AN INVESTIGATION OF A RADIO FREQUENCY GENERATED CYLINDRICAL PLASMA WITH ALKALI METAL INJECTION

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Abstract

This investigation was concerned with the theoretical and experimental study of the thermochemical and electrical properties of a moderate temperature cylindrical plasma column. The column consisted of a mixture of a low ionization potential alkali metal and a carrier gas heated by a radio frequency field to elevated temperatures and thus partially ionized. It was the purpose of this study to produce a suitable experimental model, analyze such a plasma theoretically, and measure the properties of the laboratory plasma for comparison with theory. The effect of low ionization potential seeding on plasma properties was of primary concern as was the applicability of various diagnostic techniques to this type plasma.

A detailed thermochemical analysis of nitrogen or air as the carrier gas and sodium, potassium, or cesium as the seeding element was made for the case of an equilibrium plasma: and the analysis with resulting data including electrical properties is given in the report. The results are presented for a range of seeding ratios representing electron number densities from 10^{10} to 10^{15} electrons per cc and temperatures ranging from 2000°K to 4000°K all at 1 atmosphere of pressure. Further, an analysis of the microwave scattering from an infinitely long cylindrical plasma is included along with computed normalized results for an extremely broad range of plasma properties and parameters. These theoretical data were obtained from an IBM 7094 computation and plotting program and are restricted to the case of the scattering of a plane electromagnetic wave from a homogeneous, cylindrical, infinite length plasma in thermal equilibrium.

The experimental facility consisted of a radio frequency plasma generator operating at 30 megacycles which produced a very low velocity cylindrical plasma, about 1 cm in diameter, at 1 atmosphere of pressure and an average temperature of 2600°K. Seeding of the alkali metals was accomplished with a nitrogen or air driven atomizer and aqueous solutions of the nitrates of the alkali metals.

Plasma temperature was measured by means of Na D spectral line techniques for monitoring average temperatures, and for determining detailed temperature profile data as the result of plasma emission and absorption measurements. The very near electric field produced by the plasma generator was measured using a subminiaturized dipole-diode in order to determine the magnitude and nature of the R-F field with regard to plasma equilibrium. Free space microwave scattering was chosen as a primary diagnostic method; and the phase and amplitude of 3 cm microwaves scattered from the cylindrical, finite length, laboratory plasma were measured by a microwave interferometer for comparison with computed theoretical values. Both forward and lateral scattering measurements were made. A comparison of theoretical and experimental results indicated agreement in electron density within 40% of theory using amplitude data: phase data were considered unusable for quantitative comparison purposes.

A discussion of the probable sources of both systematic and random error and their relative importances is included; however, unexplained differences between theory and experiment remain. Even though these differences were anticipated due to the difficulty of producing a well-defined laboratory plasma, it is indicated that further investigation, perhaps with other complimentary diagnostic techniques, may explain such differences.

It is significant to note that the R-F plasma and the seeding apparatus used in this study appeared to be quite suitable for plasma studies in further research efforts and perhaps also for purposes of demonstration or instruction of plasma phenomena and plasma diagnostics. The plasma temperature profiles which resulted from Na D spectral line emission and absorption data are significant results which appear to support the equilibrium assumption as well as the homogeneous cylinder approximation.

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