

IEA Task32-Workshop:

“Fine particulate emissions from small-scale biomass furnaces“

Electrostatic precipitators for small-scale wood combustion systems – Results from lab- and field tests

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für Nachwachsende Rohstoffe (TFZ), Straubing



Structure

- Overview on small-scale particle separators
- Field test with 3 ESP-types
- Results from test stand trials (4 ESP's)
- Summary and conclusions



Overview on particle separator types for residential applications

Principle	Advantage	Disadvantage
Electrostatic precipitator (ESP)	low pressure drop, low cost	problems with organic particles
Filtering separators (e.g. baghouse filters)	good separation effect	high pressure drop, high technical efforts
Cyclone separators	low cost	low effect on fine particles
Scrubber	flue gas condensation possible	high technical efforts medium separation effect
Flue gas condensation	additional heat gain	low separation effect
Catalyst	effect on gases, lower C_{org} load on particles	very low separation effect



Configuration of ESP's



Separators for flue gas tube integration
(living rooms)



Chimney-top separators



ESP-chimney systems



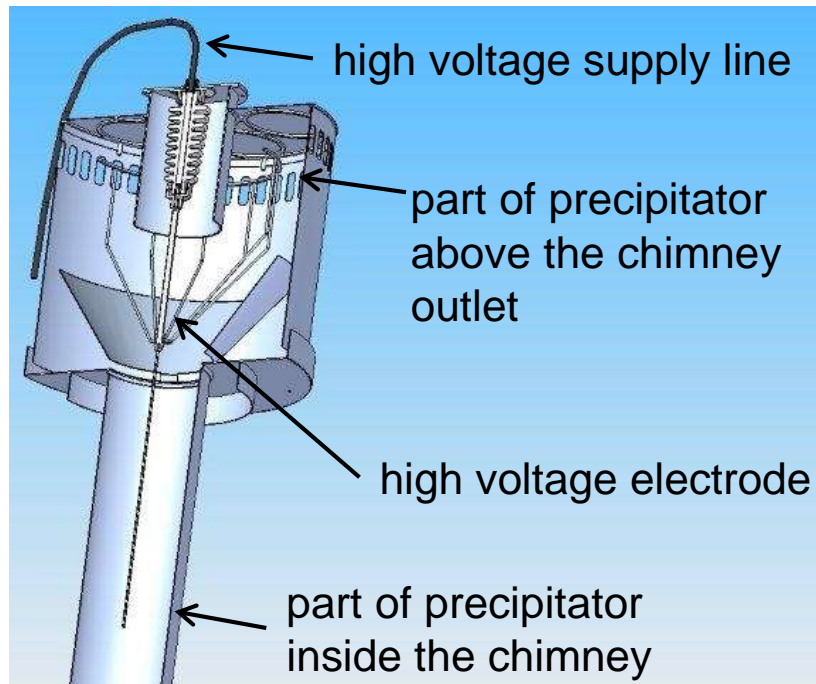
Separators for central heating boilers

Chimney-top ESP (1): Applied Plasma Physics (Norway)

- Type: APP R_{esidential} ESP
- Cleaning/maintenance from chimney top
- effective length : ca. 1 m
- High voltage; max. 33 kV
- No active mechanical removal of PM deposits
- *Status: development*



Photos:TFZ



Graph: APP

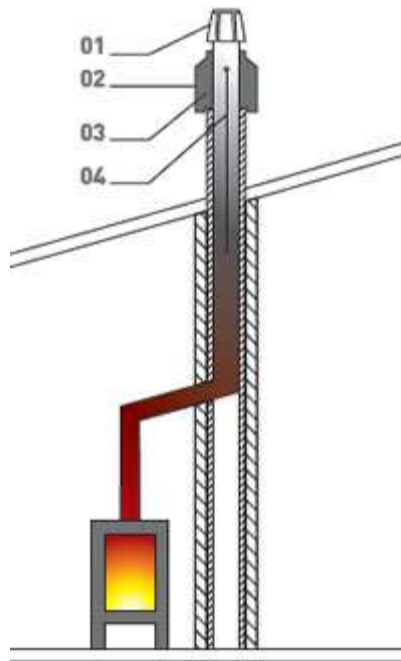


Chimney-top ESP (2): OekoTube (by OekoSolve, Liechtenstein)

- Type: Oekotube
- no active removal of deposits
- max 70 kW heat power output
- *Status: market available (only Switzerland)*

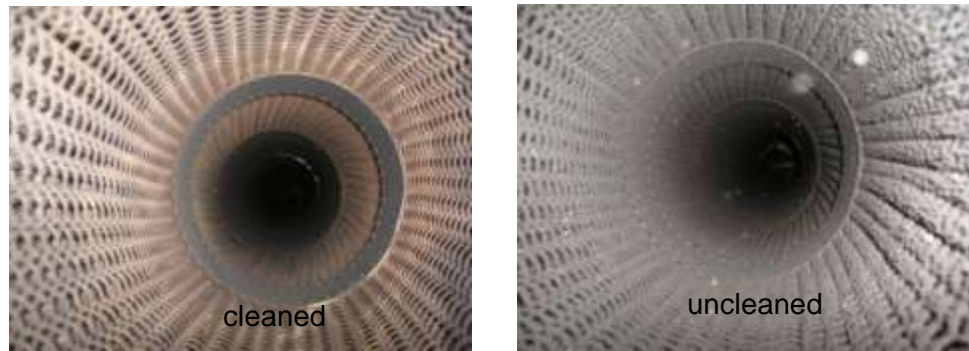


Photos / Image: Oekosolve



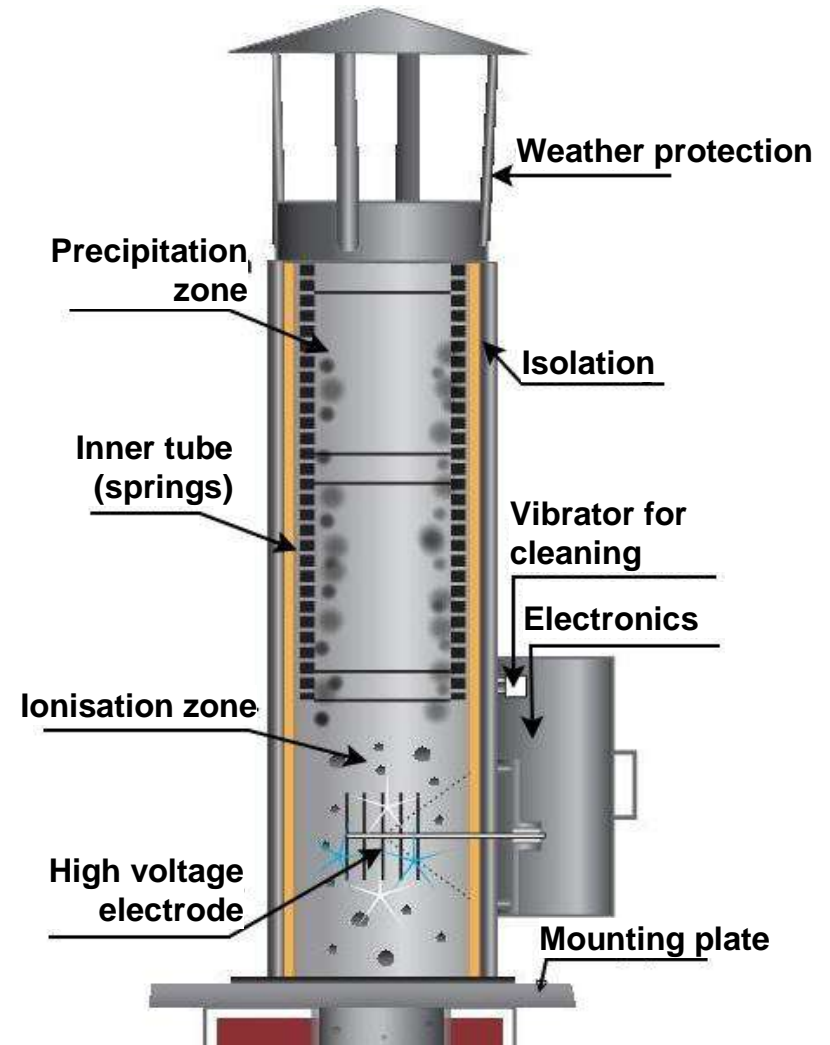
Chimney-top ESP (3): Ruff-Kat GmbH, Holzkirchen

- Type: Ruff-Kat
- Chimney mounted
- Voltage: 20 kV
- Mechanical removal of deposits (vibration)
- Length: ca. 1 m above chimney opening
- *Status: Certified, field test*



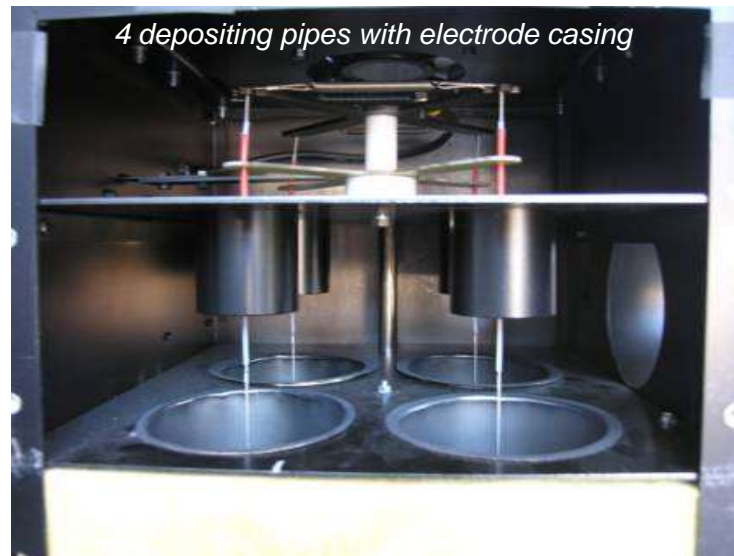
Separation surface (inner walls)

Photos / Image: Ruff-Kat

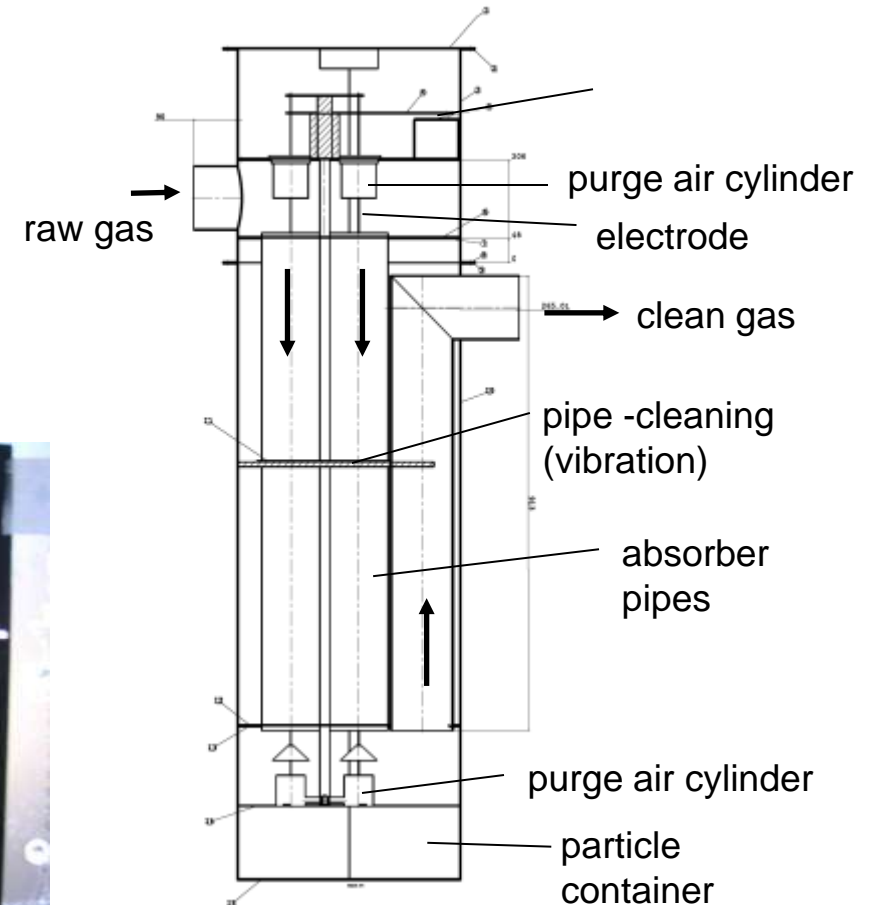


Boiler attached ESP (1): **Spanner SFF (by Fa. Spanner Re²)**

- Types: Spanner SFF 20 / SFF50 / SFF100
- Mounted beside a boiler
- Voltage: 15 kV
- Mechanical removal of deposits (vibration)
- With purge air cleaning of electrodes
- Pressure drop: 40 pa
- *Status: Field tests*



Photos: TFZ



Werkbild : Spanner

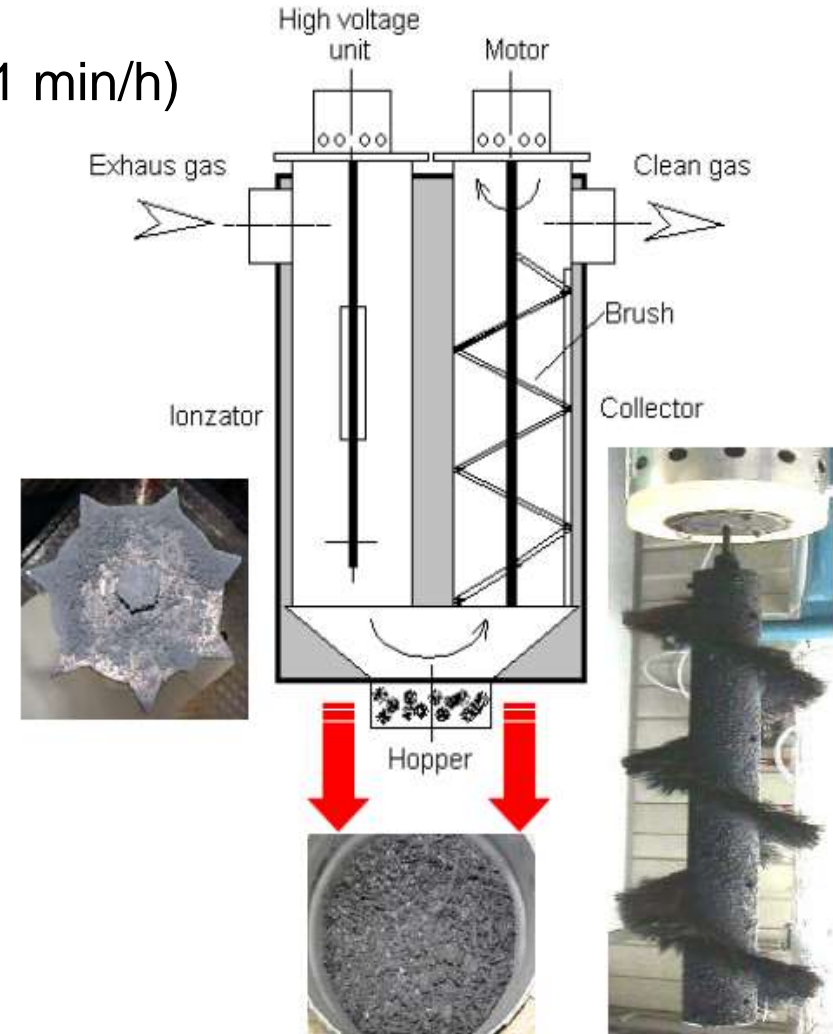


Boiler attached ESP (2): Carola – Separator (by KIT, Karlsruhe)

- Type: CAROLA (Development: Karlsruhe Institut of Technology)
- Mounted beside a boiler
- Mechanical removal of deposits (rot. brush, 1 min/h)
- Pressure drop: 10 pa
- Voltage 16-18 kV
- Tested with up to 30 kW
- *Status: development*

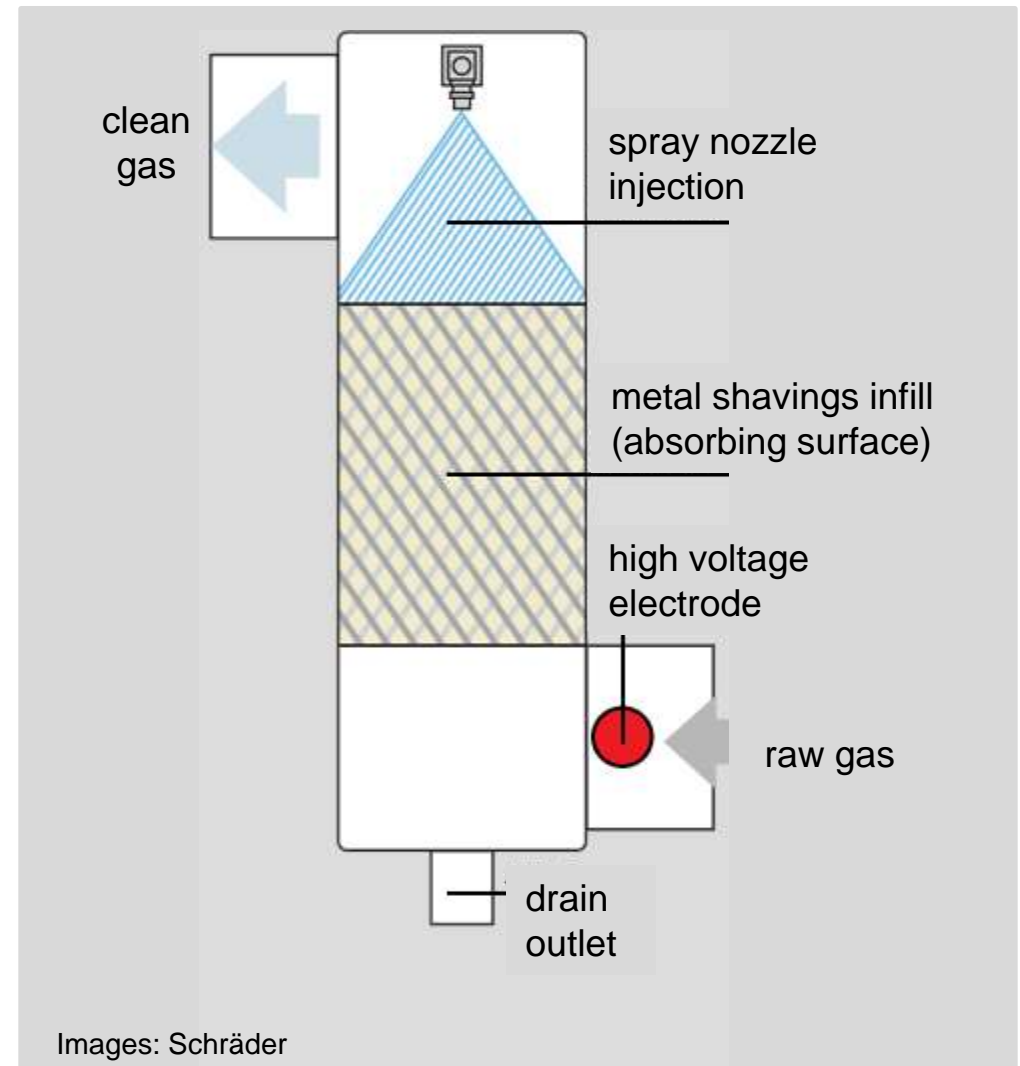


Images: KIT



Boiler attached ESP (3): AL-Top (by Schröder, Kamen)

- Type: AL-Top, ESP with infill of wetted metal shavings as absorbing surface
- Mounted beside a boiler
- *Status: development*



Integrated ESP (1): "Airbox" by Spartherm Feuerungstechnik

- Type: Airbox (for fireplace inserts),
- Supplement exclusively for manufacturer 's furnaces (>15 kW)
- Plate-type ESP, manually switched-on
- Manual removal of PM deposits required after 100 h operation
- *Status: market-available*



Photo / Images: Spartherm



Integrated ESP (2): Zumikron (by Rüegg, Switzerland)

- Type: Zumikron
- Developed by Rüegg (Switzerland), built by: Kutzner+Weber
- Mainly for single room heaters
- Use of purge air for electrode cleaning
- Manual removal of PM deposits required
- *Status: market-available (only Switzerland)*

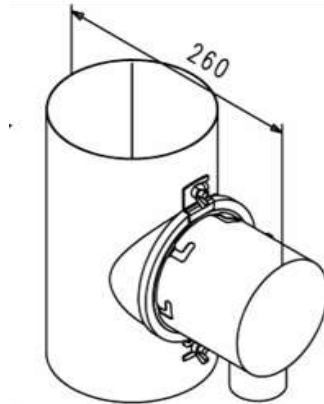
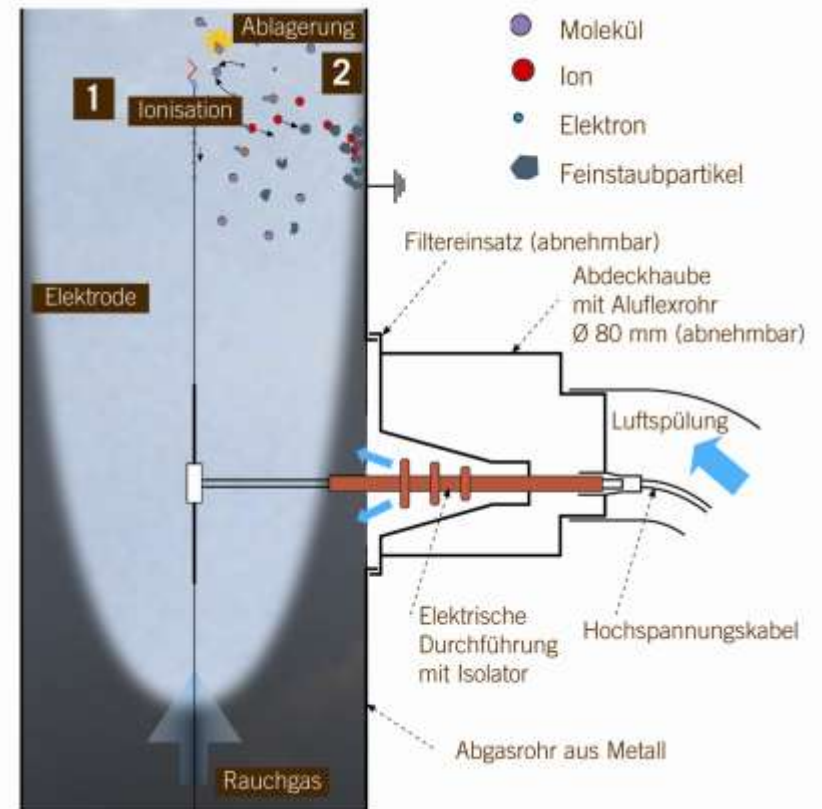


Photo / Images: Rüegg

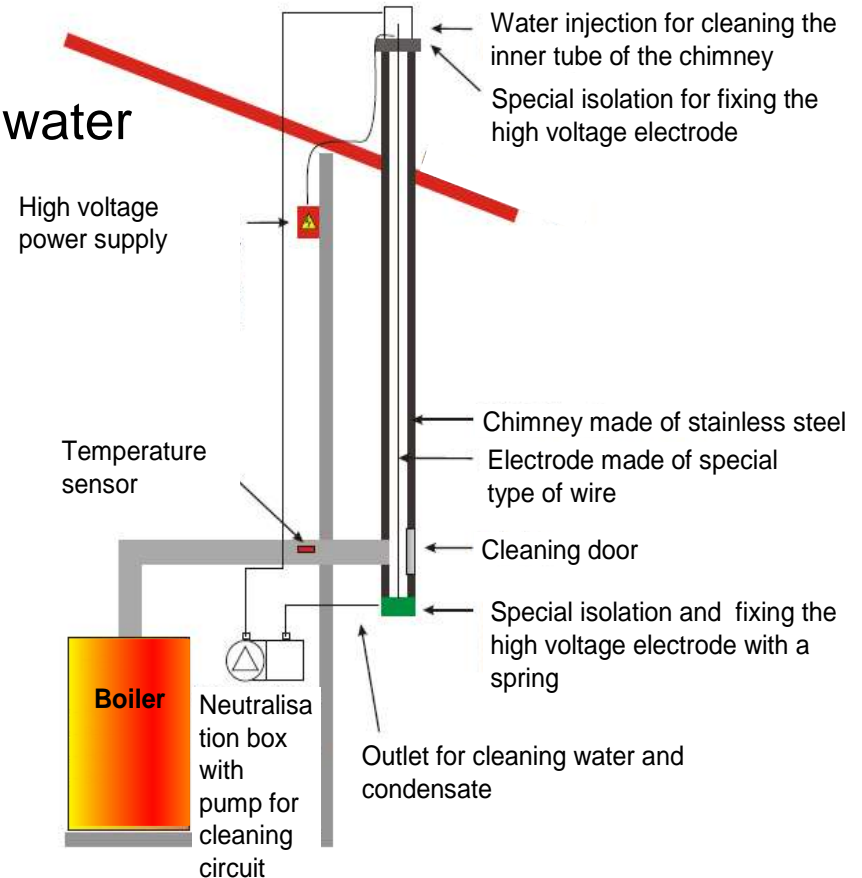


ESP-Chimney-type: Feinstaubkiller (by TH-Alternativ-Energie)

- Type: “Feinstaubkiller“ (ESP-chimney)
- Electrode over full length of chimney
- Automatic periodic cleaning by rinsing with water from surge tank
- Particle removal as sludge deposit
- *Status: single built and single approval*



Photos: TFZ



TH Alternativ Energie
Stand: 18.03.2009
www.th-alternativ-energie.de

Image: TH-Alternativ-Energie



Procedure of field tests performed by TFZ

- Selection of 10 private households
- Assembling of filters and automatic data recording (electricity consumption, operating hours)
- Instruction of users concerning documentation
- Continuous operation of ESP's during heating period 2008/2009
- Regular cleaning and observation by chimney sweep
- Collection of deposited ash from the chimneys and the ESP's over the full period and
- Determination of fuel consumption



ESP-types applied in field test (1)



APP R_{esidential} ESP,
example here: with chimney stove (6 kW)

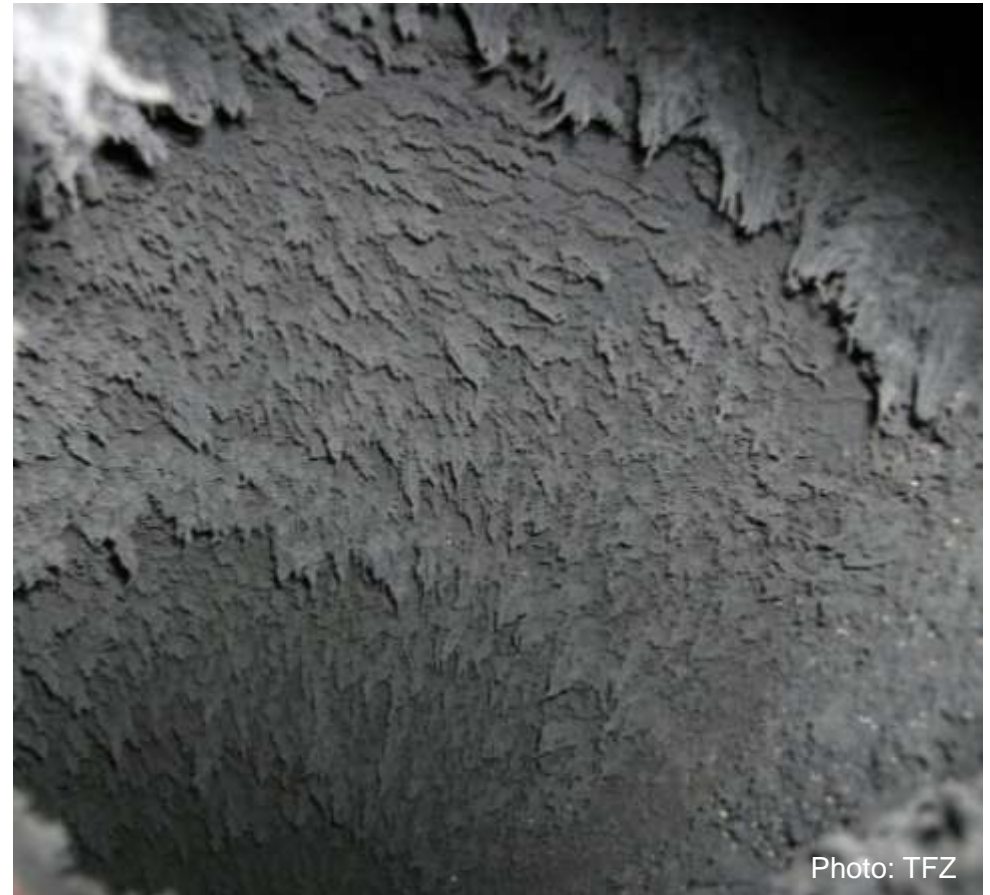


Photos: TFZ

ESP-types applied in field test (2)



K&W Zumik®on,
example here: with cooking stove (6 kW)



ESP-types applied in field test (3)



Spanner SFF 20

- example here: with log wood boiler, 15 kW
- mechanical cleaning was here activated manually by press button

Photos: Ritt



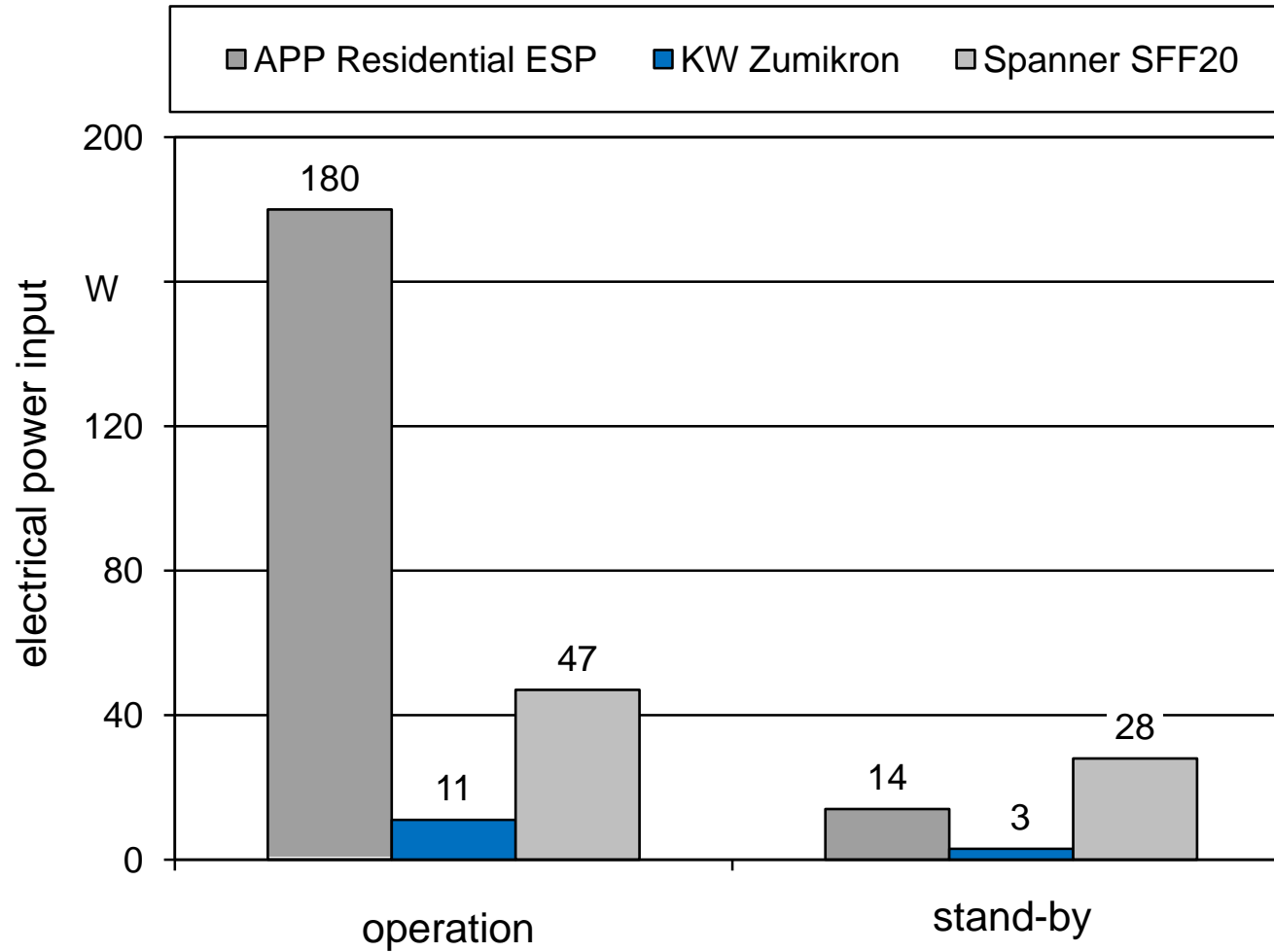
Observations from field tests

Observed failures/troubles:

- short circuits
- failure of electrode purge air supply
- burn-out of fuses
- display failure
- breaking of electrode
- fixation problems (at chimney top)
- sensor defects
- high voltage failure
- chimney draft problems
- rain water intrusion into chimney
- counteraction of ESP-purge air with furnace air supply
- noise harassment



Results field tests: electrical power input



Field test results: Calculated particle reduction

Participant	Furnace	ESP-type	Fuel	Collected particle mass ^{b)}	Theoretical reduction of PM emission ^{c)}
1	Chimney stove	K&W Zumikron	log wood (spruce, pine)	0.18 kg	9 mg/m ³
2	Chimney stove	K&W Zumikron	log wood (spruce, pine)	2.38 kg	54 mg/m ³
4 a)	Kitchen stove	K&W Zumikron	log wood (spruce, pine, beech)	0.06 kg	5 mg/m ³
5	Chimney stove	APP Residential ESP	log wood (beech)	0.30 kg	17 mg/m ³
6	2 Chimney stoves	APP Residential ESP	log wood (spruce, pine)	0.36 kg	52 mg/m ³
7	Tiled stove	APP Residential ESP	log wood (spruce, pine)	0.83 kg	25 mg/m ³
8	Log wood boiler	Spanner SFF 20	log wood (spruce, pine)	3.60 kg	122 mg/m ³
9	Pellet boiler	Spanner SFF 20	Wood pellets	0.15 kg	5 mg/m ³
10	Wood chip boiler	Spanner SFF 50	Wood chips	18.59 kg	158 mg/m ³

^a Only ash from connecting pipe and ESP because further furnaces were connected to the same chimney

^b Particle mass in ESP + connecting pipe + chimney

^c Calculated from fuel mass and specific flue gas volume, based at 13 % O₂



Field test results: Investigation of PAH-content in PM deposits

- Materials with more than 50 ppm PAH are considered as cancerogeneous in Germany
- Above 1000 ppm they are considered as dangerous waste.

PAH-contents of PM collected from connecting pipes + ESP + chimney

Participant	1	2	3	4	5	6	7	8	9	10
Furnace	chimney stove	chimney stove	tiled stove	kitchen stove	chimney stove	chimney stove	tiled stove	log wood boiler	pellet boiler	wood chip boiler
Separator	K & W	K & W	K & W	K & W	APP	APP	APP	Spanner	Spanner	Spanner
Total PAH	183ppm	744ppm	1344ppm	922ppm	66ppm	470ppm	1713ppm	380ppm	21ppm	197ppm



Trials performed at TFZ test laboratory

- Selection of 2 suitable chimney stoves (a simple and a high value product)
- Tests with of 2 ESP's (*Zumik®on* and *APP*) at both stoves \Rightarrow 4 test series
- Tests with *Spanner SFF20* at log wood boiler (simple natural draft type)
- Test duration: 5 to 6 weeks per test series (typical operation)
- Weekly measurements of particle separation in raw and clean gas (gravimetric determination)
- Additional trials with ESP-chimney type by “*TH-Alternative Energie*“



Additional tests: ESP-chimney system by TH-Alternativ Energie

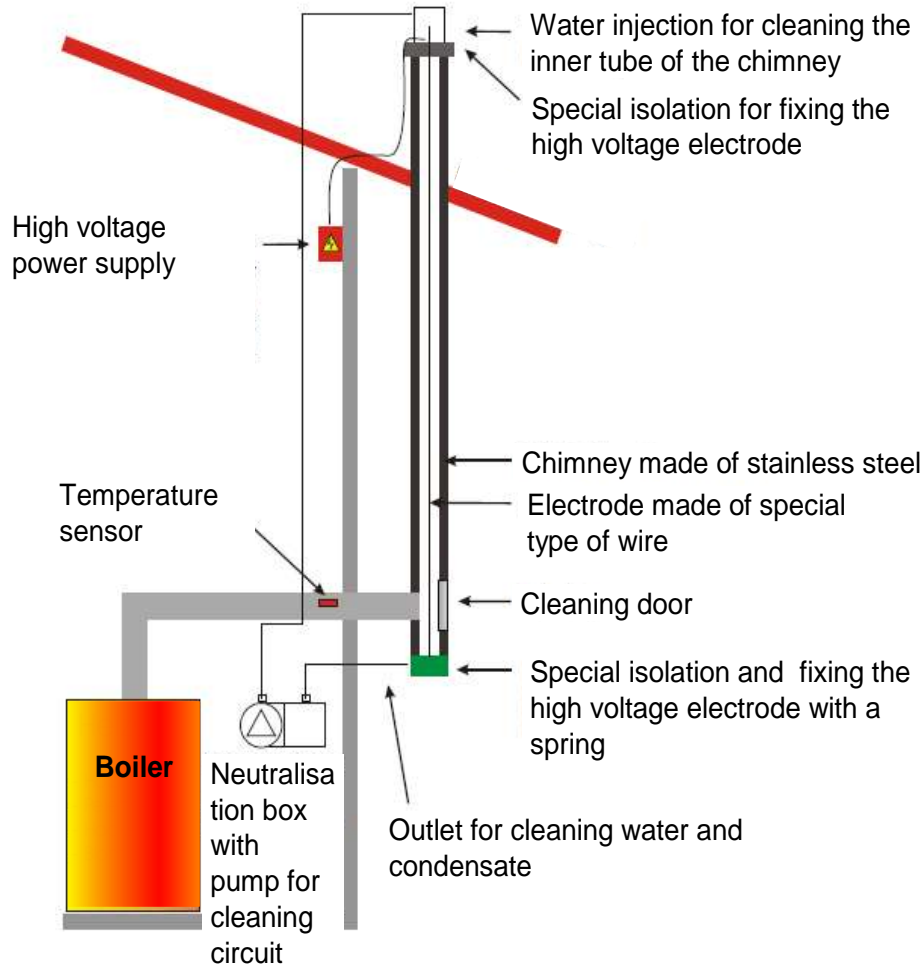
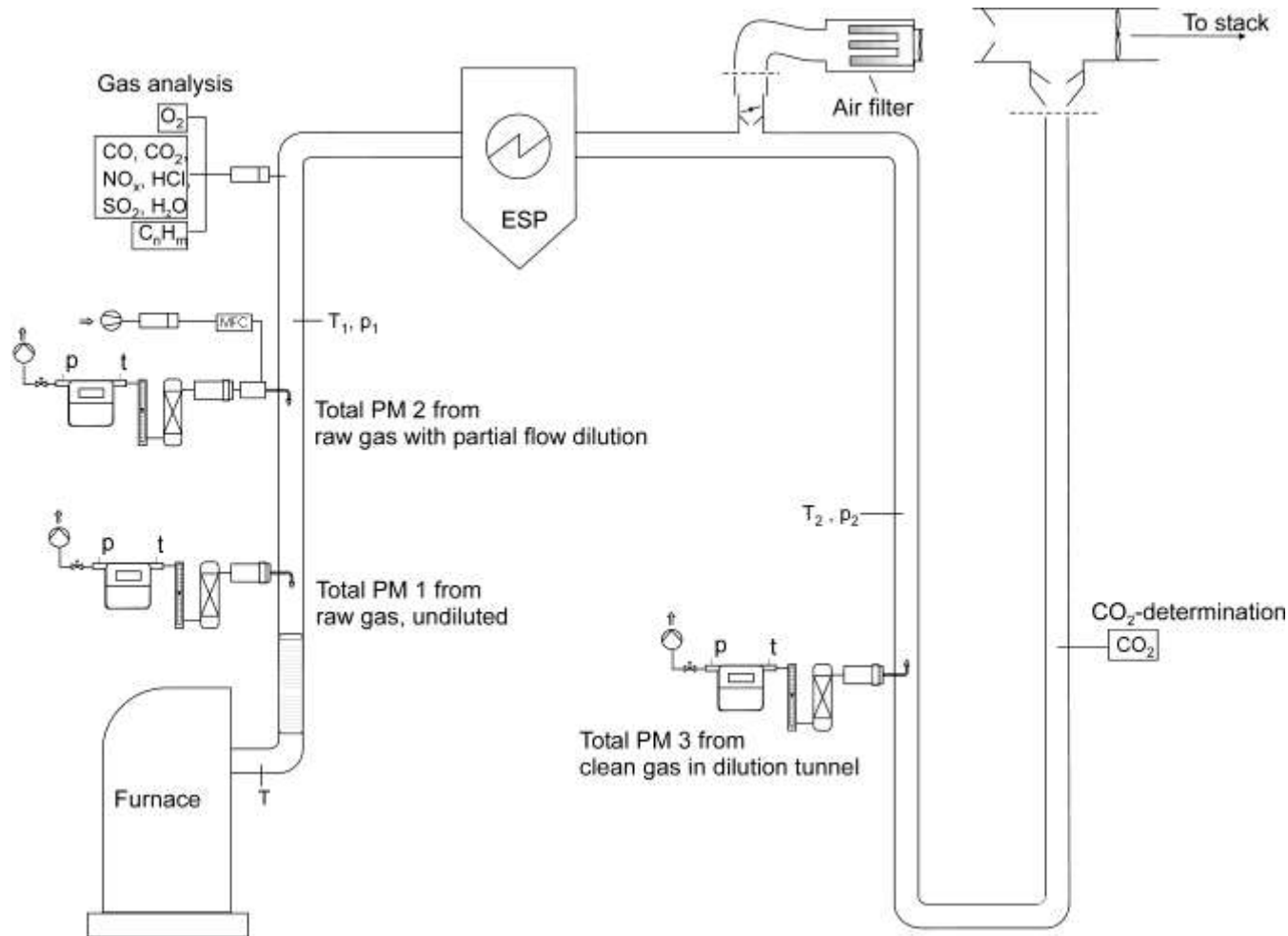


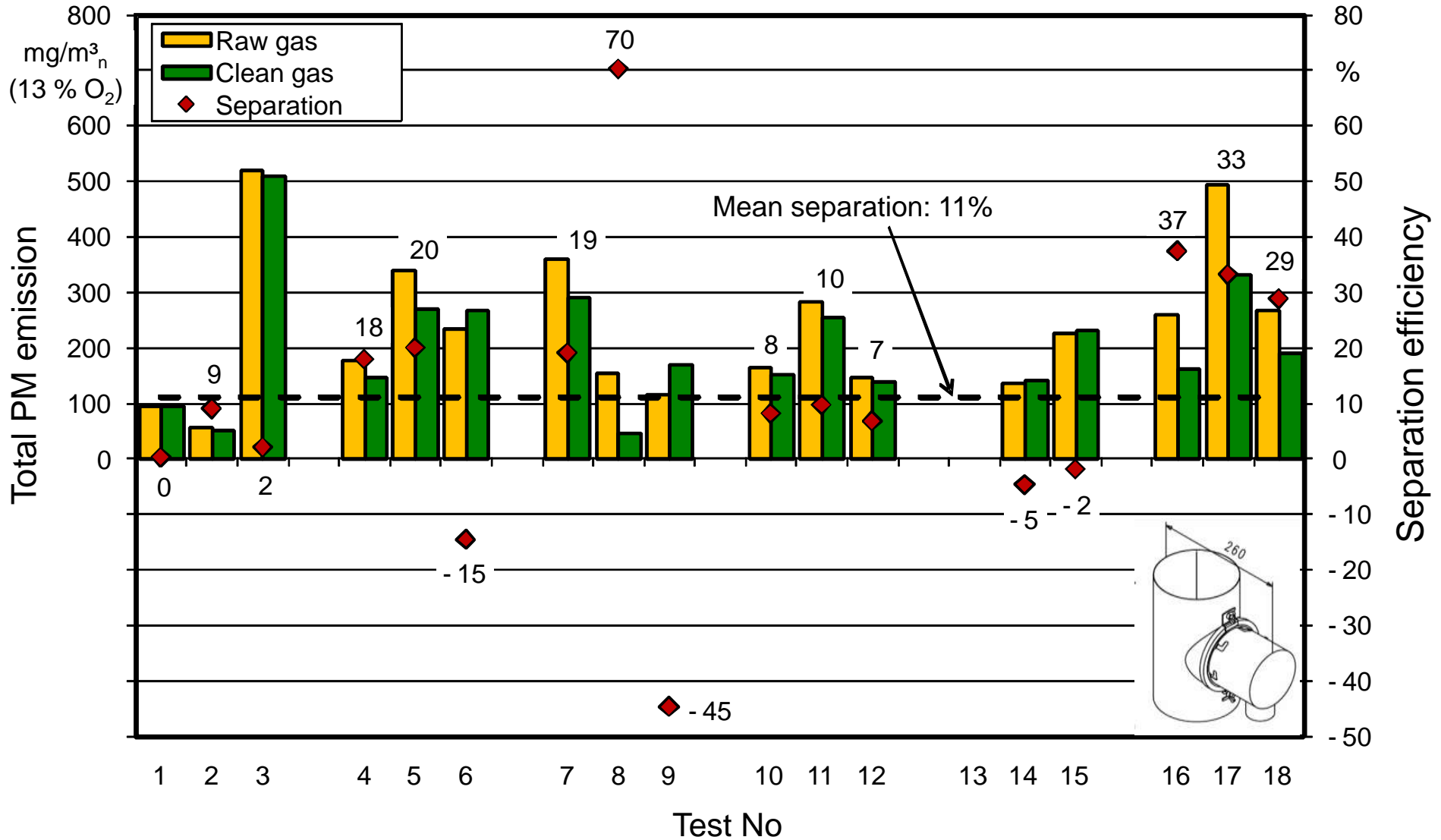
Image: TH-Alternativ-Energie

Test stand setup

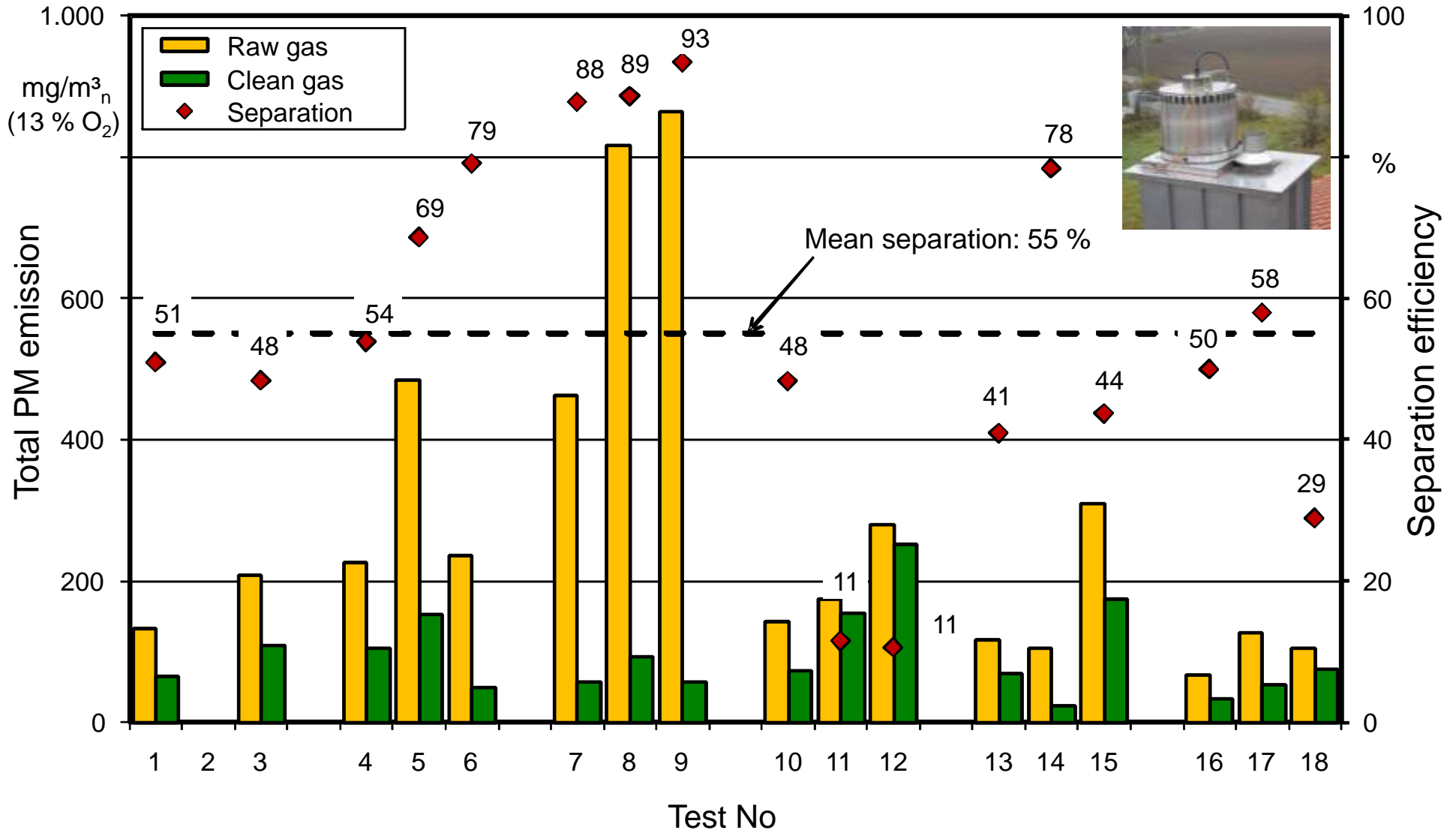


- Dilution ratio: 1 : 4 – 6
- Diluted temperature: < 52 °C
- Gravimetric PM-determination
- Measuring over the full batch
- 3 fuel batches per trial

Test stand results: Zumikron ESP with simple-type chimney stove

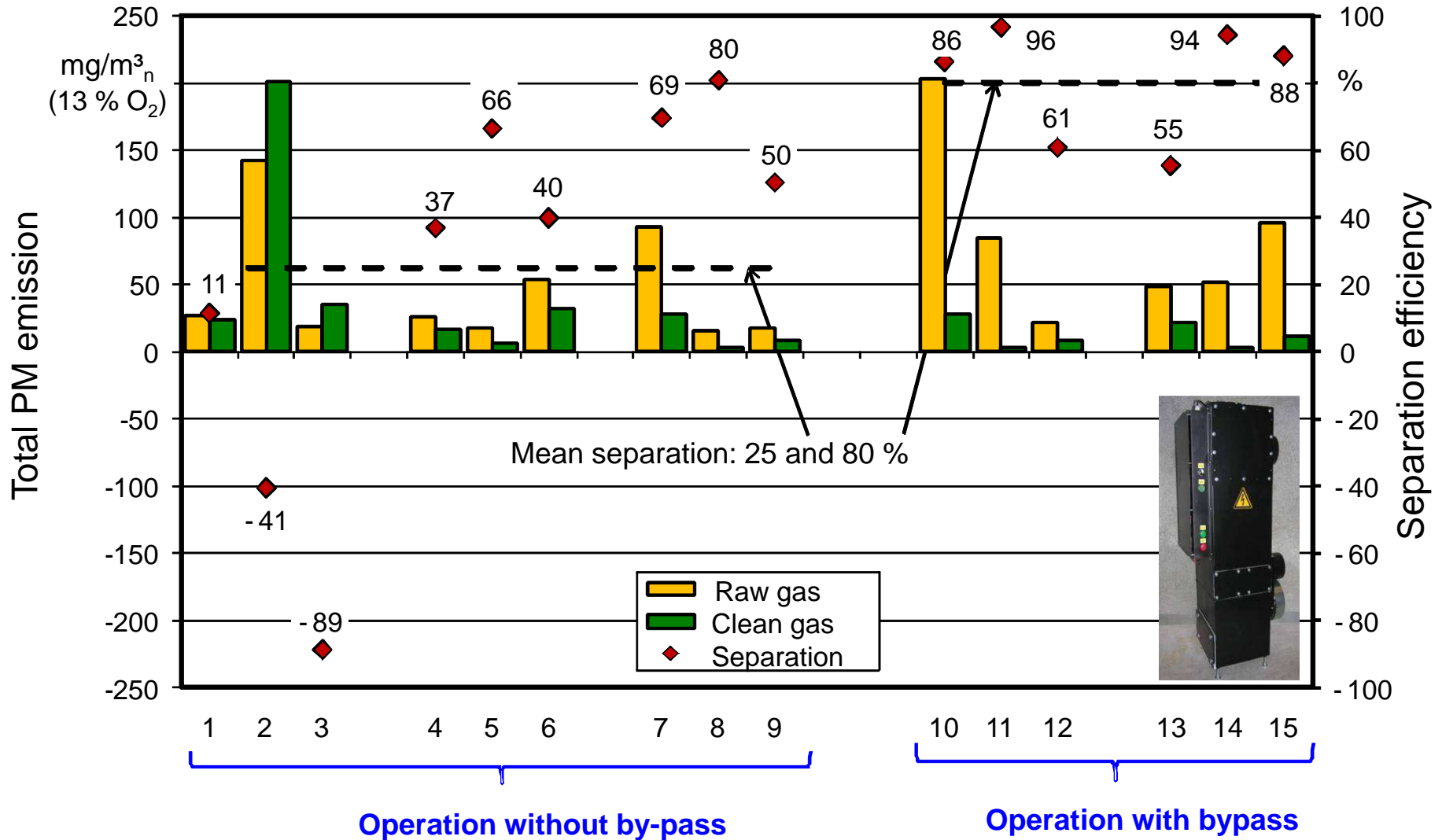


Test stand results : APP Residential ESP with simple-type chimney stove



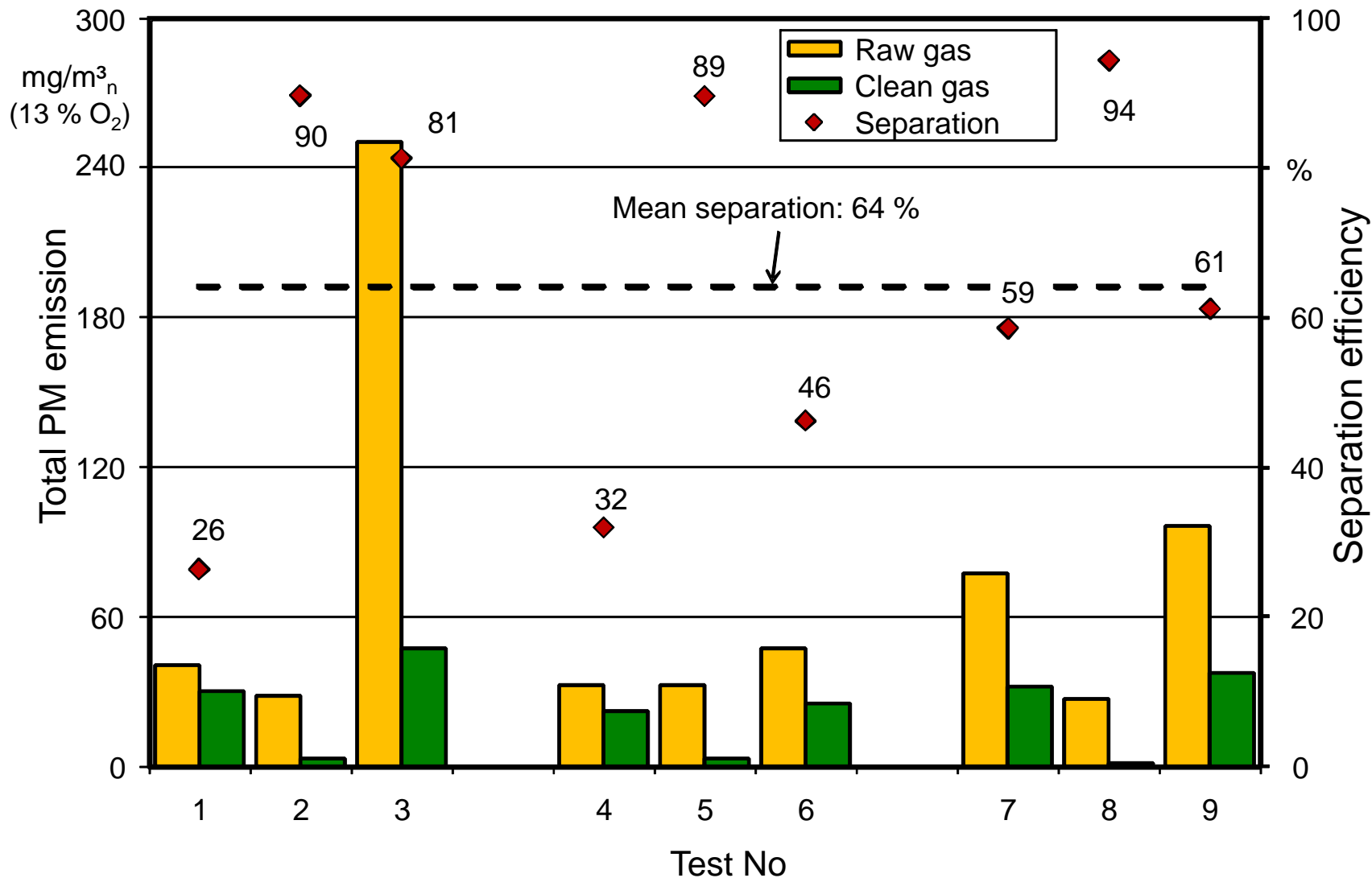
Test stand results :

Spanner SFF 20 with log wood boiler (simple natural draft)



Test stand results :

TH Feinstaubkiller with log wood boiler (simple natural draft)



Summary and conclusions

- Three of four ESP's showed acceptable PM separations in both, field and laboratory tests.
- An active mechanical cleaning of the deposited particles seems inevitable for an undisturbed ESP-operation.
- Bevor market introduction the observed failures should be avoided reliably.
- An installation in living rooms is not accepted by the residents.
- Specific rules for handling and disposal of collected PM-mass need to be elaborated due to the observed high PAH-contents.
- For determining the separation efficiency, a reliable and repeatable test method needs to be elaborated.





Download of the complete research report
(in German language):

TFZ-report No. 23

www.tfz.bayern.de

Thanks for listening !

