F I N A L R E P O R T

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RADIO FREQUENCY AND MICROWAVE SPECTROSCOPY OF MAGNETIZED PLASMAS

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ABSTRACT

This report summarizes the original proposed research, the reports prepared, the expenditures, and the results of research performed under NASA Research Grant NsG 106-61.

INTRODUCTION

Our original proposal was to investigate Faraday Effect and/or electron spin resonance (ESR) in a gas discharge. We intended to use a Penning Ionization Gauge to produce the discharge for the ESR experiments, but preliminary investigations led to the discovery of coherent oscillations in the very high frequency (VHF) range. The largest effort has been devoted to an investigation of these oscillations and related phenomena. The Faraday Effect was investigated in a cylindrical cavity, in order to avoid difficulties with end effects. In the process of this work several FORTRAN programs were developed which may be of use in other areas. The details of this work are covered in several reports listed in the next section of this report, and we will only summarize the work here.

TECHNICAL REPORTS SUBMITTED, AND MEETING PAPERS PRESENTED

The following technical reports have been prepared:

No. 1: VHF Oscillations in a Penning Gauge, by R. N. Dennis, Jr. (M. A. Thesis), June 1962.

No. 2: Bimodal-Cavity Measurement of the Microwave Faraday Effect in a Gaseous Magnetoplasma, by M. T. Raiford (M. A. Thesis), June 1963.

No. 3: Nonlinear Response of an Oscillating Discharge to Applied Very High Frequency Signals, by D. B. Raiford (M.A. Thesis) July 1965.

No. 4: Apparatus for Recording Oscillation Properties of a Penning Ionization Gauge at Very High Frequencies, by M. D. Holt & D. B. Raiford, June 1965.

In addition, the following mathematical reports have been prepared:

No. 1: A Generalized Least-Squares Computer Program for the IBM 1620, by M. D. Holt and D. B. Raiford, June 1964.

No. 2: Listing of FORTRAN Programs Developed in Connection with NASA Grant No. NsG 106-61, by F. R. Crownfield, Jr., M. D. Holt and D. B. Raiford.

The following meeting papers were presented; in the case of the two international meetings the full papers have appeared or will appear in the Proceedings. In the other cases (American Physical Society and Virginia Academy of Science) the reference in each case is to the published abstract. Copies of these have been transmitted to NASA except when the talk was a presentation of the results included in a technical of mathematical report.

VHF Oscillations in a Penning Gauge, by R. N. Dennis, Jr., Virginia Journal of Science 13, 226 (1962) (1962 meeting of Virginia Academy of Science)

VHF Oscillations and Anomolous Volt-Ampere Characteristic of a Penning Gauge, by F. R. Crownfield, Jr. and R. N. Dennis, Jr., Bull. Am. Phys. Soc. 7, 641 (1962) (Fifteenth Annual Gaseous Electronics Conference)

Microwave Cavity Measurement of the Faraday Effect in a Magneto-plasma, by F. R. Crownfield and M. T. Raiford, Bull. Am. Phys. Soc. 8, 298 (1963), (1963 Washington Meeting of the American Physical Society).

Microwave Cavity Measurements of the Faraday Effect in a Magnetized Gaseous Plasma, by M. T. Raiford, Va. Journal of Science 14, 192 (1963) (1963 Va. Academy of Science Meeting).

Plasma Oscillations and Conduction Phenomena in a Penning Gauge, by F. R. Crownfield, Jr., Va. Journal of Science 14, 184 (1963) (1963 Va. Academy of Science Meeting).

Microwave Cavity Measurement of the Faraday Effect in a Magneto-plasma, by M. T. Raiford and F. R. Crownfield, Jr., Proc. VI Int. Conf. on Ionization Phenomena in Gases, Vol. III, 167 (SERMA, Paris 1964).

Interaction of Plasma Oscillations with Conduction in a Penning Gauge, by F. R. Crownfield, Jr., Proc. VI Int. Conf. on Ionization Phenomena in Gases, Vol. II, 451 (SERMA, Paris 1964).

A Generalized Least-Squares Computer Program by M. D. Holt and D. B. Raiford, Va. Journal of Science 15, 275 (1964) (1964 Meeting of the Virginia Academy of Science)

Application of a Generalized Least-Square Program to the Analysis of Wave and Oscillation Properties of a Gas Discharge by D. B. Raiford and M. D. Holt, Va. Journal of Science 15, 282 (1964) (1964 Meeting of the Va. Academy of Science)

Oscillation Properties of a Penning Ionization Gauge at Very High Frequencies by M. D. Holt, D. B. Raiford, and F. R. Crownfield, Jr., Bull. Am. Phys. Soc. 10, 476 (1965) (1965 Washington Meeting of the American Physical Society).

Perturbation of the DC Current Drawn by a Penning Ionization Gauge by Applied Very High Frequency Signals by D. B. Raiford, M. D. Holt, and F. R. Crownfield, Jr. Bull. Am. Phys. Soc. 10, 477 (1965) (1965 Washington Meeting of the American Physical Society).

Perturbation of the DC Current in a Penning Ionization Gauge Discharge by Applied VHF Signals by D. B. Raiford and M. D. Holt, Va. Journal of Science 16, 316 (1965) (1965 Meeting of the Virginia Academy of Science).

Oscillation Properties of a Penning Gauge by M. D. Holt and D. B. Raiford, Va. Journal of Science 16, 317 (1965) (1965 Meeting of the Va. Academy of Science).

Non-Linear Response of a Penning Ionization Gauge Discharge to Applied Very High Frequency Signals by Frederic R. Crownfield, Jr., Daniel Raiford, and David Holt. Proc. VII International Conference on Phenomena in Ionized Gases, Gradevinska Knjiga, Beograd 1965 (to be published).

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CONCLUSIONS

As a result of the research performed under the grant, four students (Dennis, Maurice Raiford, Holt, and Dan Raiford) have received Master's degrees in Physics and three papers have been published in the proceedings of international conferences. Technical results are summarized below.

Very high frequency oscillations have been discovered which interact with conduction in the Penning Ionization Gauge. These oscillations seem to be associated with the interaction between longitudinal electron motion and the slow-wave modes of a plasma-filled conducting cylinder. This suggests that one might approach problems of the stability of self-consistent stationary solutions of the non-linear Vlasov equation in a similar way: one should look for cases where the frequency of the wave modes in a plasma correspond to the oscillations of electrons in the self-consistent potential distribution. When these frequencies agree, one may expect instability.

The oscillations in the Penning Gauge also have been found to interact with external VHF signals applied to the anode, causing small changes in the direct current drawn by the discharge. In addition, we observed that the current drawn by the gauge was not a linear function of gas pressure when oscillations occur.

In connection with this research, a recording system was developed to allow rapid (rather than point-by-point) recording of oscillation frequencies, amplitudes, and spectra simultaneously with current and pressure.

The Faraday Effect has been observed in a TE_{111} microwave cavity with a coaxially located plasma, and a generalized least-squares program developed which allowed us to show that our original simplified

theory was inadequate. This work was then suspended, and was later resumed under grant NsG 567 D.