COPS Instrument Modes

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Issue	Rev.	Pages changed, added, removed	Date	Reasons for Changes	Approval
1	-	All	16-11-2001	Initial Issue	
1	1	All	26-11-2001	Updates proposed by Kathrin Altwegg	
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1	3	All	19-12-2001	Consolidation by K. Altwegg	
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1	6B	7, 12-13	27-09-2007	Update to Software V6.B	
1	7	All	5-01-2011	Clean-up of document Addition of calibration	

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List of Abbreviations

COPS	Comet Pressure Sensor
DPU	Digital Processing Unit
FM	Flight Model (which is the one in the lab)
FS	Flight spare model (which is the one flying)
HK	Housekeeping
ROSINA	Rosetta Orbiter Spectrometer for Ion and Neutral Analysis
S/C	Spacecraft
TBD	To Be Defined
TBC	To Be Confirmed

1 Scope

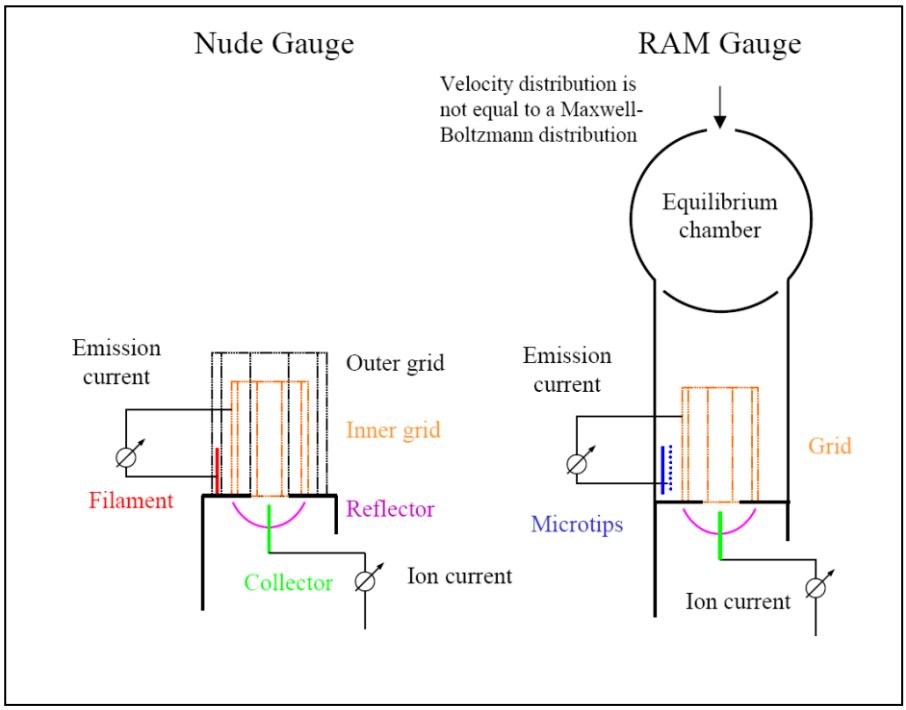
The Comet Pressure Sensor will measure the ambient total density as well as the comet ram pressure. These two quantities can be used to derive the speed and the Mach number of the cometary gas. COPS will also serve as a pressure monitor for safety purposes. It will distribute the total pressure to all Rosetta instruments via service 19.
This document contains the COPS instrument modes and measurement sequences.

1.1 Reference documents

N°	Institution	Document Title	Reference	Issue
[1]	UoB	EID-B: ROSETTA-Rosina Experiment Interface Document	RO-EST-RS3013/EID B	Issue 1, Rev. 0 15-01-1999
[1]	UoB	Rosina Users Manual	RO-ROS-MAN-1007 prepared by Kathrin Altwegg	Draft 2, Rev. 0 19-09-2000

1.2 Introduction

The Comet Pressure Sensor (COPS) consists of two gauges. The first gauge called “nude gauge” measures the total pressure (more exactly the density) of the comet gas. The second gauge called the “ram gauge” measures the ram pressure (equivalent to the comet gas flux). The nude gauge uses filaments to emit electrons and to ionize the gas, the ram gauge uses microtip arrays.



2 COPS Modes and measurement sequences

COPS Instrument Parameters Settings

Channel	NUDe gauge	
	RAM gauge	
	BOTh	
Task	NONe	
	AMBient{ R_N, R_M }	
	OFfSet	
Emission	EMIssion{ Fil, Mic, I_F, I_M }	

3 Explanations of the COPS Parameters

To measure the pressure, COPS can work with the both gauges (nude and ram gauges) or just one.

3.1 Channel

The NUDe gauge mode is used for monitoring purposes. In case there is not enough power available the RAM gauge mode (which uses less power) can also be used for monitoring, however the result is somewhat less precise. The mode BOTh is the science mode of COPS. From this mode only the gas dynamics can be derived.

3.2 Task

AMBient means that the instrument measures the cometary (asteroidal, spacecraft background) ambient pressure. The R_N (nude gauge range) and R_M (ram gauge range) parameters indicate the operating electrometer range.

- R_N / R_M : nude/ram gauge electrometer range

  0 = Automatic range by the DPU

  1 = Low

  2 = Medium

  3 = High

OFfSet is the measurement of the offsets of one or both gauges.

EMIssion means that the COPS set up the voltages to have the specified emission.

The parameters that set the emission current and the active emitter(s) are:

- Fil (1bit): 0 for left filament or 1 for right filament active.

- Mic (8 bits): Microtip group status
  - Bit 1: Mic 1 status (0 = disable, 1=enable)
  - Bit 2: Mic 2 status (0 = disable, 1=enable)
  - Bit 3: Mic 3 status (0 = disable, 1=enable)
  - Bit 4: Mic 4 status (0 = disable, 1=enable)
  - Bit 5: Mic 5 status (0 = disable, 1=enable)
  - Bit 6: Mic 6 status (0 = disable, 1=enable)
  - Bit 7: Mic 7 status (0 = disable, 1=enable)
  - Bit 8: Mic 8 status (0 = disable, 1=enable)

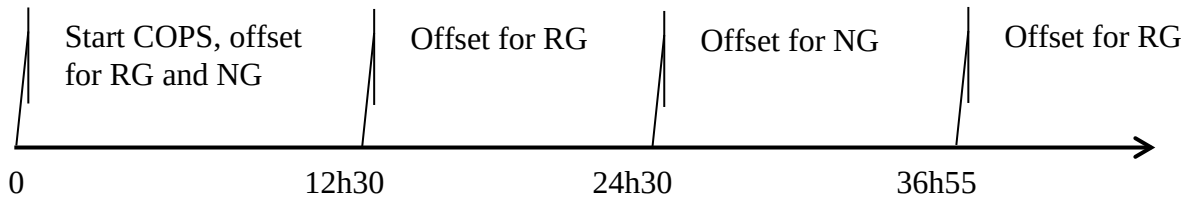
The current levels (parameters I_I and I_M) set the filament and the microtip(s) emission.

- I_I (0-3): emission filament to 100µA low ion, 15µA low ion, 15µA med ion, 15µA high ion
- I_M (0-3):: emission microtip(s) to 100µA, 15µA, 50µA, not used

4 Measurements

4.1 Offset

When commanding a COPS measurement mode the first step is to determine the electrometer offsets. In order to do so, the electron emission has to be turned off. In the offset measurement mode, which can be selected / deselected when commanding any measurement/monitoring mode the instrument will switch through all three sensitivity levels of the electrometers and record the offset values. This takes appr. 5 min. due to the fact that the values are transmitted in the normal housekeeping data (1 value per minute). The subsequent measurements and monitoring modes are indefinite in time. No renewal is necessary. After every 24h after the end of the previous offset measurement the DPU will again command an offset measurement mode which takes appr. 25 min (5 min for the offset, 20 min to switch on the filaments/microtips again). In order not to have the complete instrument inactive for this time the offset measurements of the nude gauge and the ram gauge are timed 12h apart. When designing a measurement sequence for ROSINA this has to be taken into account. The new 24h interval starts once COPS is again in measurement mode, that is appr. 24h 25m after the start of the previous one.



4.2 Timing

COPS pressure measurements are read out by the DPU every two seconds. However, the internal integration time is appr. 10s due to the time constant of the electrometers. What is read out is therefore a running average over the last 10 s. The DPU itself builds a running average over the last 5 measurements. This value is transmitted in the normal monitoring modes once every minute. The time stamp of this value has therefore to be corrected by -5s.

COPS also has a scientific mode which can be commanded independently of the normal measurement mode. In this mode all read mout housekeeping are transmitted in science blocks containing 150 data points (5 min) for each gauge. In this mode the correction of the time stamp is -1s. However, it has to be kept in mind that the time resolution is not really 2s but 10s as given by the electrometers.

5 Mode numbering

The numbering of the Mode used the following last digits (combination of channel and task):

0: General for COPS Instrument / DPU action modes
1: NUD, OFS
2: NUD, AMB{ R_N, R_M }
3: RAM, OFS
4: RAM, AMB{ R_N, R_M }
5: BOT, OFS
6: BOT, AMB{ R_N, R_M }

The numbering should be arranged as follows:

0 to 49: Basic modes for switch on/off
49 to 99: Basic offset modes
100 to 299: Basic emission modes
300 to 499: Standard survey modes
500 to 999: Custom modes

6 Tables necessary to run COPS autonomously

To calculated the pressure, the DPU use the following formula:

For the nude gauge:

$$p(\text{mbar})_{NG} = \frac{(\text{Ion\_current}_{fil}(A) - \text{Ion\_offset}_{fil}(A))}{(\text{Immission\_current}_{fil}(A) - \text{Immission\_offset}_{fil}(A)) \cdot S_{NG}}$$

For the ram gauge:

$$p(\text{mbar})_{RG} = \frac{(\text{Ion\_current}_{mic}(A) - \text{Ion\_offset}_{mic}(A))}{(\text{Immission\_current}_{mic}(A) - \text{Immission\_offset}_{mic}(A)) \cdot S_{RG}}$$

The Ion offset value is measured in background mode.

S is the calibration factor, it is about 30 for the nude gauge and 5 for the ram gauge.

This factor depends of the temperature and the ambient gas.

Flux formula for the Ram gauge:

$$\text{phi\_out} = 0.25 * \sqrt{\frac{8 \cdot kB \cdot T\_RG}{\pi \cdot \text{mass}}} * \frac{p\_RG}{T\_RG * kB}$$

phi_out = gas flux [$1/m^2*s$]

kB = Boltzmann-constant = $1.38e^{-23}$ [J/K]

T_RG = ram gauge temp. [K]

mass = 18 amu = $2.9889e^{-26}$ [Kg] (H_2o is the default mass)

p_RG = ram pressure [Pa] = 100*[$p(mbar)_{RG}$]

The pressure values given directly in the COPS housekeeping are pressures for N_2 at 20°C. In order to derive the density this pressure value has therefore to be converted to density as follows:

n (m^{-3}) = p /(kT) with p in Pa; T=293K, k=1.380 · 10^{-23} J/K

e.g. if p=1x10^{-10} mbar n=2.4x10^{12} m^{-3} = 2.4x10^6 cm^3

6.1 Calibration overview (S. Graf, 2003)

- All measurements were performed with COPS mounted at CASYMIR (CAlibration SYstem for the Mass spectrometer Instrument Rosina)
- Reference gauge : Granville-Phillips Stabil-Ion (Series 370) ionization gauge
- Argon was used as the calibration gas for all measurements over a pressure range from ~5×10^{-10} to ~1×10^{-6} mbar
- All pressure values are normalized for Nitrogen
- One single data point represents the average over 20 house keeping values taken within 40 s

Pressure calibration with and without offset:

a) $\frac{I_{Ion}}{I_{Emission}} = s \cdot p + a$ $\quad s = \text{sensitivity}, \; a = \text{offset}$

b) $\frac{I_{Ion}}{I_{Emission}} = s \cdot p$ $\quad$ used by the DPU software

•As the calibration was done over several orders of magnitude the least squares fit was performed using relative errors instead of absolute differences => rel. errors will be similar in the low and high pressure range

6.1.1 COPS-FS Nude Gauge calibration

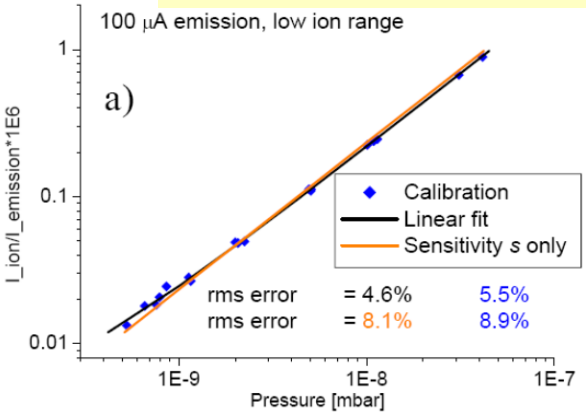
The two filaments of the Nude Gauge were calibrated in 3 different modes:

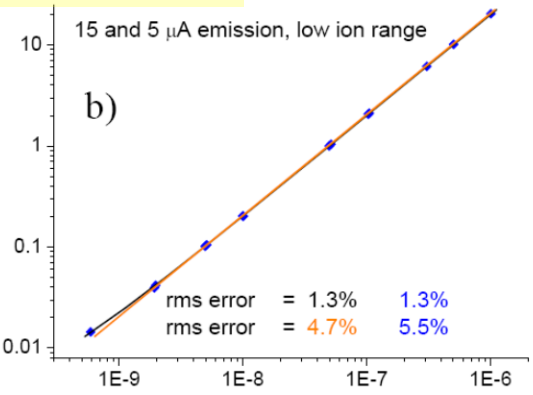
1.High emission with 100 µAand low ion current (< 100 pA)

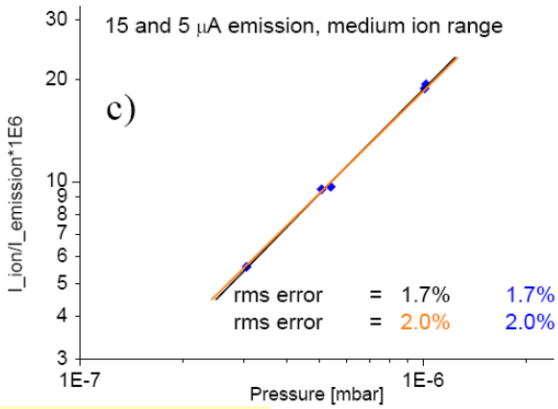
2.Low emission with 5 or 15 µAand low ion current

3.Same as above but with medium ion current (> 100pAup to 10´000 pA)

COPS-FS Nude Gauge, left filament





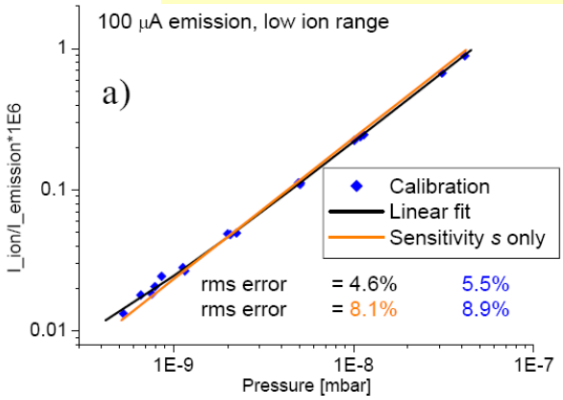


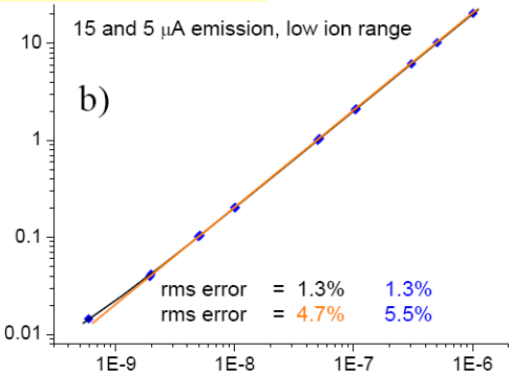
a) $\frac{I_{Ion}}{I_{Emission}} = 21.7 \cdot p + 2.8 \times 10^{-9}$ or $23.3 \cdot p$

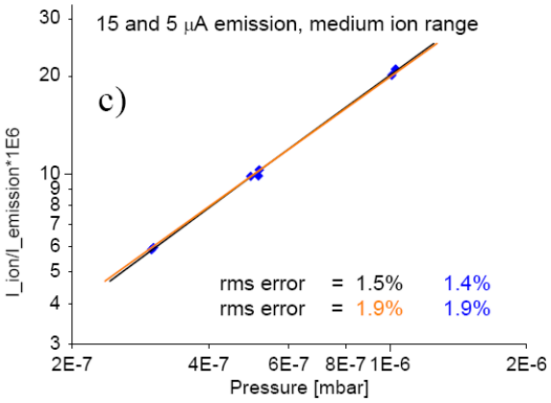
b) $\frac{I_{Ion}}{I_{Emission}} = 20.0 \cdot p + 2.4 \times 10^{-9}$ or $20.5 \cdot p$

c) $\frac{I_{Ion}}{I_{Emission}} = 18.9 \cdot p - 2.2 \times 10^{-7}$ or $18.5 \cdot p$

COPS-FS Nude Gauge, right filament





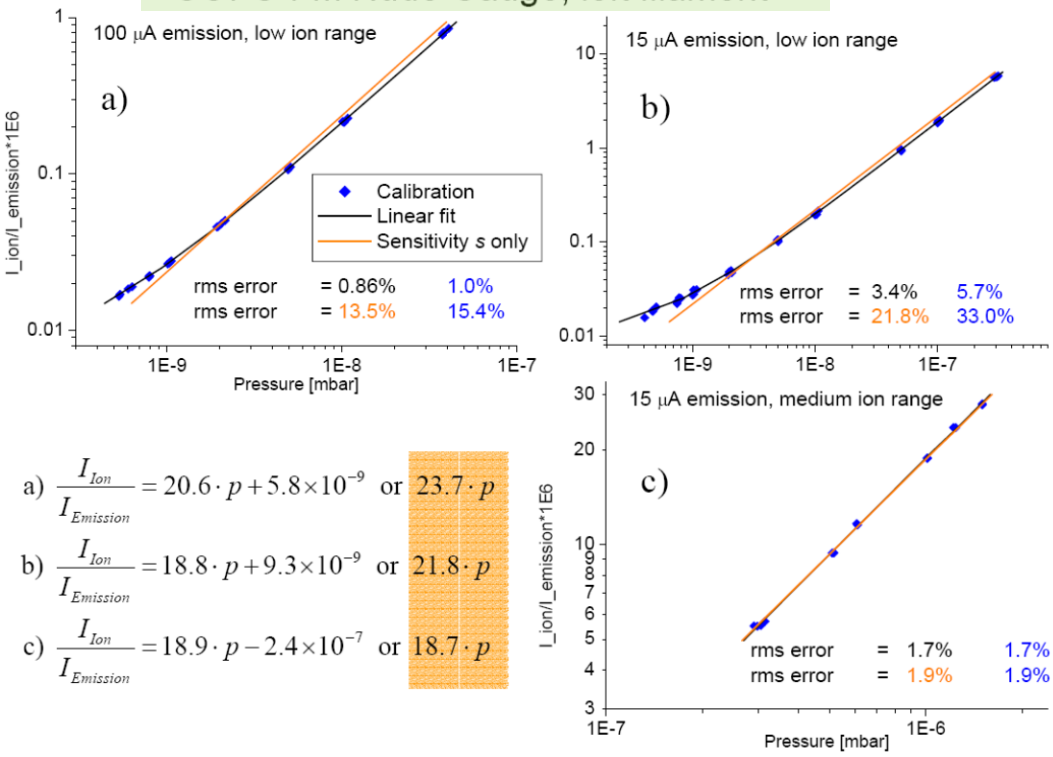


a) $\frac{I_{Ion}}{I_{Emission}} = 23.1 \cdot p + 3.2 \times 10^{-9}$ or $24.7 \cdot p$

b) $\frac{I_{Ion}}{I_{Emission}} = 21.3 \cdot p + 2.6 \times 10^{-9}$ or $21.8 \cdot p$

c) $\frac{I_{Ion}}{I_{Emission}} = 20.3 \cdot p - 2.5 \times 10^{-7}$ or $19.9 \cdot p$

COPS-FM Nude Gauge, left filament

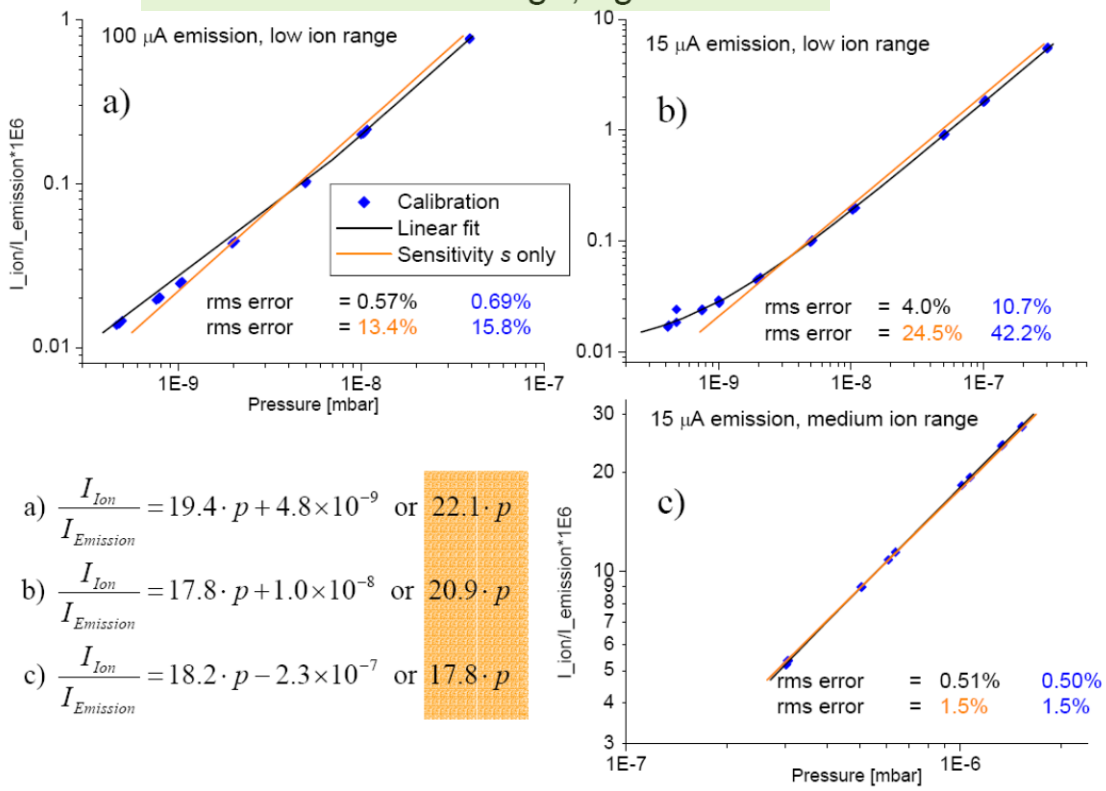


a) $\frac{I_{Ion}}{I_{Emission}} = 20.6 \cdot p + 5.8 \times 10^{-9}$ or $23.7 \cdot p$

b) $\frac{I_{Ion}}{I_{Emission}} = 18.8 \cdot p + 9.3 \times 10^{-9}$ or $21.8 \cdot p$

c) $\frac{I_{Ion}}{I_{Emission}} = 18.9 \cdot p - 2.4 \times 10^{-7}$ or $18.7 \cdot p$

COPS-FM Nude Gauge, right filament



a) $\frac{I_{Ion}}{I_{Emission}} = 19.4 \cdot p + 4.8 \times 10^{-9}$ or $22.1 \cdot p$

b) $\frac{I_{Ion}}{I_{Emission}} = 17.8 \cdot p + 1.0 \times 10^{-8}$ or $20.9 \cdot p$

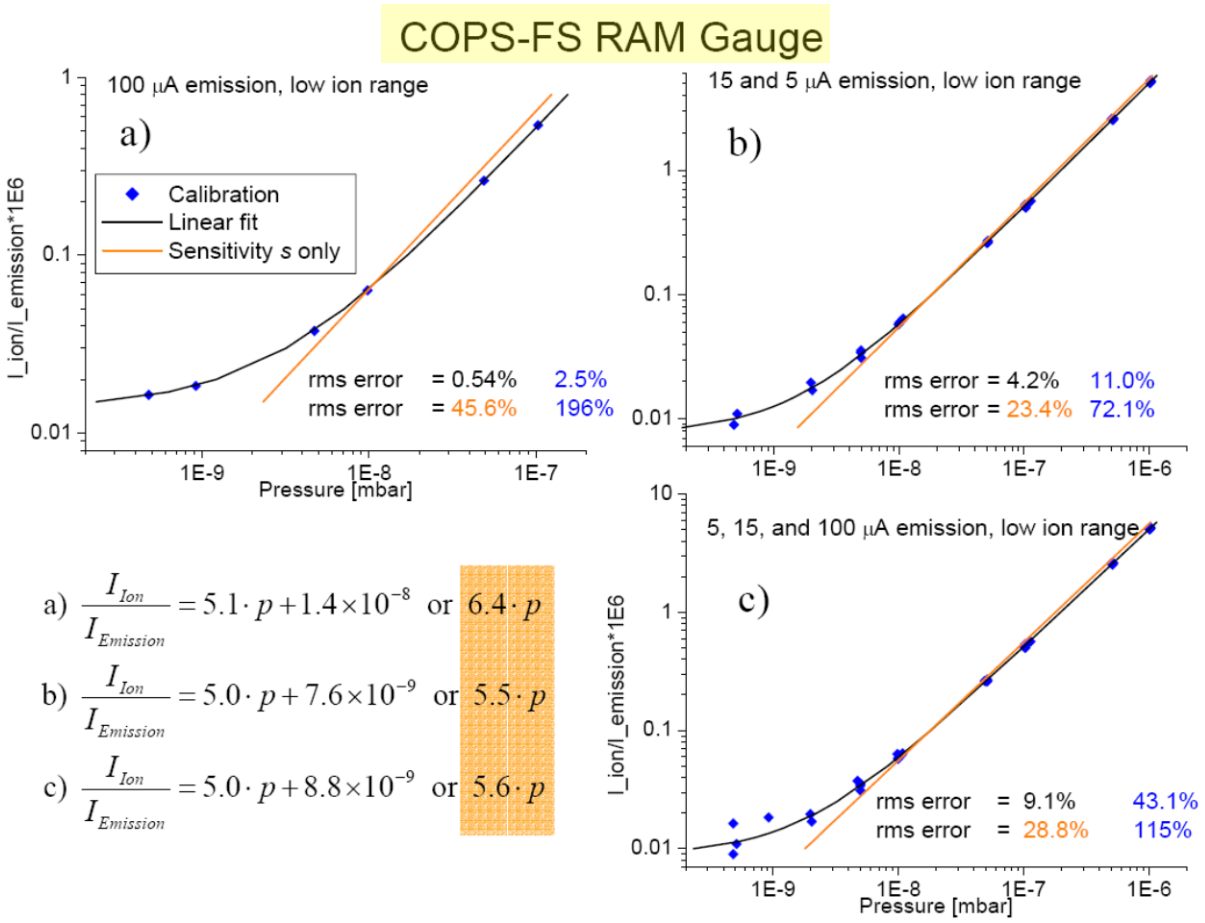
c) $\frac{I_{Ion}}{I_{Emission}} = 18.2 \cdot p - 2.3 \times 10^{-7}$ or $17.8 \cdot p$

6.1.2 COPS RAM Gauge calibration

All 8 microtipgroups were used in the following modes:

1. High emission with 100 µA and low ion current (< 100 pA)
2. Low emission with 5 or 15 µAand low ion current

Additionally some measurements at 15 µAemission were performed with a single group.

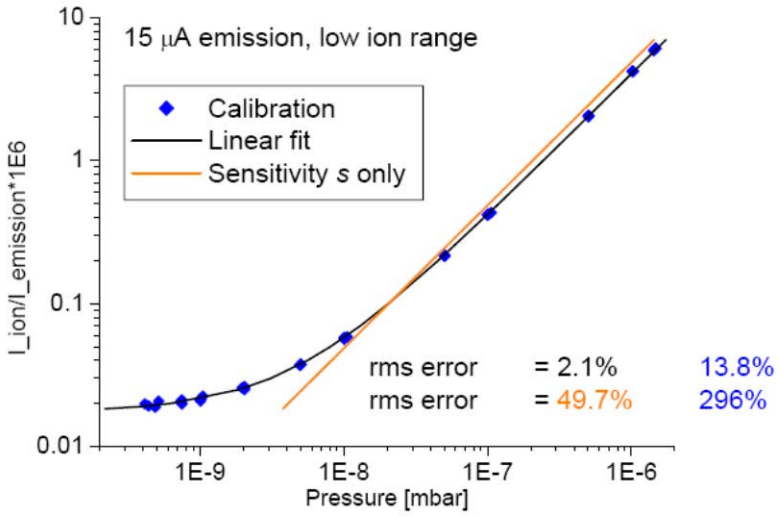


a) $\frac{I_{Ion}}{I_{Emission}} = 5.1 \cdot p + 1.4 \times 10^{-8}$ or $6.4 \cdot p$

b) $\frac{I_{Ion}}{I_{Emission}} = 5.0 \cdot p + 7.6 \times 10^{-9}$ or $5.5 \cdot p$

c) $\frac{I_{Ion}}{I_{Emission}} = 5.0 \cdot p + 8.8 \times 10^{-9}$ or $5.6 \cdot p$

COPS-FM RAM Gauge



$$\frac{I_{Ion}}{I_{Emission}} = 4.02 \cdot p + 1.7 \times 10^{-8} \text{ or } 4.86 \cdot p$$

Although fits a) and b) are very similar, collecting all data points into one fit introduces large errors for low pressure values.

•Proportional fits are only usable for high pressure values, above ~10^{-8} mbar. Errors for lower calibration points are large,> 100%!

•The RAM Gauge sensitivity is roughly 4 times lower compared to the Nude Gauge.

6.1.3 Conclusions

•Very good agreement between the Stabil-Ion reference gauge and both COPS models, rmserrors for the linear fits are below 5%

•The FS NG sensitivity is between 19 to 23 mbar-1or about 2 A·bar-1at 100 μAemission

•The FM sensitivity is lower compared to the FS,up to 16% for the NG and 20% for the RG

•The RAM Gauge sensitivity is about 4 times lower compared to the Nude Gauge and the offsets in the linear fits are higher

7 Table of General settings

In this table are the parameter values in function of the mode.

Table Legend:

- x : means that the value is defined by the last mode

The COPS Instrument Modes are detailed in a separated document named COPS_MODE_DESC.ASC.

M322 and M326 are the normal monitoring modes with automatic scaling, the nude gauge only and both gauges respectively.

8 A word of Caution:

The microtips have to be switched on very carefully after a prolonged period of non-operation. For this a commissioning phase has to be foreseen, especially after hibernation. Such a commissioning was last performed in 2006 (PC4). The same procedures can be used again.

Use ARN070A with the following parameters:

C2_Function 10, condition microtip groups 1-3, at the end of this sequence COPS is in stby	ZRNC2003	PRNGG206 = 10 PRNGG207 = 1 PRNGG208 = 3 PRNGG209 = 18 PRNGG20A = 60
C2_Function 10, condition microtip groups 4-6, at the end of this sequence COPS is in stby	ZRNC2003	PRNGG206 = 10 PRNGG207 = 4 PRNGG208 = 6 PRNGG209 = 18 PRNGG20A = 60
C2_Function 10, condition microtip groups 7,8, at the end of this sequence COPS is in stby	ZRNC2003	PRNGG206 = 10 PRNGG207 = 7 PRNGG208 = 8 PRNGG209 = 18 PRNGG20A = 60

Each command needs appr. 8h.