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Federal Department of the Environment, Transport, Energy and
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Federal Office of Civil Aviation FOCA
Aviation Policy and Strategy
Environmental Affairs

AIRCRAFT PISTON ENGINE EMISSIONS

Appendix 1: Measurement System



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a) Minimum requirements that are met by FOCA low cost gas measurement system

- Class 0 of OIML R99 ¹
- Capable of NO measurements with electrochemical cell
- Calibration Intervals three months ore more
- Condensation water separation, capable of cold sampling line measurement
- Capable of direct λ monitoring
- Ambient temperature range of +1 to +40°C
- Ambient relative humidity range 0 to 95%
- Ambient pressure compensation between 770 and 1030 hPa (for in-flight tests)
- Portable, no calibration gases and fuel during operation necessary (for in-flight tests)
- Battery power possible (for in-flight tests)
- Aviation fuel flow meter FAA TSO/STC approved

FOCA uses Tecnotest S.r.l STARGAS 898 with implemented NO sensor (Andros) and jp fuel scan 450 with corresponding fuel flow transducers.

b) Measurement Method

NDIR (Non-dispersive Infrared Spectroscopy) for HC, CO, CO₂
 Electrochemical detection for O₂ and NO

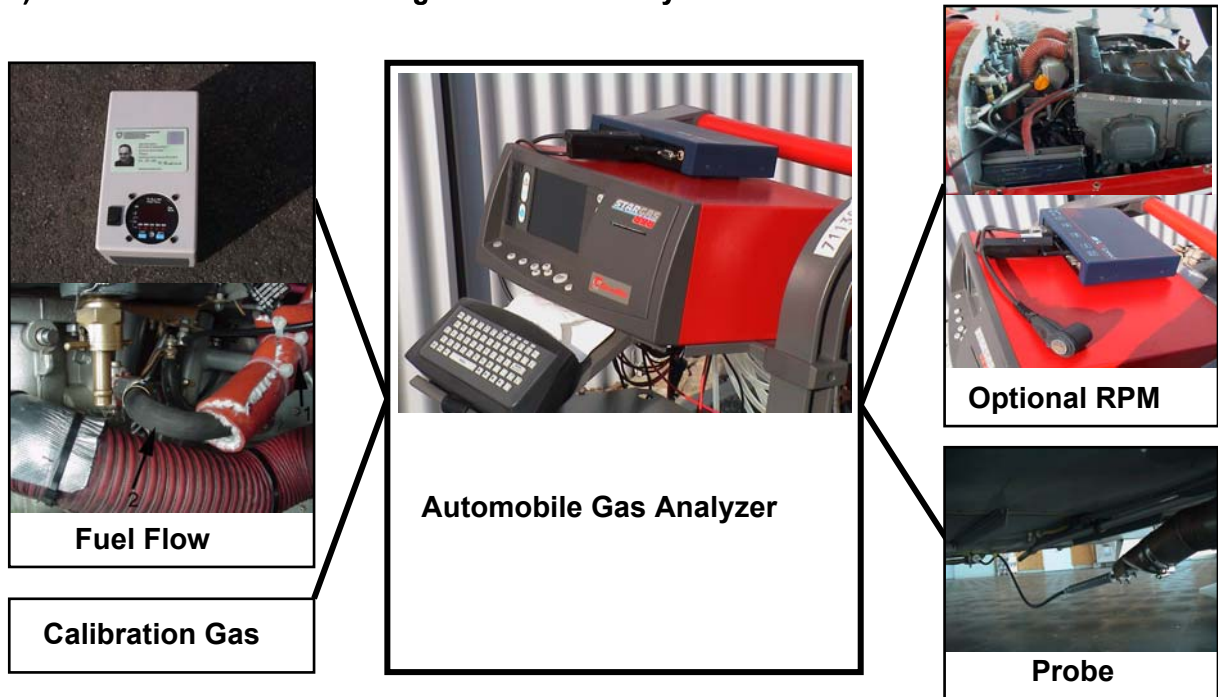
c) Measured Gaseous Emissions

HC calibrated with propane, results given as ppm n-hexane (see Appendix 4 for corrections to ppmC)
 CO, CO₂; O₂, NO

| d) Ranges | | Resolution | | Accuracy |
|------------------|---------------|-------------------|--|--|
| CO | 0 - 15 Vol% | 0.001 | 0..10 l% 10.01..15 % | +0.02% abs. / +-3% rel. +5% rel. |
| CO2 | 0 - 20 Vol% | 0.01 | 0.00..16.00 % 16.01..20.00 % | +0.03% abs. / +-3% rel. +5% rel. |
| HC | 0 - 30000 ppm | 1 | 0..2000 ppm 2001..15000 ppm 15001..30000 ppm | +4ppm abs. / +-3% rel. +5% rel. +8% rel. |
| O2 | 0 - 25 Vol% | 0.01 | 0.00..25.00 % | +0.1% abs. / +-3% rel. |
| NO | 0 - 5000 ppm | 1 | 0..4000 ppm 4001..5000 ppm | +25ppm abs. / +-4% rel. +5% rel. |
| λ | 0.5 - 2.000 | 0.01 | | +0.3% abs. ² |
| jp fuel flow | | | | |
| | 0 – 60 GPH | 1% | | + - 1 liter / hour (test result) |

¹ Organisation Internationale de Métrologie : „Instruments de mesure de gaz d’échappement des véhicules“
² Roberto Amadasi, Tecnotest S.r.l, Sala Bagaza, Italy

e) Illustration of FOCA low cost gas measurement system



Probe Design



The exhaust probe which goes into the exhaust pipe has a length of 30 cm (left part of the probe). The tip of the probe is closed and has four small holes, drilled sideways into the probe. Normally, aircraft piston engines have rather short exhaust pipes. Therefore a cooling device as seen on the right hand side is necessary for cooling the exhaust gas in the probe from around 600°C to 200°C measuring temperature.

Gaz Analyzer STARGAS 898, MEXA 1170 HFID, calibration gas and FID operating gas installed in FOCA environmental measurement car



f) Measurement systems for total HC measurements (certification standard)

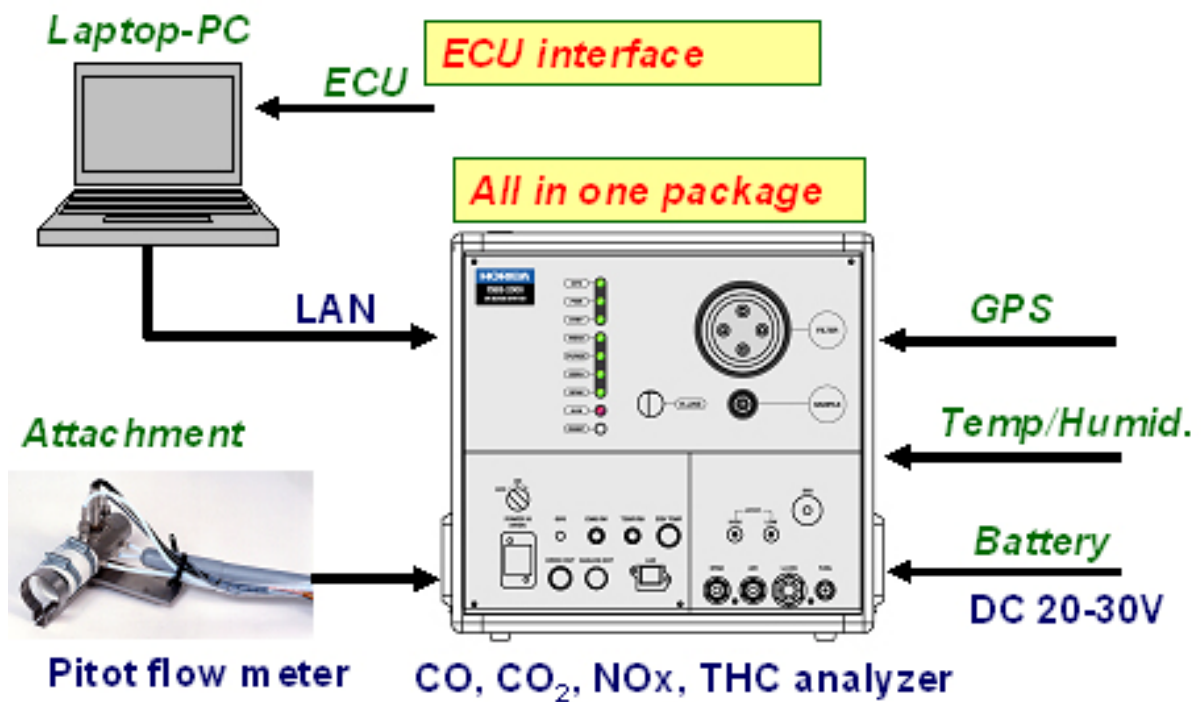
FOCA uses HORIBA Model MEXA-1170-HFID (Hot Flame Ionization Detector) for total HC measurements. The MEXA-1170-HFID is a stand-alone total HC analyzer with heated sample line at 191°C. This system is very accurate but not suitable for in-flight tests. It is used for static on ground total HC emission measurements. On ground, FOCA uses both the low cost NDIR HC and the HFID in parallel. **However, HC data on FOCA data sheets (and CO, NOx corrections) are solely based on the more accurate HFID measurements.**

g) Measurement systems for comparative gas measurements (certification standard)

HORIBA OBS 2200 (provided by HORIBA, not owned by FOCA):

All in one system. Dimensions: 40 x 35 x 50 cm Utilizing HFID for total HC measurement, HCLD (hot chemiluminescence) for NOx measurement, HNDIR (hot NDIR) for CO and CO2 measurement. GPS, Temp./Humidity, Engine Control Unit Interface, patented exhaust flow meters, heated sampling line at 191°C. System mass (incl. batteries, calibration and utility gases): 120 kg
 This system has been used by FOCA in order to compare in-flight tests results with very sophisticated gas analyzer data. At the same time, the provider was able to demonstrate that its system even works in an aircraft up to 7000ft.

OBS-2X00 System configuration



Performance:

| | |
|-----------------|----------------------------|
| THC | HFID (0 – 100 ~10 000 ppm) |
| NOx | HCLD (0 – 100 ~3000 ppm) |
| CO ₂ | HNDIR (0 – 5 ~ 20vol%) |
| CO | HNDIR (0 – 0.5 ~ 12vol%) |

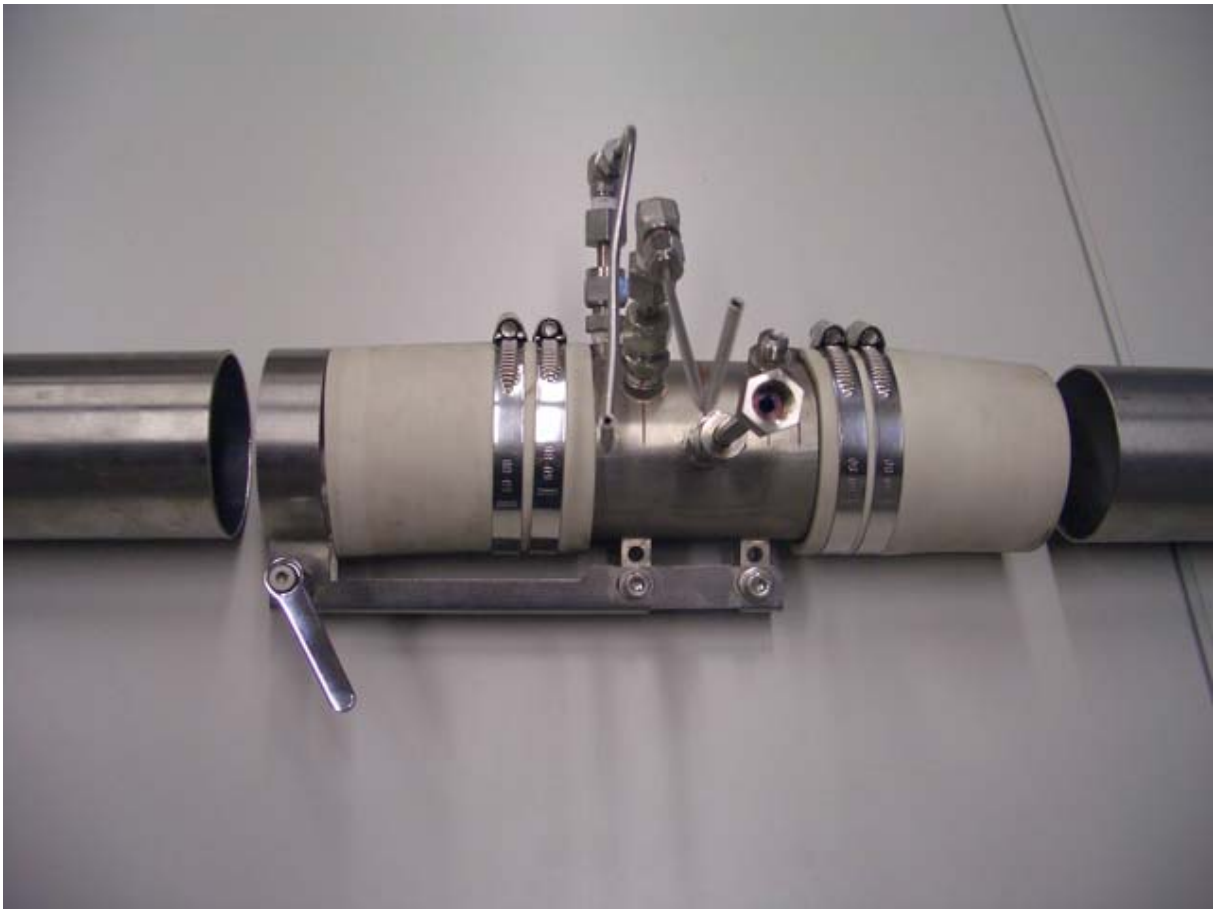


Illustration: OBS 2200 pitot exhaust flow meter, ready for installation in light aircraft (AS02, HB-HFX) for in-flight measurements (see Appendix 2).



Exhaust flow meter, heated sampling line and installation on backseat of HB-HFX

h) Measurement system for nanoparticle measurements

The measurement system and expertise is provided by German DLR, Institute of Combustion Technology. The 2004 measurement system consists of

- TSI™ SMPS (Scanning Mobility Particle Sizer) System
- 4.5 meter stainless steel sampling line at 150°C, calibrated sampling line loss
- Dekati Diluter 1:10

In 2005 the SMPS has been replaced by a TSI™ EEPS (Engine Exhaust Particle Sizer), providing fast response number-size distributions (see Appendix 4).