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DESTINATION GREEN: THE NEXT CHAPTER

Switzerland's Contribution to the New Particle Emissions Standards and First Regulatory Limits for Aircraft Engines

Theo Rindlisbacher

Swiss CAA (FOCA)





Air Quality Matters

- Human daily «fuel consumption»:

- 1 kg of food;
- 2 liters of water;
- 10'000 liters of air.



- Lung surface: 140 m² with 500 millions of alveoli;
- Air-blood tissue barrier thickness around 2 μm.



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Key Presentation in 2008



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Office for Civil
Aviation FOCA

PM characterisation and regulation: Ways forward for aircraft engines

ASME Turbo Expo, Berlin, June 10, 2008
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2010: Search for a Measurement System Development Test Cell

- Concept developed by the Swiss CAA (FOCA) to make use of engine maintenance facilities and their daily engine maintenance runs to develop the new particulate sampling and measurement system as a very cost efficient way forward.
- SR Technics engine maintenance facility in Switzerland was the only supporting company, which could be found among CAEP states in 2010.

SR Technics 



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First Prototype Sampling System



Pre-Assembly of system prototype in FOCA office

M. Brunner GmbH



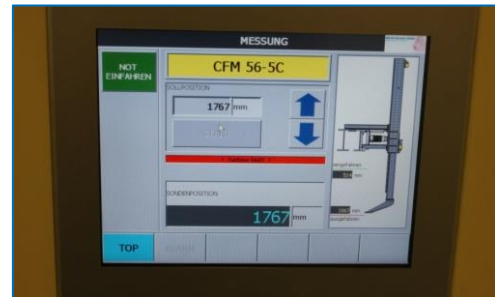
SR Technics

Installation at SR Technics, including retractable sampling probe





First Measurements, 25 May 2011





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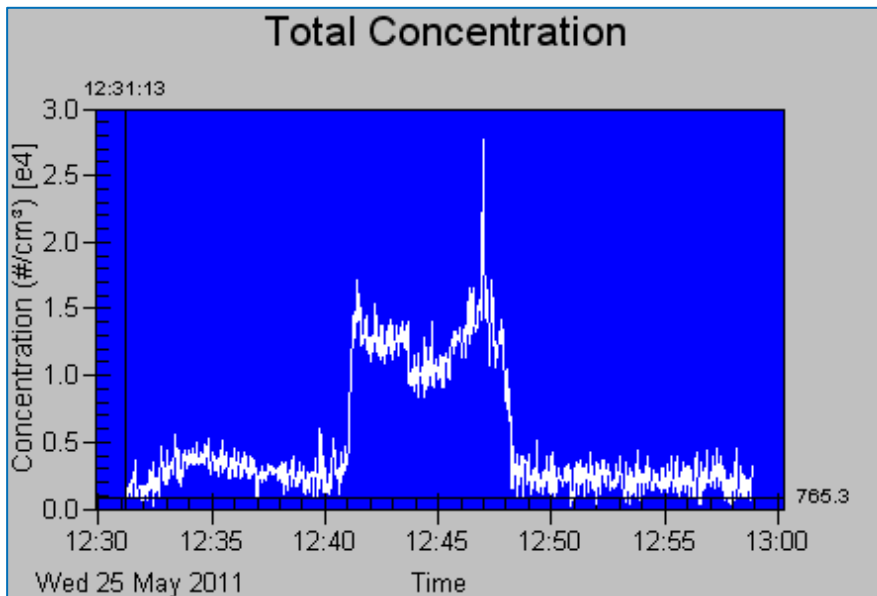
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First Ultrafine Particle Measurement

The first ultrafine particle measurement results obtained by FOCA with prototype system on 25 May, 2011.

Engine Exhaust
Particle sizer





A-PRIDE Campaigns in Switzerland

- **A-PRIDE = Aviation Particle Regulatory Instrumentation Demonstration Experiments** (funded by FOCA and international partners, goal to make measurements mature for certification and regulate in the future);
- **A-PRIDE 1 (2011): Particle Number measurement instrument development** (with AVL Graz), Lead FOCA;
- **A-PRIDE 2 (2011): Comparison of Swiss system with US system;**
 - **Start of strong collaboration of Swiss FOCA with USA (FAA), Canada (TC), Europe (through EASA);**
- **A-PRIDE 3 (2012): EASA SAMPLE III, Verify concept sampling system, develop aerospace recommended practice, comparison of Swiss with improved US system, Demonstration that Lean Burn combustion can eliminate particle emissions, Use of SR Technics CFM56-..DAC engine.**



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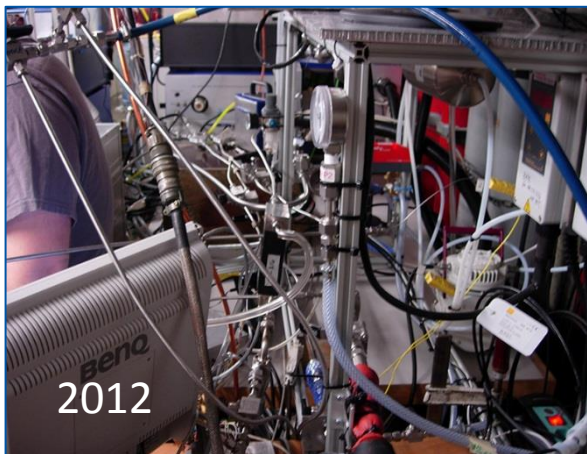
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A-PRIDE Campaigns in Switzerland



Conversion of Swiss prototype into Industrial Standard Measurement System (SMARTEMIS)



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A-PRIDE Campaigns in Switzerland

- **A-PRIDE 4 (2012): Performance evaluation and comparison** of Swiss and North American system built to the same draft specifications; mass instrument comparison, particle density measurements;
- **A-PRIDE 5 (2013): First in the world certification like particle emission test of a turbofan engine**, side by side comparison of North American, EASA and Swiss system, validation of aerospace recommended practice;
- **A-PRIDE 6 (2013):** Comparison of Swiss reference system with commercial system built by AVL, purchased by a number of engine manufacturers;
- **A-PRIDE 7 (2014):** Installation of full traverse sampling probe, engine exhaust plane emission mapping, **fuel sensitivity testing and development of fuel correction for certification measurements**, mass instrument intercomparison, smoke number to soot particle mass correlation;
- **GE / SNECMA providing a test engine;**
- **A-PRIDE 8 (2015):** mass instruments intercomparison, fuel doping and exit plane mapping.



Additional Swiss Campaigns

EMPAIREX 1 (2017)

- Dedicated tests using a CFM56-7B26 burning a certified alternative fuel blend (32% HEFA):
 - Investigation of nvPM emissions reduction using alternative fuels;
 - Optical properties of particles and their morphology.



Unique fuel doping system

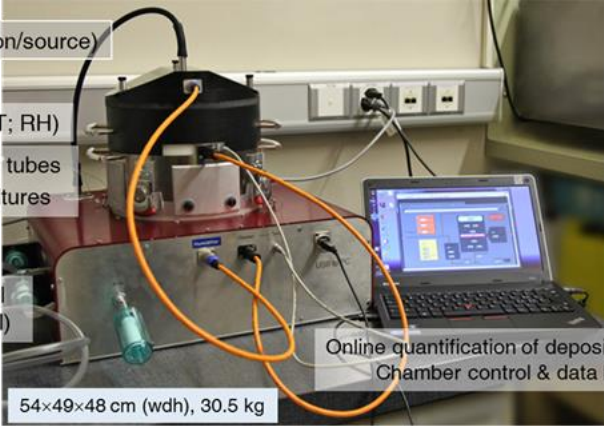


Additional Swiss Campaigns

- **EMPAIREX 1 (2017)**
(continued):

- Deposition of particles on human lung cells and measurement of health reactions.

- First in the world test of this kind using controlled and characterized aircraft gas turbine particle emissions and living human lung.



Aerosol (external production/source)

Aerosol conditioning (T; RH)

Aerosol distribution to 24 delivery tubes
Particle deposition on 24 cell cultures

Custom electronics (aerosol charger, pumps, flow control)

Online quantification of deposited particles
Chamber control & data logging

54x49x48 cm (wdh), 30.5 kg

- “All-in-one”, mobile system for direct use at any particle source
- Mimics particle deposition in lungs (T, RH, gas, air flow, N_P , N_{Dep})
- Simultaneous exposure of 24 cell cultures
- Controlled & stable conditions allowing long-term exposures

Courtesy: M. Geiser
University of Bern
VERT 2018



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Additional Swiss Campaigns

- **EMPAIREX 2 (2018)**

Dedicated tests using a
CFM56-7B26:

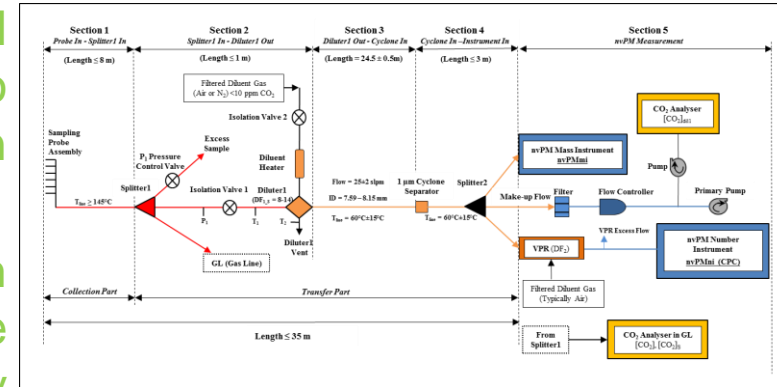
- Measurements at the engine exit and also in the exhaust silencer and the top of the stack;
- Investigation of the exhaust plume evolution with distance.





Major Contribution to Technical Documentation for the Standard

- FOCA and FAA were leading an international working group at ICAO for the last 9 years, to develop the technical basis and documentation for the new engine emissions standard;
- The test results obtained at SR Technics with A-PRIDE and EMPAIREX campaigns were vital to achieve the sufficient technical maturity and develop the first standards.



System drawing from ICAO Annex 16 Vol. II (Theo Rindlisbacher)



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Conclusions

- The engine test cell at SR Technics is still equipped with a sampling probe suitable for different engine types;
- Particle and gaseous emissions measurements are performed regularly;
- Currently, the effect of engine ageing on emissions is studied. Results expected to be provided during CAEP/12.



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