SEMI-ANNUAL TECHNICAL SUMMARY
for the period ending 30 September 1968

to

ADVANCED RESEARCH PROJECTS AGENCY

RESEARCH OF AERODYNAMIC PHYSICS INSTITUTE
FOR PROJECT STRATEGIC TECHNOLOGY
ARPA Order No. 529 Program Code No. 5730

Report
R-1295.7-68

for
Office of Naval Research
Contract Nonr-839(38)

POLYTECHNIC INSTITUTE OF BROOKLYN

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Date of Contract: 1 February 1964

Expiration Date: 31 August 1969

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Submitted by: Martin H. Bloom
Principal Investigator
Director of Gas Dynamics Research
Dean of Engineering

POLYTECHNIC INSTITUTE OF BROOKLYN

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ACKNOWLEDGEMENT

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ABSTRACT

This report contains a compilation of abstracts of papers which were either accepted for publication or were published. The papers are on the subjects of Fluid Dynamics, Electromagnetics and Plasmas. The work described was carried out under an ARPA contract, Order No. 529. This summary also contains a listing of papers submitted to journals, lectures, internal reports and staff activities.

TABLE OF CONTENTS

I. INTRODUCTION

The Polytechnic Institute of Brooklyn is conducting a broad interdisciplinary theoretical and experimental research program in plasma aerodynamics, electromagnetic scattering theory and experimental plasma research applicable to both the immediate and long-range interests of the ARPA Ballistic Missile Defense Program. Emphasis is being placed on fluid dynamics, electromagnetic radiation and their interaction with media characteristic of the ballistic missile defense environment.

II. SUMMARY OF RESEARCH

In this section are presented abstracts of technical papers which have been either published or accepted for publication during the reporting period covered by this report.

A. FLUID DYNAMICS

P. M. Sforza, "Probe Interference in Hypersonic Near Wakes," AIAA Journal, Vol. 6, No. 9, pp. 1800-1802, September 1968. (Also published as PIBAL Report No. 1011, April 1967.)

Preliminary results concerning the effects of probing the recirculation region of a slender cone in hypersonic flow with conventional diagnostic techniques are presented. Experiments were performed at a free stream Mach number of 11.8 and unit Reynolds number of 0.6×10^6 per foot on a 5° half-angle cone with a base diameter of 10 in. The centerline axis of the recirculation region was investigated with various probes extended from the base (probe diameters were roughly one-hundredth of the base diameter) while base pressure at the base centerline and centerline pitot pressure at a station in the supersonic near wake were monitored. Similar studies were made while monitoring only the stagnation temperature profile in the supersonic near wake. It was found, for the above experimental conditions at least, that probes placed along the axis distorted downstream pitot pressures while off-axis curved probes did not appreciably alter either base pressure or downstream pitot pressure. In addition, it was found that extending even the off-axis probe too far from the base into the recirculation region (into the vicinity of the rear stagnation point) greatly disturbs the stagnation temperature profile at a station in the supersonic near wake.

B. ELECTROMAGNETICS

H. Berger, "Reflection and Transmission of Electromagnetic Power at Moving Interfaces,"[†] published in the Journal of Applied Physics, Vol. 39, No. 7, June 1968.[‡]

There have been a number of recent papers which have studied the problem of the reflection and transmission of electromagnetic power at moving interfaces. In these studies, the calculations of reflected and transmitted time averaged power flow are based on the same formula that is used for the stationary interface problem [i.e., $1/2\,\mathrm{Re}\,(E \times H^*)$], and $E \cdot D^*$ for a portion of the stored time-average energy density[5]. However, some justification and clarification is required for moving interfaces when these calculations are made. The basic reason is that the above formulas for time-average quantities were derived for time-harmonic fields, which may exist when the boundary is stationary. However, the fields are not time harmonic in the ordinary sense when the interaction involves a moving boundary. The present note discusses these calculations for moving boundaries.

H. Berger and J. W. E. Griemsmann, "Transient Electromagnetic Guided Wave Propagation in Moving Media,"[†] to be published in the IEEE Transactions on Microwave Theory and Techniques, MTT-16, No. 10, October 1968.

This paper presents an analytical study of the influence of moving media on the propagation of transient electromagnetic modal waves in dispersive waveguides. The response to impulsive excitation is determined in exact closed form and used to demonstrate that the nature of the pulse distortion differs in each of the three cases (1) $0<v<c \equiv (\varepsilon\mu)^{-1/2}$, (2) $v = c$, and (3) $c<v<c_o \equiv (\varepsilon_o\mu_o)^{-1/2}$ (v = speed of the medium). An expression is derived from which the pulse waveform generated by an input of arbitrary form can be readily determined when $0<v<c$ if the transient response to a similar input is known for $v = 0$. An untabulated Laplace transform pair is derived and used to determine the unusual pulse distortion in case (3) which shows a markedly discontinuous change from the pulse distortion in case (2). The theory illuminates a singular

[†] Work was done in part under Contract No. AF 49(638)-1402

[‡] Note: Printer's error. Acknowledgement to Contract No. NONR 839(38) was inadvertently omitted.

circumstance in which the Lorentz transformation is consistent with the "speed of light" differing from one inertial reference frame to another.

L. B. Felsen, "Propagation in Inhomogeneous and Dispersive Media," to be published in Alta Frequenza.

This paper is concerned with a review of methods currently employed in the theory of propagation in inhomogeneous and (or) dispersive media. Emphasis is placed on physical concepts underlying various procedures and the discussion is slanted especially toward papers in the subject area which were presented in a session bearing this title at the URSI Symposium on Electromagnetic Waves in Stresa, Italy.

E. Ott and J. Shmoys, "Transition Radiation and the Cerenkov Effect," published in the Quarterly of Applied Mathematics, Vol. XXVI, No. 2, July 1968.

The analysis of transient radiation emitted by a line charge moving at a constant velocity at right angles both to itself and to a plane interface between two dielectric half-spaces has been generalized to include the possibility of Cerenkov emission in either medium. Just as in the special case of charge velocity lower than the wave velocity in either medium, the exact solution of the problem is obtained, but with additional pole contributions. The wavefront configuration corresponding to various relative values of the three velocities is obtained and discussed. In particular, the build-up of Cerenkov radiation as the line charge enters a medium with sufficiently high dielectric constant is studied.

S. Rosenbaum, "On Energy-Conserving Formulations in a Randomly Fluctuating Medium," to be published in the Proceedings of the Symposium on Turbulence of Fluids and Plasmas, Vol. XVIII, April 1968.

Under study are the propagation and scattering characteristics of a scalar wave propagating through an unbounded transmission medium. The wave is assumed to be generated by a monochromatic source, and

the medium properties (electromagnetic or acoustical) are completely determined by its index of refraction $n(\underline{r}, t)$ which is taken to be a real, randomly fluctuating function of $\underline{r}$ and $\underline{t}$. The irregular time variations are presumed slow and are regarded as changes in the time independent realizations of the random field $n(\underline{r})$ (quasimonochromatic approximation). The process $n(\underline{r})$ is assumed to be statistically homogeneous, isotropic and normal although the last two features are unessential for some of the considerations. The reduced wave equation together with the appropriate radiation condition forms a convenient starting point for this analytical study in which the limit of small-scale fluctuations is emphasized.

The (exact) Dyson and Bethe-Salpeter equations for the coherent wave and the covariance function, respectively, are given, and alternative approximate forms and their solutions are discussed and compared. The exact field problem as stated above constitutes an energy conserving system; however, the approximations imposed on the Dyson and the Bethe-Salpeter equations may be, and generally are, inconsistent with the required conservation of energy (even to the stated order of accuracy). These aspects are illustrated briefly for the Born and "bilocal" approximations, and a higher-order approximation is presented which accounts partially for multiple scattering and which is energetically self-consistent (to the pertinent order). The resultant approximate form of the Dyson equation is nonlinear and cannot be solved exactly. An approximate solution (dispersion relation), however, may be obtained in the limit of small-scale fluctuations, and compared with the well-known result, obtained via the "bilocal" approximation. A discrepancy in the results within their common range of validity is pointed out and explained.

C. PLASMAS

R. Chimenti, "A Sampling Technique for Time-Resolved Spectroscopy," to be published in Applied Optics, Vol. 7, No. 10, October 1968.

A sampling technique to obtain spectrograms of light emitted at a given time in a repetitively pulsed discharge is described.

K. Chung and D. J. Rose, "Low Frequency Fluctuations in the Weakly Turbulent Hollow Cathode Arc Plasma," to be published in the Proceedings of the Symposium on Turbulence of Fluids and Plasmas, Vol. XVIII, April 1968.

The long hollow cathode arc of M. I. T. demonstrated that it could produce remarkably quiescent Argon plasma. The system employs a hot hollow cathode, a differential pumping scheme, and a long, uniform magnetic field. Typically, the plasma is a highly ionized ($\geq 90\%$ ionization), moderate temperature ($T_i \leq 1$ eV, $T_e \leq 10$ eV) plasma with a density of $10^{12} \sim 10^{14}$ cm^{-3}. Although the plasma could be quiescent ($\Delta n/n < 1\%$) at optimal operating conditions, it usually exhibits plasma fluctuations of the density and the floating potential. We have studied the low frequency plasma fluctuations using electrostatic probes. For a detailed analysis of the coherent part of the fluctuations, an electronic correlator was used.

In this study our main attention was focused on the coherent fluctuations in order to attempt an interpretation of the fluctuations by the weak plasma turbulence theory. The variations of frequency and amplitude of the coherent oscillations with respect to plasma parameters are mapped out. In this plasma we found two kinds of coherent oscillations at two different operating conditions. One mode is found to be a drift wave instability due to the density gradient at the plasma boundary. This mode is a pure $m = 1$ azimuthal mode and is localized at the boundary. The frequency of this mode is 8-20 kHz and harmonics are strong for this mode. This mode is interpreted as the electrostatic ion cyclotron waves generated in the source region and propagating through the long drift region.

In this paper, we will describe the machine, the characteristics of the plasma, the experimental techniques, and the properties of the coherent oscillations. The rationale for the identification of these modes will be given. Also, it will be pointed out that the steady state density distribution indicates a disagreement with the classical diffusion process in the weakly turbulent plasma. In order to obtain quiescent plasma, we have to run the machine so that there are no coherent oscillations in the plasma.

G. Dorman, "Interaction of a Relativistic Electron Beam With an Inhomogeneous Plasma," accepted for publication in the Journal of Plasma Physics.

The investigation of the high frequency interaction of a relativistic electron beam and a plasma is extended to include arbitrary variation of the plasma density. Analyzing the coupled linearized Vlasov-Maxwell equations by means of a low temperature expansion of the orbit integrals, a general equation for the electric field accurate to first order in the plasma temperature, beam temperature, and betatron frequency is obtained. This equation is applied to the investigation of transverse and longitudinal modes. A new transverse mode with $\omega - kV_o \sim \omega_\beta$ is found to be collisionally unstable. The electrostatic instability is found to be slowed down by both low plasma temperature and low beam temperature, but the betatron oscillations increase the growth rate. A new longitudinal mode with $\omega - kV_o \sim \omega_\beta$ is found to be unstable for nonzero beam temperatures. The lowest order correction to the electrostatic growth rate due to a small plasma nonuniformity is obtained. The sign of this correction is found to depend critically on the shape of the inhomogeneity.

J. P. Freidberg, "Nonlinear Plasma Waves. III. Nonlinear Temperature Effects in the Electron-Ion Two-Stream Instability," published in The Physics of Fluids, Vol. 10, No. 11, November 1967, pp. 2417-2426.

The nonlinear interaction of two warm interpenetrating electron and ion streams is treated by investigating the traveling wave solutions to the two fluid macroscopic plasma equations. These equations are reduced to the form of a nonlinear differential equation with an additional small nonlinear term. Application of the perturbation procedure, described previously by [J. P. Freidberg, Phys. Fluids 10, 171 (1967)], leads to (1) conditions on the maximum amplitudes for which traveling wave solutions exist and (2) a nonlinear amplitude dependent dispersion relation. An examination of this dispersion relation indicates that below a certain critical temperature there is a range of wavenumbers where the two stream instability may level off before the amplitude reaches the maximum amplitude for existence of traveling wave solutions. This range of wavenumbers decreases with increasing temperature and therefore is largest when the temperature is zero.

III. ARPA-RELATED ACTIVITIES, LECTURES, CONSULTANTS, PAPERS SUBMITTED TO OUTSIDE JOURNALS, AND INTERNAL REPORTS

A. ARPA-RELATED ACTIVITIES

Dean Martin H. Bloom is a member of the Atomic and Molecular Physics Panel of the Institute for Defense Analyses (IDA)

Dean Bloom is Associate Editor of the Journal of Ballistic Missile Defense Research, published by IDA for ARPA.

Participation at meetings relevant to the program:

April 1968:

(a) Annual ARPA Institutes Review Meeting (Host: Polytechnic Institute of Brooklyn):

I. Report of Institute Programs by the Directors of the Institutes (Chairman: R. G. E. Hutter, PIB)

R. M. Dowe, Jr., ARPA	D. E. Mann, ARPA
M. H. Bloom, PIB	S. S. Penner, UCSD
K. G. Kessler, NBS	M. Biondi, U. of Pittsburgh

Tour of the Laboratories of the Long Island Graduate Center, PIB

II. Aerophysics (Chairman: M. H. Bloom, PIB)

S. C. Lin (UCSD), "Turbulence Research at UCSD"
P. A. Libby (UCSD), "Theoretical Studies on Boundary Layers"
M. Uberoi (JILA), "Strong Shocks and Cosmic Fluid Dynamics"
R. J. Cresci*, S. Lederman, (PIB), "Flow Field Experiments"
G. Moretti (PIB), "Flow Field Analysis"
P. M. Sforza (PIB), "Turbulence Research at PIB"
K. Chung (PIB), "Plasma Turbulence"

III. Atomic and Molecular Research (Chairman: D. Rapp, PIB)

University of Pittsburgh:

W. L. Fite* and A. Farragher, "Thermal Energy Charge Transfer Involving Sodium Atoms and Atmospheric Ions"
F. Kaufman*, L. F. Keyser and E. C. Zipf, "Radiative and Collisional Processes in Excited NO_2"
E. Gerjuoy* and J. D. Garcia, "Evaluation of Gryzinskii's Classical Procedures for Proton Induced Charge Transfer and Ionization"

* Speaker

National Bureau of Standards:

W. L. Wiese, "Systematic Trends of Atomic Oscillator Strengths"

F. H. Mies, "Resonance Theory of Associative Reactions"

University of California, San Diego:

J. C. Y. Chen, "Research in Atomic and Molecular Reactions"

S. S. Penner, "Recent Ionization and f-Number Measurements in the Shock Tube"

Joint Institute for Laboratory Astrophysics:

J. Hall, "Negative Ion Structure Studied by Laser Photodetachment"

R. N. Zare, "Chemical Physics at JILA"

Polytechnic Institute of Brooklyn:

D. Rapp, "Collision Research at PIB"

IV. Devices and Diagnostics Research (Chairman, R. G. E. Hutter, PIB)

R. J. Cresci (PIB), "Slingshot"

A. A. Oliner (PIB), "Unexpected Radiation Nulls in Phased Array Performance"

J. W. E. Griemsmann (PIB), "Non-Uniformity Effects in Resonant Microwave Cavities"

S. Lederman*, M. H. Bloom (PIB), "Langmuir Probe Behavior"

L. B. Felsen (PIB), "Scattering from Fluctuating Media"

G. Gould (PIB), "Laser Research at PIB".

(b) Symposium on Turbulence of Fluids and Plasmas
(Polytechnic Institute of Brooklyn, Microwave Research Institute Symposia Series)

Welcoming address:

Dr. Ernst Weber
President, Polytechnic Institute of Brooklyn

Opening remarks:

Brig. Gen. C. D. Y. Ostrom, Jr.
Director of Army Research

Col. I. C. Atkinson
Commander, Air Force Office of Scientific Research

*Speaker

Dr. E. H. Weinberg
Director of Physical Sciences Division
Office of Naval Research

Dr. H. R. Mimno
Director Region I
Institute of Electrical and Electronics Engineers

Dr. A. F. Turner
President, Optical Society of America

I. Introduction to Turbulence (Chairman: F. N. Frenkiel, Navy Ship Research and Development Center)

F. N. Frenkiel, Navy Ship Research and Development Center, "Remarks on Turbulence"

T. H. Dupree, M. I. T., "Introduction to Basic Phenomena of Turbulence in Plasmas"

L. S. G. Kovasznay, Johns Hopkins University, "Turbulence in Fluids"

II. Turbulence in Plasmas - Theory (Chairman: E. A. Frieman, Princeton University)

B. Coppi, Princeton University, "Turbulent Particle Transport in Laboratory Plasmas"

S. A. Orszag, M. I. T., and R. H. Kraichnan, Peterborough, N. H., "Theory of Strong Plasma Turbulence"

H. Lashinsky, University of Maryland, "Periodic Puiling and the Transition to Turbulence in a System with Discrete Modes"

C. M. Tchen, The City University of New York, "Turbulent Diffusion of a Plasma Across a Magnetic Field"

R. L. W. Chen, Emory University, "Thermodynamic Limits on the Growth of Turbulence in a Homogeneous Plasma"

I. P. Shkarofsky, RCA Victor Co., Ltd., Montreal, Canada, "Analytic Forms for Decaying Space/Time Turbulence Functions"

Guest Speaker (Banquet): Dr. J. P. Ruina, Massachusetts Institute of Technology, "Technology, Leadership, and the Great Society"

III. Plasma Phenomena and Experiments (Chairman: I. B. Bernstein, Yale University)

W. E. Drummond, University of Texas, "The Theory of Plasma Turbulence as Applied to Experimental Phenomena"

K. Chung, P. I. B., and D. J. Rose, M. I. T., "Low Frequency Fluctuations in the Weakly Turbulent Hollow Cathode Arc Plasma"

P. J. Coleman, Jr., U. C. L. A., "Turbulence, Viscosity, and Dissipation in the Solar-Wind Plasma"

R. Moreau, Universite de Grenoble, France, "On Magneto-hydrodynamics Turbulence"

P. S. Lykoudis, Purdue University, "Magnetc Fluid-Mechanic Shear Turbulence in the Presence of Transverse and Aligned Magnetic Fields"

P. H. Handel, Institut Max Von Laue - Paul Langevin, Munich, Germany, "Turbulence Theory for Solid State Plasmas"

IV. Turbulence in Fluids (Chairman: P. S. Klebanoff, National Bureau of Standards, Washington, D. C.)

A. P. Proudian, Heliodyne Corporation, Calif., "Approximate Modeling of Wake Turbulence"

R. E. Slattery, W. G. Clay and J. Herrmann, M. I. T., "Gas and Electron Density Fluctuations in a Weakly Ionized Hypersonic Wake"

D. Heckman, L. Tardif and C. Lahaye, Canadian Armament Research and Development Establishment, Quebec, "Experimental Study of Turbulent Wakes in the Carde Free-Flight Ranges"

P. J. Bryant, University of Canterbury, Christchurch, New Zealand, "Representation of the Air-Water Interaction"

B. Mandelbrot, IBM Research Center, Yorktown Heights, N. Y., "On Intermittent Free Turbulence"

K. T. Yen, General Electric Co., Philadelphia, Pa., "Role of Intermittency in Free Turbulent Flows and Scattering of Electromagnetic Waves by Hypersonic Wakes"

T. W. Johnston, C. Richard, A. K. Ghosh, A. I. Carswell and K. Graf, RCA Victor Co., Ltd., Montreal, Canada, "Correlation Study in Neutral-Dominated Plasma Turbulence"

V. Beam-Plasma Interactions (Chairman: R. G. E. Hutter, P. I. B.)

J. A. Davis and A. Bers, M. I. T., "Nonlinear Aspects of the Beam-Plasma Interaction"

K. E. Lonngren and H. C. S. Hsuan, University of Iowa, "A Nonlinear Effect in Beam-Plasma Interactions"

P. V. Bradford, T. C. Marshall and S. P. Schlesinger, Columbia University, "Correlated Microwave Radiation from a Beam Generated Turbulent Magneto-Plasma"

VI. Scattering from Random Media (Chairman: L. B. Felsen, P. I. B.)

J. B. Keller, N. Y. U., "A Survey of the Theory of Wave Propagation in Continuous Random Media"

V. Twersky, University of Illinois, "Scattering by Discrete Random Media"

S. Rosenbaum, P. I. B., "On Energy-Conserving Formulations in a Randomly Fluctuating Medium"

VII. Propagation and Scattering in Turbulent Media (Chairman: J. Menkes, Institute for Defense Analyses)

A. R. Hochstim and C. P. Martens, IDA, "Scattering of Electromagnetic Waves from Near-Overdense and Overdense Random Plasma Slabs"

D. A. deWolf, RCA Laboratories, Princeton, N. J., "Effects of Turbulence Upon Line-Of-Sight Wave Propagation"

V. L. Granatstein and S. J. Buchsbaum, Bell Telephone Labs., "Microwave Scattering from a Turbulent Plasma Column"

D. E. Weissman, H. Guthart and T. Morita, Stanford Research Institute, "Radar Interferometry Measurements of the Properties of a Turbulent Plasma"

(c) G. Moretti presented a seminar entitled "Numerical Analysis of Fluid Mechanics Problems: The Fabric and the Dress" at New York University, Aerospace Department (Guggenheim Laboratory)

(d) M. H. Bloom visited The Pentagon to confer with Dr. D. E. Mann, ARPA

(e) 25th Anti-Missile Research Advisory Council (AMRAC) Meeting at IDA

M. H. Bloom E. Levi J. T. LaTourrette

(f) E. Levi presented a paper, "Singularities of the Fluid Equations and Their Relation to Anomalous Diffusion" (co-author: H. W. Friedman), at The American Physical Society Meeting held in Washington, D. C.

(g) M. H. Bloom visited IDA, Arlington, Va. and Mr. K. Kresa at ARPA in Washington

(h) G. Moretti presented a talk entitled "Computer-Made Movies, A New Tool for the Analysis of Numerical Techniques," at the General Electric Co., Valley Forge, Pa.

May 1968:

(i) AGARD Conference held at Royal Aeronautical Society, London, England:

R. J. Cresci delivered a paper, "Hypersonic Flow in Rectangular and Non-Rectangular Corners" (co-authors: S. Rubin and C. Nardo)

S. Rubin presented "Hypersonic Viscous-Inviscid Interactions by a New Type of Analysis" (co-authors: S. Rudman, T. Lin and M. Pierucci)

(j) R. J. Cresci visited the Flygtekniska Försöks-Anstalten (Aeronautical Research Institute) in Stockholm, Sweden

(k) M. H. Bloom discussed contractual matters with Mr. M. Cooper at ONR, Washington; then attended an ARPA meeting on entry vehicle controls held in Arlington, Va.

(l) A. A. Oliner and L. B. Felsen conferred with Dr. A. Hochstim at IDA, and Dr. D. E. Mann and Mr. K. Kresa at ARPA, regarding contract activities

(m) Dr. K. B. Persson of NBS, Boulder, Colorado held discussions with J. Griemsmann, R. Hutter, E. Levi, K. Chung and H. Farber; then toured the laboratories of the Long Island Graduate Center. His expressed interest in visiting the Polytechnic was to determine what NBS should be doing to help advance the plasma area.

(n) E. Levi and K. Chung met with Dr. A. Thomson at IDA, and Dr. A. Hochstim and Mr. K. Kresa at ARPA to discuss contractual matters

June:

(o) AIAA Fluid and Plasma Dynamics Conference, Los Angeles, California:

M. H. Bloom S. Lederman

(p) American Physical Society Meeting, Los Alamos, New Mexico:

E. Levi presented two papers, "Derivation of Macroscopic Stability Criterion" and "Stability of the Plasma Sheath" (both co-authored by H. W. Friedman)

E. L. Rubin gave a paper entitled "Shock Structure of a Viscous Heat Conducting Radiating Gas" (co-author: P. K. Khosla)

K. Chung

(q) L. B. Felsen presented an invited paper at the International Symposium on Electromagnetic Waves held in Stresa, Italy, entitled "Propagation in Inhomogeneous and Dispersive Media" (to be published in Alta Frequenza).

July:

(r) K. Chung and E. Levi were present at the Project SECEDE Meeting at IDA

August:

(s) L. B. Felsen attended the ARPA Workshop, "Microwave Scattering from Ionized Plasmas" at IPAPS (University of California) at LaJolla

(t) International Symposium on High-Speed Computing in Fluid Dynamics at Monterey, California:

G. Moretti presented a paper entitled "Boundary Conditions and Discontinuities Effects," and a movie "Transient Flow in a Laval Nozzle"

M. H. Bloom

September:

(u) E. Levi and K. Chung presented a proposal to Dr. W. Berning at the Defense Atomic Support Agency, Arlington, Va.

(v) Second Annual Review of the ARPA/Army-sponsored programs at the Catholic University of America and the Naval Ordnance Laboratory. This meeting was held at The Pentagon, Washington, D.C.

M. H. Bloom R. J. Cresci

B. LECTURES

There have been many formal seminars and informal discussion groups; a partial listing is given here:

April 1968:

E. Torrero	Drift-Wave Instabilities, Part I
R. Chimenti	Time-Resolved Spectroscopic Study of Electrodeless Discharge in Hydrogen
Dr. Ye. V. Bogdanov Soviet Exchange Scientist Institute of Radiotechnique and Electronics Academy of Sciences, USSR	Distribution Function of Electron Beam During Plasma Beam Interaction
P. Serafim	Resonant Diffusion of Plasmas in Magnetostatic Fields
R. Zirkind	Geophysical Satellites and Their Applications
Dr. M. Epstein Aerodynamics and Propulsion Research Laboratory Aerospace Corporation Los Angeles, California	Recent Developments in Antenna Breakdown
M. Lubelski	Microwave Diagnostics of Plasma Filled Cavities
Professor J. Gavis Johns Hopkins University	Electrostatic Charge Build-Up in Flowing Hydrocarbons

May:

S. Rosenbaum	Wave Propagation in Random Media, Part I
Dr. J. E. Peebles Princeton University	The Primeval Fireball
E. Torrero	Drift-Wave Instabilities, Part II
W. C. Ko	Electrostatic Probe Methods in Magneto-plasmas
M. P. Tulin Hydronautics, Inc. Laurel, Md.	Hydrodynamics Aspects of Macromolecular Solutions
E. Levi	Stability Study of Plasma Sheath
R. McGill	Discharge Characteristics of Water Vapor

June:

S. Rosenbaum	Wave Propagation in Random Media, Part II
K. C. Huang	Design Factors of a Hollow Cathode Discharge Device

July:

Professor H. Hsu Ohio State University	Parametric Interactions in Nonlinear Scattering Processes
S. Rosenbaum	Wave Propagation in Random Media, Part III

During the course of this six-month period, Dr. Nathan Marcuvitz (of N. Y. U.) presented a series of lectures on Plasma Turbulence.

C. CONSULTANTS

Dr. Nathan Marcuvitz, Professor of Applied Physics, New York University

D. PAPERS SUBMITTED TO OUTSIDE JOURNALS

H. Berger and J. W. E. Griemsmann, "Complex Doppler Effect in Dispersive Media," submitted to the Journal of the Optical Society

G. Dorman, "Interaction of a Relativistic Electron Beam with an Inhomogeneous Plasma," submitted to the Journal of Plasma Physics

H. W. Friedman and E. Levi, "Plasma Shielding and Stability. Part I - Derivation of a Macroscopic Stability Criterion," submitted to the Physics of Fluids

H. W. Friedman and E. Levi, "Plasma Shielding and Stability. Part II - Stability of the Plasma Sheath," submitted to the Physics of Fluids

H. W. Friedman and E. Levi, "The Stability of Space Charge Sheaths in MHD Devices," submitted to the journal "Magneto-hydrodynamics" of The Institute of Physics, USSR

D. J. Palumbo and E. L. Rubin, "The Inviscid Chemical Non-equilibrium Flow Behind a Moving Normal Shock Wave," submitted to the AIAA Journal. (Published as PIBAL Report No. 68-18, June 1968.)

K. Stuart and E. Levi, "Observation of Rayleigh-Taylor Instabilities," submitted to the Journal of Applied Physics

E. INTERNAL REPORTS

D. J. Palumbo and E. L. Rubin, "The Inviscid Chemical Non-equilibrium Flow Behind a Moving Normal Shock Wave,"† PIBAL Report No. 68-18, Department of Aerospace Engineering and Applied Mathematics, Polytech. Inst. of Brooklyn, June 1968.

E. M Schmidt and R. J. Cresci, "Near Wake of a Slender Cone at Large Angle of Attack," PIBAL Report No. 68-23, Department of Aerospace Engineering and Applied Mathematics, Polytech. Inst. of Brooklyn, July 1968.

Coordinated by R. Hutter, "Research on Electromagnetics for Project DEFENDER," Semi-Annual Technical Summary for the period ending 31 March 1968, PIBMRI-1295.6-68.

† Partly sponsored under Contract NONR 839(34)

G. Louie and H. Farber, "The Characteristics of the Screen Anode Discharge,"† PIBEP-68-006, Electrophysics Memo, Department of Electrophysics, Polytech. Inst. of Brooklyn, Nay 7, 1968. (Also a Master's Thesis, Polytech. Inst. of Brooklyn.)

K. Chung, "Plasma Turbulence," PIBEP-68-012, Electrophysics Memo, Department of Electrophysics, Polytech. Inst. of Brooklyn, May 7, 1968.

M. Pierucci, "Hypersonic Interactions," Ph. D. Thesis, Polytech. Inst. of Brooklyn, June 1968.

K. Stuart, "Experiments on Resistive Instabilities in a Toroidal Plasma," Ph. D. Thesis, Polytech. Inst. of Brooklyn, June 1968. (Also published as Research Report No. PIBMRI-1379-67, December 1967.)

B. Weinberg, "Anemometer Diagnostics of Flow Fields," Master's Thesis, Polytech. Inst. of Brooklyn, June 1968.

IV. PERSONNEL

M. H. Bloom	Principal Investigator Director, Gas Dynamics Research Dean of Engineering
K. Chung	Associate Professor
R. J. Cresci	Professor
E. Dawson	Research Assistant
M. Eschwei	Research Associate
H. Farber	Associate Professor
L. B. Felsen	Professor
J. W. E. Griemsmann	Professor
R. G. E. Hutter	Professor
D. Jacenko	Research Associate
K. R. Jolls	Assistant Professor
D. Krenkel	Associate Professor
S. Lederman	Associate Professor

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