SRS Tech Note

BGA244 Physics Overview

The speed of sound in a gas can be approximated by the equation:

$$W = \sqrt{\frac{\gamma\, R\, T}{M}}$$

Where W is the speed of sound, γ the ratio of heat capacities ($\gamma = c_p/c_v$), M the molar mass, T the absolute temperature, and R the ideal gas constant. The γ and M for the mixture are determined by the properties of each gas and their mole fractions within the mixture.

The speed of sound at 20 ^{o}C, and at low pressure, ranges from about 135.18 m/s in SF_6, to 343.26 m/s in air, to 1304.24 m/s in H_2. By measuring the speed of sound and the temperature of a binary gas mixture, and knowing the properties of both gases, the mole fractions of the constituents can be precisely determined.

The BGA244 improves upon this approximation by including temperature corrections for heat capacities and pressure corrections for virial effects. This allows gas ratios to be determined with an error as low as 100 ppm.

Measurement of the Speed of Sound

The gas flows through a cylindrical cavity in the BGA244. The cavity has acoustic resonances whose frequencies are proportional to the speed of sound in the cavity. The gas ports are located at nodes of the acoustic standing wave so as not to disturb the resonance.

Internally, two acoustic transducers are coupled to the cavity through narrow slots on opposite ends of the cylinder. One functions as a speaker, the other as a microphone. The BGA244 measures the transfer function from speaker to microphone (though the cavity) and fits Lorentzian line shapes to the data to accurately determine the resonant frequencies. Part of a typical spectrum for argon is shown here:

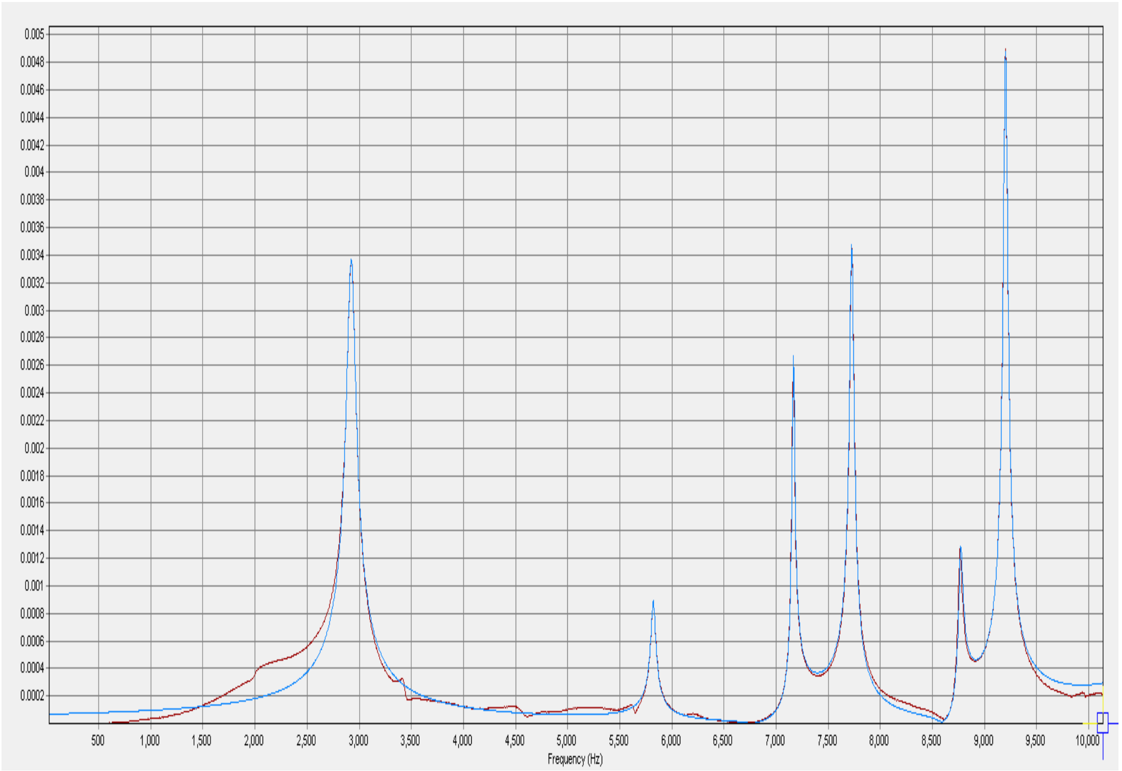

Figure. Sound transfer (red) though the cavity filled with argon with Lorentzian fits (blue) to six acoustic resonances.

The measured resonant frequencies are corrected for thermoviscous wall effects and multiplied by a size-dependent cavity factor (which is determined during calibration and stored in the instrument) to provide the speed of sound in the gas.