

AD 714286

SEMI-ANNUAL TECHNICAL SUMMARY  
for the period ending 31 August 1970

to  
ADVANCED RESEARCH PROJECTS AGENCY

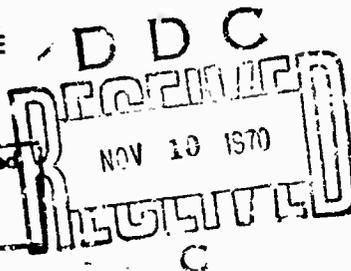
RESEARCH OF AEROPHYSICS INSTITUTE  
FOR STRATEGIC TECHNOLOGY  
ARPA Order No. 1442                      Program Code 9E30

PIBAL  
Report 70-31

for  
U.S. Army Research Office-Durham  
Contract No. DAHCO4-69-C-0077

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POLYTECHNIC INSTITUTE OF BROOKLYN

**SEMI-ANNUAL TECHNICAL SUMMARY**  
for the period ending 31 August 1970

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**RESEARCH OF AEROPHYSICS INSTITUTE  
FOR STRATEGIC TECHNOLOGY**

**ARPA Order No. 1442**

**Program Code No. 9E**

**Date of Contract: 1 September 1969**

**Expiration Date: 31 October 1970**

**PIBAL  
Report 70-31**

for  
**U.S. Army Research Office-Durham  
Contract No. DAHCO4-69-C-0077**

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

**POLYTECHNIC INSTITUTE OF BROOKLYN  
333 Jay Street, Brooklyn, N.Y. 11201**

### ACKNOWLEDGEMENT

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by U.S. Army Research Office-Durham, Box CM, Duke Station, Durham, North Carolina 27706, under Contract No. DAHCO4-69-C-0077.

### ABSTRACT

This report contains a compilation of abstracts of papers which were either accepted for publication or were published. The papers are on subjects of Fluid Dynamics, Electromagnetics and Plasmas. The work described was carried out under an ARPA contract, Order No. 1442. This summary also contains a listing of papers submitted to journals, lectures, internal reports and staff activities.

## I. INTRODUCTION

The Polytechnic Institute of Brooklyn is conducting an interdisciplinary program involving both theoretical and experimental research in the areas of aerodynamics, plasma dynamics and turbulence. These studies are generally applicable to both current and long-range interests of the ARPA Strategic Technology Office. Particular emphasis is placed on items relating to defense situations.

## II. SUMMARY OF RESEARCH PUBLICATIONS

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

S. Lederman, M.H. Bloom and J. Avidor, "The Electrostatic Probe: Some Applications to Hypersonic Flow Diagnostics",\* published in the Proceedings of the Twelfth Israel Annual Conference on Aviation and Astronautics, Weizmann Science Press of Israel, 1970.

Results of an experimental investigation of the applicability of electrostatic cylindrical probes for flow field diagnostics are presented. An experimental extension of the formulation of the free-molecular collisionless operation of cylindrical probes into the transitional and continuum regime is provided. It is shown that the power law valid for the free-molecular collisionless regime with

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\*Work supported in part under Contract Nonr 839(38).

$0.1 < r_p/\lambda_D < 3$  is applicable in transitional and continuum regime where  $r_p/\lambda_D$  may exceed 3. Experimental results obtained in the wake of several models, using the electrostatic probe technique, are compared with results obtained by other means. These results confirm the basic principle and soundness of this technique.

G. Widhopf and S. Lederman, "Specie Concentration Measurements Utilizing Raman Scattering of a Laser Beam",\* accepted for publication in the AIAA Journal.

The feasibility of utilizing Raman scattering as a diagnostic technique to measure individual specie concentrations in typical gas mixtures found in gas dynamic applications have been investigated and demonstrated. Utilizing this technique, either the local density of a pure gas or the concentration of individual diatomic (or polyatomic) species in a gas mixture can be uniquely determined.

The range and limitations of this technique were investigated and evaluated under controlled static conditions. A Q-switched ruby laser, which has a pulse duration of approximately 10 nanoseconds, was used as a radiation source. The scattered radiation was monitored utilizing a high gain, wide spectral range photomultiplier tube in conjunction with a spectrograph. Measurements were also made utilizing narrow bandpass filters in place of the spectrograph. The species which were investigated include  $O_2$ ,  $N_2$ ,  $CO_2$ , and  $CH_4$ . Quantitative results are given for these gases in their pure state as well as in various mixture proportions.

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It was determined that, with the present experimental configuration, the density of a pure gas or the concentration of a particular specie in a mixture can be determined with good accuracy over a density range of approximately two and one-half orders of magnitude. The lower range for most of the species is a few torr. This capability is independent of the presence of any suspended dust particles in the gas mixtures.

The relative and absolute intensity of the scattered radiation from the species investigated were compared with that predicted by theory. Good agreement was obtained. Measurements were also made of the vibrational temperatures of  $O_2$ . Fair agreement was obtained for the spectrograph measurements and very good agreement was obtained for those made utilizing the narrow bandpass filter.

A description of the pertinent theory and concepts of Raman scattering is also included as well as a discussion of the limitations of the technique.

C.H. Shih and E. Levi, "The Effect of Collisions on Cold Ion Collection by Means of Langmuir Probes", presented at the AIAA 3rd Fluid and Plasma Dynamics Conference, held in Los Angeles, Calif., June 29-July 1, 1970; also accepted for publication in the AIAA Journal.

Langmuir probes are extensively used to sample plasma densities. However, the theoretical background, which is required in order to interpret probe data correctly, is well established only for the case in which the plasma particles are not subject to collisions. Such an ideal condition is hard to find in practice.

In particular, collision effects are important, even though the plasma may be highly rarefied, when the ions are colder than the electrons, as is the case in some fluid-dynamic situations and in all electrical discharges. In a series of experiments on cold ion collection conducted with the aid of a shock tunnel at PIB, Lederman, Bloom and Widhopf have shown that the plasma densities evaluated on the basis of the collisionless theory may be in error by more than one order of magnitude. These findings have been confirmed by others in flow fields and by Self and Shih in electrical discharges.

A theory which accounts separately for the often counteracting effects of collisions between charged particles and collisions with neutrals will be presented. When this theory is applied to all published experimental data, taken with cylindrical as well as spherical probes, the discrepancies between actual and calculated plasma densities become reduced to less than ten percent.

#### B. Plasmas

H.W. Friedman and E. Levi, "Plasma Shielding", published in *The Physics of Fluids*, Vol. 13, No. 4, pp. 1049-1054, April 1970.

Necessary and sufficient conditions are established for the shielding of current-carrying plasmas by means of space charge sheaths. These conditions reduce to Bohm's shielding criterion in the particular case of zero current and, in general, are consistent with measurements obtained by means of Langmuir probes and their current interpretation.

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

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); Associate Editor of the Journal of Ballistic Missile Defense Research, published by IDA for ARPA; and is a consulting member of the Plume Technology Working Group, Joint Army-Navy-Air Force.

Professor Robert J. Cresci is a member of the AIAA Ground Test and Simulation Technical Committee of AIAA.

Participation at meetings relevant to the program:

March 1970:

- (a) S. Lederman, M.H. Bloom and J. Avdor are authors of a paper, "The Electrostatic Probe: Some Applications to Hypersonic Flow Diagnostics", which was presented at the Twelfth Israel Annual Conference on Aviation and Astronautics, held at Tel Aviv, Israel, March 4-5, 1970.
- (b) G. Moretti presented a seminar entitled "Numerical Techniques in Gas Dynamics" at Columbia University, New York, Dept. of Mechanical Engineering, March 18, 1970.

May 1970:

- (c) M.H. Bloom attended the ARPA Workshop on the Application of Air Cushioned Landing Gear to Aircraft, held at the Institute for Defense Analyses, Arlington, Va., May 13-15, 1970.

June 1970:

- (d) M.H. Bloom gave an invited talk on "Corner Flow: A Study in Fluid Mechanics" at the NASA-ASEE Summer Faculty Research Program, held at Langley Research Center, Hampton, Va., June 9, 1970.
- (e) E. Levi attended the BMD Experimental Measurements Meeting, held in Washington, D.C., June 16, 1970.
- (f) E. Levi and C.H. Shih are authors of a paper, "The Effect of Collisions on Cold Ion Collection by Means of Langmuir Probes", which was presented at the AIAA 3rd Fluid and Plasma Dynamics Conference, held in Los Angeles, Calif., June 29-July 1, 1970.
- (g) G. Moretti was requested by a branch of NATO to engage in a series of NATO-supported lectures and conferences throughout Europe in May and June 1970. His lectures were on Computational Gas Dynamics. Under these auspices he lectured at universities and government laboratories in Paris, Marseilles, Brussels, Aachen, Delft, Amsterdam, Darmstadt, Munich, Turin, Milan, Rome, Udine, and Farnborough.

July 1970:

- (h) E. Levi visited the Mitre Corporation and the AVCO-Everett Corp. in Boston, Mass. on July 6, 1970 for discussions with Dr. Meltz of the Mitre Corporation and to see Drs. Linson and Workman of AVCO-Everett Corp.

- (j) E. Levi participated at the Project Secede Summer Study, held at the Stanford Research Institute, Menlo Park, Calif., July 12-30, 1970.
- (k) S. Lederman visited the NASA Langley Air Research Center on July 14, 1970 to brief NASA Scientists about PIB's innovative work on the application of Raman scattering to fluid dynamic diagnostics.
- (m) S. Rosenbaum participated in the Workshop on Radar Scattering from Turbulent Media, held in San Diego, Calif., July 15-18, 1970.

B. Lectures at P.I.B.

March 1970:

Professor S.H. Lam  
Princeton University

Dispersive Wave Systems About  
High Altitude Satellites

Dr. I. Kupiec  
Polytechnic Institute of  
Brooklyn

Scattering by a Randomly  
Fluctuating Slab

Dr. J. Whitman  
Polytechnic Institute of  
Brooklyn

Transients in Time-Varying  
Media

Dr. A.W. Snyder  
Yale University

Waveguide Mode Theory of  
Color Vision

April 1970:

Professor S. Corrsin  
The Johns Hopkins University

Experiments on Nearly Homogeneous  
Turbulent Shear Flows

May 1970:

Dr. J.P. Freidberg Univ. of California Los Alamos Scientific Lab.	A Survey of Sherwood Activities at Los Alamos Scientific Laboratory
Dr. A. Pallone AVCO Corporation	Prediction of Nose Shape Change During Atmospheric Reentry
Mr. R.S. Chu Polytechnic Institute of Brooklyn	Coupled Mode Theory for the Diffraction of Light by Ultrasound
Prof. E.T. Jaynes Washington University	A Theory of the Schwartz Effect--Optical Modulation of Electron Beams
Dr. D.A. deWolf RCA Laboratories	Wave Propagation in Random Media

During the course of this six-month period, Professor N. Marcuvitz (of N.Y.U.) gave a weekly lecture series on Plasma Turbulence.

C. Consultants

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

D. Internal Reports and Books

G. Moretti, "Transients and Asymptotically Steady Flow of an Inviscid, Compressible Gas Past a Circular Cylinder", PIBAL Report No. 70-20, Dept. of Aerospace Engineering and Applied Mechanics, Polytechnic Institute of Brooklyn, April 1970.

T. Koga, "Difficulty and Possibility of Kinetic Theory of Quantum-Mechanical Systems. Part II- The Quantum-Mechanical Liouville Equation and Its Solutions"\* PIBAL Report No. 70-26, Dept. of Aerospace Engineering and Applied Mechanics, Polytechnic Institute of Brooklyn, May 1970.

\* Work supported in part under Contract Nonr 839(38).

Coordinated by M.H. Bloom, "Research of Aerophysics Institute for PROJECT STRATEGIC TECHNOLOGY". Semi-Annual Technical Summary for the period ending 28 February 1970, PIBAL Report No. 70-28.

T. Koga, "Difficulty and Possibility of Kinetic Theory of Quantum-Mechanical Systems. Part III- Inconsistent Scale Effects in the Theory of Scattering. Part IV- Inconsistencies in Representation of Photon-Electron Interaction".\* PIBAL Report No. 70-35, Dept. of Aerospace Engineering and Applied Mechanics, Polytechnic Institute of Brooklyn, July 1970.

T. Koga, "Difficulty and Possibility of Kinetic Theory of Quantum-Mechanical Systems. Part V- Particular and General Solutions of the Schrodinger Equation and their Significance in Kinetic Theory",\* PIBAL Report No. 70-36, Dept. of Aerospace Engineering and Applied Mechanics, Polytechnic Institute of Brooklyn, August 1970.

G.F. Widhopf, "Specie Concentration Measurements Utilizing Raman Scattering of a Laser Beam",\* Ph.D. Thesis, Polytechnic Institute of Brooklyn, June 1970.

T. Koga, "Introduction to Kinetic Theory: Stochastic Processes in Gaseous Systems",\* Volume 28 of the International Series of Monographs in Natural Philosophy, published by Pergamon Press, Inc., New York, 1970.

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IV. PERSONNEL

M.H. Bloom	Principal Investigator Director of Gas Dynamics Research Dean of Engineering
J. Avidor	Research Assistant
R. Dushman	Research Assistant
K. Chung	Associate Professor
R.J. Cresci	Professor
E.F. Dawson	Research Assistant
R. Eichler	Graduate Assistant, Senior Grade
H. Farber	Associate Professor
L.B. Felsen	Professor
J.W.E. Griemsmann	Professor
K. Huang	Graduate Assistant, Senior Grade
R.G.E. Hutter	Professor
E. Kawecki	Research Assistant
P. Khosla	Assistant Professor
D. Landsberg	Research Fellow, Junior Grade
E. Levi	Professor
S. Lederman	Associate Professor
J. Librizzi	Research Associate
R. Mons	Research Associate
G. Moretti	Professor
S. Rosenbaum	Assistant Professor
P. Rosner	Research Assistant
P.M. Sforza	Associate Professor
C. Shih	Graduate Assistant, Senior Grade
R. Valentine	Research Assistant

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Polytechnic Institute of Brooklyn 333 Jay Street Brooklyn, New York 11201		2a. REPORT SECURITY CLASSIFICATION Unclassified	
		2b. GROUP	
3. REPORT TITLE Research of Aerophysics Institute for STRATEGIC TECHNOLOGY			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Semi Annual Technical Summary for period ending 31 August 1970			
5. AUTHOR(S) (First name, middle initial, last name) Principal Investigator: Martin H. Bloom			
6. REPORT DATE		7a. TOTAL NO. OF PAGES 10	7b. NO. OF REFS 0
8a. CONTRACT OR GRANT NO. DAHCO4-69-C-0077		9a. ORIGINATOR'S REPORT NUMBER(S) PIBAL Report No. 70-31	
b. PROJECT NO. ARPA Order No. 1442			
c. Program Code No. 9E30		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d.			
10. DISTRIBUTION STATEMENT Distribution of this document is unlimited.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Advanced Research Projects Agency and U.S. Army Research Office-Durham	
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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Dispersive media Electron density distributions Kinetic theory Langmuir probes Near wake Numerical techniques Plasma striations Raman scattering Shock tube diagnostics Test facilities						