

In-situ calibration of RGA's, Oleg Malyshev, ASTeC Vacuum Science Group

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In-situ Calibrations of RGAs

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Need of RGA calibration

- Lack of space for gauge + RGA installation
- Outgassing of assembly gauge + RGA
- 'Strange' experimental results received with RGA output data

- **It was found that:**
 - RGAs are not calibrated – they have a number of factory set parameters
 - RGAs are adjusted with injection of noble gases – not for residual gases in UHV

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Main steps of in-situ 'calibration' on the research rig

- Choice of injected gases
- Cleaning of injected gases
- Filling the gas chamber with known volume and high accuracy Baratron gauge
- If necessary, checking the Extractor gauge calibration vs High Accuracy Baratron gauge (FS=1 mbar; res.= 10^{-6} mbar)
- Calibrating RGA vs Extractor gauge
- Analysis of calibration data to obtain calibration coefficients.

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Injected gases

- H_2 , CH_4 , CO , N_2 , CO_2 , same as in the residual gas spectrum
- LN_2 trap for cleaning of injected gases
 - Very useful to reduce an impurity of injected gases (even for class 9999 gases)

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Filling the gas chamber

- **Gas chamber in two parts:**
 - 1.5-l and 0.15-l chambers
 - Volumes of these chambers measured by filling with demineralised water, by water volume and weight measurement
 - Cross-check of chamber volumes by expansion of noble gas (done or Ar) from 0.15-l chamber to 1.5-l chamber and to the test vacuum chamber with different combination of open and closed valves between them
- **Pressure measurements:**
 - High Accuracy Baratron gauge (FS=1 mbar with res.= 10^{-4} mbar to FS= 10^{-2} mbar with res.= 10^{-6} mbar) connected to 0.15-l chamber
 - Ideally another gauge is needed with FS=1000 mbar

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Injection chamber

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Checking the extractor gauge

- The extractor gauge is calibrated on calibration rig in ASTeC Vacuum Laboratory against two primary calibrated (at PTB and NPL) extractor gauges
- If there are any doubt about the gauge error in factor 2 or more:
 - The 0.15-l chamber filled with N₂ at about 10⁻³ mbar
 - Then expanded to the 1.5-l chamber
 - Valve between the 0.15-l and 1.5-l chambers closed and the 1.5-l chamber pumped out. Pressure at the 0.15-l chamber is in the range of 10⁻⁴ mbar.
 - Expansion to the 1.5-l chamber repeated.
 - Pressure at 0.15-l chamber is a few 10⁻⁶ mbar (not accurately measurable by Baratron gauge but well calculated).
 - Expansion to the test chamber (valve to the pump closed). Equilibrium pressure is in the range of 10⁻⁷ mbar
 - Comparison of calculated and measured pressures.

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NEG-1 Experimental Set-up

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Calibrating RGA vs Extractor gauge

- Valve between the test chamber and a pump is opened. Background pressure recorded for the gauge (10⁻¹⁰ mbar range) and the RGA.
- RGA is in Faraday mode
- Injecting gases:
 - Pressure in the RGA port and the gauge port should be the same due to test chamber symmetry
 - RGA and the gauge should not be on directly seen by each other
 - Pressure in the test chamber varied between a few 10⁻¹⁰ to 10⁻⁶ mbar.
 - Pressure recorded for the gauge and RGA peaks
 - At 10⁻¹⁰ to 10⁻⁸ mbar the injected gas might be not dominant in gas spectrum

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NEG-1 rig test chamber

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Analysis of the measurements

- RGA spectrum: there is always a mixture of gases
- Assuming that pressure P_i for i -th gas corresponds to gauge reading I_i^{gauge} and to RGA reading I_i^{RGA}

Then the calibration coefficients a_i for a gauge and b_i for RGA are defined as:

$$I_i^{gauge} = a_i P_i$$

$$I_i^{RGA} = b_i P_i$$

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Analysis of the measurements

- The gauge and RGA reading are related as:

$$I^{gauge} = \sum_i a_i P_i = \sum_i \frac{a_i}{b_i} I_i^{RGA}$$
- Assuming that the gauge is calibrated, coefficients a_i for a gauge are known than coefficients b_i for RGA can be found as the following

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Analysis of the measurements

- Assuming 5 gases were dominant in gas spectrum:
 - H₂, CH₄, CO, Ar, CO₂
- That means five unknowns: b_j , System of 5 equations allows to find them.
- Any five measurements, can be used even if only 3 gases were injected. If used data taken at different total pressure measurements

$$I_j^{gauge} = \sum_i \frac{a_i}{b_i} I_{i,j}^{RGA} \quad \text{where } j \text{ is selected reading}$$

- If solution exists it is a good set of approximated values for b_i

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Analysis of the measurements

- Another way:
- Use data at 10⁻⁷ mbar where injected gas is already dominant and calculate approximated values for $b_i^{(0)}$ as:

$$b_i^{(0)} = a_i \frac{I_i^{RGA}}{I^{gauge}}$$

- Then insert these values $b_i^{(0)}$ into all measured data

$$b_i^{(1)} = \frac{a_i I_i^{RGA}}{I^{gauge} - \sum_{k \neq i} \frac{a_k}{b_k^{(0)}} I_k^{RGA}}$$

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Analysis of the measurements

- In common case, if

$$\left| \frac{b_i^{(n)} - b_i^{(n-1)}}{b_i^{(n)}} \right| > 0.1$$

- Then insert these values $b_i^{(n)}$ into

$$b_i^{(n+1)} = \frac{a_i I_i^{RGA}}{I^{gauge} - \sum_{k \neq i} \frac{a_k}{b_k^{(n)}} I_k^{RGA}}$$

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Two typical results

10 RGAs of 5 manufacturers were tested

	gauge	RGA1 (1-200)	RGA1 re-set	RGA2 (1-50)
H2	0.44	2	5	2.5
CH4	1.5	0.5	1.25	1.4
CO	1.04	0.4	1	1
N2	1	---		
Ar	1.3	0.35	0.88	1.2
CO2	1.6	0.25	0.63	1.4

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Example of RGA Calibration

Relative Probabilities of Ionisation

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SEM mode calibration

- SEM calibration coefficients may change after each air venting.
- SEM calibrated just before or immediately after experiment comparing to faraday mode measurements.

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Conclusions

- Tested RGAs weren't factory calibrated
- Ionisation coefficients for gauges should not be used for RGAs
- RGA is usually much more sensitive to H₂ than ionisation gauges
- Calibration in-situ allows to use RGA as an accurate device for the gas spectrum analysis
- Faraday mode calibration is quite stable while SEM mode calibration needed after every air vent

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International Workshop on Vacuum Gas Dynamics

The workshop aims to bring together vacuum scientists and engineers interested in all aspects of gas flow modeling in vacuum systems and researchers who develop numerical and analytical methods of calculations of gas flows in the whole range of the gas rarefaction including the free molecular, transitional, and hydrodynamic regimes.

The Workshop is organised by Accelerator Science and Technology Centre (UK) and Federal University of Parana (Brazil) with support of IUVESTA and commercial sponsors.

Djurönäset, Värmdö, Sweden.
9 th - 12 th July 2007.

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