13. Accurate Measurements of the Dielectric Constants with Toroidal Cross Capacitors

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Objective: To provide high accuracy data supporting the metering of the heating value of natural gas via in-pipeline measurements.

Problem: Natural gas is a mixture of methane, heavier hydrocarbons, non-combustible gases (*e.g.* N_2, CO_2), and numerous minor constituents. In pipelines, natural gas is metered by volume; however, many consumers purchase the heating value of the gas. Presently, the conversion from volume to heating value is made by drawing samples from the pipeline and either burning them in a calorimeter or analyzing their composition in a gas chromatograph. The natural gas production and transportation industries plan to replace these batch procedures with in-pipeline measurements. One proposal for doing this is to determine the CO_2 content of the gas by measuring infrared absorption and to determine the methane-to-N_2 and methane-to-heavy hydrocarbon ratios by measuring both the speed of sound and the dielectric constant $\varepsilon(p,T)$. NIST will provide reference values of dielectric constants to facilitate this.

Approach: PMD is making new dielectric constant measurements that exploit the expertise that PMD has gained in its project to develop an atomic standard of pressure. For the natural gas measurements, we used a prototype cross capacitor developed for the pressure standard project.

Results and Future Plans: During FY00, a cross capacitor was installed in a newly constructed pressure vessel. Test measurements of ε(p, 50 °C) were made with helium using a commercially manufactured capacitance bridge and piston pressure gage. The results for ε(p, 50 °C) were compared with values calculated from quantum mechanics. The comparison verified the performance of the cross capacitor and the associated instruments at the level of approximately 0.3×10^{-6} ×ε(p) for helium at pressures up to 7 MPa. These results are more than a factor of ten better than the best previous measurements. We completed reference-quality measurements of ε(p) for methane, nitrogen, carbon dioxide, argon, and helium at 50°C. We hope to extend this work to other temperatures and to mixtures with compositions spanning the range of conditions encountered in pipeline metering.

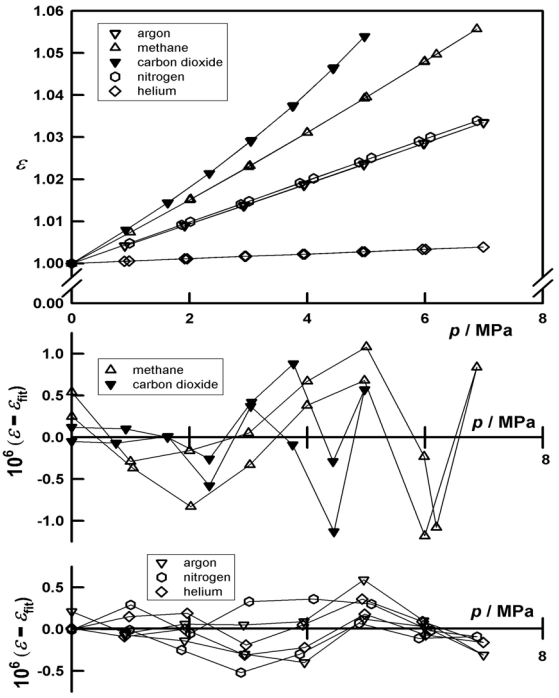

Figure 1. Top: Pressure dependence of the dielectric constants $\varepsilon(p,50°C)$ of argon, methane, carbon dioxide, nitrogen, and helium at 50 °C. Lower panels: Deviations of $\varepsilon(p, 50\ °C)$ data from *ab initio* calculation for helium and from fitted functions for the other gases.

Publications:

Buckley, T. J. Hamelin, J. O. and Moldover, M. R. ***"Toroidal Cross-Capacitor for Measuring the Dielectric Constant of Gases"*** Review of Scientific Instruments, 71, 2914-2921 (2000).

Moldover, M. R. and Buckley, T. J. ***"Reference Values of the Dielectric Constant of Natural Gas Components Determined with a Cross Capacitor",*** Int. J. Thermophysics (in press).