slightly lower than by particle numbers (SMPS)
- Separation is largely independent from total dust concentrations
APP-type ESP (Residential ESP, by APP Applied Plasma Physics, Norway): Electrostatic precipitator for chimney-top applications

- Mainly for wood or coal stoves and boilers
- Voltage: not specified
- Electr. consumption: not specified
- Price: yet unknown (below 1000,- €)
- State: field testing of prototypes

Source: APP, Norway
Oeko Tube ESP (by OekoSolve AG, Liechtenstein/Switzerland) Electrostatic precipitator for chimney-top applications

- Mainly for wood stoves
- Max. power output: 35 kW
- Voltage: not specified
- Cleaning by hand (chimney sweep?): first revision after 2 months
- Electr. consumption: 20 - 30 W
- Price: about 1400,- €
- State: series

Source: OekoSolve, Switzerland
Spartherm ESP ("Airbox", Germany)
Electrostatic precipitator for living room applications

- Mainly for wood stoves or fireplaces
- Max. power output: 15 kW
- Manual bypass operation
- Voltage: not specified
- Cleaning by hand (every 100 hours, using vacuum cleaner)
- Electr. consumption: not specified
- Price: yet unknown
- Ptate: yet unknown

Source: Spartherm, Germany
Developing an "electrostatic scrubber" (Project FH Gelsenkirchen/Germany)

Scrubber by Schräder Abgastechnik

Load distribution and orientation of electrical field

Test setup for "electrostatic scrubber"

Source: Prof. R. Rawe, FH Gelsenkirchen, Germany
Filter test programme by TFZ (starting October 2008)

Field test: 10 filters installed in the City of Straubing:
4 x Ruegg/K&W; 3 x Spanner type, 3 x APP-type)
- Monitoring of function
- Cleaning requirements
- Operational errors

Test stand trials:
Each filter is tested over 6 weeks semi-permanent operation for
- Particle reduction (diluted/ undiluted flue gas) with old&new stove or boiler
- Monitoring of function
- Cleaning requirements (depositions)
- Dust composition changes
- Electricity consumption
Absolute increase of measured total dust emission after flue gas dilution as function of OGC-emission

Evaluation of 95 parallel measurements at a chimney stove and a tiled stove using various wood fuels at different operational modes (wood logs, briquettes, various moisture contents, charging modes and times etc.)

\[ y = 5 \times 10^{-5}x^2 + 0.1078x + 3.5295 \]

\[ R^2 = 0.9709 \]

Source: TFZ unpublished (2008)
Particle sampling using dilution tunnel

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean value (from 95 trials)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂, undiluted</td>
<td>4.8 Vol.-%</td>
</tr>
<tr>
<td>CO₂, diluted</td>
<td>0.9 Vol.-%</td>
</tr>
<tr>
<td>dilution ratio</td>
<td>5.7</td>
</tr>
<tr>
<td>flue gas temperature, undiluted</td>
<td>262 °C</td>
</tr>
<tr>
<td>flue gas temperature, diluted</td>
<td>56 °C</td>
</tr>
</tbody>
</table>

*Dilution tunnel at TFZ*
Open questions on filter test setup

• Testing with/without flue gas dilution? (TFZ: both variants!)

• Consideration of any purge air of the filters (relevant for Spanner- and Ruegg-type). ⇒ similar air injection is required for dust sampling before filter (in parallel tests)

• Method for flue gas dilution (e.g. partial flow dilution combined with full flow dilution method?)

• TFZ: Partial flow dilution (2x): controlled air ratio adjusted to temperature requirements of <52 °C (acc. to engine standard ISO 8178)
Conclusions

• Several concepts or products for low cost ESP are currently available for small scale furnaces.
• Suitable in-room applications are rarely given (chimney based solutions are easier)
• Cleaning and withdrawal of precipitated dust is often not mechanized (high manual efforts)
• Still only few experimental data and long term experience are available

• Internationally accepted testing procedures for ESP need to be developed!
Thank you for your attention!

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