SRS Tech Note

Using the BGA244 to measure methane in argon
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An experiment was performed to verify the performance of the BGA244 for measuring the concentration of methane in argon. Starting with a BGA filled with pure argon, methane concentrations from 0% to 21% were mixed in situ. The BGA's internal gas temperature sensor, an external pressure gauge (which was read by the BGA's 4-20 mA powered interface), and the ideal gas law, allowed the computation of the methane concentration as methane was added to the cell. The BGA's measured values for methane concentration were compared to the concentration computed from the ideal gas law. The mean error for the concentration of methane was 0.041% and the RMS error was 0.084%.

Apparatus

We used a demo BGA244 which had been calibrated six months previously. A 4-20 mA pressure gauge was attached to one side of the cell, and a gas manifold was connected to the other side. The unit was cleaned and dried by operating at 70 C under high vacuum with a mass spec, then cooled and backfilled with 30 psia of 5-nines argon.

After filling the BGA with argon, the manifold was evacuated and filled with 80 psia of methane. The gas manifold had two diaphragm valves in series at the BGA input. The small volume between the two valves was filled with methane at 80 psia. By operating the values sequentially, small amounts of methane could be injected into the BGA. The amount of injected methane could be determined with high accuracy by measuring the temperature and pressure in the cell.

Computing the concentration of methane

Using the ideal gas law, the initial temperature, T_0 , and pressure, P_0 , of the argon fill gives us the number of moles of argon, n_{Ar}, in the cell:

$$n_{Ar} = P_0 V / R T_0$$

Where V is the volume of the cell and R is the ideal gas constant.

As methane is added to the cell, the total number of moles of gas in the cell, n_{total} , is given by:

$$n_{total} = n_{CH4} + n_{Ar} = PV/RT$$

And so the concentration of methane in the methane argon mixture is given by:

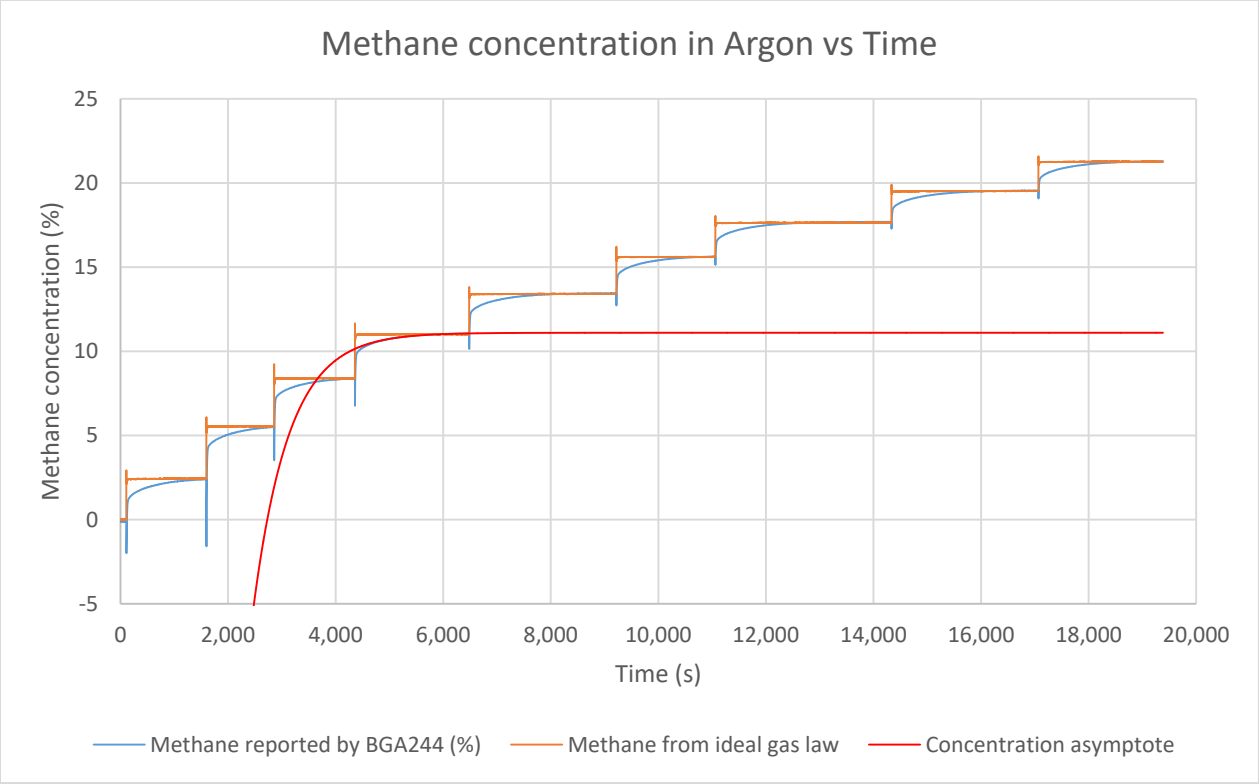
$$CH_4\ (\%) = 100 \cdot \frac{n_{CH4}}{n_{CH4} + n_{Ar}} = \frac{n_{total} - n_{Ar}}{n_{total}} = \frac{PV/RT - P_0 V/RT_0}{PV/RT} = \frac{P/T - P_0/T_0}{P/T}$$

This value will be compared to the measurement reported by the BGA.

Experimental results

The speed of sound in argon at NTP is about 318.89 m/s and about 450.1 m/s in methane. Filled with pure argon and configured as a gas purity analyzer, the BGA reported a speed of sound error of $\Delta W/W$ of -0.009%. This offset could have been Rel'd out via a GUI menu or an interface command, but we choose not to do so. When configured as a binary gas analyzer, the negative speed of sound offset caused the BGA to report the concentration of methane in argon as -0.14 %, consistent with the error estimate of ±0.28 % reported on the GUI display.

The methane concentration was increase from 0 % to about 21 % in nine steps, increasing the pressure from about 30 psia to 38 psia. After each step, a portion of the injected methane remained in the 0.2" ID tubing between the value and the BGA cell. Eventually, this methane would defuse into the cell, as shown in the graph below.



In the graph above, the methane concentration (computed from the temperature and pressure measurements and the ideal gas law) is shown in orange. The value reported by the BGA244 (showing the diffusion tails) is shown in blue. To estimate the asymptotic value of the concentration measurement, *A*, an equation was fit to each diffusion tail:

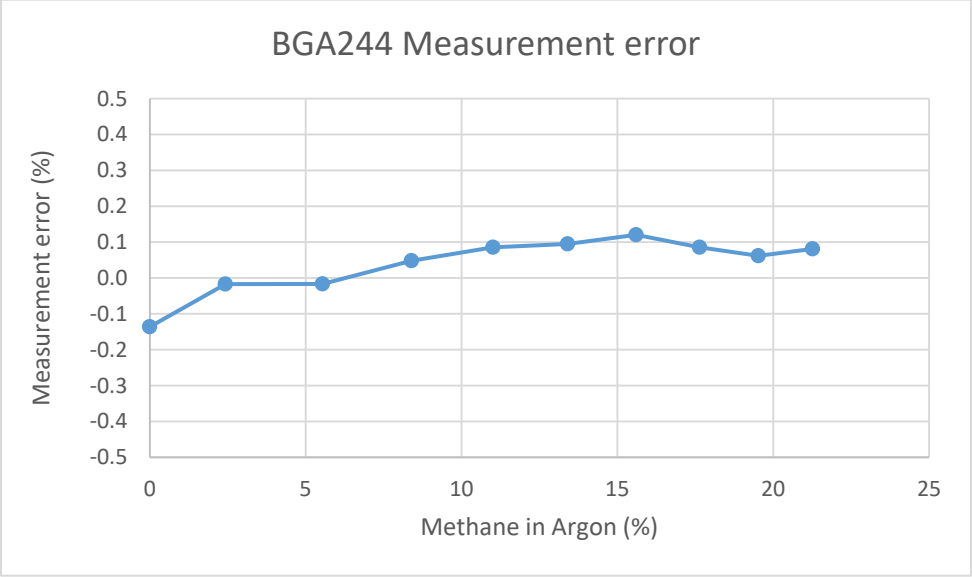
$$Methane\ concentration = A\left[1 - B \cdot e^{-(t-t_0)/\tau}\right]$$

The fit to the forth of the nine diffusion tails is shown in red in the graph above.

Measurement results

The table and graph below detail the measurement errors for the concentration of methane in argon:

Step	Methane (From ideal gas law)	Methane (BGA measurement)	Measurement Error
0	0.00 %	-0.14 %	-0.14 %
1	2.43 %	2.41 %	-0.02 %
2	5.54 %	5.53 %	-0.02 %
3	8.40 %	8.44 %	0.05 %
4	11.02 %	11.10 %	0.09 %
5	13.41 %	13.50 %	0.09 %
6	15.60 %	15.72 %	0.12 %
7	17.64 %	17.72 %	0.09 %
8	19.52 %	19.59 %	0.06 %
9	21.26 %	21.34 %	0.08 %



Error summary

For ten measurements of the concentration of methane in argon (between 0 % and 21 %) we have the following results:

Peak errors: -0.14 % and +0.12%

Mean error: +0.041%
RMS error: +0.084%