# A new device for fast solid-volatile nanoparticle differentiation

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# **Motivation**

 Even the best physical nanoparticle characterization is always incomplete







#### SMPS, TSI inc.

#### ACSM, Aerodyne



# **Motivation**

- Great devices available for size distribution measurements and chemical fingerprinting, but...
- Can we build a device that
  - Gives limited insight into particle composition
  - Gives limited insight into particle sizes
  - Is comparatively low cost
  - Is comparatively robust + easy to use



## Concept

- Catalytic stripper operating at e.g. 350°C will evaporate things like oil droplets
- Oil vapor will be oxidized to CO<sub>2</sub> in the catalytic stripper
- Only nonvolatile particles can pass through





hot technologies • clean solutions

#### https://catalytic-instruments.com/product/cs015/



# **Options**



#### **Dual detector**

High time resolution



### Single detector

- Cheaper
- No drift between detectors







#### Detector

- Wide choice of possible detectors (in principle)
- We use a modified "automotive Partector" diffusion-charging-based particle number counter





# **Automotive Partector principle**



Charging current measurement



#### **Instrument response**

 Standard automotive Partector, counting efficiency similar to CPC (no size information)

- Modified version used:
  - down to 10nm
  - can also measure average particle diameter
- 10-second measurement cycle for volatile/nonvolatile fraction each, so 20s for full measurement





# **Example application: Airport measurements**

Session 7: Health effects A: aircraft Chairs: Nino Künzli, Barbara Rothen

# Luckily, an image of the past!



- Modern jet engines produce no more visible smoke
- "Smoke number" standard is being complemented with a new nonvolatile particle number standard



### Particles from modern jet engines are small!



Nonvolatile particles only

- Smaller than most other sources
- Size measurement can be used as "fingerprint"

Fig. 9. Particle size distributions (a) and characteristic parameters - GMD (b) and GSD (c) for the CFM56-7B26/3 engine.

Lobo et al. Comparison of standardized sampling and measurement reference systems for aircraft engine non-volatile particulate matter emissions Journal of Aerosol Science, 2020, <u>https://doi.org/10.1016/j.jaerosci.2020.105557</u>



# **Sampling location**



Images: Flughafen Zürich AG



# **Monitoring @Pier A**



- Airport has been operating SMPS with switching catalytic stripper since 2018
- Our instrument added this spring for testing



# **Challenges (besides tiny particles!)**

- High peak concentrations (too high for direct CPC measurement), 1-2 orders of magnitude higher than average
- Short duration of plume peaks (30-120s) is problematic for the SMPS



![](_page_14_Picture_0.jpeg)

# **Example time series & fingerprinting by diameter**

Volatile + nonvolatile (all) vs nonvolatiles only

![](_page_14_Figure_3.jpeg)

![](_page_15_Picture_0.jpeg)

# **Solid-volatile differentiation**

#### Calculate volatile/nonvolatile fraction – e.g. for a day, or even a single peak

![](_page_15_Figure_3.jpeg)

![](_page_16_Picture_0.jpeg)

# Advantage of high time resolution

#### Differentiate peaks from baseline:

![](_page_16_Figure_3.jpeg)

#### number

![](_page_17_Picture_0.jpeg)

# **Statistics**

 Combine the two ideas: Calculate volatile/nonvolatile fractions for peaks (fresh jet engine emissions) and baselines (background) separately

- Averaged over 6 weeks (15.4.-31.5. 2022)
- Peaks: nonvolatile fraction ~22%
- Baseline: nonvolatile fraction ~46%

![](_page_17_Figure_6.jpeg)

![](_page_17_Figure_7.jpeg)

![](_page_18_Picture_0.jpeg)

# Conclusion

- 2 month unattended operation demonstrated
- Volatile/nonvolatile discrimination with 20s time resolution
- In this particular location, ~80% of jet engine related particles are volatile (and unregulated)

![](_page_19_Picture_0.jpeg)

# Outlook

- Verify robust operation over longer times
- Time resolution nearly sufficient for single-plume detection/resolution (might need dual detector design after all)
- ICAO nonvolatile particle number standard corresponds to type approval tests for cars
- Could potentially be verified in-use by such devices in appropriate locations

![](_page_20_Picture_0.jpeg)

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