IRGA gas sampling system dimensioning: laboratory and field experiments

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IRGA GAS SAMPLING SYSTEM DIMENSIONING: LABORATORY AND FIELD EXPERIMENTS

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1. Introduction

- The gas sampling system (GSS), which carries air from the sampling point to the IRGA, has to minimize high frequency attenuation of concentration measurement and keep pressure drop in the measurement cell in an acceptable range.
- The use of a filter was found necessary for the model of IRGA LICOR-7200 selected by ICOS in order to avoid rapid cell contamination and premature cell thermocouple destruction caused by dust particle impacts. But filters also cause a pressure drop and could perturb the air flow and introduce additional alterations of the concentration measurements.

2. Objectives

Dimension the filter and rain cup in order to meet the following constraints :

- Cell renewal rate of at least 10 cell volume exchanges per second (flow > 9.6 l/min)
- GSS **cut-off frequency as large as possible** (ideally larger than 5 Hz);
- **Pressure drop** in the cell that is **lower than 9 kPa.**

3. Materials and Methods

Field measurements

- 3 IRGA LICOR-7200 at the same position with the same standard tube (1 m length ; 5.3 mm diameter) but equipped with the different filters were installed and run at the Dorinne Terrestrial Observatory (ICOS-Belgium) from July to September 2013.

Laboratory measurements

- In the laboratory (University of Reims), a dynamic calibration bench was developed to investigate experimentally the pressure drop and the concentration fluctuation attenuation caused by different filters without rain cup.

Fig 1: 3 LICOR-7200 with different filters

Filters : Different filters have been tested on field and in laboratory :

- ACRO 50 (1µm),

- Swagelok FW (2µm),

- PALL Open Face filter holder (2, 3 and 5 µm)

- Savillex (2µm)

Rain cups : Different rain cup designs have been tested on field :

- LICOR 9972-043 bought in April 2013

- 1 : single inlet

- 2 : Rain cup with the tube getting down until the screen

- 3 : Rain cup with a lateral insertion and a small volume

- LICOR 9972-072 received in May 2014

4. Results and Discussion

Filters : Compromise between porosity and pressure drop

- The ACRO 50 1 µm filter provoked a too large pressure drop : constraints cannot be met.
- The PALL Open Face filter holder and SWAGELOK FW 2µm provoked an acceptable pressure drop.

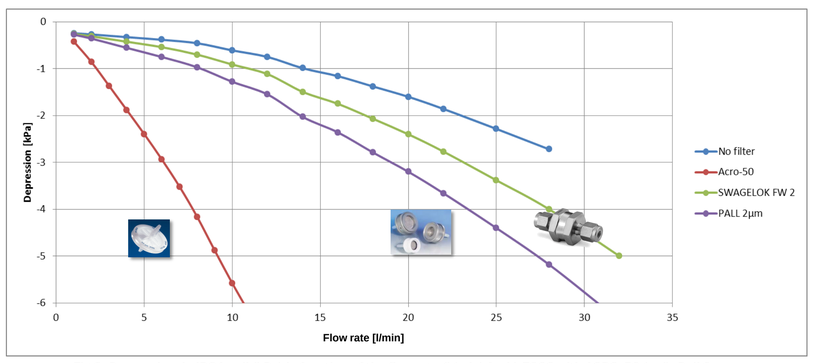

Fig 2: Depression in IRGA cell (kPa) in function of the flow rate (l/min) for LI-7200 with ACRO-50 (red), Pall 2µm (purple), Swagelok FW 2µm (green), and without any filter (blue)

- 5 µm filter led to chamber dirtying after a few days.
- The SWAGELOK FW 2µm duration is several weeks or months, compared to 1or 2 weeks for the PALL 2 and 3 µm filters.

➢ The best compromise would be met today with the SWAGELOK FW 2µm but we wonder about its long-term behavior.

Filters : Practical considerations

- The PALL membranes are very delicate and can tear easily.
- The SWAGELOK FW and PALL filters were subjected to clogging by dew but the problem could be solved by including the filter in the tube heating envelope.

Filters : Cut-off frequencies

- Lab experiment showed that the cut-off frequency of a LI-7200 with the standard tube and without rain cup was not significantly reduced by the addition of one of those filters.
- Cut-off frequencies were found significantly higher in the lab (7.5 Hz) than at the site (0.9-1.4 Hz) suggesting that the major effect on cut-off frequency is not exerted by the tube or the filters.

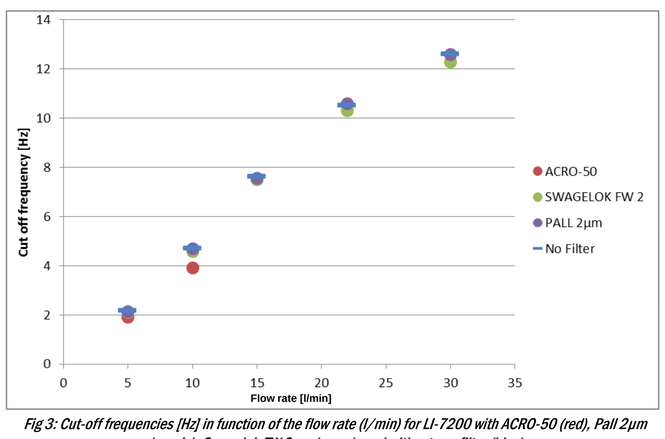

Fig 3: Cut-off frequencies [Hz] in function of the flow rate (l/min) for LI-7200 with ACRO-50 (red), Pall 2µm (purple), Swagelok FW 2µm (green), and without any filter (blue)

➢ Impact of other GSS elements were investigated.
➢ Attention was directed on rain cup. Different rain cup profiles were tested

Rain cups : Cut-off frequencies and pressure drop

- Cut-off frequencies and pressure drops have been calculated for GSS with different profiles of rain cup.
- The LI-7200 rain cup 9972-043 was found to affect significantly the cut-off frequency, probably due to a too big inlet volume.

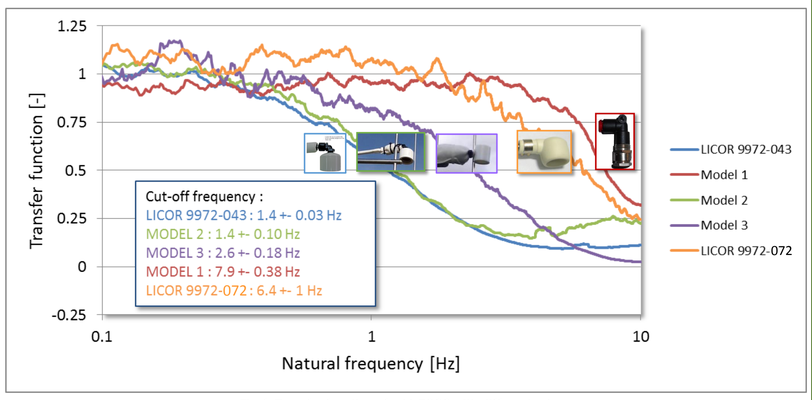

Fig 4: Transfer functions for LI-7200 with different rain cups

- This rain cup 9972-043 was also found to affect significantly pressure drop (1.4 kPa at 15 slpm) probably due to the small tube diameter and to the 90° turn.
- Our models 1 & 3 do not offer enough rain protection.

➢ The new LI-7200 rain cup 9972-072 has a higher cut-off frequency and an insignificant pressure drop. It has not been tested under rain conditions yet.

5. Conclusions

These experiments helped to define the GSS proposed in the ICOS IRGA protocol.

Main experiment conclusions were that:

- **The filter porosity and size have a critical impact on pressure drop**
  - ICOS IRGA protocol > To use the Swagelok FW 2 µm appears as the best compromise.
  - However long term behavior of the system (several months) remains to be investigated: is 2 µm pore diameter sufficient to prevent system from dust ?
- **Filter heating is necessary in order to avoid condensation and filter blocking**
  - ICOS IRGA protocol > to heat the tube (4 W m^{-1}) and include the filter in the tube heating envelope;
- **The shape and size of the rain cup have a critical impact on cut-off frequencies**
  - ICOS IRGA protocol > to use a rain cup with inner tubes of the same diameter as the main tube, no turns and a small volume (< 5 cm^3) in order to avoid excess pressure drops and high frequency losses.

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