

AD-A088 006

PURDUE UNIV LAFAYETTE IN PROJECT SQUID HEADQUARTERS

F/G 21/5

PROJECT SQUID, (U)

FEB 80 R F HOGLUND, R GOULARD, S N MURTHY

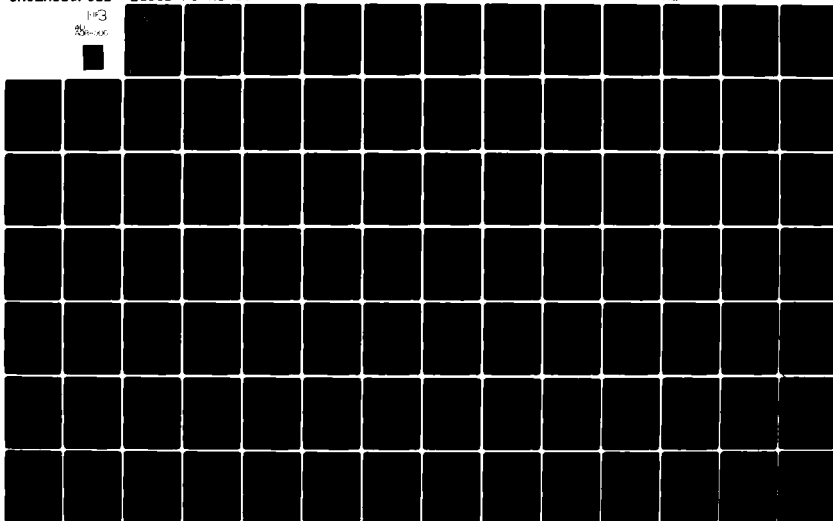
N00014-75-C-1143

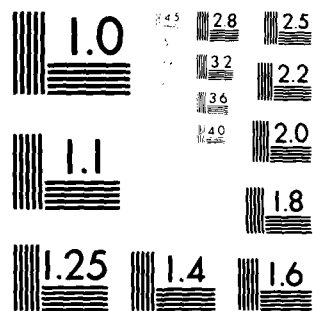
UNCLASSIFIED

SQUID-PU-R2-80

NL

11/3
20/1-006





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A088006

PROJECT SQUID
FINAL TECHNICAL REPORT

REPORT NO. PU-R2-80

Contract Nos.
N00014-67-0226, N00014-67-A-0226
and
N00014-75-C-1143

FEBRUARY 1980

Project SQUID is a cooperative program of basic research relating to Jet Propulsion. It is sponsored by the Office of Naval Research and is assisted by Purdue University through Contract N00014-75-C-1143, NR-098-038.

Published for ONR by
School of Mechanical Engineering
Chaffee Hall
Purdue University
West Lafayette, Indiana 47907

SE
AUG 14 1980
A

This document has been approved for public release and sale;
its distribution is unlimited.

DDC FILE COPY

80 8 14 038

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER SQUID-PU-R2-80	2. GOVT ACCESSION NO. AD-A088 006	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Project SQUID Final Technical Report	5. TYPE OF REPORT & PERIOD COVERED Final Technical Report	6. PERFORMING ORG. REPORT NUMBER Oct 67-Dec 79
7. AUTHOR(s) Various K. F. Hazelund	8. CONTRACT OR GRANT NUMBER(s) N00014-75-C-1143 NR 098-038	9. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS N00014-67-A-0226
10. PERFORMING ORGANIZATION NAME AND ADDRESS K. F. Hazelund S. N. D. Murphy	11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Power Program Code 473 Arlington, VA 22217	12. REPORT DATE Feb 80
13. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) ONR - Power Program through Purdue Univ. West Lafayette, Indiana 47907	14. SECURITY CLASS. (of this report) Unclassified	15. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) This document has been approved for public release and sale; it's distribution is unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Combustion Jet Propulsion Turbulence Workshops Chemical Kinetics, Aerodynamics, Fluid Mechanics Colloquia Molecular Processes Turbomachinery Measurement Techniques Rate Processes		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The Final Technical Report provides a summary report of the activities under Project SQUID carried out under Contracts N00014-67-0226, N00014-67-A-0226 and N00014-75-C-1143 during the Period Oct. 1967-Dec. 1979 with the Office of Naval Research. Research projects carried out under sub-contract to Purdue University as well as Workshops and Colloquia organized under the auspices of Project SQUID are discussed. Project SQUID is a continuing program devoted to fundamental research of long range relevance to the technology of jet propulsion.		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601443617
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)



SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PROJECT SQUID

FINAL TECHNICAL REPORT

Report No. PU-R2-80

Contract Nos.

N00014-67-0226

N00014-67-A-0226

and

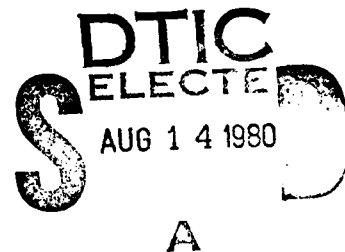
N00014-75-C-1143

February, 1980

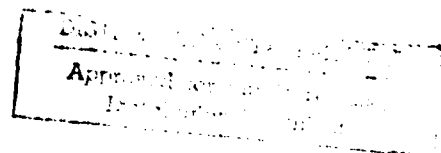
School of Mechanical Engineering

Purdue University

West Lafayette, Indiana 47907



A



ABSTRACT

The Final Technical Report provides a summary report of the activities under Project SQUID carried out under Contracts N00014-67-0226, N00014-67-A-0226 and N00014-75-C-1143. Research projects carried out under sub-contract to Purdue University as well as Workshops and Colloquia organized under the auspices of Project SQUID are discussed.

Accession For	
NTIS GCMAL	☒
DDI TAB	☐
Unprocessed	☐
Justification	
By	
Distribution	
Availability Codes	
Dist	Availability
A	Special

ACKNOWLEDGEMENT

Project SQUID, administered by the Power Program of the Office of Naval Research, has been devoted to fundamental research of long range relevance in propulsion. It has been assisted, from October 1967 till December 1979, under Contracts Nos. N00014-67-0226, N00014-67-A-0226 and N00014-75-C-1143, by the School of Mechanical Engineering at Purdue University, where jet propulsion has been a thrust area in research and teaching for over forty years.

Thirty university institutions and fourteen industrial research centers have participated in Project SQUID in the period 1967-1979. They were selected each year based entirely on the excellence of their proposals in relation to long-term Navy needs. Their research, which is their primary excitement, has contributed not only great advances but also trained nearly 100 researchers in the field.

Purdue University has been assisted, over the years, by about fifteen external consultants, selected by the ONR, in reviewing on-going and proposed work under Project SQUID. Their service to the research community and the ONR are well-recognized.

Mr. James R. Patton of the Power Program has been the ONR director of SQUID over the entire period, 1967-1979. His sympathy for fundamental research, especially in university institutions, his guidance in the organization of SQUID Workshops and Colloquia and his continuous attempts at relating SQUID research programs to advance development in industry have been greatly appreciated by the research community and the consultants.

Dr. Ralph Roberts and Mr. John Satkowski have been directors of the Power Program during 1967-1975 and 1975-1979 respectively. Their support of a project-type operation in propulsion research with emphasis on three or four selected subject areas at any one time has made Project SQUID as effective as is evident in this Report.

Purdue University is very pleased with its participation in Project SQUID, and looks upon such collaborative efforts with government agencies as a continuing activity of the University in public service.

West Lafayette
February 28, 1980

S.N.B. Murthy

CONTENTS

1. Introduction	1/1 - 1/2
1.1. Outline of Report	1/3
2. Sub-Contracts for Research	2/1 - 2/106
3. Reports and Publications	3/1 - 3/84
4. Reviews, Workshops and Colloquia	4/1 - 4/31
5. Special Services	5/1 - 5/3
6. Discussion	6/1 - 6/6

1. INTRODUCTION

The Office of Naval Research Power Program was assisted by Purdue University under two Contracts as follows.

- i) Contract No. N00014-67-A-0226 beginning October 1, 1967 and ending September 30, 1975; and
- ii) Contract No. N00014-75-C-1143 beginning October 1, 1975 and ending December 31, 1979.

The Principal Investigators at Purdue University during the period Oct. 1, 1967 through Dec. 31, 1979 were the following.

- i) Dr. R.F. Hoglund;
- ii) Dr. R. Goulard; and
- iii) Dr. S. N. B. Murthy.

The Principal Investigators were assisted by a secretary.

The activities under Project SQUID at Purdue University consisted of the following. Each of the activities was carried out under specific direction and approval of the ONR Power Program.

- i) Issuing Call for Proposals, receiving proposals, reviewing proposals along with consultants at an Annual Review Meeting, and submitting a Review Report upon the Proposals to the ONR Power Program.
- ii) Assisting the ONR Power Program in the review of on-going research.
- iii) Awarding Sub-Contracts for research and administering them as directed and approved by the ONR Power Program; and
- iv) Organizing Workshops and Colloquia.

Three types of Reports have been submitted to the ONR Power Program in connection with work accomplished under Project SQUID. They

are the following.

- i) Semi-Annual Progress Reports which described the work accomplished under various research projects that were on-going in the period covered by the Report;
- ii) Annual Status Reports which provided the status of each project that was on-going in the period covered by the Report; and
- iii) Reports on Workshops and Colloquia organized under the Project and issued as and when completed.

It has been the policy of the ONR Power Program to make all reports published under Project SQUID available to public, except the Status Reports which were prepared for official use only.

Proposals submitted to Project SQUID and on-going research contracts under Project SQUID have been reviewed at Annual Review Meetings. Annual Review Meetings have been held as follows.

- 1) October, 1979: California Institute of Technology, Pasadena, Calif.
- 2) October, 1978: Yale University, Hartford, Connecticut.
- 3) March, 1977: Scripps Institution of Oceanography, University of California - San Diego, La Jolla, California.
- 4) March, 1976: Naval Research Laboratory, Washington, D.C.
- 5) March, 1975: Southern Methodist University, Dallas, Texas.
- 6) March, 1974: The University of Michigan, Ann Arbor, Michigan.
- 7) March, 1973: Virginia Polytechnic Institute and State University, Blacksburg, Virginia.
- 8) March, 1972: University of California - San Diego, La Jolla, California.
- 9) March, 1971: Yale University, Hartford, Connecticut.
- 10) March, 1970: Massachusetts Institute of Technology, Boston, Massachusetts.
- 11) March, 1969: University of Denver, Denver, Colorado.
- 12) February, 1968: U.S. Naval Weapons Center, China Lake, California.
- 13) March, 1967: Purdue University, West Lafayette, Indiana.

1.1. Outline of Report

Section 2 provides a listing of the Sub-Contracts for Research awarded during the years 1967-79. Following the listing, each Sub-Contract is described along with the name of the Principal Investigator, objective of research, its significance, the project period, the SQUID Reports published and other publications.

A list of Technical Reports published under each Sub-Contract and the overall list of "other publications" during 1967-79 are provided in Section 3.

Reviews, Workshops and Colloquia conducted under Project SQUID during 1967-79 are described in Section 4.

Other Special Services provided under Project SQUID are described in Section 5.

Finally, Section 6 provides a short discussion of objectives, procedure, achievements and some possible future directions. It is proposed to elaborate on this Section with the ONR Power Program as and when need arises.

2. SUB-CONTRACTS FOR RESEARCH

The Sub-Contracts for Research awarded by Purdue University, upon specific approval by the ONR Power Program, are listed as follows along with the Semi-Annual and Status Reports that covered the research accomplished in that period.

Section 2.1	3.1.1978	through	12.31.1979
Section 2.2	10.1.1977	through	2.28.1978
Section 2.3	10.1.1976	through	9.30.1977
Section 2.4	10.1.1975	through	9.30.1976
Section 2.5	10.1.1974	through	9.30.1975
Section 2.6	10.1.1973	through	9.30.1974
Section 2.7	10.1.1972	through	9.30.1973
Section 2.8	10.1.1971	through	9.30.1972
Section 2.9	10.1.1970	through	9.30.1971
Section 2.10	10.1.1969	through	9.30.1970
Section 2.11	10.1.1968	through	9.30.1969
Section 2.12	10.1.1967	through	9.30.1968

In a particular period as above, it will be observed that occasionally a Sub-Contractor has changed the title of his research project. In such cases, both titles are provided, and the investigator's name is marked with an asterisk.

2.1 March 1, 1978 through December 31, 1979

It will be observed that this period covers the following.

- i) 3.1.1978 to 2.28.1979; and
- ii) 3.1.1979 to 12.31.1979.

No new Sub-Contracts were awarded in the period 3.1.1979 to 12.31.1979. Sub-Contracts in operation in the period 3.1.1978 to 2.28.1979 were given extensions where necessary.

2.1.1 Reference Reports

- 1. Semi-Annual Report dated 4.1.1978.
- 2. Semi-Annual Report dated 10.1.1978.
- 3. Status Report dated November 1978.
- 4. Semi-Annual Report dated 4.1.1979.

Reference should be made to Section 3.1 for Final Reports received on each of the Projects completed as of 12.31.1979.

2.1.2 Projects

No.	a) Institution b) Title	Principal Investigator
	<u>AERODYNAMICS AND TURBOMACHINERY</u>	
1.	a. The University of Michigan b. Three Dimensional Transonic Flows in Compressors and Channels	T.C. Adamson, Jr., M. Sichel
2.	a. The Pennsylvania State University b. Axial Flow Fan Stage Unsteady Performance	E. P. Bruce
3.	a. United Technologies Research Center b. Investigation of the Effects of High Aerodynamic Loading on a Cascade of Oscillation Airfoils	F.O. Carta, A.O. St. Hilaire

No.	a) Institution b) Title	Principal Investigator
4.	a) The University of Washington b) Investigation of Adverse Pressure Gradient Corner Flows	F.B. Gessner,
5.	a) Stanford University b) Transitory Stall in Diffusers	J.P. Johnston, S.J. Kline,
6.	a) Virginia Polytechnic Institute and State University b) An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	W.F. O'Brien, Jr., H.L. Moses
7.	a) Colorado State University b) Effects of Turbulence on Flow Through an Axial Compressor Blade Cascade	Willy Z. Sadeh
8.	a) Southern Methodist University b) Fundamental Research on Adverse Pressure Gradient Induced Turbulent Boundary Layer Separation	Roger L. Simpson
<u>COMBUSTION AND CHEMICAL KINETICS</u>		
1.	a) AeroChem Research Laboratories, Inc. b) Preparation of Manuscript on Ionization in Flames	Hartwell F. Calcote
2.	a) University of Missouri - Columbia b) A Shock Tube Study of H ₂ and CH ₄ Oxidation with N ₂ O as Oxidant	Anthony M. Dean
3.	a) AeroChem Research Laboratories b) High Temperature Fast-Flow Reactor Chemical Kinetics Studies	Arthur Fontijn
4.	a) Kansas State University b) Isotopic Studies of the Chemical Mechanisms of Soot Nucleation	T.W. Lester, J.F. Merklin

No.	a) Institution b) Title	Principal Investigator
5.	a) Cornell University b) Pyrolysis of Synthetic Fuels Using the Laser-Powered Homogeneous	W.J. McLean
6.	a) Princeton University b) Fundamental Studies on Turbulent, Swirling Jet Ignition	W.A. Sirignano
7.	a) Yale University b) Combustion Kinetics and Reactive Scattering Experiments	J.B. Fenn
8.	a) Massachusetts Institute of Technology b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	John Ross
<u>MEASUREMENTS</u>		
1.	a) Yale University b) Turbulent Structure Determination by Ramanography	R.K. Chang, B.T. Chu
2.	a) United Technologies Research Center b) CARS Investigation in Sooting and Turbulent Flames	Alan C. Eckbreth
3.	a) General Electric Company b) Laser Raman Probe for Combustion Diagnostics	M. Lapp
4.	a) Polytechnic Institute of New York b) An Experimental Study of Reactive and Non-reactive Flows in a Jet and Channel	S. Lederman*
5.	a) Polytechnic Institute of New York b) Turbulence Measurements in Jets Flames and Combustors	S. Lederman*

No.	a) Institution b) Title	Principal Investigator
	<u>TURBULENCE</u>	
1.	a) University of Southern California b) Large-Scale Structure Interactions in a Two-Dimensional Turbulent Mixing-Layer	F.K. Browand
2.	a) The University of Sheffield b) The Structure of Eddies in Turbulent Flames	N.A. Chigier
3.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby
4.	a) California Institute of Technology b) Research on Turbulent Mixing	A. Roshko
5.	a) The University of Colorado b) Swirling Heated Turbulent Flows as Related to Combustion Chambers	M.S. Uberoi
6.	a) Aeronautical Research Associates of Princeton, Inc. b) Second-Order Closure Modeling of Turbulent Combustion	Ashok K. Varma
7.	a) University of Southern California b) Large Scale Structure and Entrainment in the Turbulent Mixing Layer	F.K. Browand
8.	a) Michigan State University b) Binary Gas Mixing with Large Density Difference in Homogeneous Turbulence	J.F. Foss

2.2 October 1, 1977 through February 28, 1978

It will be observed that this period covers a period of five (5) months.

The ONR Power Program decided in 1977 to change the Project SQUID year from October 1 a year to September 30 of the following year. Accordingly the period 10.1.1977 to 2.28.1978 was treated as a distinct period in itself.

2.2.1 Reference Reports

Semi-Annual Report dated October 1, 1977.

2.2.2 Projects

No.	a) Institution b) Title	Principal Investigator
	<u>AERODYNAMICS AND TURBOMACHINERY</u>	
1.	a) The University of Michigan Three Dimensional Transonic Flows in Compressors and Channels	T.C. Adamson, Jr., M. Sichel
2.	a) The Pennsylvania State University b) Axial Flow Fan Stage Unsteady Performance	Edgar P. Bruce
3.	a) United Technologies Research Center b) Investigation of the Effects of High Aerodynamic Loading on a Cascade of Oscillating Airfoils	Franklin O. Carta, Arthur O. St. Hilaire
4.	a) The University of Washington b) Investigation of Adverse Pressure Gradient Corner Flows	F.B. Gessner

No.	a) Institution b)	Principal Investigator
5.	a) Stanford University	James P. Johnston, Stephen J. Kline
	b) Transitory Stall in Diffusers	
6.	a) Virginia Polytechnic Institute and State University	H.L. Moses, W.F. O'Brien
	b) An Investigation of Pressure Fluctua- tions and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	
7.	a) Colorado State University	Willy Z. Sadeh
	b) Effects of Turbulence on Flow Through an Axial Compressor Blade Cascade	
8.	a) Southern Methodist University	Roger L. Simpson
	b) Fundamental Research on Adverse Pressure Gradient Induced Turbulent Boundary Layer Separation	
<u>COMBUSTION AND CHEMICAL KINETICS</u>		
1.	a) University of Missouri - Columbia	Anthony M. Dean
	b) A Shock Tube Study of H ₂ and CH ₄ Oxidation with N ₂ O as Oxidant	
2.	a) Yale University	J.B. Fenn
	b) Combustion Kinetics and Reactive Scattering Experiments	
3.	a) AeroChem Research Laboratories	Arthur Fontijn
	b) High Temperature Fast-Flow Reactor Chemical Kinetics Studies	
4.	a) Massachusetts Institute of Technology	John Ross
	b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	

No.	a) Institution b) Title	Principal Investigator
<u>MEASUREMENTS</u>		
1.	a) Polytechnic Institute of New York b) Turbulence Measurements in Jets Flames and Combustors	S. Lederman
2.	a) General Electric Company b) Laser Raman Probe for Combustion Diagnostics	Marshall Lapp
3.	a) Stanford University b) Investigation of Novel Laser Anemometer and Particle-Sizing Instrument	S.A. Self
<u>TURBULENCE</u>		
1.	a) University of Southern California b) Large Scale Structure and Entrainment in the Turbulent Mixing Layer	F.K. Browand
2.	a) Michigan State University b) Binary Gas Mixing with Large Density Difference in Homogeneous Turbulence	J.F. Foss
3.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby
4.	a) California Institute of Technology b) Research on Turbulent Mixing	A. Roshko
5.	a) The University of Colorado b) Swirling Heated Turbulent Flows as Related to Combustion	Mahinder S. Uberoi
6.	a) Aeronautical Research Associates of Princeton, Inc. b) Second-Order Closure Modeling of Turbulent Combustion	Ashok K. Varma

2.3 October 1, 1976 through September 30, 1977

2.3.1 Reference Reports

1. Semi Annual Report dated October 1, 1976.
2. Semi-Annual Report dated April 1, 1977.
3. Status Report dated November, 1976.

2.3.2 Projects

No.	a) Institution b) Title	Principal Investigator
	<u>AERODYNAMICS AND TURBOMACHINERY</u>	
1.	a) The University of Michigan b) Three Dimensional Transonic Flows in Compressors and Channels	T.C. Adamson, M. Sichel
2.	a) The Pennsylvania State University b) Axial Flow Fan Stage Unsteady Performance	Edgar P. Bruce*
3.	a) The Pennsylvania State University b) The Unsteady Response of an Axial Flow Rotor to Distorted Inflows	Edgar P. Bruce*
4.	a) United Technologies Research Center b) Investigation of the Effects of High Aerodynamic Loading on a Cascade of Oscillating Airfoils	Franklin O. Carta, Arthur O. St. Hilaire
5.	a) The University of Washington b) Investigation of Adverse Pressure Gradient Corner Flows	F.B. Gessner
6.	a) Stanford University b) Transitory Stall in Diffusers	James P. Johnston, Stephen J. Kline
7.	a) Virginia Polytechnic Institute and State University	H.L. Moses, W.F. O'Brien, Jr.

No.	a) Institution b) Title	Principal Investigator
7.	b) An Investigation of pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	Willy C. Sadeh
8.	a) Colorado State University b) Effects of Turbulence on Flow Through an Axial Compressor Blade Cascade	
9.	a) Southern Methodist University b) Fundamental Research on Relaminarization Phenomena as Produced in Nozzles and Turbines	Roger L. Simpson
	<u>COMBUSTION AND CHEMICAL KINETICS</u>	
1.	a) University of Missouri - Columbia b) A Shock Tube Study of H_2 and CH_4 Oxidation with N_2O as Oxidant	Anthony M. Dean
2.	a) Yale University b) Kinetics of Phase Change and Energy Exchange	
3.	a) AeroChem Research Laboratories b) High Temperature Fast-Flow Reactor Chemical Kinetics Studies	Arthur Fontijn
4.	a) Massachusetts Institute of Technology b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	
5.	a) Case Western Reserve University b) A Basic Study on the Mechanism of Inflammability Limits and the Behavior of Near-Limit Flames	James, S. T'ien
	<u>MEASUREMENTS</u>	
1.	a) United Technologies Research Center b) Investigation to Extend the Applicability of Laser Raman Scattering Diagnostic Techniques to Practical Combustion Systems	Alan C. Eckbreth

No.	a) Institution b) Title	Principal Investigator
2.	a) Polytechnic Institute of New York b) Temperature, Concentration and Velocity Measurements in a Jet and Flame	S. Lederman
3.	a) General Electric Company b) Laser Raman Probe for Combustion Diagnostics	Marshall Lapp
4.	a) Stanford University b) Investigation of Novel Laser Anemometer and Particle-Sizing Instrument	S.A. Self
<u>TURBULENCE</u>		
1.	a) TRW Systems, Inc. b) The Coherent Flame Model for Turbulent Chemical Reactions	James E. Broadwell
2.	a) University of Southern California b) Large Scale Structure and Entrainment in the Turbulent Mixing Layer	F.K. Browand
3.	a) Michigan State University b) Binary Gas Mixing with Large Density Difference in Homogeneous Turbulence	J.F. Foss
4.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby
5.	a) California Institute of Technology b) Research on Turbulent Mixing	A. Roshko
6.	a) The University of Colorado b) Swirling Heated Turbulent Flows as Related to Combustion Chambers	Mahinder S. Uberoi
7.	a) Aeronautical Research Associates of Princeton, Inc. b) Second-Order Closure Modeling of Turbulent Combustion	Ashok K. Varma

2.4 October 1, 1975 through September 30, 19762.4.1 Reference Reports

1. Semi-Annual Report dated October 1, 1975.
2. Semi-Annual Report dated April 1, 1976.
3. Status Report dated November, 1975.

2.4.2 Projects

No.	a) Institution b) Title	Principal Investigator
	<u>AERODYNAMICS AND TURBOMACHINERY</u>	
1.	a) The University of Michigan b) Unsteady Transonic Flows in Two Dimensional Channels	T.C. Adamson, Jr., M. Sichel *
2.	a) The University of Michigan b) Three Dimensional Transonic Flows in Compressors and Channels	T.C. Adamson, Jr., M. Sichel *
3.	a) The Pennsylvania State University b) Measurement and Analysis of the Unsteady Normal Force and Pitching Moment of an Axial Flow Fan Rotor Blade Element	E.P. Bruce *
4.	a) The Pennsylvania State University b) The Unsteady Response of an Axial Flow Rotor to Distorted Inflows	E.P. Bruce *
5.	a) United Technologies Research Center b) Investigation of Dynamic Stall on a Cascade of Oscillating Airfoils	Franklin O. Carta *
6.	a) United Technologies Research Center b) Investigation of the Effects of High Aerodynamic Loading on a Cascade of Oscillating Airfoils	Franklin O. Carta *

No.	a) Institution b) Title	Principal Investigator
7.	a) Virginia Polytechnic Institute and State University b) An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	W.F. O'Brien, H.L. Moses
8.	a) Bell Aerospace Company b) Nontangential Injection of Single and Two-Phase Jets into Subsonic Flow	G. Rudinger
9.	a) Colorado State University b) Effects of Turbulence on Flow Through an Axial Compressor Blade Cascade	Willy C. Sadeh
10.	a) Southern Methodist University b) Fundamental Research on Relaminarization Phenomena as Produced in Nozzles and Turbines	Roger L. Simpson
<u>COMBUSTION AND CHEMICAL KINETICS</u>		
1.	a) University of Missouri - Columbia b) A Shock Tube Study of H_2 and CH_4 Oxidation with N_2O as Oxidant	Anthony M. Dean
2.	a) Yale University b) Kinetics of Phase Change and Energy Exchange	J.B. Fenn
3.	a) AeroChem Research Laboratories b) High Temperature Fast-Flow Reactor Chemical Kinetics Studies	Arthur Fontijn
4.	a) Massachusetts Institute of Technology b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	John Ross
5.	a) Case Western Reserve University b) A Basic Study on the Mechanism of Inflammability Limits and the Behavior of Near-Limit Flames	James S. T'ien

No.	a) Institution b) Title	Principal Investigator
	<u>MEASUREMENTS</u>	
1.	a) United Technologies Research Center b) Investigation to Extend the Applicability of Laser Raman Scattering Diagnostic Techniques to Practical Combustion Systems	Alan C. Eckbreth
2.	a) Polytechnic Institute of New York b) Temperature, Concentration and Velocity Measurements in a Jet and Flame	S. Lederman
3.	a) General Electric Company b) Laser Raman Probe for Combustion Diagnostics	Marshall Lapp
4.	a) Stanford University b) Investigation of Novel Laser Anemometer and Particle-Sizing Instrument	S.A. Self
	<u>TURBULENCE</u>	
1.	a) TRW Systems, Inc. b) The Coherent Flame Model for Turbulent Chemical Reactions	J.E. Broadwell
2.	a) University of Southern California b) Large Scale Structure and Entrainment in the Turbulent Mixing Layer	Frederick K. Browand
3.	a) Michigan State University b) Binary Gas Mixing with Large Density Difference in Homogeneous Turbulence	J.F. Foss *
4.	a) Michigan State University b) Large Density Difference Binary Gas Mixing in Homogeneous Turbulence	J.F. Foss *
5.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby
6.	a) California Institute of Technology	A. Roshko

No.	a) Institution b) Title	Principal Investigator
7.	b) Research on Turbulent Mixing a) University of Colorado b) Swirling Heated Turbulent Flows as Related to Combustion Chambers	Mahinder S. Uberoi

2.5 October 1, 1974 through September 30, 19752.5.1 Reference Reports

1. Semi-Annual Report dated October 1, 1974.
2. Semi-Annual Report dated April 1, 1975.
3. Status Report dated November, 1974.

2.5.2 Projects

No.	a) Institution b) Title	Principal Investigator
	<u>AERODYNAMICS AND TURBO MACHINERY</u>	
1.	a) The University of Michigan b) Unsteady Transonic Flows in Two Dimensional Channels	T.C. Adamson, M. Sichel
2.	a) The Pennsylvania State University b) Measurement and Analysis of the Unsteady Normal Force and Pitching Moment on an Axial Flow Fan Rotor Blade Element	Edgar P. Bruce *
3.	a) The Pennsylvania State University b) Direct Measurement of the Unsteady Normal Force and Pitching Moment on an Axial Flow Fan Rotor Blade Element	Edgar P. Bruce *
4.	a) United Aircraft Research Laboratories b) Investigation of Dynamic Stall on a Cascade of Oscillating Airfoils	Franklin O. Carta
5.	a) Virginia Polytechnic Institute b) An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	W.F. O'Brien, H.L. Moses
6.	a) Southern Methodist University b) Fundamental Research on Relaminarization Phenomena as Produced in Nozzles and Turbines	Roger L. Simpson

No.	a) Institution b) Title	Principal Investigator
7.	a) Bell Aerospace Company b) Nontangential Injection of Single and Two- Phase Jets into Subsonic Flow <u>COMBUSTION AND CHEMICAL KINETICS</u>	G. Rudinger
1.	a) Yale University b) Kinetics of Phase Change and Energy Exchange	J.B. Fenn
2.	a) AeroChem Research Laboratories, Inc. b) High-Temperature Fast-Flow Reactor Chemical Kinetics Studies	Arthur Fontijn
3.	a) Massachusetts Institute of Technology b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	John Ross
4.	a) Case Western Reserve University b) A Basic Study on the Mechanism of Inflammability Limits and the Behavior of Near-Limit Flames	James S. T'ien
5.	a) Massachusetts Institute of Technology b) Complex Nucleation Mechanism in Flames <u>MEASUREMENTS</u>	J.B. Howard
1.	a) Polytechnic Institute of New York b) Temperature, Concentration and Velocity Measurements in a Jet and Flame	S. Lederman *
2.	a) Polytechnic Institute of New York b) Concentration and Temperature Measurements in Jets	S. Lederman *
3.	a) General Electric Co. b) Laser Raman Probe for Combustion Diagnostics	Marshall Lapp

No.	a) b)	Principal Investigator
	<u>TURBULENCE</u>	
1.	a) University of Southern California b) Large Scale Structure and Entrainment in the Turbulent Mixing Layer	Frederick K. Browand
2.	a) Michigan State University b) Large Density Difference Binary Gas Mixing in Homogeneous Turbulence	J.F. Foss
3.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby
4.	a) California Institute of Technology b) Research on Turbulent Mixing	A. Roshko
5.	a) University of Colorado b) Swirling Heated Turbulent Flows as Related to Combustion Chambers	Mahinder S. Uberoi
6.	a) University of Illinois b) Turbulent Chemically Reacting Shear Flows According to Kinetic Theory Approach	Paul M. Chung

2.6 October 1, 1973 through September 30, 1974

2.6.1 Reference Reports

1. Semi-Annual Report dated October 1, 1973.
2. Semi-Annual Report dated April 1, 1974.
3. Status Report dated November, 1973.

2.6.2 Projects

No.	a) Institution b) Title	Principal Investigator
	<u>AERODYNAMICS - FLUID MECHANICS</u>	
1.	a) The University of Michigan b) Unsteady Transonic Flow in Two Dimensional Channels	T.C. Adamson, M. Sichel
2.	a) Pennsylvania State University b) Direct Measurement of the Unsteady Normal Force and Pitching Moment on an Axial Flow Fan Rotor Blade Element	Edgar P. Bruce
3.	a) Virginia Polytechnic Institute and State University b) An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	W.F. O'Brien, H.L. Moses
4.	a) Southern Methodist University b) Fundamental Research on Relaminarization Phenomena as Produced in Nozzles and Turbines	Roger L. Simpson
5.	a) Bell Aerospace Company b) Nontangential Injection of Single and Two-Phase Jets into Subsonic Flow	G. Rudinger
6.	a) Nielsen Engineering and Research, Inc.	Jack N. Nielsen

No.	a) Institution b) Title	Principal Investigator
	b) Analytical Studies of Turbulent Separated Boundary Layers	
7.	a) United Aircraft Research Laboratories b) Analysis of the Aerodynamic Response of an Axial Compressor Blade Row Operating in a Distorted Inlet Flow	John J. Adamczyk
	<u>TURBULENCE</u>	
1.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby, F.W. Williams
2.	a) California Institute of Technology b) Research on Turbulent Mixing	A. Roshko
3.	a) University of Illinois b) Turbulent Chemically Reacting Shear Flows According to Kinetic Theory Approach	Paul M. Chung
4.	a) TRW Systems b) Turbulent Reacting Flow	F.E. Fendell
	<u>COMBUSTION AND MOLECULAR PROCESSES</u>	
1.	a) Massachusetts Institute of Technology b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	John Ross
2.	a) AeroChem Research Laboratories, Inc. b) High-Temperature Fast-Flow Reactor Chemical Kinetics Studies	Arthur Fontijn
3.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček
4.	a) Calspan Corporation b) Investigation of Condensation in Flames by Scattering of Laser Radiation	J.W. Daiber

No.	a) Institution b) Title	Principal Investigator
5.	a) Yale University b) Kinetics of Phase Change and Energy Exchange	J.B. Fenn
6.	a) Massachusetts Institute of Technology b) Complex Nucleation Mechanism in Flames	J.B. Howard
7.	a) Case Western Reserve University b) A Basic Study on the Mechanism of Inflammability Limits and the Behavior of Near-Limit Flames	James S. T'ien
8.	a) AeroChem Research Laboratories b) Chemi-Ionization	Arthur Fontijn
9.	a) Massachusetts Institute of Technology b) Research on Carbon Formation in Flames	J.B. Howard
	<u>MEASUREMENTS</u>	
1.	a) Polytechnic Institute of New York b) Concentration and Temperature Measurements in Jets	S. Lederman
2.	a) General Electric Company b) Laser Raman Probe for Combustion Diagnostics	Marshall Lapp
3.	a) AVCO Everett Research Laboratory b) Research on the Measurements of Gas Properties in Jet Engines	D.A. Leonard

2.7 October 1, 1972 through September 30, 1973.2.7.1 Reference Reports

1. Semi-Annual Report dated October 1, 1972.
2. Semi-Annual Report dated April 1, 1973.
3. Status Report dated November, 1972.

2.7.2 Projects

No.	a) Institution b) Title	Principal Investigator
	<u>FLUID MECHANICS</u>	
1.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby, F.A. Williams
2.	a) University of Illinois b) Turbulent Chemically Reacting Shear Flows	Paul M. Chung
3.	a) University of Michigan b) Unsteady Transonic Flows in Two Dimensional Nozzles	T.C. Adamson, M. Sichel
4.	a) Nielsen Engineering and Research, Inc. b) Analytical Studies of Turbulent Separated Boundary Layers	Jack N. Nielsen
5.	a) TRW Systems b) Turbulent Reacting Flow	F.E. Fendell
6.	a) United Aircraft Research Laboratories b) Analysis of the Aerodynamic Response of an Axial Compressor Blade Row Operating in a Distorted Inlet Flow	John J. Adamczyk, Franklin O. Carta

No.	a) Institution b) Title	Principal Investigator
7.	a) Nielsen Engineering and Research, Inc. b) Analytical Method for Predicting Turbulent Separation in Adverse Pressure Gradients	Jack N. Nielsen
8.	a) Colorado State University b) Boundary Layer Separation Studies <u>COMBUSTION AND MOLECULAR PROCESSES</u>	V.A. Sandborn, W.Z. Sadeh
1.	a) AeroChem Research Laboratories b) Chemi-Ionization	Arthur Fontijn
2.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček
3.	a) Calspan Corporation b) Investigation of Condensation in Flames by Scattering of Laser Radiation	J.W. Daiber
4.	a) Massachusetts Institute of Technology b) Research on Carbon Formation in Flames	J.B. Howard
5.	a) Massachusetts Institute of Technology b) Experimental and Theoretical Studies of Molecular Collisions and Chemical Instabilities	John Ross *
6.	a) Massachusetts Institute of Technology b) Molecular Interactions. Experimental and Theoretical Studies of Molecular Collisions and Transport Properties of Gases	John Ross *
7.	a) Yale University b) Kinetics of Phase Change and Energy Exchange	J.B. Fenn *
8.	a) Yale University b) Energy Exchange in Gases	J.B. Fenn *
9.	a) Brown University b) Photochemical Excitation and Ionization Ahead of Shock Waves	R.A. Dobbins

No.	a) Institution b) Title	Principal Investigator
	<u>MEASUREMENT TECHNIQUES</u>	
1.	a) AVCO Everett Research Laboratory b) Research on the Measurements of Gas Properties in Jet Engines	D.A. Leonard
2.	a) Polytechnic Institute of Brooklyn b) Concentration and Temperature Measurements in Jets	S. Lederman, P.M. Sforza
3.	a) General Electric Company b) Laser Raman Probe for Combustion Diagnostics	Marshall Lapp
4.	a) Virginia Polytechnic Institute and State University b) An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades	W.F. O'Brien, H.L. Moses

2.8 October 1, 1971 through September 30, 19722.8.1 Reference Reports

1. Semi-Annual Report dated October 1, 1971.
2. Semi-Annual Report dated April 1, 1972.
3. Status Report dated November, 1971.

2.8.2 Projects

No.	a) Institution b) Title	Principal Investigator
	<u>FLUID MECHANICS</u>	
1.	a) The University of Michigan b) Unsteady Transonic Flow in Two Dimensional Nozzles	T.C. Adamson, M. Sichel
2.	a) Nielsen Engineering and Research, Inc. b) Analytical Method for Predicting Turbulent Separation in Adverse Pressure Gradients	Jack N. Nielsen
3.	a) Colorado State University b) Boundary Layer Separation Studies	V.A. Sandborn, W.Z. Sadeh
4.	a) Purdue University b) Research on Unsteady Diffuser Flows	Alan T. McDonald
5.	a) United Aircraft Research Laboratories b) Analysis of Unsteady Aerodynamic Effects on an Axial-Flow Compressor Stage with Distorted Inflow	Franklin O. Carta
6.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby, F.A. Williams
7.	a) TRW Systems b) Turbulent Reacting Flow	F.E. Fendell

No.	a) Institution b) Title	Principal Investigator
8.	a) University of Illinois b) A Simplified Statistical Theory of Turbulent Chemically Reacting Shear Flows	Paul M. Chung
9.	a) Stanford University b) Properties of Particles in Two-Phase Flow Using a Laser-Doppler Technique	H.S. Seifert
	<u>ATOMIC AND MOLECULAR COLLISIONS</u>	
1.	a) Massachusetts Institute of Technology b) Molecular Interactions. Experimental and Theoretical Studies of Molecular Collisions and Transport Properties of Gas	John Ross
2.	a) Yale University b) Energy Exchange in Gases	J.B. Anderson, J.B. Fenn
3.	a) AeroChem Research Laboratories b) Chemi-Ionization	Arthur Fontijn
4.	a) Brown University b) Photochemical Excitation and Ionization Ahead of Shock Waves	R.A. Dobbins
5.	a) Georgia Institute of Technology b) Mass Spectrometric Study of Drift Velocities, Diffusion, and Reactions of Ions in Gases	E.W. McDaniel, D.W. Martin
6.	a) Rice University b) Measurement of Proton Affinities	J.L. Franklin
	<u>MEASUREMENT TECHNIQUES</u>	
1.	a) Polytechnic Institute of Brooklyn b) Concentration and Temperature Measurements in Jets	S. Lederman, P.M. Sforza
2.	a) AVCO-Everett Research Laboratory b) Research on the Measurement of Gas Properties in Jet Engines	R.M. Patrick, D.A. Leonard

2/27

No.	a) Institution b) Title	Principal Investigator
3.	a) Virginia Polytechnic Institute b) An Investigation of Pressure Fluctuations and Stalling Characteristics on Rotating Axial-Flow Compressor Blades <u>COMBUSTION AND CHEMICAL RATE PROCESSES</u>	W.F. O'Brien, H.L. Moses
1.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček
2.	a) Cornell Aeronautical Laboratory b) Investigation of Condensation in Flames by Scattering of Laser Radiation	J.W. Daiber
3.	a) Massachusetts Institute of Technology b) Research on Carbon Formation in Flames	J.B. Howard, B.L. Wersborg, G.C. Williams

2.9 October 1, 1970 through September 30, 19712.9.1 Reference Reports

1. Semi-Annual Report dated October 1, 1970.
2. Semi-Annual Report dated April 1, 1971.
3. Status Report dated February, 1971.

2.9.2 Projects

No.	a) Institution b) Title	Principal Investigator
	<u>FLUID MECHANICS</u>	
1.	a) AVCO-Everett Research Laboratory b) Research on the measurement of Gas Properties in Jet Engines	Donald A. Leonard
2.	a) Stanford University b) Properties of Particles in Two-Phase Flow Using a Laser-Doppler Technique	H.S. Seifert
3.	a) The University of Michigan b) Unsteady Transonic Flow in Two Dimensional Nozzles	T.C. Adamson
4.	a) Nielsen Engineering and Research, Inc. b) Analytical Method for Predicting Turbulent Separation in Adverse Pressure Gradients	Jack N. Nielsen
5.	a) Colorado State University b) Boundary Layer Separation Studies	V.A. Sandborn
6.	a) Purdue University b) Research on Unsteady Diffuser Flows	A.T. McDonald
7.	a) United Aircraft Research Laboratories b) Analysis of Unsteady Aerodynamic Effects on an Axial-Flow Compressor Stage with Dis- torted Inflow	Franklin O. Carta

No.	a) Institution b) Title	Principal Investigator
8.	a) University of California - San Diego b) Heterogeneous Turbulent Flows Related to Propulsive Devices	Paul A. Libby, F.A. Williams
9.	a) TRW Systems b) Turbulent Reacting Flow	F. Fendell
10.	a) Cornell Aeronautical Laboratory b) Fundamental Investigation of Nonsteady and Nonequilibrium Flow	G. Rudinger
11.	a) Martin Marietta Corporation b) Turbulent Mixing with Combustion	R.J. Sanderson
12.	a) Brown University b) Photochemical Excitation and Ionization Ahead of Shock Waves	R.A. Dobbins
13.	a) The City College of New York b) Research on Free Jet Expansion	B.B. Hamel
14.	a) Johns Hopkins University b) Local Turbulence Measurements in Turbulent Flames	Kim H. Parker
<u>ATOMIC AND MOLECULAR COLLISIONS</u>		
1.	a) Massachusetts Institute of Technology b) Molecular Interactions. Experimental and Theoretical Studies of Molecular Collisions and Transport Properties of Gases	John Ross
2.	a) Yale University b) Energy Exchange in Gases	J.B. Anderson, J.B. Fenn
3.	a) Stanford Research Institute b) Transport Coefficients of Dissociated Gases	Henry Wise
<u>COMBUSTION AND CHEMICAL RATE PROCESSES</u>		
1.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček

No.	a) Institution b) Title	Principal Investigator
2.	a) Cornell Aeronautical Laboratory b) Investigation of Condensation in Flames by Scattering of Laser Radiation	G.H. Markstein
3.	a) Massachusetts Institute of Technology b) Research on Carbon Formation in Flames	J.B. Howard
4.	a) University of Denver b) Combustion Kinetics of Particulate Boron	C.M. Kelley, R.E. Williams, A. Takemoto
<u>CHEMI-IONIZATION AND ION-MOLECULE REACTIONS</u>		
1.	a) AeroChem Research Laboratories b) Chemi-Ionization	Arthur Fontijn
2.	a) Georgia Institute of Technology b) Mass Spectrometric Study of Drift Velocities, Diffusion, and Reactions of Ions in Gases	E.W. McDaniel, D.W. Martin
3.	a) Rice University b) Measurement of Proton Affinities	J.L. Franklin

2.10 October 1, 1969 through September 30, 19702.10.1 Reference Reports

1. Semi-Annual Report dated October 1, 1969.
2. Semi-Annual Report dated May 1, 1970.

2.10.2 Projects

No.	a) Institution b) Title	Principal Investigator
	<u>FLUID MECHANICS</u>	
1.	a) Cornell Aeronautical Laboratory b) Fundamental Investigation of Nonsteady and Nonequilibrium Flow	G. Rudinger
2.	a) Dynamic Science b) Investigations on Nonsimilar Turbulent Boundary Development	Thomas J. Tyson
3.	a) Martin Marietta Corporation b) Turbulent Mixing with Combustion	R.J. Sanderson *
4.	a) Martin Marietta Corporation b) The Influence of Constituent Stream Properties on the Turbulent Mixing of Two-Dimensional Gas Streams	R.J. Sanderson *
5.	a) Brown University b) Ionization in the Precursor Region of a Strong Shock	R.A. Dobbins
6.	a) Stanford University b) Properties of Particles in Two-Phase Flow Using a Laser-Doppler Technique	H.S. Seifert

No.	a) Institution b) Title	Principal Investigator
7.	a) City College of the City University of New York	B.B. Hamel
	b) Research on Free Jet Expansion	
8.	a) Massachusetts Institute of Technology b) Magnetohydrodynamics of Partially Ionized Gases	James A. Fay
	<u>ATOMIC AND MOLECULAR COLLISIONS</u>	
1.	a) Massachusetts Institute of Technology b) Molecular Interactions. Experimental and Theoretical Studies of Molecular Colli- sions and Transport Properties of Gases	John Ross
2.	a) Yale University b) Energy Exchange in Gases	J.B. Anderson, J.B. Fenn
3.	a) Stanford Research Institute b) Transport Coefficients of Reacting Gases <u>COMBUSTION AND CHEMICAL RATE PROCESSES</u>	Henry Wise
1.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček
2.	a) University of Denver b) Combustion Kinetics of Particulate Boron	C.M. Kelley, R.E. Williams, A. Takemoto
3.	a) Cornell Aeronautical Laboratory b) Investigation of Condensation in Flames by Scattering of Laser Radiation	G.H. Markstein
4.	a) Stanford Research Institute b) Bulk Cavitation in Monopropellants	David C. Wooten
5.	a) Massachusetts Institute of Technology b) Research on Carbon Formation in Flames	Jack B. Howard

No.	a) Institution b) Title	Principal Investigator
1.	<u>CHEMI-IONIZATION AND ION-MOLECULE REACTIONS</u> a) AeroChem Research Laboratories b) Chemi-Ionization	Arthur Fontijn
2.	a) Georgia Institute of Technology b) Mass Spectrometric Study of Drift Velocities, Diffusion, and Reactions of Ions in Gases	E.W. McDaniel, D.W. Martin
3.	a) Rice University b) Ionic Chemistry of CO and CO-CH ₄ Systems	J.L. Franklin

2.11 October 1, 1968 through September 30, 19692.11.1 Reference Reports

1. Semi-Annual Report dated October 1, 1968.
2. Semi-Annual Report dated April 1, 1969.

2.11.2 Projects

No.	a) Institution b) Title	Principal Investigator
	<u>FLUID MECHANICS AND MHD</u>	
1.	a) Cornell Aeronautical Laboratory b) Fundamental Investigation of Nonsteady and Nonequilibrium Flow	G. Rudinger
2.	a) Dynamic Science b) Investigations on Non-Similar Turbulent Boundary Layer Development	Irwin E. Alber
3.	a) Martin Marietta Corporation b) The Influence of Constituent Stream Properties on the Turbulent Mixing of Two-Dimensional Gas Stream	R.J. Sanderson
4.	a) Massachusetts Institute of Technology b) Magnetohydrodynamics of Partially Ionized Gases	James A. Fay
5.	a) City College of New York b) Research on Free Jet Expansion	B.B. Hamel
6.	a) University of Illinois b) Convective Electric Discharge Phenomena	Charles E. Bond

No.	a) Institution b) Title	Principal Investigator
<u>ATOMIC AND MOLECULAR COLLISIONS</u>		
1.	a) Massachusetts Institute of Technology b) Molecular Interactions. Experimental and Theoretical Studies of Molecular Collisions and Transport Properties of Gases	John Ross
2.	a) Princeton University b) Energy Exchange in Gases	J.B. Anderson, J.B. Fenn
3.	a) Stanford Research Institute b) Transport Coefficients of Reacting Gases	Henry Wise
4.	a) The University of Virginia b) Atomic and Molecular Collisions <u>COMBUSTION AND CHEMICAL RATE PROCESSES</u>	J.E. Scott, Jr., G.D. Magnuson
1.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček
2.	a) University of Denver b) The Combustion Kinetics of Particulate Boron	C.M. Kelley
3.	a) Cornell Aeronautical Laboratory b) Investigation of Reaction Kinetics in High-Temperature Gases	G.H. Markstein
4.	a) Cornell University b) Mechanism of Production of CN at High Temperatures and Estimates of Populations in Excited States	S.H. Bauer
<u>CHEMI-IONIZATION AND ION-MOLECULE REACTIONS</u>		
1.	a) AeroChem Research Laboratories, Inc. b) Chemi-Ionization	Arthur Fontijn
2.	a) Georgia Institute of Technology b) Mass Spectrometric Study of Drift Velocities, Diffusion, and Reactions of Ions in Gases	E.W. McDaniel, D.W. Martin

No.	a) Institution b) Title	Principal Investigator
3.	a) Rice University b) Ionic Chemistry in Electron-Impact Systems and Electrical Discharges	J.L. Franklin *
4.	a) Rice University b) Ionic Chemistry in Electrical Discharges	J.L. Franklin

2.12 October 1, 1967 through September 30, 19682.12.1 Reference Reports

1. Semi-Annual Report dated May 1, 1968.

2.12.2 Projects

No.	a) Institution b) Title	Principal Investigator
<u>FLUID MECHANICS AND MHD</u>		
1.	a) City College of New York b) Research on Free Jet Expansion	B. Hamel
2.	a) Cornell Aeronautical Laboratory, Inc. b) Fundamental Investigation of Nonsteady and Nonequilibrium Flow	G. Rudinger
3.	a) University of Illinois b) Convective Electric Discharge Phenomena	Charles E. Bond
4.	a) Massachusetts Institute of Technology b) Magnetohydrodynamics of Partially Ionized Gases	James A. Fay
<u>ATOMIC AND MOLECULAR COLLISIONS</u>		
1.	a) Massachusetts Institute of Technology b) Molecular Interactions. Experimental and Theoretical Studies of Molecular Collisions and Transport Properties of Gases	John Ross
2.	a) Princeton University b) Energy Exchange in Gases	J.B. Anderson, J.B. Fenn
3.	a) Stanford Research Laboratory b) Transport Properties of Reacting Gases	Henry Wise
4.	a) University of Virginia b) Atomic and Molecular Collisions	John E. Scott, Jr.

No.	a) Institution b) Title	Principal Investigator
<u>COMBUSTION AND CHEMICAL RATE PROCESSES</u>		
1.	a) Atlantic Research Corporation b) Solid-Propellant Flame Mechanisms	A. Maček
2.	a) Cornell Aeronautical Laboratory b) Investigation of Reaction Kinetics in High-Temperature Gases	G.H. Markstein
3.	a) Cornell University b) Mechanism of Production of CN at High Temperatures and Estimates of Populations	S.H. Bauer
<u>CHEMI-IONIZATION AND ION-MOLECULE REATIONS</u>		
1.	a) AeroChem Research Laboratory b) Chemi-Ionization	Arthur Fontijn
2.	a) Georgia Institute of Technology b) Mass Spectrometric Study of Drift Velocities, Diffusion, and Reactions of Ions in Gases	E.W. McDaniel,
3.	a) Rice University b) Ionic Chemistry in Electrical Discharges	J.L. Franklin

<u>Contractor</u>	<u>Page</u>
1. AeroChem Research Laboratories, Inc.	2/38 - 2/40
2. Aeronautical Research Associates of Princeton, Inc.	2/41
3. Atlantic Research	2/42
4. AVCO Everett Research Laboratory	2/43
5. Bell Aerospace Company	2/44
6. Brown University	2/45
7. California Institute of Technology	2/46
8. University of California - San Diego	2/47
9. CALSPAN (formerly Cornell Aeronautical Laboratory)	2/48 - 2/49
10. Case Western Reserve University	2/50
11. City College of New York	2/51
12. University of Colorado	2/52
13. Colorado State University	2/53 - 2/54
14. Cornell University	2/55 - 2/56
15. University of Denver	2/57
16. Dynamic Science	2/58
17. General Electric Company	2/59
18. Georgia Institute of Technology	2/60
19. University of Illinois	2/61
20. University of Illinois at Chicago Circle	2/62
21. Johns Hopkins University	2/63
22. Kansas State University	2/64
23. Martin Marietta Corporation	2/65
24. Massachusetts Institute of Technology	2/66 - 2/70
25. The University of Michigan	2/71 - 2/72
26. Michigan State University	2/73
27. University of Missouri	2/74
28. Nielsen Engineering & Research, Inc.	2/75
29. The Pennsylvania State University	2/76
30. Polytechnic Institute of New York (formerly of Brooklyn)	2/77 - 2/80
31. Princeton University	2/81
32. Purdue University	2/82
33. Rice University	2/83
34. University of Sheffield	2/84
35. University of Southern California	2/85
36. Southern Methodist University	2/86 - 2/87
37. Stanford Research Institute	2/88 - 2/89
38. Stanford University	2/90 - 2/92
39. TRW Systems	2/93 - 2/94
40. United Aircraft Research Laboratories	2/95
41. United Technologies Research Center	2/96 - 2/98
42. University of Virginia	2/99
43. Virginia Polytechnic Institute and State University	2/100
44. University of Washington	2/101
45. Yale University	2/102 - 2/104

Contractor: AEROCHEM RESEARCH LABORATORIES, INC.
Princeton, New Jersey

Subject: Chemi-Ionization

Principal Investigator: Arthur Fontijn

Objective: The study of the kinetics and mechanisms of chemi-ionization reactions and closely related phenomena.

Significance: Chemi-ions and electrons are produced in rocket motors and plumes as well as re-entry wakes. The electrons influence radar response. For design of missile systems it is crucial to know what reactions occur and to what extent they participate. Knowledge of chemi-ionization is also of importance to advanced power generation and upper atmospheric studies.

Project Period: 1963 - 1973

SQUID Technical Reports: See Pages: 3/2 - 3/3

Other Publications: See Under Section 3.2, Items: 17; 21; 38, 39; 53; 67; 78; 83; 93.

Contractor: AEROCHEM RESEARCH LABORATORIES, INC.
Princeton, New Jersey 08540

Subject: High-Temperature Fast-Flow Reactor Chemical
Kinetics Studies

Principal Investigator: Arthur Fontijn

Objective: The elucidation of reaction mechanisms and measurements of rate coefficients of metal atom and metal oxide reactions by experiments using the fast-flow reactor technique adapted to cover the 300 to 2000 K range.

Significance: Rocket motor performance and observable properties of rocket exhausts are influenced by reactions of metal atoms and metal oxides. For design, prediction and modeling, the mechanisms and rate coefficients (with temperature dependence) of the governing reactions should be known. Quantitative knowledge of the kinetics of such reactions can also be important to the solution of other combustion problems, in the development of electronic transition chemical lasers, in studying natural, disturbed and polluted atmospheres and in re-entry flow field calculations.

Project Period: 1977 - 1979

SQUID Technical Reports: See Pages: 3/2 - 3/3

Other Publications: See Under Section 3.2, Items: 128; 149-151.

Contractor: AEROCHEM RESEARCH LABORATORIES, INC.
Princeton, New Jersey

Subject: Preparation of Manuscript on Ionization in Flames

Principal Investigator: H. F. Calcote

Objective: To critically organize the literature on the
mechanism of ionization in flames and the
practical implications or uses of flame ionization.

Significance: Hydrocarbon combustion flames contain ions in
excess of their equilibrium value. This has
important implications for radar interference effects in rocket and jet
exhausts, soot formation in flames, flame ionization detectors for gas
chromatography, MHD power generation from combustion and flame, and
smoke detectors.

Project Period: 1977 - 1979

SQUID Technical Reports: See Pages: 3/2 - 3/3

Other Publications: None on record.

Contractor: AERONAUTICAL RESEARCH ASSOCIATES OF PRINCETON, Inc.
Princeton, New Jersey

Subject: Second-Order Closure Modeling of Turbulent
Combustion

Principal Investigator: Ashok K. Varma

Objective: To develop the "typical eddy" model for the
scalar probability density function and to
analyze turbulence chemistry interactions using a second-order closure
approach.

Significance: The interaction between turbulence and chemistry
is important in determining many key design and
performance parameters of combustion and propulsion systems and any pre-
dictive modeling of the flowfield has to properly account for the effects
of turbulence. Many current analytical models do not do so and are inade-
quate in this regard. A second-order closure procedure provides a rational
approach to incorporating these interactions in a flowfield calculation.

Project Period: 1976 - 1979

SQUID Technical Reports: See Page 3/4

Other Publications: See Under Section 3.2, Items: 217, 218; 239;
244, 245.

Contractor: ATLANTIC RESEARCH
A Division of the Susquehanna Corporation
Alexandria, Virginia 22314

Subject: Solid Propellant Flame Mechanisms

Principal Investigator: Andrej Maček

Objective: To determine quantitatively burning rates
of single boron particles in various gaseous
atmospheres up to 500 psi pressure, and to obtain an understanding of
fundamentals of combustion mechanisms(s) of such particles.

Significance: Metallic boron is very attractive thermo-
dynamically as a propellant ingredient in
air-breathing propulsion systems, such as supersonic jet propulsion and
air-augmented solid rockets. This study will provide fundamental infor-
mation concerning the ignition and combustion mechanisms of particulate
boron in support of current programs utilizing propellants loaded with
boron powder.

Project Period: 1967 - 1973

SQUID Technical Reports: See Page: 3/5

Other Publications: See Under Section 3.2, Items: 10; 22; 40.

Contractor: AVCO EVERETT RESEARCH LABORATORY
Everett, Massachusetts

Subject: Research on the Measurement of Gas Properties
in Jet Engines

Principal Investigators: D.A. Leonard and R.M. Patrick

Objective: To investigate in detail the causes of jet
engine compressor stall at high compression rate.

Significance: Jet engines tend to stall at high compression.
Knowledge of flows around compressor blades,
boundary layers, vortices and turbulence, density, pressure and temperatures
will provide design information to expedite optimization of efficiency.

Project Period: 1970 - 1973

SQUID Technical Reports: See Page 3/6

Other Publications: None on record.

Contractor: BELL AEROSPACE COMPANY
Buffalo, New York

Subject: Nontangential Injection of Single and
Two-Phase Jets into Subsonic Flow

Principal Investigator: George Rudinger

Objective: To gain detailed understanding of penetration
of gas-particle jets into a subsonic cross
flow and comparison with the behavior of pure-gas jets.

Significance: Knowledge about the dynamics of injected jets
is essential for the development of advanced
rocket and ramjet combustion chambers, for the design of thrust vector con-
trols and radar-signature modification of rockets and for the development of
water-augmented air cushion vehicles.

Project Period: 1973 - 1975

SQUID Technical Reports: See Page 3/7

Other Publications: See Under Section 3.2, Items: 8; 24.

Contractor: BROWN UNIVERSITY
Providence, Rhode Island

Subject: Photochemical Excitation and Ionization Ahead
of Shock Waves

Principal Investigator: R. A. Dobbins

Objective: To determine the factors controlling the concentration of electronically excited species ahead of a shock wave in a monatomic gas and the relationship between precursor electronic excitation and ionization.

Significance: The occurrence of electronic excitation ahead of shock waves is important to the understanding of shock and detonation wave structure. Theoretical calculations have indicated that the photoexcitation precursor becomes a much stronger effect than photoionization when the pressure is increased above 1 torr. The purpose of this research is to explore the feasibility of and to develop the techniques for the utilization of atomic absorption spectroscopy for diagnosis of shock wave precursor effects.

Project Period: 1969 - 1972

SQUID Technical Reports: See Page: 3/8

Other Publications: None on record.

Contractor: CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, California

Subject: Research on Turbulent Mixing

Principal Investigator: Anatol Roshko

Objective: To describe the mechanics and extent of mixing in
turbulent shear flow and to develop experimental
techniques for this purpose.

Significance: Information on and understanding of the physical
processes occurring in turbulent mixing are needed
to provide design information and test scaling laws for many engineering
devices, e.g., combustion chambers in propulsive devices, chemical laser
systems, ejector systems. This program addresses itself especially to the
role of the organized structures in turbulent shear flow; discovered only
a few years ago, these have improved our understanding of the physical
processes and may hold the key to better engineering models and calculating
methods.

Project Period: 1973 - 1975
1975 - 1979

SQUID Technical Reports: See Page: 3/9

Other Publications: See Under Section 3.2, Items: 99, 100; 155;
189, 190; 246; 262.

Contractor: UNIVERSITY OF CALIFORNIA - SAN DIEGO
La Jolla, California

Subject: Heterogeneous Turbulent Flows Related to
Propulsive Devices

Principal Investigator: Paul A. Libby

Objective: To elucidate the processes of mass, momentum,
and energy transport and of chemical reaction
in internal turbulent flows relevant to propulsive devices.

Significance: Combustion in practical propulsive devices
generally involves turbulent flow and
significant heat release. Thus there arises in such devices an interaction
between the fluid mechanical and chemical behavior of the turbulence. Our
research relates to a combined experimental and theoretical effort concerned
with the characteristics of turbulence involving significant density varia-
tions such as arise in combustion.

Project Period: 1970 - 1975
1975 - 1979

SQUID Technical Reports: See Pages: 3/10 - 3/11

Other Publications: See Under Section 3.2, Items: 95-98; 152-154;
188; 197; 263-265.

Contractor: CALSPAN (formerly Cornell Aeronautical Laboratory, Inc.)
Buffalo, New York

Subject: Fundamental Theoretical and Experimental Investigations of Unsteady and Nonequilibrium Flow

Principal Investigator: George Rudinger

Objective: Studies of flows in which nonequilibrium effects are produced by a dispersed second phase which may be solid, liquid, or gaseous.

Significance: Nonequilibrium and nonsteady two-phase flows are important for various jet engines and in connection with many problems of high-speed flight. Theoretical and experimental methods are needed for the analysis of problems of two-phase flow in which a gas transports large numbers of small particles (solid, liquid, or gaseous) whose temperature and velocity are not able to follow rapid changes in the carrier gas. This study is intended to enhance the understanding of flows in which considerable deviations from equilibrium may occur when the particles represent an appreciable mass fraction of the mixture.

Project Period: 1967 - 1970

SQUID Technical Reports: See Page: 3/12

Other Publications: See Under Section 3.2, Item: 8.

Contractor: CALSPAN (formerly Cornell Aeronautical Laboratory, Inc.)
Buffalo, New York

Subject: Investigation of Condensation in Flames by
Scattering of Laser Radiation

Principal Investigator: J.W. Daiber and G.H. Markstein

Objective: To determine rates of nucleation, particle sizes, number densities and rates of growth, of condensed-phase products that form in metal-containing flames.

Significance: Condensation processes are relevant to the combustion process in propulsion devices that use propellants containing metals or metal compounds. The burning rate of individual metal particles depends on the structure of the reaction zone that surrounds the particle, and therefore in turn on the condensation rate of oxide particles in that zone. The presence of oxide particles in the combustion chamber and nozzle affects radiative energy transfer, chemical kinetics and fluid dynamics.

Project Period: 1969 - 1973

SQUID Technical Reports: See Page: 3/12

Other Publications: See Under Section 3.2, Item: 80.

Contractor: CASE WESTERN RESERVE UNIVERSITY
Cleveland, Ohio

Subject: A Basic Study on the Mechanism of Inflammability
Limits and the Behavior of Near-limit Flames

Principal Investigator: James S. T'ien

Objective: To elucidate the inflammability mechanism of
premixed and diffusion flames, including extinction induced by unsteady processes.

Significance: Flammability is one of the most important problems
in combustion. It is directly related to fire safety, flame spread, ignition and extinction phenomena.

Project Period: 1973 - 1975
1975 - 1976

SQUID Technical Reports: See Page 3/13

Other Publications: See Under Section 3.2, Items: 101; 139-141;
156; 234.

Contractor: CITY COLLEGE OF NEW YORK
New York, New York

Subject: Research on Free Jet Expansion

Principal Investigator: B.B. Hamel

Objective: To investigate the rarefaction effects in free jet expansion, in particular the expansion of a free jet into a region of finite back pressure.

Significance: Free jet expansion is of particular interest in connection with rocket exhaust plumes for the prediction of exhaust plume flow fields at high altitudes. An application of kinetic theory is employed to provide a quantitative understanding of the rarefaction effects in free jet expansion.

Project Period: 1967 - 1971

SQUID Technical Reports: See Page: 3/14

Other Publications: See Under Section 3.2, Items: 19; 26; 32.

Contractor: UNIVERSITY OF COLORADO
Boulder, Colorado 80302

Subject: Swirling Heated Turbulent Flows as Related to
Combustion Chambers

Principal Investigator: Mahinder S. Uberoi

Objective: To experimentally study the change in turbulent
mixing due to swirl and heating of jets. Measure-
ments of mean velocity, temperature and the fluctuations will be made in
non-recirculating and recirculating swirling flows. The prediction of the
flow development for a swirling and chemically reacting free jet will be
made analytically for various degrees of swirl. An annular swirling and
chemically reacting jet in a divergent combustion chamber will also be
studied.

Significance: Turbulence and mixing determines level of com-
bustion efficiency, noise generation and heat
transfer in swirling flows. The measurements will provide design informa-
tion for combustion chambers used in turbojets, rockets and various internal
combustion engines.

Project Period: 1974 - 1979

SQUID Technical Reports: See Page: 3/15

Other Publications: See Under Section 3.2, Items: 142-144; 158-161; 198.

Contractor: COLORADO STATE UNIVERSITY
Fort Collins, Colorado 80521

Subject: Boundary Layer Separation Studies

Principal Investigators: V.A. Sandborn and W.Z. Sadeh

Objective: Measurements of turbulent boundary layer characteristics up to and through separation.

Significance: Boundary layer separation is a limiting factor in the performance of nearly all fluid flow devices. In turbomachinery, for example, turbulent boundary layer separation is encountered in diffuser flows. The present study is being done to obtain data on the flow up to and through separation. This study is being done in conjunction with Nielsen Engineering and Research Inc. (NEAR). The experimental data is supplied to NEAR, and they are developing analytical techniques of predicting turbulent boundary layer separation.

Project Period: 1970 - 1972

SQUID Technical Reports: See Page: 3/16

Other Publications: None on record.

Contractor: COLORADO STATE UNIVERSITY
Fort Collins, Colorado

Subject: Effects of Turbulence on Flow Through an
Axial Compressor Blade Cascade

Principal Investigator: Willy Z. Sadeh

Objective: To determine the effects of outer turbulence in
reducing the aerodynamic losses in flow through
a blade cascade of an axial-flow compressor at moderate Reynolds numbers
of order of 2×10^5 or smaller.

Significance: At moderate Reynolds numbers of order of 2×10^5
or smaller prohibitively high aerodynamic losses
and even fully stalled blades are induced by laminar separation of the
profile boundary layer. Arresting the growth of the laminar separation
bubble and even forestalling its own occurrence can be controlled by
supplying oncoming turbulence of sufficient energy concentrated at scales
commensurate with the thickness of the prevalent profile laminar boundary
layer. Accumulation of turbulent energy at desired scales can be produced
through selective amplification of turbulence. This turbulence amplifica-
tion is, in turn, governed by the vortex stretching mechanism characteris-
tic to forward stagnation flow. The research program focuses on investi-
gating the vortex stretching mechanism for determining the characteristics
of the interaction between the amplified turbulence and the body boundary
layer. The ultimate goal is to put forth a predictive model regarding
the management of profile laminar separation by means of the oncoming
amplified turbulence.

Project Period: 1975 - 1979

SQUID Technical Reports: See Page: 3/16

Other Publications: See Under Section 3.2, Item: 283.

Contractor: CORNELL UNIVERSITY
Ithica, New York

Subject: Mechanism of Production of CN at High Temperatures and Estimates of Populations in Excited States

Principal Investigator: S. H. Bauer

Objective: To establish the mechanism of production of CN and of simple molecules which incorporate this radical, in mixtures of hydrocarbons and nitrogen (or air), as dependent on the thermal history of such samples. Technique: Record time resolved spectra in emission and absorption of shock heated mixtures; analyze mixtures subjected to single-pulse shocks by mass spectrometry and v.p.c.; correlate results with relative concentrations and total gas densities.

Significance: These studies comprise the initial steps for modelling compositions, densities and temperatures as present in rocket chambers and plumes, for the investigation of the mechanism of CN production---a radical which plays a major role in much of combustion kinetics.

Project Period: 1967 - 1969

SQUID Technical Reports: See Page: 3/17

Other Publications: None on record.

Contractor: CORNELL UNIVERSITY
Ithica, New York

Subject: Pyrolysis of Synthetic Fuels Using the Laser-
Powered Homogeneous Pyrolysis Technique

Principal Investigator: William J. McLean

Objective: To examine the homogeneous pyrolysis process of
hydrocarbon fuels as a function of their hydrogen
content with emphasis on formation of soot precursors during pyrolysis of
high carbon-to-hydrogen ratio synthetic fuels.

Significance: Future synthetic fuels derived from nonpetroleum
fossil resources will almost certainly have a much
higher carbon-to-hydrogen ratio than current fuels, mainly because of their
higher aromatic content. Flame luminosity and soot formation tendencies
of their fuels in jet engine combustors is intimately related to the chemical
dynamics of the pyrolysis process.

Project Period: 1977 - 1979

SQUID Technical Reports: See Page: 3/17

Other Publications: None on record.

Contractor: UNIVERSITY OF DENVER
Denver Research Institute
Denver, Colorado

Subject: Combustion Kinetics of Particulate Boron

Principal Investigator: C. M. Kelley

Objective: To determine the reaction rate and combustion phenomena of particulate boron as a function of temperature and to compare these with data obtained by coating the particles with a relatively more reactive material.

Significance: Boron, as a potentially efficient fuel additive, will not burn efficiently at the lower temperatures associated with the lean overall fuel/air ratios required at low flight Mach numbers. One of the primary causes for the combustion inefficiency is the incomplete reaction of boron at the low engine temperature. The influence of a high temperature environment produced by coating the boron with a more reactive material is studied to assess the potential for accelerated ignition and improved combustion efficiency of the particles.

Project Period: 1969 - 1970

SQUID Technical Reports: See Page: 3/18

Other Publications: See Under Section 3.2, Item: 25.

Contractor: DYNAMIC SCIENCE
Monrovia, California

Subject: Investigation on Nonsimilar Turbulent Boundary
Layer Development

Principal Investigator: Irwin E. Alber, Thomas J. Tyson

Objective: To establish a sound basis for the accurate and
rapid engineering calculations of compressible
and incompressible nonsimilar turbulent boundary layer development.

Significance: Knowledge of turbulent boundary layer behavior is
necessary for the prediction of heat transfer,
skin friction, and performance degradation due to separation in many engi-
neering devices, e.g., rocket nozzles, engine inlets, turbine blades, and
aerodynamic lifting surfaces. This program involves the development of
rapid and accurate computational techniques for the analysis of high speed
turbulent boundary gradients, and changes in wall temperature.

Project Period: 1969 - 1970

SQUID Technical Reports: See Page: 3/19

Other Publications: None on record.

Contractor: GENERAL ELECTRIC COMPANY
Schenectady, New York

Subject: Laser Raman Probe for Combustion Diagnostics

Principal Investigator: Dr. Marshall Lapp

Objective: To provide a scientific basis for a non-perturbing,
space and time resolved optical probe of gas
temperature and constituency in combustion systems.

Significance: Advanced combustion systems are utilizing pres-
sures and temperatures such that physical probes
cannot survive. Optical sensors will be useful initially for providing
detailed access to temperature and species concentrations in post-combustor
flow, later in the combustor itself, and may ultimately be used to provide a
signal for control purposes. Application will also be to non-equilibrium
gases such as found in lasers and rapid expansions.

Project Period: 1972 - 1975
1975 - 1979

SQUID Technical Reports: See Page: 3/20

Other Publications: See Under Section 3.2, Items: 102-104; 129-132;
165-169; 191; 204; 224.

Contractor: GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

Subject: Mass Spectrometric Study of Drift Velocities,
Diffusion, and Reactions of Ions in Gases

Principal Investigators: Dr. E.W. McDaniel and Dr. D.W. Martin

Objective: To measure the drift velocities and diffusion coefficients of negative ions of carbon monoxide in the parent gas and to determine the rate coefficients for reactions between these ions and carbon monoxide molecules. In addition, to make similar measurements on the ions of carbon dioxide in the parent gas.

Significance: The initial goal under the previous sub-contract with the University of Virginia was to design and build a drift tube mass spectrometer which would enable us to make accurate, quantitative studies of the behavior of mass-identified ions drifting, diffusing, and reacting in gases at thermal and supra-thermal energies at room temperature. This goal was accomplished. Under the present sub-contract with Purdue University, the apparatus was to be used to study ions in their various parent gases. At the same time, a theoretical program was to be undertaken which would provide the analysis necessary for the extraction of basic information on ionic drift, diffusion, and reactions from the raw data provided by the experiments.

Project Period: 1968 - 1971

SQUID Technical Reports: See Pages: 3/21 - 3/22

Other Publications: See Under Section 3.2, Items: 31; 34, 35; 41-43; 54-59.

Contractor: UNIVERSITY OF ILLINOIS
Urbana, Illinois

Subject: Research in Convective Electric Discharge
Phenomena

Principal Investigator: C.E. Bond

Objective: Diagnostic measurements and analysis of the flow
field, electric current distribution and energy
transfer processes associated with the magnetically-stabilized plasma
column of the supersonic electronic arc. Schlieren, Rogowski coil, and
potential-probe measurements, on, as well as high-speed streak photographic
acceleration studies of, stable convective plasma columns produced by the
thermionic rail accelerator.

Significance: Diagnostics of the stable convective plasma
column is of fundamental importance to the
development of magnetoplasmadynamic propulsion systems.

Project Period: 1967-1969

SQUID Technical Reports: See Page: 3/23

Other Publications: See Under Section 3.2, Items: 12; 20.

2/64

Contractor: UNIVERSITY OF ILLINOIS AT CHICAGO CIRCLE
Chicago, Illinois

Subject: Turbulent Chemically Reacting Shear Flows

Principal Investigator: Paul M. Chung

Objective: To analyze the mixing and chemical reactions, particularly the combustion, taking place in turbulent shear flow fields. The existing phenomenological assumptions will be continuously replaced by a correct yet tractable theory which is applicable to engineering problems.

Significance: It has been shown that neither the existing mixing-length theories nor the recent second order moment theories can describe the turbulent chemical reactions involving many chemical species correctly. The correct description of the chemical reactions, in particular turbulent combustion, is important in analyzing the various propulsion as well as chemical-laser systems.

Project Period: 1971 - 1974

SQUID Technical Reports: See Page: None

Other Publications: See Under Section 3.2, Items: 76; 84-86.

Contractor: JOHNS HOPKINS UNIVERSITY
Baltimore, Maryland

Subject: Local Turbulence Measurements in a Turbulent
Flame

Principal Investigator: K. H. Parker

Objective: To measure the local velocity and temperature
fluctuations in a turbulent flame field.

Significance: Turbulence affects mixing, combustion processes,
heat transfer and noise in any jet propulsion
device. Knowledge of the structure and turbulent properties in a turbulent
flame resulting from this study will aid substantially in the understanding
of the phenomena governing the performance of these devices.

Project Period: 1969 - 1971

SQUID Technical Reports: None

Other Publications: See Under Section 3.2, Item: 28.

2/66

Contractor: KANSAS STATE UNIVERSITY
Manhattan, Kansas

Subject: Isotopic Studies of the Chemical
Mechanisms of Soot Nucleation

Principal Investigators: Thomas W. Lester and Joseph F. Merklin

Objective: To determine experimentally to what extent
soot nucleation occurs from heteratomic species
by ring condensation and fragmentation, and to identify the kinetic
paths important in each route.

Significance: Soot formation will be aggravated with the intro-
duction of synthetic fuels. Soot formation
causes an increased radiative heat load on turbine combustor liners and
fouls turbine blades. Knowledge of the chemical mechanisms will help identi-
fy which thermodynamic conditions are conducive to suppressing the yield of
soot from synthetic fuel constituents.

Project Period: 1978 - 1979

SQUID Technical Reports: None

Other Publications: See Under Section 3.2, Item: 266.

2/67

Contractor: MARTIN MARIETTA CORPORATION
Denver, Colorado

Subject: Turbulent Mixing with Combustion

Principal Investigator: R. J. Sanderson

Objective: To investigate the relationship between turbulent transport and the kinetics of the H_2-O_2 -M reaction.

Significance: Combustion occurs in turbulent mixing regions in many practical flow situations. Examples include fuel rich propulsion system exhausts and air augmented propulsion systems. Additionally, the characteristics of rocket and jet plumes and associated heating and impingement problems can be substantially changed by the presence of exothermic reactions. This study was undertaken to obtain experimental data for two-dimensional mixing layers for streams with large velocity difference and density ratios and to examine the effects of energy liberation on the structure of the mixing layer.

Project Period: 1969 - 1970

SQUID Technical Reports: See Page: 3/24

Other Publications: See Under Section 3.2, Item: 36.

2/68

Contractor: MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts

Subject: Magnetohydrodynamics of Partially Ionized Gases

Principal Investigator: J.A. Fay

Objective: To study experimentally and theoretically the mechanisms for increasing the momentum and energy of a continuum-type plasma by application of MHD forces. In a rotating, quasi-steady state plasma, the distribution of current will be measured and compared with several theoretical models.

Significance: The detailed mechanism by which Lorentz forces accelerate a plasma flow determines the performance and efficiency of MHD accelerators used to simulate hypersonic flow, MPD arcs used for propulsion, and also magnetic circuit breakers.

Project Period: 1967-1969

SQUID Technical Reports: See Pages: 3/25 - 3/31

Other Publications: None on record.

2/69

Contractor: MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts

Subject: Research on Carbon Formation in Flames

Principal Investigator: J.B. Howard

Objective: To assess the importance of positive ions as
nuclei for the formation of carbon particles in
flames and to determine the degree to which carbon particles are charged
during growth and agglomeration.

Significance: Solid carbon formed during combustion in jet
engines results in loss of operating efficiency,
decreased life of flame tubes, and air pollution around airports, and it
aids enemy detection and aiming devices. The proposed work is directed
toward the development of a working theory to be used in designing techniques
for preventing carbon formation.

Project Period: 1969 - 1973

SQUID Technical Reports: See Pages: 3/25 - 3/31

Other Publications: See Under Section 3.2, Item: 37.

Contractor: MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts

Subject: Complex Nucleation Mechanisms in Flames

Principal Investigator: J. B. Howard

Objective: To identify the nucleation reactions of soot particle formation and to determine quantitatively effects of pressure, temperature, and gas composition on nucleation and growth rates.

Significance: Soot formation leads to design limitations in gas turbines, pollution of aircraft bases, carrier decks, and airports, and problems in military aircraft operation. A better understanding of soot nucleation would permit the improvement of soot-control techniques.

Project Period: 1973 - 1974

SQUID Technical Reports: See Pages: 3/25 - 3/31

Other Publications: See Under Section 3.2, Items: 60, 61.

2/71

Contractor: MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Boston, Massachusetts

Subject: Molecular Interactions: Experimental and
Theoretical Studies of Molecular Collisions and
Transport Properties of Gases

Principal Investigator: John Ross

Objective: Experimental and theoretical studies of molecular
collisions and transport properties in gases.

Significance: Detailed experimental and theoretical studies
of molecular collisions are of fundamental importance for the prediction of mechanisms and rates of chemical reactions, energy transfer problems, and transport properties. These physical and chemical properties are essential for basic understanding of problems in jet propulsion.

Project Period: 1967 - 1972

SQUID Technical Reports: See Pages: 3/25 - 3/31

Other Publications: See Under Section 3.2, Items: 2-4; 6; 13; 15, 16;
18; 23-25; 27; 29; 33; 45-48; 62; 66; 70-72; 77;
81, 82; 105-107; 133-136; 170-178.

Contractor: MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts.

Subject: Experimental and Theoretical Studies of Chemical
Dynamics and Chemical Instabilities.

Principal Investigator: John Ross

Objective: Experimental and theoretical studies of molecular
collisions, chemical dynamics and instabilities
in irreversible processes.

Significance: The study of complex systems included in combustion problems such as flames, propulsion, rockets and plumes, requires investigations directed at both molecular and macroscopic approaches. Molecular beam experiments yield information on the dynamics of chemical reactions such as reaction cross section and probabilities, rate coefficients, energy distributions of exothermicities, predictions of reaction channels, the influence of internal excitation of reactants on reaction properties, problems of energy transfer and the possibility of laser actions. In combustion systems there frequently occur couplings of reaction rates with flows, transport processes and variation of state variables such as temperature and pressure. These nonlinear couplings may lead to instabilities in which a variety of interesting phenomena may take place, such as oscillations, multiple stationary states, the formation of macroscopic spatial structures and nonlinear waves.

Project Period: 1972 - 1975
1975 - 1979

SQUID Technical Reports: See Pages: 3/25 - 3/31

Other Publications: See Under Section 3.2, Items: 192, 193; 200-203;
206-212; 235-238; 251-261.

Contractor: THE UNIVERSITY OF MICHIGAN
Ann Arbor, Michigan

Subject: Unsteady Transonic Flow in Two Dimensional
Nozzles

Principal Investigators: T.C. Adamson, Jr. and M. Sichel

Objective: To study inviscid unsteady transonic nozzle
flows and then to include longitudinal viscous
stresses so that the formation and collapse of shocks in such flows may
be studied.

Significance: The nozzle problems studied to date and those
proposed, fall in the parametric range corres-
ponding to unsteady flow in turbines and compressors of jet engines,
caused by gusts, nonuniform air inlet conditions, and low frequency rotor
blade motion. They are also applicable to starting and stopping flows
which occur in thruster nozzles and recoilless rifles.

Project Period: 1970 - 1975

SQUID Technical Reports: See Pages: 3/32 - 3/33

Other Publications: See Under Section 3.2, Items: 121-124.

Contractor: THE UNIVERSITY OF MICHIGAN
Ann Arbor, Michigan

Subject: Three Dimensional Transonic Flows in
Compressors and Channels

Principal Investigators: Thomas C. Adamson, Jr. and Martin Sichel

Objective: To use systematic asymptotic methods to analyze
three dimensional inviscid steady transonic
flow through axial blade rows in turbomachinery.

Significance: Present day compressors and turbines are designed
such that flows relative to the blades are transonic; this necessitates the consideration of three dimensional flow fields. The asymptotic methods of analysis used in this study allow a general study of the flow field at successive levels of approximation and definition and analysis of those regions of flow where special problems arise.

Project Period: 1975 - 1979

SQUID Technical Reports: See Pages: 3/32 - 3/33

Other Publications: See Under Section 3.2, Items: 199; 229; 241.

Contractor: MICHIGAN STATE UNIVERSITY
East Lansing, Michigan

Subject: Binary Gas Mixing

Principal Investigator: John F. Foss

Objective: To identify the role of the distinctive control variables such as an alteration of the Reynolds number $\mu\lambda/\nu$ with independent changes in μ , λ and ν , a large density difference, etc., on the molecular commingling of two gaseous species in turbulent motion.

Significance: Jet engine combustion requires the molecular commingling of air and vaporized jet fuel. The latter is a heavy hydrocarbon which results in a pronounced density difference between the two gases. The role of the turbulence is to both convectively transport the two gases into juxtaposition and to also steepen the concentration gradients by the action of the strain rate field; these basic processes are under investigation.

Project Period: 1974 - 1975
1975 - 1976

SQUID Technical Reports: See Page: 3/34

Other Publications: None on record.

Contractor: UNIVERSITY OF MISSOURI
Columbia, Missouri

Subject: A Shock Tube Study of H_2 and CH_4
Oxidation with N_2O as Oxidant⁴

Principal Investigator: Anthony M. Dean

Objective: To determine reliable high temperature rate constants for reactions of atomic oxygen with hydrogen and methane.

Significance: Reliable high temperature values of rate constants are required to more completely characterize combustion mechanisms. This mechanistic information is required for accurate modeling studies of combustion processes.

Project Period: 1975 - 1979

SQUID Technical Reports: See Page: 3/35

Other Publications: See Under Section 3.2, Items: 239/1; 248; 275, 276.

Contractor: NIELSEN ENGINEERING & RESEARCH, INC.

Subject: Analytical Method for Predicting Turbulent Separation in Adverse Pressure Gradients

Principal Investigator: Dr. Jack N. Nielsen

Objective: To develop a method for predicting the position of turbulent separation resulting from adverse pressure gradients for two-dimensional and axisymmetric flows.

Significance: By developing good methods for estimating the turbulent separation point with adverse pressure gradients, it will be possible to alleviate or avoid unsteady inlet flow which causes compression surge in jet engines. The research has a much wider range of applicability than engine inlet applications, since it treats a basic scientific problem in its own right.

Project Period: 1970 - 1973

SQUID Technical Reports: See Page: 3/36

Other Publications: See Under Section 3.2, Item: 92.

Contractor: THE PENNSYLVANIA STATE UNIVERSITY
State College, Pennsylvania

Subject: Axial Flow Fan Stage Unsteady Performance

Principal Investigator: Edgar P. Bruce

Objective: Initially, to measure the unsteady normal force and pitching moment experienced by an axial flow fan rotor blade due to operation in a flow with a sinusoidally varying axial velocity component as a function of reduced frequency and rotor blade space-to-chord ratio, stagger angle, mean angle of incidence and design loading level. The present experimental effort includes a more detailed evaluation of the flow on the blades and an evaluation of the effect of an isolated rotor and of a rotor-stator stage on time-mean and instantaneous flow field properties. A related theoretical effort is directed toward development of an unsteady cascade pitching moment expression using Henderson's vortex representation of the flow.

Significance: Axial flow turbomachines operating in distorted inflow develop unsteady blade pressures, forces and moments. These unsteady quantities can cause vibration, stall and losses in efficiency and can contribute significantly to radiated noise. Measurements of the significant unsteady quantities on the blades and in the surrounding flow field are scarce and are essential to the development of models that can be used with confidence in design and analysis.

Project Period: 1973 - 1975
1975 - 1979

SQUID Technical Reports: See Page: 3/37

Other Publications: See Under Section 3.2, Items: 109, 110.

Contractor: POLYTECHNIC INSTITUTE OF NEW YORK
(formerly of Brooklyn)
Brooklyn, New York

Subject: Concentration Measurements in Jets

Principal Investigators: S. Lederman and P.M. Sforza

Objective: To construct a prototype apparatus utilizing the Raman effect to determine concentration and temperature in a free turbulent jet, based on the feasibility study completed in the current period. Quantitative concentration and temperature profiles in the jet are to be obtained.

Significance: The understanding of mass, momentum, and energy transport and their relation in turbulent flow is basic to advancing jet propulsion technology. Measurements of these properties, unimpaired by probe interference and independent of the state variables involved, will provide basic information for improving the means for prediction and analysis of turbulent mixing flows.

Project Period: 1971 - 1973

SQUID Technical Reports: See Page: 3/38

Other Publications: See Under Section 3.2, Items: 111-113.

Contractor: POLYTECHNIC INSTITUTE OF NEW YORK
Farmingdale, New York 11735

Subject: Concentration, Temperature and Velocity
Measurements in Jets

Principal Investigator: S. Lederman

Objective: To construct a prototype apparatus utilizing
the Raman Effect and an LDVM to determine
concentration temperature and velocity in a free turbulent jet and flame.

Significance: The advancement in jet propulsion technology
depends heavily on the ability to recognize
and understand the interacting phenomena taking place. To that end, experi-
mental data, concerning instantaneous specie concentration, temperature,
velocity, spectral distribution of turbulent power density, as well as
particulate concentration, is of major importance. This kind of data may
provide basic information towards the advancement of the state-of-the-art.

Project Period: 1973 - 1975
1975 - 1976

SQUID Technical Reports: See Page: 3/38

Other Publications: See Under Section 3.2, Items: 179, 180; 194.

Contractor: POLYTECHNIC INSTITUTE OF NEW YORK
Farmingdale, New York

Subject: Turbulence Measurements in Jets, Flames
and Combustors

Principal Investigator: S. Lederman

Objective: Development of nonintrusive diagnostic techniques
applicable to jets, flames and combustors.
Extend the laser Raman and LDV techniques to the extraction of turbulence
information from flow fields associated with propulsion devices. Attempt
at correlation of experimental data with mathematical models are being made.

Significance: The advancement of propulsion technology
depends heavily on the ability to recognize,
understand and control the interacting phenomena taking place in the pro-
pulsion devices. To that end, experimental data concerning specie concen-
tration, temperature, velocity, turbulent intensity and frequency, mixedness
parameters as well as particulate concentration is of major importance.
This kind of data obtained nonintrusively, may provide basic information
helpful in advancing the state-of-the-art.

Project Period: 1976 - 1977

SQUID Technical Reports: See Page: 3/38

Other Publications: See Under Section 3.2, Items: 213-215.

Contractor: POLYTECHNIC INSTITUTE OF NEW YORK
Farmingdale, New York

Subject: Experimental Study of Nonreactive and
Reactive Turbulent Jets and Internal Combustors

Principal Investigator: S. Lederman

Objective: To continue the research effort in the field of
laser diagnostics, as applied to jets flames
and internal combustion systems with particular emphasis on the development
of an integrated system involving LDV, CARS and Spontaneous Raman. Compare
experimental data obtained by the above techniques with some existing
mathematical models, and data obtained by conventional means.

Significance: The advancement of propulsion technology depends
heavily on the ability to recognize, understand
and control the many interacting phenomena taking place in the propulsion
devices. While a number of codes have been recently developed, dealing with
some of the problems encountered, most of those are idealized and need for
their confirmation and even application some reliable experimental data.
The latter may consist of data concerning specie concentration, temperature,
velocity, turbulence intensity, diffusivity, correlation and cross-correlation
parameters, as well as particulate concentration. This kind of data ob-
tained nonintrusively, may provide basic information helpful in advancing
the state-of-the-art.

Project Period: 1977 - 1979

SQUID Technical Reports: See Page: 3/38

Other Publications: See Under Section 3.2, Items: 232, 233; 267.

Contractor: PRINCETON UNIVERSITY
Princeton, New Jersey

Subject: Fundamental Studies on Turbulent Swirling
Jet Ignition

Principal Investigator: William A Sirignano

Objective: The determination via experimental and theoretical
studies of the effect of the swirl and turbulence
on combustion, ignition, and flame stabilization in continuous flow
combustors.

Significance: Turbulence and swirl drastically affect scalar
transport of heat and mass in continuous com-
bustors, thereby profoundly affecting ignition, flame stabilization, and
burning characteristics. This study would lead to relevant information for
the combustor designer for ramjets, turbojets, and rockets.

Project Period: 1977 - 1979

SQUID Technical Reports: See Page: 3/39 - 3/40

Other Publications: None on record.

AD-A088 006

PURDUE UNIV LAFAYETTE IN PROJECT SQUID HEADQUARTERS
PROJECT SQUID.(U)

F/6 21/5

FEB 80 R F HOGLUND, R GOULARD, S N MURTHY
SQUID-PU-R2-80

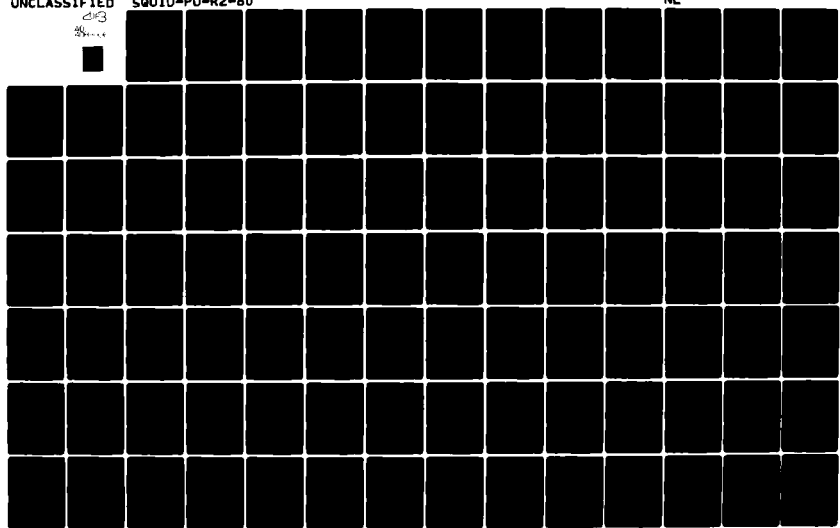
N00014-75-C-1143

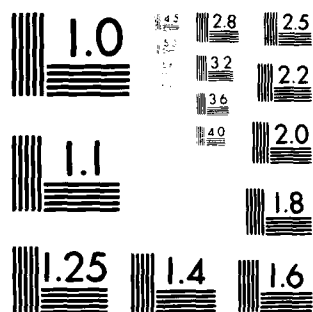
NL

UNCLASSIFIED

dir3

25-11-11





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Contractor: PURDUE UNIVERSITY
West Lafayette, Indiana 47907

Subject: Unsteady Diffuser Flows

Principal Investigator: Alan T. McDonald

Objective: To model time-varying inlet flow distortions in the combustor diffusers of turbine engines, in order to study their effects on pressure recovery and outlet flow profiles.

Significance: Flow leaving the combustor diffusers in a turbine engine must be undistorted to obtain satisfactory combustion. Overall powerplant efficiency is affected by the pressure recovery of the combustor diffusers; they should be made as small as possible to obtain a compact engine. Theoretical predictions of these complicated internal flows are not now possible, so the empirical information obtained in this study will provide design data to help meet performance and distortion objectives with compact diffuser geometries.

Project Period: 1970 - 1971

SQUID Technical Reports: See Pages: 3/41 - 3/42

Other Publications: See Under Section 3.2, Items: 63, 64.

Contractor: RICE UNIVERSITY
Houston, Texas

Subject: Research on Chemi-ionization and Ion-Molecule
Reactions in Electric Discharges

Principal Investigator: J.L. Franklin

Objective: To identify ion-molecule and chemi-ionization
reactions and to determine their rates with
special attention given to reactions occurring in flames.

Significance: Ions and excited neutrals undergo many exten-
sive reactions with neutral species. They are
present in great abundance in flames and in electric discharges. This
study will lead to a better understanding of electric discharges and, by
concentrating on reactions of certain kinds of ions, to an understanding
of the chemistry of flames.

Project Period: 1967 - 1971

SQUID Technical Reports: See Pages: 3/43 - 3/44

Other Publications: See Under Section 3.2, Items: 9; 14; 23; 44;
50, 51.

Contractor: UNIVERSITY OF SHEFFIELD
Sheffield, England

Subject: The Structure of Eddies in Turbulent Flames

Principal Investigator: Norman A. Chigier

Objective: To measure the structure of turbulent flames
with particular emphasis on identifying and
quantifying the roles of the large eddies in these flames.

Significance: Turbulent combustion determines the rate of
heat release, combustion performance and emis-
sion of pollutants in gas turbine and other forms of combustor. Under-
standing of the fundamental physical mechanisms of the turbulent flow with
chemical reaction will aid in the solution of practical problems associated
with combustion inefficiency, emission of pollutants, and over-heating
of walls in combustors.

Project Period: 1977 - 1979

SQUID Technical Reports: See Page: 3/45

Other Publications: None on record.

Contractor: UNIVERSITY OF SOUTHERN CALIFORNIA
Los Angeles, California

Subject: Large Scale Structure and Entrainment in
the Turbulent Mixing Layer

Principal Investigator: Frederick K. Browand

Objective: To improve understanding of the turbulent mixing layer by studying the interactions between the large scale, quasi-organized features.

Significance: The two-dimensional mixing region formed between parallel streams of different speed is probably the simplest example of turbulent free shear flow. It is a case of great practical importance--occurring frequently in external aerodynamics and in various combustion devices. The large scale features of the turbulence are particularly prominent in the mixing layer. A more definitive description of the dynamics of these large scale features will contribute to a better understanding of the mixing layer. The results are probably extendable to other free turbulent flows also.

Project Period: 1974 - 1975
1975 - 1979

SQUID Technical Reports: See Page: 3/46

Other Publications: See Under Section 3.2, Items: 126, 127; 230; 281, 282.

Contractor: SOUTHERN METHODIST UNIVERSITY
Dallas, Texas

Subject: Fundamental Research on Relaminarization
Phenomena as Produced in Nozzles and Turbines

Principal Investigator: Roger L. Simpson

Objective: To determine the turbulence flow structure of
turbulent boundary layers undergoing strong
acceleration and relaminarization, especially the wall "bursting" and wall
spanwise vortex structure.

Significance: Under a strong acceleration, a turbulent boundary
layer can achieve a laminar-like character with
the accompanying lower heat transfer rate of a laminar flow. Under such
acceleration conditions in nozzles and turbines, a reduced heat transfer
rate is desirable. Little detailed flow structure information has been
previously obtained.

Project Period: 1973 - 1975
1975 - 1976

SQUID Technical Reports: See Page: 3/47

Other Publications: See Under Section 3.2, Item: 225.

Contractor: SOUTHERN METHODIST UNIVERSITY
Dallas, Texas

Subject: Fundamental Research on Adverse Pressure
Gradient Induced Turbulent Boundary Layer
Separation Using Laser Anemometry

Principal Investigator: Roger L. Simpson

Objective: To determine quantitatively the turbulence flow structure of a separating, separated, and re-attached turbulent boundary layer. This information will provide new insight about the role of large eddy structures in producing separation, the role and nature of the backflow, and the interaction between the free-stream and the separated flow. This information is necessary if improved prediction methods for separating flows are to be achieved.

Significance: The classical problem of adverse pressure gradient induced boundary layer separation is important in the design of jet engines and rocket nozzles. Very little quantitative information is now available on the nature of the separated flow, so current predictions of the flow downstream of separation and its interaction with the freestream are uncertain.

Project Period: 1976 - 1979

SQUID Technical Reports: See Page: 3/47

Other Publications: None on record.

Contractor: STANFORD RESEARCH INSTITUTE
Menlo Park, California

Subject: Transport Coefficients of Reacting Gases

Principal Investigator: Henry Wise

Objective/Significance: Experimental measurements of the transport coefficients of dissociated gases at elevated temperatures are lacking for systems of interest to advanced propulsion studies. To fill this gap, the work in progress in our laboratory at this time concerns the determinations of the multicomponent diffusion coefficients of dissociated gas mixtures over a range of temperatures. In addition, the results are applied to an examination of various interaction-potential functions for the description of the collision process between species with an unpaired electron (atoms, free radicals) and polyatomic molecules. Such a comparison offers some indication of the validity of the approximations made in the theoretical calculation of transport parameters by the Chapman-Enskog theory.

Project Period: 1967-1969

SQUID Technical Reports: See Pages: 3/48 - 3/49

Other Publications: See Under Section 3.2, Items: 11, 79.

Contractor: STANFORD RESEARCH INSTITUTE
Menlo Park, California

Subject: Bulk Cavitation in Monopropellants

Principal Investigator: D. C. Wooten

Objective: To determine the environmental conditions that cause bulk cavitation and/or effervescence in liquid monopropellants, and to assess the importance of the presence of cavitation in the formation of hot spots.

Significance: The existence of cavitation-produced "hot spots" has been shown to cause detonations in liquid organic nitrate compounds and is suspected to be responsible for some accidental detonations in such monopropellants as hydrazine and nitromethane. The presence of cavitation or effervescence in liquid monopropellants permits the initiation of chemical reactions at much lower shock impulses than normally necessary to initiate a detonation in the propellants and thus presents a considerable safety hazard.

Project Period: 1969 - 1970

SQUID Technical Reports: See Pages: 3/48 - 3/49

Other Publications: None on record.

Contractor: STANFORD UNIVERSITY
Stanford, California

Subject: Properties of Particles in Two-Phase Flow
Using a Laser-Doppler Technique

Principal Investigators: H.S. Seifert and D. Bershader

Objective: To simultaneously determine the distribution of velocity, number count and size of particles in a gas-particle flow.

Significance: The slip velocity, size distribution, and concentration of solid particles in a rocket exhaust affect performance (specific impulse). Knowledge of these quantities permits accurate performance prediction. Similar two-phase fields such as carbon-laden jet engine flow and atomized sprays can also be surveyed and mapped using the technique being developed. In addition to mapping two-phase flows, the technique can be applied to the monitoring of mass flow rates of such particulates as those in jet engine or automobile exhaust. Such capability could be used for real time monitoring of particulate emissions.

Project Period: 1969 - 1971

SQUID Technical Reports: See Page: 3/50

Other Publications: None on record.

Contractor: STANFORD UNIVERSITY
Stanford, California

Subject: Transitory Stall in Diffusers

Principal Investigator: James P. Johnston and Stephen J. Kline

Objective: Experimental study of velocity and pressure fluctuations in the transitory stall regime of a set of diffusers in order to: (i) develop basic understanding of this flow regime; (ii) provide new detailed data to allow confirmation and extension of new prediction methods (e.g., Ghose and Kline) for internal flows, with either incipient or full separation.

Significance: Gas turbine compressors, jet engine inlets and combustion systems all contain diffusers. In many instances, excess noise, combustion instabilities and even destructive mechanical vibrations are triggered by flow oscillations which may be traced to diffusers operating in the transitory stall regime. Study of this regime and discovery of means of control of its unsteadiness without sacrifice of diffuser performance is needed to advance the state of the art.

Project Period: 1976 - 1979

SQUID Technical Reports: See Page: 3/50

Other Publications: See Under Section 3.2, Items: 268-270.

Contractor: STANFORD UNIVERSITY
Stanford, California

Subject: Investigation of Novel Laser Anemometer and
Particle-Sizing Instrument

Principal Investigator: Professor Sidney A. Self

Objective: Investigation and development of a laser anemometer
and particle-sizing instrument capable of making
simultaneous, remote, in-situ measurements of velocity and particle size in
two-phase flows, with particular reference to liquid spray combustors.

Significance: The understanding of spray combustors is pre-
sently limited by our ability to measure parti-
cle concentration and size distribution as a function of position by a
non-intrusive method. The ability to simultaneously measure particle
size and velocity on an individual particle basis would allow the evaluation
of the important influence of particle-gas slip on droplet combustion.

Project Period: 1975 - 1977

SQUID Technical Reports: See Page: 3/50

Other Publications: None on record.

Contractor: TRW SYSTEMS
Redondo Beach, California

Subject: Turbulent Reacting Flow

Principal Investigator: F.E. Fendell

Objective: To apply modern asymptotic methods (especially multiple-scaling techniques) to the analysis of fully turbulent shear layers near walls. In particular, to reveal the macroscopic structure of turbulent pipe/channel and boundary-layer flows predicted by state-of-the-art closures of the Reynolds time-averaged equations, and, further, to determine what may be stated even without an explicit closure condition.

Significance: Turbulent shear layers occur on all ducts, blades, and solid surfaces in jet engines, for large-Reynolds-number flow. The wall friction and separation of these turbulent boundary layers is critical to predicting losses from ideal performances. Furthermore, the basic fluid dynamics is a prerequisite to examining aerothermochemical phenomena in turbulent flow (for militarily practical chemical lasers, rocket chambers, jet engines, etc.). Of the hundreds of existing schemes for predicting the behavior of turbulent shear layers near walls, almost all are very minor variants on a very few physical concepts; and almost all schemes predict results with about equal success, as evidenced by the 1968 Stanford conference. This program seeks to avoid senselessly repetitive numerical integration of basically similar models by using modern asymptotic techniques to achieve analytic solution for broadly encompassing classes of closure conditions. In this way the essential common features of closures producing results compatible with experiments are revealed.

Project Period: 1970 - 1973

SQUID Technical Reports: See Pages: 3/51 - 3/52

Other Publications: See Under Section 3.2, Items: 69; 125.

Contractor: TRW DEFENSE AND SPACE SYSTEMS
Redondo Beach, California

Subject: The Coherent Flame Model for Turbulent
Chemical Reactions

Principal Investigator: J. E. Broadwell

Objective: To develop a model for fast reactions in turbulent flow.

Significance: One of the most ambitious aims of aerothermochemistry is the rational analysis of turbulent chemical reactions. The problem arises in almost all technological combustion units and turbulent combustion processes are nearly universal in propulsion systems. Understanding of this process is essential for the systematic design of these systems as well as to the derivation of scaling laws which could give added significance to sub-scale experiments.

Project Period: 1974 - 1975
1975 - 1976

SQUID Technical Reports: See Pages: 3/51 - 3/52

Other Publications: None on record.

Contractor: UNITED AIRCRAFT RESEARCH LABORATORIES
East Hartford, Connecticut

Subject: Unsteady Aerodynamic Effects on Inlet Distortion
in a Turbomachine

Principal Investigator: Franklin O. Carta

Objective: To assess the importance of including unsteady
aerodynamic effects in computing the character-
istics of a compressor stage operating near stall and in a distorted inlet
flow.

Significance: The pressure of a non-uniform inflow can adverse-
ly affect the performance of an axial-flow com-
pressor. The ability to predict the response of a compressor stage to a
distorted inflow will increase our understanding of a compressor sensitivity
to distortion phenomena and will provide us with an improved analytical
tool for designing surge-tolerant compressors.

Project Period: 1970 - 1973

SQUID Technical Reports: See Page: 3/53

Other Publications: See Under Section 3.2, Item: 195.

Contractor: UNITED TECHNOLOGIES RESEARCH CENTER
East Hartford, Connecticut

Subject: Investigation of Dynamic Stall in a
Cascade of Oscillating Airfoils

Principal Investigator: Franklin O. Carta, Arthur O. St. Hilaire

Objective: To conduct an experimental investigation of
the effects of high aerodynamic loading on a
cascade of oscillating airfoils.

Significance: The problem of stall flutter of turbomachinery
blades has resisted solution since the earliest
days of the jet age. The inability of designers to adequately account
for its presence impedes the attainment of maximum engine thrust to weight
ratio consistent with conservative, safe design. However, before the stall
flutter problem can be attacked directly, it is necessary to investigate
the more fundamental problem of dynamic stall on cascaded airfoils. Once
the underlying causes and details of this problem are known, the stall
flutter problem may then be attacked by a direct empirical assault, using
data from this and other test programs, and by an indirect procedure in
which the fundamental experimental information is used to modify and/or
formulate advanced theories for heavily loaded multiblade systems.

Project Period: 1974 - 1975
1975 - 1979

SQUID Technical Reports: See Page: 3/54

Other Publications: See Under Section 3.2, Items: 249; 280.

Contractor: UNITED TECHNOLOGIES RESEARCH CENTER
East Hartford, Connecticut

Subject: Investigation to Extend the Applicability of
Laser Raman Diagnostic Techniques to Practical
Combustion Systems

Principal Investigator: Alan C. Eckbreth

Objective: With the development of high power, visible laser sources, Raman scattering techniques have received considerable attention for combustion diagnosis in the past several years. Laser Raman approaches have been advanced to the point where they are being routinely employed in a variety of fundamental flame investigations. However, successful application of laser Raman techniques to practical combustion devices such as gas turbines, hydrocarbon-fueled combustors, furnaces, has not been demonstrated. From an instrumentation view, practical devices contain flames which differ markedly from those employed in fundamental flame studies. Practical environments are turbulent, highly luminous and particulate laden. The high luminosity levels preclude the use of cw laser sources for Raman work in these environments. Pulsed laser sources are required to produce peak Raman powers in excess of the background luminous power. However, the use of pulsed sources engenders a variety of laser-particulate interaction interference effects which jeopardize successful application of Raman scattering. Of these, the most severe is laser modulated soot incandescence. Soot particles in the measurement volume absorb the incident laser radiation, heat to temperatures (4000°K) far above ambient, and emit greatly increased amounts of broadband radiation which can exceed the Raman signal levels. The objective of the investigation was to experimentally investigate this problem and to formulate potential solutions to circumvent it.

Project Period: 1976 - 1977

SQUID Technical Reports: See Page: 3/54

Other Publications: See Under Section 3.2, Item: 196.

Contractor: UNITED TECHNOLOGIES RESEARCH CENTER
East Hartford, Connecticut

Subject: CARS Investigations in Sooting Flames

Principal Investigator: Alan C. Eckbreth

Objective: To investigate the applicability of rapid Raman (CARS) thermometry to practical (i.e. turbulent, sooting) combustion environments.

Significance: Rapid temperature measurements are required to determine the temperature probability distribution functions in practical combustion devices. Such measurements will aid the understanding of turbulent combustion phenomena and enhance the accuracy of predictive modelling theories particularly in regard to pollutant levels. This investigation will examine potential nonlinear, soot interference effects in coherent anti-Stokes Raman spectroscopy (CARS) which looks very promising for practical combustor probing. If necessary, techniques will be developed and refined to suppress laser-induced soot CARS interferences. CARS temperature measurements will be performed in steady, laminar, hydrocarbon-fueled diffusion (i.e. sooting) flames using the best of the above developed techniques.

Project Period: 1977 - 1979

SQUID Technical Reports: See Page: 3/54

Other Publications: See Under Section 3.2, Items: 226-228; 247; 272-274; 279.

Contractor: UNIVERSITY OF VIRGINIA

Subject: Research on Atomic and Molecular Collisions

Principal Investigators: J.E. Scott, Jr. and G.D. Magnuson

Objective/Significance: To study, by means of atomic and molecular beam techniques, various aspects of atomic and molecular collision dynamics with particular emphasis on elastic scattering of the rare gases. Measured scattering cross sections are used for the determination of the long range interatomic forces.

Project Period: 1967 - 1969

SQUID Technical Reports: See Page: 3/55

Other Publications: None on record.

Contractor: VIRGINIA POLYTECHNIC INSTITUTE AND
STATE UNIVERSITY
Blacksburg, Virginia

Subject: An Investigation of Pressure Fluctuations and
Stalling Characteristics on Rotating Axial-
Flow Compressor Blades

Principal Investigators: W.F. O'Brien, Jr. and H.L. Moses

Objective: To study the fundamental aspects of stalling and
unsteady behavior in axial-flow compressors; to
measure pressure and other flow variables on the rotors of turbomachines
employing special instrumentation techniques; to develop calculation tech-
niques for the prediction of off-design and separated flows in compressor
blade rows.

Significance: Unsteady behavior in axial-flow compressors
limits performance and can cause structural
failure. The fundamental aspects of the unsteady flow are not well under-
stood. Calculation techniques which can accurately predict unsteady, separa-
ted flows are needed. On-rotor measurements provide one of the best means
for study of the several phenomena.

Project Period: 1971 - 1975
1975 - 1979

SQUID Technical Reports: See Page: None.

Other Publications: See Under Section 3.2, Items: 90, 91; 114-116;
137, 138; 181-184; 219-223; 231.

Contractor: UNIVERSITY OF WASHINGTON
Seattle, Washington

Subject: Investigation of Adverse Pressure Gradient
Corner Flows

Principal Investigator: Frederick B. Gessner

Objective: To measure and analyze the local mean flow and
turbulence structure in the vicinity of a stream-
wise corner under decelerating flow conditions.

Significance: The measurements will provide a body of three-
dimensional flow data not previously available
and yield insight into the nature of turbulent corner flow under adverse
pressure gradient conditions. The data can also serve as a testing ground
for higher-order closure models which have been formulated recently.
Analysis of the data will facilitate the development of methods for pre-
dicting local flow development in various configurations with streamwise
corners. In terms of jet propulsion applications, these configurations
include rectangular ducts and diffusers, wing-body junctions, and vanes or
stabilizers attached to a bounding surface.

Project Period: 1976 - 1979

SQUID Technical Reports: See Page: 3/56

Other Publications: See Under Section 3.2, Item: 271.

Contractor: YALE UNIVERSITY (1969-1971)
New Haven, Connecticut
and
PRINCETON UNIVERSITY (1967-1969)
Princeton, New Jersey

Subject: Relaxation Processes in Gases

Principal Investigators: J.B. Fenn and J.B. Anderson

Objective: To determine the rates at which gaseous systems in a non-equilibrium state can relax to equilibrium. In particular to measure the rate at which internal degrees of vibration and rotation can give up their energy to translation. In addition, to study rates and mechanisms of vaporization-condensation processes including nucleation.

Significance: Rates of energy exchange can have a strong influence on the efficiency of jet engines, especially at the low pressures and small scales of advanced propulsion systems. They play a vital role in such technologically important kinetic processes as chemical reaction, nucleation-condensation, and population inversions leading to laser action. Nucleation-condensation, still something of a mystery, has a direct impact on the energy release in metal-containing fuel systems and governs many meteorological phenomena.

Project Period: 1969-1971 (Yale University)
1967-1969 (Princeton University)

SQUID Technical Reports: See Page: 3/57

Other Publications: See Under Section 3.2, Items: 1; 7.

Contractor: YALE UNIVERSITY
New Haven, Connecticut

Subject: Kinetics of Phase Change, Energy Exchange and
Hydrocarbon Combustion

Principal Investigator: John B. Fenn

Objective: To determine rates and mechanism of mass and
energy transfer during gas-gas and gas-surface
molecular collisions. To measure rates at which energy is exchanged be-
tween internal and translational degrees of freedom in molecules. To
measure absolute rates of evaporation. To study the kinetics and thermo-
dynamics of nucleation-condensation for neutral molecules and the clustering
of neutral molecules on ions. To probe combustion mechanisms.

Significance: Rates of intermolecular energy exchange and inter-
phase mass exchange can have a profound influence
on the propulsive efficiency of jet engines. They play a role in other
technologically important processes including chemical reaction, heat and
mass transfer, and population inversions leading to laser action. Natural
and artificial meteorological phenomena also depend in large measure upon
these elementary processes. Propulsion depends on combustion.

Project Period: 1970 - 1975
1975 - 1978

SQUID Technical Reports: See Page: 3/57

Other Publications: See Under Section 3.2, Items: 30; 52; 68; 117-120;
146-148; 185-187.

Contractor: YALE UNIVERSITY
New Haven, Connecticut

Subject: Turbulent Structure Determination by
Ramanography

Principal Investigators: Richard K. Chang, Boa-Teh Chu

Objective: The objective of our research is to develop new
spectroscopic techniques which are capable of
providing fundamental information in the areas of turbulence and combustion.

Significance: Non-intrusive, instantaneous, and two-dimen-
sional experimental data on well characterized
nozzles and new measurement techniques are needed for the study of com-
bustors, turbine and nozzle entry flows and engine exhaust flows.

Project Period: 1977 - 1979

SQUID Technical Reports: See Page: 3/57

Other Publications: See Under Section 3.2, Items: 277, 278.

3. REPORTS AND PUBLICATIONS

Project SQUID Technical Reports published over the period 1967-1979 are presented in Section 3.1.

Other (archival) publications are presented in Section 3.2.

3.1 REPORTS

1 AeroChem Research Laboratories, Inc.

1. TR No.: AC-7-PU

"Formation of Electronically Excited Species in
N-Atom/O-Atom Recombination Reactions Catalyzed
by Carbon Compounds: NO [$A^2 \Sigma$, $B^2 \Pi$] and O [^1S]"

Arthur Fontijn and Roy Ellison

July 1968

2. TR No.: AC-8-PU

"Chemiluminescence and Chemi-ionization in Nitrogen
Atom/Oxygen Atom/Carbon Compound Reactions"

Arthur Fontijn

April 1969

3. TR No.: AC-9-PU

"Chemi-ionization Reactions in the Gas Phase"

Arthur Fontijn

January 1970

4. TR No.: AC-10-PU

"Chemiluminescent Emission of CO Fourth Positive
Bands in Nitrogen Atom/Oxygen Atom/Reactive Carbon
Compound Systems"

Arthur Fontijn and Roy Ellison

April 1970

5. TR No.: AC-11-PU

"Comparison of the Absolute Quantum Yields of the Gas
Phase O/NO Reaction and the Liquid Phase Luminol Oxida-
tion Chemiluminescence Light Standards"

Arthur Fontijn and John Lee

December 1971

6. TR No.: AC-12-PU
"A Review of Experimental Measurement Methods Based
on Gas-Phase Chemiluminescence"
Arthur Fontijn, Dan Golomb and Jimmie A. Hodgeson
November 1972
7. TR No.: AC-13-PU
"Recent Progress in Chemi-ionization Kinetics"
Arthur Fontijn
September 1973
8. TR No.: AC-14-PU
"Chemi-ionization Reactions of Photo-Excited K Atoms"
Arthur Fontijn, Paul F. Fennelly and Roy Ellison
September 1974
9. TR No.: AC-15-PU
"Elementary Combustion Reaction Kinetics Measurements
over Large Temperature Ranges. The HTFFR Technique"
Arthur Fontijn
January 1976
10. TR No.: AC-16-PU
"HTFFR Kinetics Studies of $\text{Al} + \text{CO}_2 \rightarrow \text{AlO} + \text{CO}$ from
300 to 1800 K A Non-Arrhenius Reaction"
Arthur Fontijn and William Felder
April 1977

2 Aeronautical Research Associates of Princeton, Inc.

1. TR No.: ARAP-1-PU

"Modeling of Scalar Probability Density Functions in
Turbulent Flames"

Ashok K. Varma, Guido Sandri, Peter J. Mansfield

September 1978

2. TR No.: ARAP-2-PU

"Second-Order Closure Modeling of Variable Density
Turbulent Flows"

Ashok K. Varma, Peter J. Mansfield and Guido Sandri

March 1979

3 Atlantic Research Corporation

1. TR No.: ARC-11-PU
"Experimental Burning Rates and Combustion Mechanisms
of Single Beryllium Particles"
A. Macek and J.M. Semple
August 1969
2. TR No.: ARC-12-PU
"Combustion of Boron Particles at Atmospheric Pressure"
A. Macek and J.M. Semple
August 1969
3. TR No.: ARC-13-PU
"Combustion of Boron Particles at Elevated Pressures"
A. Macek and J.M. Semple
June 1970
4. TR No.: ARC-14-PU
"Combustion of Boron Particles: Experiment and Theory"
A. Macek
May 1972

4 Avco Everett Research Laboratory

1. TR No.: AVCO-1-PU

"Point Measurement of Density by Laser Raman
Scattering"

Donald A. Leonard

June 1972

5 Bell Aerospace Company

1. TR No.: BA-1-PU

"Nontangential Injection of Single and Two-Phase
Jets into Subsonic Flow"

George Rudinger

January 1976

6 Brown University

1. TR No.: BRN-21-PU

"Trajectories of Shock Wave and Contact Surface
in Real Shock-Tube Flow"

H.J. Gerhardt

March 1971

2. TR No.: BRN-22-PU

" Spectroscopic Study of the Behavior of Xenon
Behind a Shock Wave

H. Semerjian

May 1972

7 California Institute of Technology

1. TR No.: CIT-7-PU

"Large Structure Dynamics and Entrainment in the Mixing
Layer at High Reynolds Number"

Paul E. Dimotakis and Garry L. Brown

August 1975

2. TR No.: CIT-8-PU

"An Experimental Investigation of Mixing in Two-Dimensional
Turbulent Shear Flows with Applications to Diffusion-Limited
Chemical Reactions"

John H. Konrad

May 1977

8 University of California - San Diego

1. TR No.: UCSD-1-PU
"A Provisional Analysis of Two-Dimensional Turbulent
Mixing with Variable Density"
Paul A. Libby
September 1972
2. TR No.: UCSD-2-PU
"On Turbulent Flows with Fast Chemical Reactions .
Part I: The Closure Problem"
Paul A. Libby
1972
3. TR No.: UCSD-3-PU
"On Turbulent Flows with Fast Chemical Reactions.
Part II. The Distribution of Reactants and Products
Near a Reacting Surface"
Carl H. Gibson and Paul A. Libby
1972
4. TR No.: UCSD-4-PU
"A Weakly Turbulent Flame with High Activation Energy"
F.A. Williams
July 1973
5. TR No.: UCSD-5-PU
"Further Applications of Hot-Wire Anemometry to Turbulence
Measurements in Helium-Air Mixtures"
Richard A. Stanford and Paul A. Libby
January 1974
6. TR No.: UCSD-6-PU
"A Note on Favre Averaging in Variable Density Flows"
R.W. Bilger
May 1975

7. TR No.: UCSD-7-PU
"The Structure of Diffusion Flames"
R.W. Bilger
June 1975
8. TR No.: UCSD-8-PU
"Turbulence Interaction Effects in Turbulent Premixed
Flames"
K.N.C. Bray and P.A. Libby
February 1976
9. TR No.: UCSD-9-PU
"Turbulence Measurements of a Two-Dimensional Helium Jet
in a Moving Airstream"
Paul Anderson, John C. La Rue and Paul A. Libby
July 1977
10. TR No.: UCSD-10-PU
"Effects of Finite Reaction Rate and Molecular Transport
in Premixed Combustion"
Paul A. Libby, K.N.C. Bray and J.B. Moss
May 1978

9 CALSPAN (Formerly Cornell Aeronautical Laboratory)

1. TR No.: CAL-95-PU

"Study of the Reaction of Magnesium Vapor and
Oxygen at the Surface of MgO Deposits by Atomic-
Absorption Spectrophotometry"

G.H. Markstein

July 1968

2. TR No.: CAL-96-PU

"Relaxation in Gas-Particle Flow"

George Rudinger

July 1968

3. TR No.: CAL-97-PU

"Effective Drag Coefficients for Gas-Particle
Flow in Shock Tubes"

George Rudinger

March 1969

4. TR No.: CAL-98-PU

"Gas-Particle Flow in Convergent Nozzles at High
Loading Ratios"

George Rudinger

July 1969

5. TR No.: CAL-99-PU

"Particle Scattering Measurements in a
Trimethylaluminum-Oxygen Diffusion Flame"

J.W. Daiber

April 1974

10 Case Western Reserve University

1. TR No.: CWRU-1-PU
"Flammability Limits and the Oscillatory Burning of
Solid Propellants at Low Pressure"
A.R. Baliga and J.S. T'ien
June 1974
2. TR No.: CWRU-2-PU
"A Discussion on the Extinction Condition of a Diffusion
Flame"
James S. T'ien
September 1974
3. TR No.: CWRU-3-PU
"Flammability Study of Polymer Fuels using Opposed-Jet
Diffusion Flame Technique"
S.N. Singhal and J.S. T'ien
August 1975

11 City College of New York

1. TR No.: CCNY-1-PU

"Interaction of a Spherical Source Flow with a
Rarefied Atmosphere"

J.W. Brook and B.B. Hamel

September 1970

12 University of Colorado

1. TR No.: UC-1-PU
"Mechanisms of Decay of Laminar and Turbulent Vortices"
M.S. Uberoi
December 1977
2. TR No.: UC-2-PU
"Axial Flow in Trailing Line Vortices"
M.S. Uberoi, Bhimsen K. Shivamoggi and Sen-Sung Chen
June 1978

13 Colorado State University

1. TR No.: CSU-1-PU

"Visualization Study of Vorticity Amplification in
Stagnation Flow"

Willy Z. Sadeh, Herbert J. Brauer and James A. Garrison
November 1977

2. TR No.: (To be submitted)

"Effect of Turbulence on Separation in Circular
Cylinders"

Willy Z. Sadeh and Herbert J. Brauer

14 Cornell University

1. TR I.O.: CU-1-Pu

"Mechanism of Production of CN at High Temperatures
in $N_2-C_2H_2$ Mixtures"

S.H. Bauer, Akiva Bar-Nun and David Lewis

June 1969

15 University of Denver

1. TR No.: DEN-1-PU

"Combustion Kinetics of Particulate Boron"

C.M. Kelley, R.E. Williams, A. Takemoto

September 1970

16 Dynamic Science

1. TR No.: DYN-1-Pu

"Analytical Investigations of Equilibrium and
Nonequilibrium Compressible Turbulent Boundary
Layers"

Irwin E. Alber and Douglas E. Coats

May 1969

17 General Electric Company

1. TR No.: GE-1-PU
"Laser Raman Probe for Flame Temperature"
M. Lapp, C.M. Penney and R.L. St. Peters
April 1973
2. TR No.: GE-2-PU
"Summary of the Laser Raman Workshop on the Measurement
of Gas Properties"
Marshall Lapp and C.M. Penney
June 1973
3. TR No.: GE-3-PU
"Raman Band Contours for Water Vapor as a Function of
Temperature"
J.L. Bribes, R. Gaufres, M. Monan, M. Lapp and C.M. Penney
July 1975

18 Georgia Institute of Technology

1. TR No.: GIT-2-PU
"Reactions of H^+ in H_2 and D^+ in D_2 ; Mobilities of Hydrogen and Alkali Ions H_2 and D_2 Gases"²
T.M. Miller, J.Y. Moseley, D.W. Martin and E.W. McDaniel
May 1968
2. TR No.: GIT-3-PU
"Motion of an Ion Swarm in a Cylindrically Symmetric Drift Tube Mass Spectrometer"
J.T. Moseley and I.R. Gatland
3. TR No.: GIT-4-PU
"Ion Swarm Analysis involving Drift, Diffusion and Reactions"
Ian R. Gatland
December 1968
4. TR No.: GIT-5-PU
"Possible Sources of Large Error in Determinations of Ion-Molecule Reaction Rates with Drift Tube-Mass Spectrometer"
E.W. McDaniel
September 1969
5. TR No.: GIT-6-PU
"Mobilities and Longitudinal Diffusion Coefficients of Mass-identified Potassium Ions and Positive and Negative Oxygen Ions in Oxygen"
R.M. Snuggs, D.J. Volz, J.H. Schummers, D.W. Martin, E.W. McDaniel
September 1970
6. TR No.: GIT-7-PU
"Reply to Longitudinal Diffusion Coefficients Misnamed by R.N. Varney"
I.R. Gatland, E.W. McDaniel
November 1970

7. TR No.: GIT-8-PU

"Tests of the Wannier Expressions for Diffusion
Coefficients of Gaseous Ions in Electric Fields"

E.W. McDaniel and J.T. Moseley

November 1970

19 University of Illinois

1. TR No.: ILL-19-PU
"Supersonic Electric Arcs in Sulfur Hexafluoride"
Charles E. Bond and Dwight N. Wickersheim
August 1969
2. TR No.: ILL-20-PU
"The Sawtooth Column of the Supersonic Electric Arc
in Sulfur Hexafluoride"
Charles E. Bond
December 1969
3. TR NO.: ILL-21-PU
"Theory of an Electric-Current-Carrying Discontinuity
Driven Through Nonconducting Gas by a Lorenz Force"
Roger W. Gallington and Charles E. Bond
March 1971

20 Martin-Marietta Corporation

1. TR No.: MAR-1-PU

"Results of a Shock Tube Experiment in Compressible
Turbulent Mixing"

Richard J. Sanderson and Peter C. Steel

March 1971

21 Massachusetts Institute of Technology

1. TR No.: MIT-43-PU
"Solutions of Boltzmann Equation and Transport Processes"
Rashmi C. Desai and John Ross
June 1968
2. TR No.: MIT-44-PU
"Some Developments of Faddeev's Theory for Reactive Scattering"
John Ross and B.C. Eu
October 1968
3. TR No.: MIT-45-PU
"The Scattering of K and Cs by Several Compounds"
E.F. Greene, L.F. Hoffman, M.W. Lee, J. Ross and C.F. Young
November 1968
4. TR No.: MIT-46-PU
"Elastic Scattering of Reactive Systems"
John Ross and E.F. Greene
January 1969
5. TR No.: MIT-47-PU
"Quantum Theory of Reactive Scattering"
John Ross
January 1969
6. TR No.: MIT-48-PU
"Non-Equilibrium Effects in Chemical Kinetics:
John Ross
January 1969
7. TR No.: MIT-49-PU
"On Bimolecular Chemical Reactions in Imperfect Gases"
Michael R. Emptage and John Ross
March 1969

8. TR No.: MIT-50-PU
"Viscosity of Nitrogen, Helium, Hydrogen and Argon from
-100 to 25 C up to 150-250 Atmospheres"
J.A. Gracki, G.P. Flynn and J. Ross
May 1969
9. TR No.: MIT-51-PU
"A Semiclassical Treatment of the Optical Model"
John Ross and R.E. Roberts
August 1969
10. TR No.: MIT-52-PU
"Relaxation in a Dilute Binary Gas Mixture"
John Ross and Raymond Kapral
September 1969
11. TR No.: MIT-53-PU
"Distorted Wave Born Series for Rotational Inelastic
Scattering"
R.E. Roberts and John Ross
January 1970
12. TR No.: MIT-54-PU
"Non-Equilibrium Kinetics: Explicit Time-Dependence of
Perturbed Distribution Functions and Auto-Correlation
Expressions"
Raymond Kapral, Suzanne Hundson and John Ross
July 1970
13. TR No.: MIT-55-PU
"Estimate of Potential Surface for K-Cl-Cl"
Carl Neyland and John Ross
September 1970
14. TR No.: MIT-56-PU
"Kinetic Energies of Ionization Products from Collisions of
Ar-Ar, He-He below 220 eV c.m. Energy"
R.H. Hammond, J.M.S. Henis, E.F. Greene and John Ross
March 1971

15. TR No.: MIT-57-PU
"Analysis of Symmetry in Chemical Reactions"
Thomas F. George and John Ross
April 1971
16. TR No.: MIT-58-PU
"Instabilities in Coupled Chemical Reactions with
Pressure-Dependent Rate Coefficients"
Peter J. Ortoleva and John Ross
June 1971
17. TR No.: MIT-59-PU
"Penetration of Boundary Perturbations in Unstable
Chemical Systems"
Peter J. Ortoleva and John Ross
Autust 1971
18. TR No.: MIT-60-PU
"Response of Unstable Chemical Systems to External
Perturbations"
Peter J. Ortoleva and John Ross
August 1971
19. TR No.: MIT-61-PU
"Local Dissipative Structures in Chemical Reactions
with Heterogeneous Catalysis"
Peter J. Ortoleva and John Ross
December 1971
20. TR No.: MIT-62-PU
"Optical Model for Vibrational Relaxation in Reactive
Systems"
Lise Lotte Poulsen, John Ross and Jeffrey I. Steinfield
February 1972

21. TR No.: MIT-63-PU
"A Relation Between Reaction Probability and Inelastic Energy Transfer"
Robert G. Gilbert and John Ross
February 1972
22. TR No.: MIT-64-PU
"Quasistatistical Complexes in Chemical Reactions"
Thomas F. George and John Ross
February 1972
23. TR No.: MIT-65-PU
"The Interaction of Sound with Gas Phase Reactions"
R.C. Gilbert, H.S. Hahn, P.J. Ortoleva and J. Ross
April 1972
24. TR No.: MIT-66-PU
"Physical Mechanisms of Carbon Formation in Flames"
B.L. Werborg, J.B. Howard and G.C. Williams
June 1972
25. TR No.: MIT-67-PU
"Dependence of Reactivity on Internal and Translational Energy in $K + SF_6$, CCl_4 and $SnCl_4$ "
T.M. Sloan, S.Y. Tang and John Ross
June 1972
26. TR No.: MIT-68-PU
"Total Cross Sections for Formation of Ions from CsBr Collisions with Ar, Xe and NaBr (Ar)"
L.G. Piper, L. Helleman, J. Sloan and J. Ross
July 1972
27. TR No.: MIT-69-PU
"Light Scattering from Systems with Chemical Oscillations and Dissipative Structures"
J.M. Deutch, S. Hudson, P.J. Ortoleva and J. Ross
July 1972

28. TR No.: MIT-70-PU
"Phase Waves in Oscillatory Chemical Reactions"
P.J. Ortoleva and J. Ross
November 1972
29. TR No.: MIT-71-PU
"Non-Equilibrium Relaxation Methods. Acoustic Effects in
Transient Chemical Reactions"
P. Ortoleva, R. Gilbert and J. Ross
November 1972
30. TR No.: MIT-72-PU
"Coagulation of Carbon Particles in Premixed Flames"
B.L. Wersborg, J.B. Howard and G.C. Williams
December 1972
31. TR No.: MIT-73-PU
"Molecular Beam Study of Polyatomic Free Radical Reactions.
Angular Distributions"
D.L. McFadden, E.A. McCullough, Jr., F. Kalos and J. Ross
February 1973
32. TR No.: MIT-74-PU
"Quantum Dynamical Theory of Molecular Collisions"
Thomas F. George and John Ross
February 1973
33. TR No.: MIT-75-PU
"Oscillations, Multiple Steady States and Instabilities
in Illuminated Systems"
A. Nitzan and J. Ross
March 1973
34. TR No.: MIT-76-PU
"On Symmetry Properties of Reaction Coordinates"
H. Metiu, J. Ross, R.J. Silbey and T.F. George
1973

35. TR No.: MIT-77-PU
"A Comment on Fluctuations around Non-Equilibrium Steady State"
A. Nitzan and John Ross
December 1973
36. TR No.: MIT-78-PU
"Far-from Equilibrium Phenomena at Local Sites of Reaction"
K. Bimpong-Bota, P. Ortoleva and J. Ross
January 1974
37. TR No.: MIT-79-PU
"Symmetry Breaking Instabilities in Illuminated Systems"
A. Nitzan, P. Ortoleva and John Ross
January 1974
38. TR No.: MIT-80-PU
"On the Coupling Between Vibrational Relaxation and Molecular Electronic Transitions"
A. Nitzan
March 1974
39. TR No.: MIT-81-PU
"Mechanism of Chemical Instability for Periodic Precipitation Phenomena"
Michele Flicker and John Ross
March 1974
40. TR No.: MIT-82-PU
"Fluctuations and Transitions at Chemical Instabilities: The Analogy to Phase Transitions"
A. Nitzan, P. Ortoleva, J. Deutch and J. Ross
March 1974
41. TR No.: MIT-83-PU
"On A Variety of Wave Phenomena in Chemical Reactions"
Peter Ortoleva and John Ross
March 1974

42. TR No.: MIT-84-PU
"Non-Concerted Reactions and Symmetry Rules"
H. Metiu, J. Ross and T.F. George
March 1974
43. TR No.: MIT-85-PU
"Concentration and Mass Distribution of Charged Species
in Sooting Flames"
B.L. Wersborg, A.C. Yeung and J.B. Howard
June 1974
44. TR No.: MIT-86-PU
"Soot Concentration and Absorption Coefficient in a
Low Pressure Flame"
B.L. Wersborg, L.K. Fox and J.B. Howard
June 1974
45. TR No.: MIT-87-PU
"On Symmetry Properties of Reaction Coordinates"
H. Metiu, J. Ross, R. Silbey and T.F. George
August 1974
46. TR No.: MIT-88-PU
"Nucleation in Systems with Multiple Stationary States"
A. Nitzan, P. Ortoleva and J. Ross
September 1974
47. TR No.: MIT-89-PU; MIT-90-PU
"Experimental and Theoretical Studies of Chemical
Dynamics and Instabilities in Irreversible Processes"
John Ross
June 1978

22 University of Michigan

1. TR No.: MICH-8-PU
"Hypersonic Blunt Body Flow of Hydrogen-Oxygen Mixtures"
Arnold Galloway and Martin Sichel
July 1968
2. TR No.: MICH-9-PU
"Unsteady Transonic Flows in Two-Dimensional Channels"
T.C. Adamson, Jr.
June 1971
3. TR No.: MICH-10-PU
"A Study of Unsteady Transonic Flows with Shock Waves in
Two Dimensional Channels"
T.C. Adamson, Jr. and G.K. Richey
November 1972
4. TR No.: MICH-11-PU
"On the Matching of Solutions for Unsteady Transonic
Nozzle Flows"
T.C. Adamson, Jr., A.F. Messiter and G.K. Richey
September 1973
5. TR No.: MICH-12-PU
"Unsteady Radial Transonic Flow with Shock Waves"
Martin Sichel
September 1973
6. TR No.: MICH-13-PU
"On the Flow Near a Weak Shock Wave Down stream of a
Nozzle Throat"
A.F. Messiter and T.C. Adamson, Jr.
July 1974

7. TR No.: MICH-14-PU
"Analysis of Unsteady Transonic Channel Flow with Shock Waves"
G.K. Richey and T.C. Adamson, Jr.
May 1975
8. TR No.: MICH-15-PU
"Unsteady Transonic Flow with Heat Addition"
Martin Sichel
February 1976
9. TR No.: MICH-16-PU
"Transonic Flow Problems in Turbomachinery"
M. Platzer and T. Adamson
February 1977
10. TR No.: MICH-17-PU
"Unsteady Transonic Flows and Shock Waves in an Asymmetric Channel"
John S.-K Chan and T.C. Adamson, Jr.
May 1977
11. TR No.: MICH-18-PU
"Summary of the Project Squid Workshop on Transonic Flow Problems in Turbomachinery"
T.C. Adamson, Jr.
July 1977

23 Michigan State University

1. TR No.: MSU-1-PU

"An Experimental Study of the Transport of a Non-Diffusive Scalar Contaminant in the Decaying Turbulence Field of an Enclosed Chamber"

K.C. Cornelius and John F. Foss

April 1978

24 University of Missouri - Columbia

1. TR No.: UM0-1-PU
"A Shock Tube Study of the Recombination of Carbon Monoxide and Oxygen Atoms"
Anthony M. Dean and Don C. Steiner
October 1976
2. TR No.: UM0-2-PU
"A Shock Tube Study of the $\text{H}_2/\text{O}_2/\text{CO}/\text{Ar}$ and $\text{H}_2/\text{N}_2\text{O}/\text{CO}/\text{Ar}$ Systems"
Anthony M. Dean, Don C. Steiner and Edward E. Wang
June 1977
3. TR No.: UM0-3-PU
"Shock Tube Studies of Formaldehyde Pyrolysis"
Dean, Craig, Johnson, Schultz and Wang
April 1978
4. TR No.: UM0-4-PU
"Shock Tube Studies of Formaldehyde Oxidation"
Dean, Johnson, Steiner
January 1979
5. TR No.: UM0-5-PU
"Shock Tube Studies of the $\text{N}_2\text{O}/\text{CH}_4/\text{CO}/\text{Ar}$ and $\text{N}_2\text{O}/\text{C}_2\text{H}_6/\text{CO}/\text{Ar}$ Systems"
Anthony M. Dean and Ron L. Johnson
April 1979

25 Nielsen Engineering and Research, Inc.

1. TR No.: NEAR-1-PU

"An Analytical Method for Calculating Turbulent Separated
Flows due to Adverse Pressure Gradients"

Gary D. Kuhn and Jack N. Nielsen

October 1971

2. TR No.: NEAR-2-PU

"Studies of an Integral Method for Calculating Time-
Dependent Turbulent Boundary Layers"

Gary D. Kuhn and Jack N. Nielsen

October 1973

26 The Pennsylvania State University

1. TR No.: PSU-13-PU

"Axial Flow Rotor Unsteady Response to Circumferential
Inflow Distortions"

E.P. Bruce and R.E. Henderson

September 1975

27 Polytechnic Institute of New York (Formerly of Brooklyn)

1. TR No.: PIB-31-PU
"Specie Concentration and Temperature Measurements in Flow Fields"
S. Lederman and J. Bronstein
March 1973
2. TR No.: PIB-32-PU
"Temperature and Concentration Measurements on an Axisymmetric Jet and Flame"
S. Lederman and J. Bornstein
December 1973
3. TR No.: PIB-33-PU
"Temperature, Concentration and Velocity Measurements in a Jet and Flame"
S. Lederman, J. Bornstein, A. Celentano and J. Glaser
November 1974
4. TR No.: PIB-34-PU
"Temperature, Concentration Velocity and Turbulence Measurements in Jet and Flames"
S. Lederman, A. Celentano and J. Glaser
March 1977
5. TR No.: PIB-35-PU
"Application of the Integrated Raman and LDV System"
S. Lederman and A. Celentano
March 1978
6. TR No.: PIB-36-PU
"Flow Field Measurement Using Raman and LDV Techniques"
S. Lederman, A. Celentano, J. Glaser
April 1979

28 Princeton University

1. TR No.: PR-115-PU
"Viscous Effects on Impact Pressure Measurements in Low
Density Flows at High Mach Numbers"
J.H. Chang and J.B. Fenn
October 1968
2. TR No.: PR-116-P
"Intermediate Energy Molecular Beams from Free Jets of
Mixed Gases"
James B. Anderson
January 1968
3. TR No.: PR-116-PU
"Strand Size and Low Pressure Deflagration Limit in a
Composite Propellant"
Roy E. Cookson and John B. Fenn
December 1968
4. TR No.: PR-117-P
"New Methods for Producing High Energy Molecular Beams"
J.B. Fenn and J.B. Anderson
January 1968
5. TR No.: PR-117-PU
"Thermal Recovery Factors in Supersonic Flows of Gas
Mixtures"
George Maise and John B. Fenn
July 1969
6. TR No.: PR-118-P
"Molecular Beam Experiments in the Lunar Environment"
J.B. Fenn, D.G.H. Marsden and J.B. Anderson
January 1968

7. TR No.: PR-118-PU
"Theoretical Determination of the Discharge of Axisymmetric
Nozzles under Critical Flows"
S.P. Tang
October 1969
8. TR No.: PR-119-PU
"Species Separation by Stagnation of Argon-Helium Mixtures
in Supersonic Flow"
John H. Chang and John B. Fenn
February 1971
9. TR No.: PR-120-PU
"Velocity Distributions of Several Gases Scattered from
High Temperature Surfaces"
A. Cassuto, S. Tang and J.B. Fenn
February 1971
10. TR No.: PR-121-PU
"Some Applications of Molecular Beam Velocity Spectroscopy
to Evaporation and Energy Exchange"
S.P. Tang, R.J. Gallagher and J.B. Fenn
October 1971
11. TR No.: PR-122-PU
"Inviscid Free Jet Flow with Low Specific Heat Ratios"
James B. Anderson
January 1972

29 Purdue University

1. TR No.: PU-R1-75
 "Summary of the Second International Workshop on Laser Velocimetry"
 H.D. Thompson and W.H. Stevenson
 March 1975
2. TR No.: PU-R2-75
 "Turbulent Mixing in Non-Reactive and Reactive Flows"
 S.N.B. Murthy
 1975
3. TR No.: PU-R1-76
 "Combustion Measurements"
 R. Goulard
 December 1975
4. TR No.: PU-R2-76
 "Summary of Activities - Contracts and Reports 1946-1976"
 April 1976
5. TR No.: PU-R3-76
 "Reporting Procedure"
 Project Squid
 October 1976
6. TR No.: PU-R1-77
 "Turbulence on Internal Flows"
 S.N.B. Murthy
 May 1977
7. TR No.: PU-R1-78
 "Engine-Airframe Integration"
 S.N.B. Murthy
 April 1978

8. TR No.: PU-R2-78
"Alternative Hydrocarbon Fuels: Combustion and Chemical Kinetics"
C.T. Bowman and J. Birkeland
August 1978
9. TR No.: PU-R1-79
"Summary Report. DOD Colloquium on Gas Turbine Combustor Modeling. September 1979"
November 1979
10. TR No.: PU-R1-80
"Gas Turbine Combustor Design Problems"
Arthur H. Lefebvre
1980

30 Rice University

1. TR No.: RICE-2-P
"Translational Energy Distribution of Electrons and Positive Ions in the Plasma of Microwave and High Frequency Discharges of He, Ne, and Ar"
J.L. Franklin, Stanley A. Studniarz and P.K. Ghosh
November 1967
2. TR No.: RICE-3-PU
"Ion Molecule Reactions in a 50 Megacycle Discharge"
Stanley A. Studniarz and J.L. Franklin
May 1968
3. TR No.: RICE-4-PU
"Electron Energies in Electrical Discharges Excited at Microwave Frequencies"
J.L. Franklin and S.A. Studniarz
June 1968
4. TR No.: RICE-5-PU
"High Pressure Mass Spectra and Ion Chemistry of Carbon Dioxide"
J.L. Franklin and Steven M. Schildcrout
May 1969
5. TR No.: RICE-6-PU
"Ion-Molecule Reactions in Hydrogen Sulfide, Methane Thiol and 2-Thiopropene"
J.L. Franklin and W.E.W. Ruska
May 1969
6. TR No.: RICE-7-PU
"High Pressure Mass Spectra and Ion Chemistry of Carbon Suboxide"
J.L. Franklin and S.M. Schildcrout
July 1969

7. TR No.: RICE-8-PU
"Mass Spectrometric Study of Ion-Neutral Reactions in
Radiofrequency Discharges in Carbon Dioxide"
J.G. Collins, J.L. Franklin and S.M. Schildcrout
September 1969
8. TR No.: RICE-9-PU
"High Pressure Ion-Molecule Reactions in Carbon Monoxide
and Carbon Monoxide-Methane Mixtures"
S.L. Chong and J.L. Franklin
July 1970
9. TR No.: RICE-10-PU
"Ion-Molecule Reactions of CH_4 - CD_4 Mixtures at High
Pressures"
S.L. Chong and J.L. Franklin
March 1971
10. TR No.: RICE-11-PU
"The Proton Affinity of Water"
S.L. Chong, Ransom A. Myers, Jr. and J.L. Franklin
September 1971
11. TR No.: RICE-12-PU
"Ion-Molecule Reactions in the System CO_2 - CH_4 "
S.F. Kasper and J.L. Franklin
September 1971
12. TR No.: RICE-13-PU
"Proton Affinities of Benzene, Toluene and the Xylenes"
S.L. Chong and J.L. Franklin
December 1971

31 University of Sheffield

1. TR No.: US-1-PU

"The Structure of Eddies in Turbulent Flames"

N.A. Chigier

March 1979

32 University of Southern California

1. TR No.: USC-1-PU

"The Growth of the Two Dimensional Mixing Layer from a
Turbulent Boundary Layer"

F.K. Browand and B.O. Latigo

November 1978

33 Southern Methodist University

1. TR No.: SMU-1-PU
"Laminariscient Turbulent Boundary Layers: Experiments
on Sink Flows"
Roger L. Simpson and D.B. Wallace
July 1975
2. TR No.: SMU-2-PU
"Laminariscient Turbulent Boundary Layers: Experiments
in Nozzle Flows"
R.L. Simpson and C.R. Shackleton
February 1977
3. TR No.: SMU-3-PU
"Summary Report on Colloquium on Flow Separation"
(January 1979)
November 1979
4. TR No.: (in preparation)
"Measurements of a Separating Turbulent Boundary Layer"
R.L. Simpson, Y.-T. Chew and B.G. Shigaprasad
(1980)

34 Stanford Research Institute

1. TR No.: SRI-25-P
"Diffusion and Heterogeneous Reaction XI. Theoretical
Analysis of Nonsteady-State Kinetics"
Y. Rajapakse and H. Wise
November 1967
2. TR No.: SRI-26-P
"Diffusion and Heterogeneous Reaction XII. Diffusion
Coefficient Measurements of Atomic Oxygen through Various
Gases"
Robert S. Yolles and Henry Wise
November 1967
3. TR No.: SRI-26-PU
"The Reaction Kinetics of Gaseous Hydrogen Atoms with Graphite"
Bernard J. Wood and Henry Wise
September 1968
4. TR No.: SRI-27-PU
"Diffusion Coefficient Measurements for Gas Mixture of
Atomic and Molecular Hydrogen"
K.M. Sancier and H. Wise
March 1969
5. TR No.: SRI-28-PU
"Transport Coefficients of Gas Mixtures of Atomic and
Molecular Hydrogen"
Henry Wise
June 1969
6. TR No.: SRI-29-PU
"Diffusion and Heterogeneous Reaction XIII. Measurements
of $O-O_2$ Diffusion as a Function of Temperature"
Henry Wise, Robert S. Yolles and Leonard McCulley
August 1969

7. TR No.: SRI-30-PU

"Dynamic Tensile Failure of Glycerol"

David C. Erlich, David C. Wooten and Richard C. Crewdson

January 1971

35 Stanford University

1. TR No.: SU-1-PU
"Investigation of Particle-Size Determination from the
Optical Response of a Laser-Doppler Velocimeter"
D.G. Andrews and H.S. Seifert
February 1972
2. TR No.: SU-2-PU
"An Optical Particle-Sizing Counter for In-Situ
Measurements"
Don Holve and Sidney Self
January 1978
3. TR No.: SU-3-PU
"A Wall-Flow-Direction Probe for Use in Separating and
Reattaching Flows"
J.K. Eaton, A.H. Jeans, J. Ashjaee and James P. Johnston
November 1978
4. TR No.: (in preparation)
"Transitory Stall in Diffusers"
J. Ashjaee and J.P. Johnston
June 1979

36 TRW Systems

1. TR No.: TRW-1-PU
"Singular Perturbation and Turbulent Shear Flow Near Walls"
Francis E. Fendell
November 1971
2. TR No.: TRW-2-PU
"Asymptotic Analysis of Turbulent Channel and Boundary Layer Flow"
William B. Bush and Francis E. Fendell
January 1972
3. TR No.: TRW-3-PU
"Asymptotic Analysis of Turbulent Channel Flow for Mixing-Length Theory"
William B. Bush and Francis E. Fendell
June 1972
4. TR No.: TRW-4-PU
"Asymptotic Analysis of Turbulent Channel Flow for Mean Turbulent Energy Closures"
William B. Bush and Francis E. Fendell
October 1972
5. TR No.: TRW-5-PU
"The Effect of Strain on Diffusion Flames"
George F. Carrier, Francis E. Fendell and Frank E. Marble
October 1973
6. TR No.: TRW-6-PU
"The Structure of Multiple Diffusion Flames for a Two-Step Chain Reaction"
William B. Bush and Francis E. Fendell
April 1973

7. TR No.: TRW-7-PU
"On Diffusion Flames in Turbulent Shear Flows"
William B. Bush and Francis E. Fendell
July 1973
8. TR No.: TRW-8-PU
"Asymptotic Analysis of the Turbulent Boundary Layer
with Zero Wall Stress"
William B. Bush and Francis E. Fendell
October 1973
9. TR No.: TRW-9-PU
"The Coherent Flame Model for Turbulent Chemical Reactions"
Frank E. Marble and James E. Broadwell
February 1977

37 United Aircraft Research Laboratories

1. TR No.: UARL-1-PU

"Analysis of Unsteady Aerodynamic Effects on an Axial-Flow
Compressor Stage with Distorted Inflow"

Franklin O. Carta

July 1972

2. TR No.: UARL-2-PU

"Unsteady Fluid Dynamic Response of an Axial-Flow
Compressor Stage with Distorted Inflow"

John J. Adamczyk and Franklin O. Carta

July 1973

38 United Technologies Research Center

1. TR No.: UTRC-1-PU
"Unsteady Surface Flow Behavior on a Cascade of
Airfoils Oscillating below Stall"
F.O. Carta
September 1975
2. TR No.: UTRC-2-PU
"An Experimental Study on the Aerodynamic Response of a
Subsonic Cascade Oscillating Near Stall"
F.O. Carta
August 1976
3. TR No.: UTRC-3-PU
"Investigation To Extend the Applicability of Laser
Raman Scattering Diagnostic Techniques to Practical
Combustion Systems"
Alan C. Eckbreth
September 1976
4. TR No.: UTRC-4-PU
"Techniques to Practical Combustion Systems"
Alan C. Eckbreth
October 1976
5. TR No.: UTRC-5-PU
"CARS Investigations in Sooting and Turbulent Flows"
A.C. Eckbreth
March 1979
6. TR No.: UTRC-6-PU
"Effect of Interblade Phase Angle, Incidence Angle and
Gap-to-Chord Ratio on Cascade Pitching Stability"
F.O. Carta
August 1979

39 University of Virginia

1. TR No.: UVA-14-R-PU
"Final Report 1961-1968"
John E. Scott, Jr.
December 1975

40 University of Washington

1. (In preparation)
"Response Behavior of Hot Wires in Planar, Skewed Flows"
F. Gessner, et al.
2. (In preparation)
"Turbulent Flows in Rectangular Diffusers with Local
Corner Flow Separation"
F. Gessner, et al.

41 Yale University

1. TR No.: YALE-1-PU
"Vacuum Sublimation of Ammonium Perchlorate"
S.P. Tang and J.B. Fenn
November 1972
2. TR No.: YALE-2-PU
"On the Existence of Monofluoroamine"
R.T.V. Kung and R. Roberts
February 1973
3. TR No.: YALE-3-PU
"The Rotational Relaxation of Molecular Hydrogen"
Robert J. Gallagher and John B. Fenn
June 1973
4. TR No.: YALE-4-PU
"Relaxation Rates from Time of Flight Analysis of Molecular Beams"
Robert J. Gallagher and John B. Fenn
December 1973
5. TR No.: YALE-5-PU
"A Free Jet Study of the Rotational Relaxation of Molecular Nitrogen from 300-1000° K"
Robert J. Gallagher and John B. Fenn
June 1974
6. TR No.: YALE-6-PU
"Clustering of Water on Hydrated Protons in a Supersonic Free Jet Expansion"
J.Q. Searcy and John B. Fenn
August 1974

3.2 Publications

Title and Author

1. "Viscous Effects on Impact Pressure Measurements in Low Density Flows at High Mach Numbers" by J. H. Chang and F. B. Fenn
2. "Elastic Scattering of Reactive Systems" by J. Ross and E. F. Greene
3. "Quantum Theory of Reactive Scattering" by J. Ross
4. "Non-Equilibrium Effects in Chemical Kinetics" by J. Ross
5. "High Pressure Mass Spectra and Ion Chemistry of Carbon Dioxide" by J. L. Franklin and S. M. Schilderout
6. "Viscosity of Nitrogen, Helium, Hydrogen and Argon from 100° to 250 up to 150-250 Atmosphere" by J. Ross, J. Gracki, and G. Flynn
7. "Thermal Recovery Factors in Supersonic Flows of Gas Mixtures" by George Maise and John B. Fenn
8. "Gas-Particle Flow in Convergent Nozzles at High Loading Ratios" by George Rudinger
9. "High Pressure Mass Spectra and Ion Chemistry of Carbon Suboxide" by J. L. Franklin and Steven M. Schilderout

Other Presentations

Sixth Rarefied Gas Dynamics Symposium

International School of Physics - July 1963 (Italy)

International School of Physics - July 1968 (Italy)

International School of Physics - July 1968 (Italy)

Journal of Chemical Physics

Journal of Chemical Physics

Symposium on Heat Transfer in Rarefied Gases - ASME Meeting - Los Angeles - Nov. 1969

AIAA 8th Aerospace Science Meeting and AIAA Journal

Journal of the American Chemical Society

<u>Title and Author</u>	<u>Other Presentations</u>
10. "Combustion of Boron Particles at Atmospheric Pressure" by Andrej Macek and J. McKenzie Semple	Combustion Science and Technology Journal AIAA 5th Propulsion Joint Specialist Conference
11. "Diffusion and Heterogeneous Reaction XIII Measurements of O-O ₂ Diffusion As a Function of Temperature" by Robert S. Yollies, Leonard McCutley and Henry Wise	Journal of Chemical Physics
12. "Supersonic Electric Arcs in Sulfur Hexafluoride" by Dwight N. Wickersheim and Charles E. Bond	AIAA Journal
13. "A Semiclassical Treatment of the Optical Model" by R. E. Roberts and John Ross	Journal of Chemical Physics
14. "Mass Spectrometric Study of Ion-Neutral Reactions in Radio-frequency Discharges in Carbon Dioxide" by Steven M. Shildcrout, J. G. Collins, and J. L. Franklin	Journal of Chemical Physics
15. "Relaxation in a Dilute Binary Gas Mixture" by Raymond Kapral and John Ross	Journal of Chemical Physics
16. "Possible Sources of Large Error in Determinations of Ion-Molecule Reaction Rates with Drift Tube-Mass Spectrometers" by Earl W. McDaniel	Gaseous Electronics Conference
17. "Chemical-Ionization Reactions in the Gas Phase" by Arthur Fontijn	Progress in Reaction Kinetics, Vol. 6
18. "Distorted Wave Born Series for Rotational Inelastic Scattering" by R. E. Roberts and John Ross	Journal of Chemical Physics

Title and Author	Other Presentations
19. "Theoretical Determination of the Discharge Coefficients of Axisymmetric Nozzles under Critical Flows" by S. P. Tang	Journal of Fluid Mechanics
20. "The Sawtooth Column of the Supersonic Electric Arc in Sulfur Hexafluoride" by Charles E. Bond	AIAA Journal
21. "Chemiluminescent Emission of CO Fourth Positive Bands in Nitrogen Atom/Oxygen Atom/Reactive Carbon Compound Systems" by Arthur Foutijn	Journal of Chemical Physics (1970)
22. "Combustion of Boron Particles at Elevated Pressures" by Andrej Macek and J. McKenzie Semple	13th International Combustion Symposium (1970)
23. "High Pressure Ion-Molecule Reactions in Carbon Monoxide and Carbon Monoxide-Methane Mixtures" by Shuang-Ling Chong and J. L. Franklin	Journal of Chemical Physics
24. "Non-Equilibrium Kinetics: Explicit Time-Dependence of Perturbed Distribution Functions and Auto-correlation Expressions" by R. Kapral, S. Hudson and J. Ross	Journal of Chemical Physics (1970)
25. "Combustion Kinetics of Particulate Boron" by C. Kelley, R. Williams and A. Takemoto	2nd International Pyrotechnics Seminar (1970)
26. "Interaction of a Spherical Source Flow with a Rarefied Atmosphere" by J. W. Brook and B. B. Hamel	7th International Symposium on Rarefied Gases (1970)
27. "Estimate of Potential Surface for K-Cl-Cl" by Carl Myeland and John Ross	Journal of Chemical Physics (1970)

Title and Author

28. "The History of Velocity Waves in a Reacting Fluid" by K. Parker and J. Cavalle
29. "Potential Inversion for the Semiclassical Optical Model" by R. Roberts and J. Ross
30. "Species Separation by Stagnation of Argon-Helium Mixtures in Supersonic Flow" by J. Fenn and J. Chang
31. "Electronic and Ionic Impact Phenomena" by E. McDaniel
32. "Exhaust Plume Rarefaction" by Muntz, Hamel, and Maguire
33. "Pole Contributions in the Distorted Wave Born Series for Inelastic Scattering" by R. Roberts and J. Ross
34. "Ion-Molecule Reaction Between O^- and O_2 at Thermal Energies and Above" by R. Snuggs, D. Volz, I. Gatland, J. Schummers, D. Martin and E. McDaniel
35. "Drift Tube Studies of the Transport Properties and Reactions of Slow Ions in Gases" by E. McDaniel
36. "Measurement of Physical Properties and Growth Rate in a Burning Supersonic Mixing Layer" by R. Sanderson and P. Steel

Other Presentations

- AIAA Paper 70-146 (1970)
- Journal of Chemical Physics (1970)
- 7th International Symposium of Rarefied Gas Dynamics (1970), Italy
- American Journal of Physics (1970)
- AIAA Journal, (1970)
- Journal of Chemical Physics (1970)
- Physical Review
- Case Studies in Atomic Collision Physics I (1969)
- Combustion Institute WSS/CI Paper 70-16, (1970)

<u>Title and Author</u>	<u>Other Presentations</u>
37. "Electrical Charge of Carbon Particles in Flames" by J. Howard and R. Ball	13th International Combustion Symposium (1970) and (The Combustion Institute)
38. "Chemi-Ionization Reactions in the Gas Phase," by Arthur Fontijn	Progress in Reaction Kinetics, Vol. 6
39. "Chemiluminescent Emission of CO Fourth Positive Bands in Nitrogen Atom/Oxygen Atom/Reactive Carbon Compound Systems. Relation to Chemi-Ionization" by Arthur Fontijn, Roy Ellison, William H. Smith and James Hesser	Journal of Chemical Physics, Vol. 54
40. "Combustion of Boron Particles at Elevated Pressures," by Macek, Andrej and Sempke, J. Mckenzie	13th International Combustion Symposium (1970)
41. "Mobilities and Longitudinal Diffusion Coefficients of Mass-Identified Potassium Ions and Positive and Negative Oxygen Ions in Oxygen," by R.M. Snuggs, D.J. Volz, J.H. Summers, D.W. Martin, and E.W. McDaniel	Physical Review, Vol. 3
42. "Reply to 'Longitudinal Diffusion Coefficients Misnamed,' by R.N. Varney," by I.R. Gatland and E.W. McDaniel	Phys. Rev. Letters, Vol. 25
43. "Tests of the Wannier Expressions for Diffusion Coefficients of Gaseous Ions in Strong Electric Fields," by E.W. McDaniel and J.T. Moseley	Physical Review, Vol. 3
44. "Kinetic Energies of Ionization Products from Collisions of Ar-Ar, He-He Below 220 eV c.m. Energy" by R.H. Hammond, J.M.S. Henis and E.F. Greene.	Journal of Chemical Physics
45. "Analysis of Symmetry in Chemical Reactions," by T.F. George and J. Ross	Journal of Chemical Physics

Title and Author	Other Presentations
46. "Instabilities in Coupled Chemical Reactions with Pressure-Dependent Rate Coefficients," by P. Ortoleva and J. Ross	Journal of Chemical Physics
47. "Penetration of Boundary Perturbations in Unstable Chemical Systems," by P. Ortoleva and J. Ross	Journal of Chemical Physics
48. "Response of Unstable Chemical Systems to External Perturbations," by P. Ortoleva and J. Ross	Journal of Chemical Physics
49. "Ion-Molecule Reactions of CH_4 - CD_4 Mixtures at High Pressures," by Shuang-Ling Chong and J.L. Franklin	Journal of Chemical Physics
50. "The Proton Affinity of Water," by Shuang-Ling Chong, A. Ransom, Jr. and J.L. Franklin	Journal of Chemical Physics
51. "Ion-Molecule Reactions in the System CO_2 - CH_4 ," by S.F. Kasper and J.L. Franklin	Journal of Chemical Physics
52. "Some Applications of Molecular Beam Velocity Spectroscopy to Evaporation and Energy Exchange," by S.P. Tang, R.J. Gallagher and J.B. Fenn	3rd International Symposium on Molecular Beams (France)
53. "Mechanism of Chemiluminescent Emission of the CO Fourth Positive Bands in Active Nitrogen CO Mixtures," by Arthur Fontijn and Roy Ellison	Journal of Chemical Physics, Vol. 54
54. "Ion-Molecule Reactions Between O^- and O_2 at Thermal Energies and Above," by R.M. Snuggs, D.J. Volz, I.R. Gatland, J.H. Schummers, D.W. Martin, and E.W. McDaniel	Physical Review
55. "Suggested Use of the Known Mobility of K^+ Ions in Nitrogen Gas for Pressure Calibration in Atomic Collisions Experiments," by E.W. McDaniel and D.W. Martin	Rev. Sci. Instr.
56. "Mobilities and Longitudinal Diffusion Coefficients of Mass-Identified Potassium and Nitric Oxide Ions in Nitric Oxide," by D.J. Volz, J.H. Schummers, R.D. Laser, D.W. Martin and E.W. McDaniel	Physical Review

<u>Title and Author</u>	<u>Other Presentations</u>
57. "Review of 'Electronic and Ionic Impact Phenomena, Vols. I and II' by Massey and Burhop," by E.W. McDaniel	Amer. J. Phys.
58. "Review of 'Introduction to the Theory of Ion-Atom Collisions', by M.R.C. McDowell and J.P. Coleman," by E.W. McDaniel	Amer. J. Phys.
59. "Ion-Molecule Reactions" by E.W. McDaniel, V. Cernak, A. Dalgarno, E.E. Ferguson, and L. Friedman	John Wiley & Sons, Inc. New York
60. "Case Studies in Atomic Collision Physics, Vol. II", edited by E.W. McDaniel and M.R.C. McDowell	North-Holland Pub. Co. Amsterdam
61. "Electrical Charge of Carbon Particles in Flames," by J.B. Howard and R.T. Ball	Thirteenth Symposium (International) on Combustion
62. "Direct Interaction Theory of Reactive Molecular Collisions: $K + Br_2$ System" by B.C. Eu, J.H. Huntington and J. Ross.	Canadian Journal of Physics
63. "Behavior of Diffusers with Distorted and Unsteady Inlet Conditions," by A.T. McDonald and P.W. Runstadler, Jr.	Project SQUID Workshop on Unsteady Boundary Layers
64. "Design and Construction of a Water Table for the Study of High Reynolds Number Diffuser Flow," by R.J. Swift	MS Thesis, Purdue University
65. "Proton Affinities of Benzene, Toluene, and the Xylenes," by Shuang-Ling Chong and J.L. Franklin	Journal of the American Chemical Society
66. "Local Dissipative Structures in Chemical Reactions with Heterogeneous Catalysis," by P. Ortoleva and J. Ross	Journal of Chemical Physics
67. "Comparison of the Absolute Quantum Yields of the Gas Phase O/NO Reaction and the Liquid Phase Luminescence Oxidation Chemiluminescence Light Standards," by Arthur Fontijn and John Lee	Journal of Chemical Physics
68. "Inviscid Free Jet Flow with Low Specific Heat Ratios," by James B. Anderson	AIAA Journal
69. "Asymptotic Analysis of Turbulent Channel and Boundary Layer Flow," by William B. Bush and Francis E. Fendell	Journal of Fluid Mechanics

Title and Author	Other Presentations
70. "Optical Model for Vibrational Relaxation in Reactive Systems," by Lise Lotte Poulsen, Jeffrey I. Steinfield and John Ross	Journal of Chemical Physics
71. "A Relation Between Reaction Probability and Inelastic Energy Transfer," by Robert G. Gilbert and John Ross	Journal of Chemical Physics
72. "Quasistatistical Complexes in Chemical Reactions," by Thomas F. George and John Ross	Journal of Chemical Physics
73. "Fluid Dynamics of Unsteady, Three-Dimensional and Separated Flows". Proceedings of a Workshop held at the Georgia Institute of Technology on June 10-11, 1971, edited by F.J. Marshall.	
74. "Aeroelasticity in Turbomachines". Proceedings of a Workshop held at Detroit Diesel Allison, Indianapolis, on June 1-2, 1972, edited by S. Fleeter.	
75. "The Use of the Laser Doppler Velocimeter for Flow Measurements". Proceedings of a Workshop held at Purdue University on March 9-10, 1972, edited by W.H. Stevenson and H.D. Thompson.	
76. "Turbulent Diffusion Flame in Couette Flow", by P.M. Chung	AIAA Preprint, No. 72-214
77. "Analysis of Symmetry in Chemical Reactions", by John Ross and Thomas F. George	Journal of Chemical Physics 55, 3851 (1971)
78. "Tubular Fast-Flow Reactor Studies at High Temperatures, I. Kinetics of the Fe/O ₂ Reaction at 1600 K", by Arthur Fontijn and S.C. Kurzius	Chemical Physics Letters
79. "Transport Coefficients of Gas Mixtures of Atomic and Molecular Hydrogen," by H. Wise	Chemical Physics Letters
80. "Structure of Low-Pressure Trimethylaluminum-Oxygen Flat Diffusion Flames," by George H. Markstein	Combustion Science and Technology

Title and Author

Other Presentations

81. "Local Structures in Chemical Reactions with Heterogeneous Catalysis," by Peter Ortoleva and John Ross
Journal of Chemical Physics,
Vol. 56, No. 9
82. "Molecular Beam Study of Polyatomic Free Radical Reactions. $\text{CH}_3 + \text{Cl}_2$ and Br_2 ," by D.L. McFadden, E.A. McCullough, Jr., F. Kafos, W.R. Gentry, and J. Ross
Journal of Chemical Physics
Vol. 57, No. 3
83. "Chemi-Ionization Reactions in a Gas Phase," by A. Fontijn
Progress in Reaction Kinetics
6, 75 (1972)
84. "Diffusion Flame in Homologous Turbulent Shear Flows," by P.M. Chung
Physics of Fluids 15, 1735
(1972)
85. "Turbulence Description of Couette Flow," by P.M. Chung
Physics of Fluids
86. "Transport Process in Turbulent Flow Fields with Two Dynamically Significant Scales," by R.J. Bywater and P.M. Chung
AIAA 6th Fluid and Plasma
Dynamics Conference, July 1973
87. "On the Performance of Turbulent Chemical Laser," by P.M. Chung
AIAA Journal
88. "Chemical Oscillations and Multiple Steady States due to Variable Boundary Permeability," by J. Ross, H. Hahn and P. Ortoleva
J. Theoretical Biology
89. "History of Physical Chemistry in Cambridge, Massachusetts," by J. Ross and E.B. Wilson
Annual Reviews of Physical
Chemistry
90. "Instrumentation for Flow Measurements in Turbomachine Rotors," by W.F. O'Brien and H.L. Moses
ASME Paper No. 72-GT-55
91. "Pressure Measurements on the Rotating Blades of an Axial-Flow Compressor," by M.F. Sexton, W.F. O'Brien and H.L. Moses
ASME Paper No. 73-GT-79
92. "Prediction of Turbulent Separated Boundary Layers," by Gary D. Kuhn
AIAA 6th Fluid and Plasma Dynamics
Conference, July (1973)
93. "Homogeneous and Teterogeneous Kinetics of the Atomic Al/O_2 Reaction in the 1000-1700 K Range," by A. Fontijn, W. Felder and J.J. Houghton
Fifteenth Symposium (International)
on Combustion

Title and Author	Other Presentations
94. "Fundamentals and Applications of Gas-Particle Flow," by G. Rudinger	Fluid Dynamics Panel (AGARD) Rome, Italy, September 1974
95. "On Turbulent Flows with Fast Chemical Reactions, Part III: Two-Dimensional Mixing with Highly Dilute Reactants," by P.A. Libby	Combustion Science and Technology
96. "Further Applications of Hot-Wire Anemometry to Measurements in Helium-Air Mixtures," by R.A. Stanford and P.A. Libby	Phy. of Fluids
97. "A Review of Some Theoretical Considerations of Turbulent Flame Structure," by F.A. Williams	Propulsion and Energetics Panel (Agard) Leige, Belgium, April 1974
98. "Studies Related to Turbulent Flows Involving Fast Chemical Reactions," by P.A. Libby	Propulsion and Energetics Panel (AGARD) Leige, Belgium, April 1974
99. "Ideas About Free Shear Flow Structures from Experiments on Turbulent Mixing Layers," by A. Roshko	Colloquium on Coherent Structures in Turbulence, Univ. of Southampton, March 1974
100. "Progress and Problems in Understanding Turbulent Shear Flows," by A. Roshko	SQUID Workshop on Turbulent Mixing, Purdue University, May 1974
101. "A Theoretical Criterion for Dynamic Extinction of Solid Propellants by Fast Depressurization," by J.S. T'ien	Combustion Science and Technology 9, 37 (1974)
102. "Comments on the Laser Raman Workshop on the Measurement of Gas Properties," by M. Lapp and C.M. Penney	GE Research and Development Report No. 74CRD064, May 1974
103. "Measurements and Gas Properties: Comments on the Laser Raman Workshop," by M. Lapp and C.M. Penney	Appl. Optics, 13 A14 (1974)
104. <u>Laser Raman Gas Diagnostics</u> , Ed. by M. Lapp and C.M. Penney	Plenum Press, New York (1974)
105. "Studies in Dissipative Phenomena with Biological Applications," by P. Ortoleva and J. Ross	Advances in Chem. Phys. (1974)
106. "On Symmetry Properties of Reaction Coordinates," by Horia Metiu, John Ross and Robert Silbey	J. Chem. Phys. (1974)

Title and Author

Other Presentations

107. "Nucleation in Systems with Multiple Stationary States," by A. Nitzan, P. Ortoleva and J. Ross
 108. "The ARL Axial-Flow Research Fan--A New Facility for Investigation of Time-Dependent Turbomachinery Flows," by E.P. Bruce
 109. "Design and Evaluation of Screens to Produce Multi-Cycle $\pm 20\%$ Amplitude Sinusoidal Velocity Profiles," by E.P. Bruce
 110. "Effect of Blade Row Geometry on Axial Flow Rotor Unsteady Response to Inflow Distortions," by R.E. Henderson and E.P. Bruce
 111. "Application of Raman Effect to Flowfield Diagnostics," by S. Lederman and J. Bornstein
 112. "Temperature and Specie Concentration Measurements in a Flow Field," by S. Lederman, M.H. Bloom, J. Bornstein and P.K. Khosla
 113. "Motion of a Spherical Particle in a Turbulent Flow," by P.K. Khosla and S. Lederman
 114. "The Chord-Wise Pressure Distribution on a Rotating Axial-Flow Compressor Blade," by H. L. Moses and W.F. O'Brien
 115. "A Multichannel Telemetry System for Flow Research on Turbo-machine Rotors," by W. O'Brien and H. Moses and H.R. Carter
 116. "On-Rotor Studies of Rotating Stall," by W. O'Brien and H. Moses
 117. "Relaxation Rates from Time-of-Flight Analysis of Molecular Beams," by R.J. Gallagher and J.B. Fenn
 118. "Rotational Relaxation in Molecular Hydrogen," by R. J. Gallagher and J. B. Fenn
- Discussions of Faraday Society on Chemical Instabilities, London
- ASME Paper No. 74-FE-27, (1974)
- AIAA Paper No. 74-623, 1974
- Project SQUID Workshop on Unsteady Flows in Jet Engines, 1974
- Progress in Astronautics and Aeronautics, 34, 1974
- Int'l. J. Heat & Mass Transfer
- PIBAL Report No. 73-22, 1973
- Proceedings, 2nd International Symposium on Air Breathing Engines, 1974
- ASME Paper No. 74-GT-112, 1974
- Project SQUID Workshop on Unsteady Flows in Jet Engines, 1974
- J. Chem. Phys. 60, 1974
- J. Chem. Phys. 60, 1974

Title and Author

119. "Rotational Relaxation in Molecular Nitrogen," by R.J. Gallagher and J.B. Fenn
120. "Clustering of Water on Hydrated Protons in a Supersonic Free Jet Expansion," by J.Q. Searcy and J.B. Fenn
121. "Analysis of Unsteady Transonic Channel Flow with Shock Waves," by G.K. Richey and T.C. Adamson, Jr.
122. "On the Flow Near a Weak Shock Wave Downstream of a Nozzle Throat," by A.F. Messiter and T.C. Adamson, Jr.
123. "Asymptotic Solutions for Nonsteady Transonic Channel Flows," by A.F. Messiter and T.C. Adamson, Jr.
124. "Unsteady Radial Transonic Flow with Shock Waves," by M. Sichel
125. "The Effect of Strain Rate on Diffusion Flames," by G.F. Carrier, F.E. Fendell and F.E. Marble
126. "Vortex Pairing: The Mechanism of Turbulent Mixing Layer Growth at Moderate Reynolds Number," by C.D. Winant and F.K. Browand
127. "Analysis of a Simple Circuit for Constant Temperature Anemometry," by P.D. Weidman and F.K. Browand
128. "Elementary Combustion Reaction Kinetic Measurements at Realistic Temperatures," by A. Fontijn
129. "Raman Scattering Studies of Combustion," by M. Lapp and D.L. Hartley
130. "The Role of Physics in Combustion" in Efficient Use of Energy, edited by D.L. Hartley, D.R. Hardesty, M. Lapp and F. Dryer

Other Presentations

- Proceedings of the 9th Symposium on Rarefied Gas Dynamics, 1974
- J. Chem. Phys.
- AIAA Paper No. 75-61 (1975)
- J. Fluid Mech., 69, 1975
- Symposium Transsonicum II, Göttingen, Germany, Sept. 1975
- Fluid Dynamics Transactions, 7, 1975
- SIAM J. Appl. Math., 28, March 1975
- JFM, 63, 1974
- J. Physics, 8, 1975
- AeroChem TA-112, May 1975
- Combustion Science and Technology and SQUID Workshop on Combustion Measurements in Jet Propulsion Systems (1975)
- American Institute of Physics Conference Proceedings No. 25 (1975)

Title and Author

Other Presentations

131. "Optical Diagnostics of Combustion Processes," by M. Lapp
 132. "Raman Band Contours for Water Vapor as a Function of Temperature," by J. Bribes, R. Gaufres, M. Monan, M. Lapp and C.M. Penney
 133. "Threshold Excitations, Relaxation Oscillations and Effect of Noise in an Enzyme Reaction," by H.S. Hahn, A. Nitzan, P. Ortoleva and J. Ross
 134. "On the Theory of Time Resolved Near-Resonance Light Scattering," by H. Metiu, A. Nitzan and John Ross
 135. "Theory of Propagation of Discontinuities in Kinetic Systems with Multiple Time Scales: Fronts and Pulses," by J. Ross and P. Ortoleva
 136. "A Stochastic Theory of Cluster Growth in Homogeneous Nucleation," by K. Kitahara, H. Metiu and J. Ross
 137. "Signature Analysis of Aerodynamic Flutter in a Rotating Blade," by J.W. Daws and W.F. O'Brien
 138. "An On-Rotor Investigation of Rotating Stall in an Axial-Flow Compressor Stage," by W.F. O'Brien, H.L. Moses and M.R. Sexton
 139. "Unsteady Effects on a Low Pressure Extinction Limit of Solid Propellants," by B.R. Baliga and J.S. T'ien
 140. "A Discussion on the Extinction Condition of a Diffusion Flame," by J.S. T'ien
- Proceedings of the Society of Photo-Optical Instrumentation Engineers, 61, Optical Methods in Energy Conversion (1975)
- GE Report No. 75CRD170 (1975)
- Proc. Nat. Acad. Sci., 71 (1974)
- J. Chem. Phys., 63 (1975)
- J. Chem. Phys. 1975
- J. Chem. Phys 1975
- Conference on "Application of Signature Analysis Techniques to Machine Reliability and Performance," N.E. College Aug. 1975
- Propulsion and Energetics Panel (AGARD) Sept. 1975
- AIAA Paper No. 75-229 (1975)
- J. Fire and Flammability, 6 1975

Title and Author

Other Presentations

141. "Flammability Study of Polymer Fuels using Counter-Flow Diffusion Flame Technique," by S. Singhal and J.S. T'ien
 142. "Turbulent Mixing in a Two-Dimensional Jet," by M.S. Uberoi and P.I. Singh
 143. "Experiments on Turbulent Structure and Heat Transfer in a Two-Dimensional Jet," by J. Bashir and M.S. Uberoi
 144. "Swirling Shallow Submerged Turbulent Plumes," by J.P. Narain
 145. "Three Dimensional Turbulent Wall Jet," by J.P. Narain
 146. "Some Observations on Condensation in Free Jets," by R.J. Gallagher, R.T.V. Kung and J.B. Fenn
 147. "Scattering of an Argon Beam by a Liquid Glycerine Surface," by M.P. Sinha and J.B. Fenn
 148. "On Aerodynamic Separation Methods," by R. Campargue, J.B. Anderson, J.B. Fenn, B.B. Hamel, E.P. Muntz and J.R. White
 149. "Elementary Combustion Reaction Kinetics Measurements over Large Temperature Ranges. The HTFER Technique," by A. Fontijn
 150. "Elementary Combustion Reaction Kinetic Measurements at Realistic Temperatures," by A. Fontijn
 151. "Concentration Measurement, by Fluorescence," by A. Fontijn
 152. "On Turbulent Flows with Fast Chemical Reactions. Part III: Two-Dimensional Mixing with Highly Dilute Reactants," by P.A. Libby
 153. "Diffusion of Heat Downstream of a Turbulence Grid," by P.A. Libby
- CWS Meeting of the Combustion Institute, April 1975
- Physics of Fluids, 18, 1975
- Physics of Fluids, 18, 1975
- ASME Paper 74-WA-APM-22, 1975
- The Canadian Journal of Chemical Engineering, 53, 1975
- 5th International Symposium on Molecular Beams, Nice, April 1975
- 5th International Symposium on Molecular Beams, Nice, April 1975
- Proceedings of the 1st European Nuclear Conference, Paris 1975
- AIAA Paper 76-131, January 1976
- Combustion Measurements in Modern Techniques and Instrumentation. R. Goulard, Ed. (Hemisphere Book Co., Washington, D.C. 1976)
- Ibid.
- Combustion Science and Technology, 13, 1976
- Astronautica Acta 2, 1975

Title and Author

154. "Remarks on a Kinetic-Theory Approach to Turbulent Chemically Reacting Flows," by P.A. Libby and R.A. Stanford
155. "An Experimental Investigation of Mixing in Two Dimensional Shear Flows with Applications to Diffusion-Limited Chemical Reactions," by John H. Konrad
156. "Unsteady Effects on the Low Pressure Limit of Solid Propellants," by B.R. Baliga and J.S. T'ien
157. "A Discussion of the Extinction Condition of a Diffusion Flame," by J.S. T'ien
158. "Swirling Shallow Submerged Turbulent Plumes," by J.P. Narain
159. "Stabilization of Turbulent Axisymmetric Rotating Flows," by J.P. Narain
160. "Turbulent Mixing in a Two-Dimensional Jet," by M.S. Uberoi and P.I. Singh
161. "Three-Dimensional Turbulent Wall Jet," by J.P. Narain
162. "Measurement Accuracy of Flow Velocity Via a Digital-Frequency-Counter Laser Velocimeter Processor," by J.C.F. Wang
163. "Laser Velocimeter Turbulence Spectra Measurements," by J.C.F. Wang
164. "Velocity Measurement of High-Temperature and High-Speed Subsonic Jet Flows Using Laser Velocimeter," by J.C.F. Wang

Other Presentations

- Combustion Science and Technology, 13, 1976
- Ph.D. Thesis, California Institute of Technology, 1976
- AIAA J., Vol. 13, 1975
- J. of Fire and Flammability, Vol. 6 1975
- J. of Hydraulics Division, ASCE Vol. 100, 1974
- ASME paper 74-WA-APM-22, 1974
- The Physics of Fluids, Vol. 18, 1975
- The Canadian Journal of Chemical Engineering, Vol. 53, 1975
- Proceedings of the LDA-Symposium (Copenhagen, 1975)
- Proceedings of the Minnesota Short Course and Symposium on Laser Anemometry (Minnesota, 1975)
- Presented at the AGARD/ISL Workshop on Laser Velocimetry at the French-German Research Institute, St. Louis, France (May 1976); also General Electric Report 76CRD136, 1976

AD-A088 006

PURDUE UNIV LAFAYETTE IN PROJECT SQUID HEADQUARTERS

F/G 21/5

PROJECT SQUID.(U)

FEB 80 R F H06LUND, R GOULARD, S N MURTHY

N00014-75-C-1143

UNCLASSIFIED

SQUID-PU-R2-80

NL

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

3-3

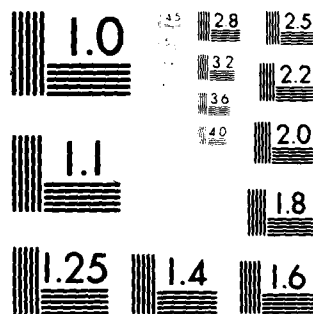
END

DATE

FILED

9-80

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1010-A

Title and Author

Other Presentations

165. "Physics in Combustion Research," by D. Hartley, M. Lapp and D. Hardesty
Physics Today 28, 1975
166. "Raman Band Contours for Water Vapor as a Function of Temperature," by J.L. Bribes, R. Gaufres, M. Monan, M. Lapp and C.M. Penney
Appl. Phys. Lett. 28, 1976
167. "Raman-Scattering Cross Sections for Water Vapor," by C.M. Penney and M. Lapp
J. Opt. Soc. Am. 66, 1976
168. "Optical Diagnostics of Combustion Processes," in Optical Methods in Energy Conversion, by M. Lapp, ed. by M. Lubin
Proceedings of the Society of Photo-Optical Instrumentation Engineers, Vol. 61, 1975
169. "Raman Scattering Studies of Combustion," by M. Lapp and D.L. Hartley
Combustion, Comb. Sci. Tech. 13, 1976; also in Combustion Measurements Modern Techniques and Instrumentation, ed. R. Goulard (1976)
170. "Concentration Enhancement in Laser Induced Mass Separation," by J. Kline and J. Ross
J. Chem. Phys. 63, 1975
171. "Derivation of Stochastic Equations for Nonequilibrium Ising Mean Field Model," by K. Kitahara, H. Metiu and J. Ross
J. Chem. Phys. 63, 1975
172. "Symmetry Rules for Nonconcerted Reactions," by H. Metiu, T. George and J. Ross
Chem. Phys. 11, 1975
173. "Stochastic Theory of the Kinetics of Phase Transitions," by H. Metiu, K. Kitahara and J. Ross
J. Chem. Phys. 64, 1976
174. "Molecular Beam Studies of Methyl Radical Reactions with Halogen Molecules: Product Angular and Velocity Distributions," by J. Makowski, C. Mims, G.W. Stewart and J. Ross
J. Chem. Phys. 64, 1976
175. "Photodissociation of NO₂ in the Region 458 to 630 nm," by C.L. Creel and J. Ross
J. Chem. Phys. 64, 1976
176. "A Derivation and Comparison of Two Equations (Landau-Ginzburg and Cahn) for the Kinetics of Phase Transitions," by H. Metiu, K. Kitahara and J. Ross
J. Chem. Phys. 65, 1976

- | <u>Title and Author</u> | <u>Other Presentations</u> |
|---|---|
| 177. "Nonequilibrium Kinetics: Exact and Approximate Solutions,"
by S. Hudson and J. Ross | J. Stat. Phys. <u>14</u> , 1976 |
| 178. "Formation of Temporal and Spatial Structures Through Chemical
Instabilities," by J. Ross | Berichte der Bunsen-Gesellschaft,
1976 |
| 179. "Modern Diagnostics of Combustion," by S. Lederman | AIAA Paper No. 76-26 |
| 180. "Some Applications of Laser Diagnostics to Fluid
Dynamics," by S. Lederman | AIAA Paper No. 76-21 |
| 181. "An On-Rotor Investigation of Rotating Stall in an Axial-
Flow Compressor," by M.R. Sexton, W.F. O'Brien and H.L. Moses | In Unsteady Flow in Turbomachinery
AGARD Conf. Proc. No. 177, Monterey,
Cal. Sept. 1975 |
| 182. "Pressure Distribution on a Rotating Axial-Flow Compressor
Blade," by P.E. Schultz | M.S. Thesis, Mech. Engr. Dept.
Va. Poly. Inst. and State Univ., 1976 |
| 183. "The Lift Response of a Rotating Blade of an Axial-Flow
Compressor to Inlet Flow Distortion," by T.E. Neal | M.S. Thesis, Mech. Engr. Dept.
Va. Poly. Inst. and State Univ., 1975 |
| 184. "The Design and Operation of the VPI&SU High-Speed Turbo-
machinery Facility," by R.R. Jones | M.S. Thesis, Mech. Engr. Dept.
Va. Poly. Inst. and State Univ., 1975 |
| 185. "Clustering of Water on Hydrated Protons in a Supersonic
Free Jet Expansion," by J.Q. Searcy and J.B. Fenn | J. Chem. Phys. 61, 1974 |
| 186. "A Kinetic Model for Clustering of Water on Hydrated Protons
in a Supersonic Free Jet Expansion," by J.Q. Searcy | J. Chem. Phys. 63, 1975 |
| 187. "Scattering of Argon by a Liquid Glycerine Surface," by
M.P. Sinha and J.B. Fenn | Proc. 5th Int. Symp. on Molecular
Beams, Nice, 1975 |
| 188. "Interaction Effects in Turbulent Premixed Flames," by K.N.C.
Bray and P.A. Libby | Phys. of Fluids, <u>19</u> , 1976 |
| 189. "Structure of Turbulent Shear Flows: A New Look," by A. Roshko | AIAA Journal <u>14</u> , 1976; Dryden Research
Lecture |

Author and TitleOther Presentations

190. "The Mixing Layer at High Reynolds Number: Large-Structure Dynamics and Entrainment," by P.E. Dimotakis and G.L. Brown
191. "Detailed Study of the Q-Branch Profile of the ν_1 of Water Molecule from 293 K to 1400 K," by J.L. Briber, R. Gaufres, M. Monan, M. Lapp and C.M. Penney
192. "Superradiance and Energy Transfer Within a System of Atoms," by P. Stone, A. Nitzan and John Ross
193. "Dynamical Theory of Migration of an Absorbed Atom on Solid Surfaces," by C.L. Creel and John Ross
194. "Experimental Techniques Applicable to Turbulent Flows,"
195. "Experimentally Determined Stability Parameters of a Subsonic Cascade Oscillating Near Stall," by F.O. Carta, and A.O. St. Hilaire
196. "Effects of Laser Modulated Particulate Incandescence on Laser Raman Scattering Diagnostics," by A.C. Eckbreth
197. "Variable Density Effects in Turbulent Premixed Flames," by P.A. Libby and K.N.C. Bray
198. "Structure of a Turbulent Swirl," by M.S. Uberoi
199. "Transonic Channel Flow with Strong Incoming Shear," by T.C. Adamson, Jr. and M. Sichel
200. "On the Quasiadiabatic Description of the Dynamics of Electronically Adiabatic Chemical Reactions," by Mukamel, Shaul and John Ross

JFM 78, 1976

Proceedings of the Fifth International Conference on Raman Spectroscopy, Universitat Freiburg, 1976, ed. by E.D. Schmid et al. (Hans Ferdinand Schulz Verlag, Freiburg im Breisgau, 1976)

Physica 84A, 1 (1976)

J. Chem. Phys. 65, 1976

Pres. at the AIAA 15th Aerospace Sciences Meeting in Los Angeles, Cal., Jan. 1977, AIAA Paper No. 77-213

ASME Paper No. 77-GT-47, March 1977

J. Applied Physics, October 1977

AIAA J. 15, 1186-1193, 1977

The Physics of Fluids, Vol 20, No. 5, May 1977.

Presented at the XIIth Biennial Fluid Dynamics Symposium, Advanced Problems and Methods in Fluid Mechanics, Sept. 1977, Olsztyn, Poland

J. Chem. Phys. 66, 3749, 1977

- | <u>Title and Author</u> | <u>Other Presentations</u> |
|---|--|
| 201. "Formation of Ensembles with Constraints and Coherence," by Procaccia, Itamar, Shaul, Mukamel, and John Ross. | J. Chem. Phys. <u>66</u> , 5064, 1977 |
| 202. "Comment on Non-Statistical Behavior in Laser Chemistry and Chemical Activation," by Mukamel, Shaul and John Ross | J. Chem. Phys. <u>66</u> , 5235, 1977 |
| 203. "Aperiodic and Periodic Oscillations in Fluorescence Intensity from Irradiated Chlorocarbon Solutions of Anthracene and 9, 10-Dimethylanthracene," by Robert L. Bose, John Ross and Mark S. Wrighton | J. Am. Chem. Soc. <u>99</u> , 1977 |
| 204. "Raman Measurements on Flames," by M. Lapp and C.M. Penney | <u>Advances in Infrared and Raman Spectroscopy</u> , Vol. 3, Ed. by Clark, R.J.H. and R.E. Hester. Heyden and Son Ltd., London, Chapt 6.

AIAA Paper No. 77-48, 1977 |
| 205. "Measurements on Turbulent Hydrogen Flames in a Circular Air Duct," J.C.F Wang and B.W. Gerhold | J. Chem. Phys. <u>66</u> , 1021, 1977 |
| 206. "Franck-Condon Factors in Studies of Dynamics of Chemical Reactions. I. General Theory, Application to Collinear Atom-Diatom Reactions," by George C. Schatz and John Ross | J. Chem. Phys. <u>66</u> , 1037, 1977 |
| 207. "Franck-Condon Factors in Studies of Dynamics of Chemical Reactions. II. Vibration-Rotation Distributions in Atom-Diatom Reactions," by George C. Schatz and John Ross | J. Chem. Phys. <u>66</u> , 2943, 1977 |
| 208. "Franck-Condon Factors in Studies of the Dynamics of Chemical Reactions. III. Analysis of Information Theory for Vibration-Rotation Distributions and Isotopic Branching Ratios," by George C. Schatz and John Ross. | J. Chem. Phys. <u>66</u> , 3609, 1977 |
| 209. "On Stochastic Reductions in Molecular Collision Theory: Projection Operator Formalism; Application to Classical and Quantum Forced Oscillator Model," by George C. Schatz, Frank J. McLafferty and John Ross | J. Chem. Phys. <u>66</u> , 3640, 1977 |
| 210. "Cooperative Instability Phenomena in Arrays of Catalytic Sites," by Bimpong-Bota, E.K., A. Nitzan, P. Ortoleva and John Ross. | |

Title and AuthorOther Presentations

211. "Coherent and Diffusional Motion of a Chemisorbed Atom,"
H. Metiu, K. Kitahara, R. Silbey and John Ross.
212. "Temporal and Spatial Structures in Chemical Instabilities,"
John Ross
213. "Some Applications of Laser Diagnostics to Fluid Dynamics,"
by S. Lederman
214. "Modern Diagnostics of Combustion," by S. Lederman
215. "Experimental Investigation of Coaxial Turbulent Jets,"
by S. Lederman
216. "HTFER Kinetics Studies of $A1 + CO_2 \rightarrow A1O + CO$ from 300 to
1900 K, A Non-Arrhenius Reaction," by A. Fontijn and W. Felder
217. "Aspects of Turbulent Combustion," by A.K. Varma, E.S. Fish-
burne and C. duP. Donaldson
218. "Investigations of Chemical Reactions in a Turbulent Media," by
E.S. Fishburne and A.K. Varma
219. "The V.P.I. Gas Turbine and Turbomachinery Research
Laboratory," by W.F. O'Brien, H.L. Moses, R.R. Jones and
J.F. Sparks
220. "Blade Pressure Distributions During Surge of an Axial-
Flow Compressor," by C. Jones
221. "An Experimental Study of Rotating Stall in an Axial-Flow
Compressor," by G. Verdesoto
- Chem. Phys. Letters 43, 189
1976
- Ber. Bunsenges, 80, 1112 (1976)
- Pres. at the AIAA 14 Aerospace
Sciences Mtg., Washington D.C. Jan.,
1976, AIAA Paper No. 76-21
- Pres. at the AIAA 14th Aerospace
Sciences Mtg., Washington, D.C., Jan.
1976, AIAA Paper No. 76-26; Published
in Experimental Diagnostics in Gas
Phase Combustion Systems, Vol. 53,
Ed. Ben T. Zinn
- Collection of Technical Papers of
the 18th Israel Annual Conference on
Aviation and Astronautics, Weizman
Science Press, May, 1976
- J. Chem. Phys. 67, 1561 (1977)
- AIAA 15th Aerospace Sciences
Meeting, AIAA Paper No. 77-100,
Jan. 1977.
- Presented at the Sixth International
Colloquium on Gasdynamics of Explo-
sions and Reactive Systems, Stockholm,
Sweden, August, 1977
- ASME Paper No. 77-GT-73, March 1977
- M.S. Thesis, VPI&SU, August, 1977
- M.S. Thesis, VPI&SU, Sept. 1977

Title and Author

222. "Performance and Stalling Behavior of an Axial-Flow Compressor Subjected to Three Circumferential Distortion Levels," by W. Gauden
223. "Simultaneous Solution of the Boundary Layer and Free Stream with Separated Flow," by H.L. Moses, R.R. Jones, W.F. O'Brien and R.S. Peterson
224. "The Study of Flames by Raman Spectroscopy," by M. Lapp
225. "Measurements in Highly Turbulent Flows: Steady and Unsteady Separated Turbulent Boundary Layers," by R.L. Simpson and Y.-T. Chew
226. "CARS Investigations in Flames," by A.C. Eckbreth
227. "Combustion Diagnostics by Coherent Anti-Stokes Raman Spectroscopy," by R.J. Hall and A.C. Eckbreth
228. "CARS Diagnostic Investigations of Flames," by A.C. Eckbreth and R. J. Hall
229. "Unsteady Transonic Flows with Shock Waves in an Asymmetric Channel," by John S.-K. Chan and T.C. Adamson, Jr.
230. "An Experimental Study of Large-Scale Structure Interactions in a Two-Dimensional Turbulent Mixing Layer," by B.O. Latigo and F.K. Browand

Other Presentations

M.S. Thesis, VPI&SU, Sept. 1977

AIAA J., V 16, No. 1, Jan. 1978

Proceedings of the Sixth International Conference on Raman Spectroscopy, Vol 1, ed. by E.D. Schmid, R.S. Krishnan, W. Kiefer and H.W. Shrotter (Heyden and Son Ltd., London, 1978)

Invited Paper, Third International Workshop on Laser Velocimetry, July, 1978

Paper presented at the XVIIth Symposium (International) on Combustion, Leeds, England, August, 1978

Paper presented at the SPIE 22nd International Technical Symposium and Instrument Display, August, 1978, San Diego, CA

Invited paper presented at the NBS 10th Materials Research Symposium on Characterization of High Temperature Vapors and Gases, Sept. 1978, Gaithersburg, MD

AIAA Journal, Vol. 16, April 1978

Bulletin of the American Physical Society, Nov. 1978, (abstract of paper presentation, APS Division of Fluid Dynamics, Los Angeles, CA)

Title and AuthorOther Presentations

231. "Cascade Performance of a Double Arc Compressor Blade at Low Reynolds Number," by Keller and J. Urs
232. "The Use of Laser Raman Diagnostics in Flow Fields and Combustion," by S. Lederman
233. "The Application of Laser Scattering to Flow Field Diagnostics," by S. Lederman
234. "An Experiment on Spontaneous Flame Oscillation Prior to Extinction," by W.Y. Chan and J.S. T'ien
235. "Stochastic Reduction for Dynamics of Reactions with Complex Formation," by D.J. Zvijac, S. Mukamel and John Ross
236. "The 1977 Nobel Prize in Chemistry," by I. Procaccia and John Ross
237. "Stability and Relative Stability in Reactive Systems Far from Equilibrium. I. Thermodynamic Analysis," by I. Procaccia and John Ross
238. "Stability and Relative Stability in Reactive Systems Far from Equilibrium. II. Kinetic Analysis of Relative Stability of Multiple Stationary States," by I. Procaccia and John Ross
239. "Investigations of Chemical Reactions in a Turbulent Media," by Ashkok K. Varma
- 239/1 "A Shock Tube Study of the Recombination of Carbon Monoxide and Oxygen Atoms," by A. M. Dean
240. "Large Scales in the Developing Mixing Layer," by F.K. Browand and P.D. Weidman
- M.S. Thesis, VPI&SU, Oct. 1978
- Published in Prog. Energy Combust. Sci., 3, 1977
- Proc. of Second Bat-Sheva Seminar on MHD-flows and Turbulence held at the Ben-Gurion University of the Negev, March, 1978, Beer-Sheva, Israel
- AIAA Paper No. 77-184
- J. Chem. Phys. 67 2007 (1977)
- Science 198, 716 (1977)
- J. Chem. Phys. 67, 5558 (1977)
- J. Chem. Phys. 67, 5565 (1977)
- Paper presented at the 6th Int'l Colloquium on Gasdynamics of Explosions and Reactive Systems, Stockholm, Sweden, Aug. 1977
- J. Chem. Phys., 66, 598 (1977)
- J. Fluid Mech., 76, 1976

Title and Author

Other Presentations

241. "Three Dimensional Transonic Flow in Channels,"
by M. Sichel and T.C. Adamson, Jr.
 242. "Kinetics of Aerosol Formation in Irradiated Gaseous
 $\text{NO}_2\text{-SO}_2$ Mixtures," by K. Iwamoto, N. Presser and J. Ross
 243. "Consequences of Size Dependence of Transition Probabilities in
Stochastic Equations," by S. Mukamel, I. Procaccia and J. Ross
 244. "Modeling of Scalar Correlations in Turbulent Mixing and
Reacting Flows," by Ashok K. Varma
 245. "Modeling of Scalar Probability Density Functions in Turbu-
lent Mixing and Reacting Flows," by Ashok K. Varma
 246. "Secondary Structures in Mixing Layers," by L. Bernal and
A. Roshko
 247. "Averaging Considerations for Pulsed, Laser Raman Signals
from Turbulent Combustion Media," by A.C. Eckbreth
 248. "A Shock Tube Study of the $\text{H}_2/\text{O}_2/\text{CO}/\text{Ar}$ and $\text{H}_2/\text{N}_2/\text{O}/\text{CO}/\text{Ar}$
Systems," by A. M. Dean
 249. "Experimentally Determined Stability Parameters of a Subsonic
Cascade Oscillating Near Stall," by F.O. Carta and A.O. St.
Hilaire
 250. "Chemical Relaxation Pulses and Waves. Analysis of Lowest
Order Multiple Time Scale Expansion," by M. Collins and
J. Ross
 251. "Statistical Reduction for Strongly Driven Simple Quantum
Systems," by S. Mukamel, I. Oppenheim and J. Ross
 252. "On the Theory of Unimolecular Reactions: Application of
Mean First Passage time to Reaction Rates," by I. Procaccia,
S. Mukamel and J. Ross
- Presented at 13th Biennial Fluid
Dynamics Symposium, Sept. 1977, Olsztyn,
Poland
- J. Chem. Phys. 68, 663 (1978)
- J. Chem. Phys. 68, 1205 (1978)
- Paper presented at the 1978 Int'l
Conference on Physicochemical Hydro-
dynamics (the Levich Conf.), Wash.D.C.
Nov. 1978
- Paper presented at the 71st Meeting
of the American Institute of Chemical
Engineers, Miami, FL, Nov. 1978
- Presented at the 31st Reg. Meeting of
the Division of Fluid Dynamics American
Physical Society, Nov. 1978; Bulletin
of the American Physical Society 23,
1978
- Combust. Flame, Vol. 31, 1978
- Combust. and Flame, 32, 73 (1978)
- Transactions, ASME, Journ. of Engineering
for Power, Vol. 100, No. 1, Jan. 1978
- J. Chem. Phys. (in press)
- Physical Review (in press)
- J. Chem. Phys. (in press)

Title and Author

Other Presentations

253. "A Basis for Orbital Symmetry Rules," by H. Metiu, G.M. Whitesides and J. Ross
Angew. Chemie (in press)
254. "Statistical Mechanical Theory of the Kinetics of Phase Transitions," by H. Metiu, K. Kitahara and J. Ross
Adv. Stat. Mech. (in press)
255. "Remarks on Chemical Instabilities," by J. Ross
Proceedings of the XVth Solvay Conf. to appear in Advances in Chemical Physics, Wiley-Interscience, N.Y., (in press)
256. "Instability and Far-from-equilibrium States of Chemically Reacting Systems," by P. Hanesse, P. Ortoleva and J. Ross
Advances in Chemical Physics (in press)
257. "Franck-Condon Factors in Studies of Dynamics of Chemical Reactions. IV. Non-adiabatic Collisions," by D.J. Zvijac and J. Ross
J. Chem. Phys. (in press)
258. "On the Efficiency of Rate Processes," by D. Gutkowitz-Krusin, I. Procaccia and J. Ross
J. Chem. Phys. (submitted)
259. "Analytic Results for Asymmetric Random Walk with Exponential Transition Probabilities," by D. Gutkowitz-Krusin, I. Procaccia and J. Ross
J. Stat. Phys. (submitted)
260. "Comment on 'Rate of Polymorphic Transformation Between Phase II and III of Hexachloroethane'," by H. Metiu and J. Ross
J. Chem. Soc. (submitted)
261. "Kinetic Instabilities in First Order Phase Transitions," by R. Lovett, P. Ortoleva and J. Ross
J. Chem. Phys. (submitted)
262. "Development of Three Dimensionality in Turbulent Mixing Layers," by L.P. Bernal, R.E. Breidenthal, G.L. Brown, J.H. Konrad and A. Roshko.
Proceedings 2nd Symposium on Turbulent Shear Flows, Imperial College, London, July, 1979
263. "Effects of Finite Reaction Rate and Molecular Transport in Premixed Turbulent Combustion," by P.A. Libby, K.N.C. Bray and J.B. Moss
Combust. Flame 34 (1979)
264. "A Non-Gradient Theory for Premixed Turbulent Flames," by P.A. Libby
Mech. Today 5 (accepted)
265. "Preferential Entrainment in a Two-Dimensional Turbulent Jet in a Moving Stream," by P. Anderson, J.C. LaRue and P.A. Libby
Phys. Fluids (accepted)

Title and Author

Other Presentations

266. "Decomposition of n-butane," by S.N. Vaughn, J.F. Merklin and T.W. Lester
 267. "Temperature, Concentration and Velocity in Jets, Flames and Shock Tubes," by S. Lederman, A. Celentano and J. Glaser
 268. "A Wall-Flow-Direction Probe for Use in Separating and Reattaching Flows," by J.K. Eaton, A.H. Jeans, J. Ashjaee and J.P. Johnston
 269. "Measurements in a Reattaching Turbulent Shear Layer," By J.K. Eaton, J.P. Johnston and A.H. Jeans.
 270. "Straight-Walled, Two-Dimensional Diffusers -- Transitory Stall and Peak Pressure Recovery," by J. Ashjaee and J.P. Johnston
 271. "Response Behavior of Hot-Wires in a Skewed Mean Flow," by F.B. Gessner and M.T. Littlefield
 272. "CARS Investigations in Sooting and Turbulent Flames" by A.C. Eckbreth
 273. "Investigations of Coherent Anti-Stokes Raman Spectroscopy (CARS) for Combustion Diagnostics," by A.C. Eckbreth, R.J. Hall and J.A. Shirley
 274. "CARS Thermometry in a Sooting Flame," by A.C. Eckbreth and R.J. Hall
 275. "Shock Tube Studies of Formaldehyde Pyrolysis," by A.M. Dean
 276. "Shock Tube Studies of Formaldehyde Oxidation," by A.M. Dean
 277. "Instantaneous Two-Dimensional Concentration Measurements in a Jet Flow by Mie Scattering," M.B. Long, B.F. Webber and R.K. Chang
- J. Chem. Phys. (submitted)
- Phys. of Fluids, 22, 1065 (1979)
- Journal of Fluids Engineering (Trans. ASME) 1979
- Proceedings of the 2nd Symposium on Turbulent Shear Flows, July 1979 Imperial College, London.
- Presented at the ASME meeting, Dec. 1979, Symposium on 'Flow in Primary, Non-Rotating Passages in Turbomachines'
- To be submitted to JFM for publication
- Project SQUID Technical Report UTRC-5-PU, March 1979
- AIAA Paper 79-0083, New Orleans, LA. January 1979
- Combust. Flame, Vol. 36, Sept. 1979
- 17th Symposium (International) on Combustion (in press)
- Combust. and Flame (submitted)
- Appl. Phys. Lett. 34, 22 (1979)

<u>Title and Author</u>	<u>Other Presentations</u>
278. "Specie Specific Two-Dimensional Average Concentration Measurements in a Jet Flow by Raman Scattering," by B.F. Webber, M.B. Long and R.K. Chang	Appl. Phys. Lett. (submitted)
279. "Spatially Resolved Coherent anti-Stokes Raman Spectroscopy from a Line across a CH_4 Jet," by D.V. Murphy, M.B. Long and R.K. Chang and A.C. Eckbreth	Opt. Lett., June 1979
280. "Effect of Interblade Phase Angle and Incidence Angle on Cascade Pitching Stability," by F.O. Carta and A.O. St. Hilaire	Presented at the ASME Gas Turbine Conf., San Diego, CA, March 1979, Paper No. 79-GT-153. (To be published in Transactions, ASME Journal of Engineering for Power)
281. "Growth of the Two-Dimensional Mixing Layer from a Turbulent and Nonturbulent Boundary Layer," by F.K. Browand and B.O. Latigo	Physics of Fluids <u>22</u> , 1979
282. "Large Scale Structure Interactions in a Two-Dimensional Turbulent Mixing Layer," by B.O. Latigo	Ph.D. Thesis presented to the Univ. of Southern California, Jan. 1979
283. "A Visual Investigation of Turbulence in Stagnation Flow about a Circular Cylinder," by W. Sadeh	Forthcoming in Journal of Fluid Mechanics

4. REVIEWS, WORKSHOPS AND COLLOQUIA

Technical reviews on selected subjects of basic research interest in propulsion were funded under Project SQUID. Each review was expected to provide a critical summary of the current state of research in the chosen subject along with a statement of fruitful directions for further research.

A Project SQUID Workshop had the following general objectives.

- 1) Providing a meeting ground for specialists and persons with definite interest in a selected subject, selected from industry, university institutions and government representatives from in-house laboratories and funding agencies.
- 2) In-depth discussion of the subject with the aid of invited papers.
- 3) Determination of useful directions for further research.

The subject for a Workshop was selected on the basis of long-term needs of the Navy in jet propulsion, taking into account the current and future thrust areas of Project SQUID.

Project SQUID Workshops were sponsored by the ONR, in most cases in cooperation with other selected funding agencies.

The Proceedings of Workshops were published as reports and made available for purchase, as all other SQUID - Technical Reports were made available, through the NTIS.

The proceedings have also become available through general publishers in several cases.

A Project SQUID Colloquium was defined as a meeting of carefully-

selected specialists deeply and personally involved in research in the subject of the Colloquium. The principal objective of a Colloquium was an in-depth discussion of the current state of research or development in the selected subject and the determination, by the participating specialists, of specific and precise needs for advances in the subject. The emphasis in a Colloquium was on a carefully-selected narrow technical/scientific area and on providing a forum for those who were actively engaged in research in the chosen area.

The proceedings of Colloquia have been published and made available by the ONR in various forms to the general public.

4.1. Technical Reviews

4.1.1. Turbulent Mixing

- a) Author: S.N.B. Murthy
- b) Publication Reference: Turbulent Mixing in Nonreactive and Reactive Flows. Edited by S.N.B. Murthy. Plenum Press: New York, 1975.

4.1.2. Combustion Measurements

- a) Author: R. Goulard
- b) Publication Reference: Combustion Measurements. Modern Techniques and Instrumentation. Edited by R. Goulard. Hemisphere Publishing Corporation: Washington, 1976.

4.1.3. Gas Turbine Combustor Design Problems

- a) Author: Arthur H. Lefebvre
- b) Publication Reference: Gas Turbine Combustor Design Problems. Edited by Arthur H. Lefebvre. Hemisphere Publishing Corporation: Washington, 1978.

4.2 Workshops

4.2.1 Gas Turbine Combustor Design Problems

- a) Chairman: A.H. Lefebvre, Purdue University, West Lafayette, Indiana.
- b) Sponsored by: Air Force Office of Scientific Research, Naval Air Systems Command and Office of Naval Research (Power Program).
- c) Date: May 31-June 1, 1978.
- d) Place: Purdue University, West Lafayette, Indiana.
- e) References to Proceedings:
 - 1. Report No. PU-RI-80: Proceedings of Workshop on Gas Turbine Combustor Design Problems.
Edited by A.H. Lefebvre, Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1980. Note that the reference number required for obtaining this document from the NTIS is not available at the date of this Report.
 - 2. Gas Turbine Combustor Design Problems
Edited by A.H. Lefebvre, Hemisphere Publishing Corporation, Washington D.C., 1980.
- f) Contents of Proceedings
Preface: Welcoming Remarks. Introduction. PROBLEMS IN GAS TURBINE COMBUSTORS: Problems and Promises in Gas Turbine Design Development. COMBUSTOR AERODYNAMICS: Performance of the Vortex-controlled Diffuser (VCD) in an Annular Combustor Flowpath. Noise from Gas Turbine Combustors. FUELS AND COMBUSTION: Fuel Property Effects on Combustor Performance. Problems due to Multifuel Operation of Gas Turbine Combustors. Residual Fuel Combustion in Industrial Gas Turbines. PATTERN FACTOR AND WALL TEMPERATURE: Pattern Factor Analysis. Gas Turbine Combustor Liner Durability - The Hot Streak Problem. Combustor Cooling - Old Problems and New Approaches. RELIGHTING: Basic Ignition Related to Altitude Relight Problems. EMISSIONS: Gas Turbine Engine Emissions Abatement - Status and Needed Advancements. Combustion of Coal-

derived Liquids and Shale Oil in Gas Turbine Combustors.
MODELING: Introduction to Sections on Modeling, Diagnostics,
and Measurement. Three-dimensional Two-Phase Mathematical
Modelling of Gas Turbine Combustors. Coalescence/Dispersion
Modeling of Gas Turbine Combustors. DIAGNOSTICS AND MEASURE-
MENTS: Spray Diagnostics. Spatially Precise Laser Diagnostics
for Practical Combustor Probing. PANEL DISCUSSION: Panel
Discussion. SUMMARY: Summary and Observations. Workshop
Participants.

4.2 Workshops

4.2.2 Alternative Hydrocarbon Fuels: Combustion and Chemical Kinetics

- a) Chairmen: Craig T. Bowman, Stanford University, Stanford, California, and Jorgen Birkeland, Department of Energy, Washington, D.C.
- b) Sponsored by: Department of Energy, Air Force of Scientific Research, Naval Air Systems Command, Office of Naval Research.
- c) Date: September 7-9, 1977.
- d) Place: Loyola College Conference Center, Columbia, Md.
- e) References to Proceedings:

1. Report No. PU-R2-78. Proceedings of Workshop on Alternative Hydrocarbon Fuels: Combustion and Chemical Kinetics.
 Edited by Craig T. Bowman and Jorgen Birkeland. Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1978. Reference No. AD 061 050.

2. Alternative Hydrocarbon Fuels: Combustion and Chemical Kinetics.

Edited by Craig T. Bowman and Jorgen Birkeland, American Institute of Aeronautics and Astronautics, New York, 1978.

f) Contents of Proceedings

Preface. INTRODUCTION. ALTERNATIVE FUEL AVAILABILITY AND ANTICIPATED COMBUSTION PROBLEMS. Alternative fuels and Combustion Problems. Future Fuels in Gas Turbine Engines. Alternative Fuels for Reciprocating Internal Combustion Engines. Use of Alternative Fuels in Stationary Combustors. CRITICAL PROCESSES IN COMBUSTION OF ALTERNATIVE FUELS. Ignition/Stabilization/Atomization: Alternative Fuels in Gas Turbine Combustors. Combustion and Chemical Kinetics Problems in Internal Combustion Engines. Combustion of Droplets and Sprays of Some Alternative Fuels. Flame Emissivities: Alternative Fuels. PYROLYSIS AND OXIDATION

KINETICS OF ALTERNATIVE FUELS. Pyrolysis and Oxidation of Aromatic Compounds. Combustion Chemistry of Chain Hydrocarbons. Liquid-Phase Reactions of Vaporizing. Hydrocarbon Fuels. POLLUTANT EMISSIONS CONSIDERATIONS FOR ALTERNATIVE FUEL COMBUSTION. Role of Aromatics in Soot Formation. Kinetics of Nitric Oxide Formation in Combustion. Emission Control Techniques for Alternative Fuel Combustion. SUMMARY AND CONCLUSIONS. Panel Discussion: Alternative Fuels Policy. Panel Discussion: Alternative Fuels Technology. Index to Contributors to Volume 62.

4.2.3. Cooling Problems in Aircraft Gas Turbines

- a) Chairman: A.D. Wood, ONR Branch Office, Boston, Mass.
- b) Sponsored by: Naval Air Systems Command, Office of Naval Research.
- c) Date: September 27-28, 1978.
- d) Place: Naval Post Graduate School, Monterey, Calif.
- e) Reference to Proceedings:
 - 1. A summary report on the Workshop submitted by A.D. Wood.

4.2.4 Engine-Airframe Integration

- a) Chairman: S.N.B. Murthy, Purdue University, West Lafayette, Indiana.
- b) Sponsored by: Air Force Office of Scientific Research, Naval Air Systems Command, Office of Naval Research.
- c) Date: May 11-12, 1977.
- d) Place: Naval Academy, Annapolis, Maryland.
- e) References to Proceedings;
 - 1. Report No. PU-RI-78. Proceedings of Workshop on Engine-Airframe Integration.
Edited by S.N.B. Murthy. Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1978. Reference No.
- f) Contents of Proceedings

Preface. Welcoming Remarks. V/STOL Aircraft Design Consideration. From the AMST to the Future. Propulsion Technology needs for V/STOL Aircraft. Engine-Airframe Integration, Current Practices and Future Requirements for Army Aircraft. Engine Cycle Considerations and Associated Installation Problems for Short Haul Aircraft. The Shaft Coupled Lift/Cruise Fan Propulsion System for V/STOL Aircraft. Flight/Propulsion Control Systems for 1990 Applications. Propulsion Research Requirements for Powered Lift Aircraft. Computational Methods in Predicting Airframe Propulsion System Interaction. Effects of Over-The-Wing Pylon-Mounted Engines on Transport Airplane Performance. Upper Surface Blowing Aerodynamic and Acoustic Characteristics. Thrust Augmentation and Noise Attenuation of Ejector Shrouds. Compatibility Technology Requirements. Propulsion Induced Effects for VTOL Aircraft in Ground Effect. The Airjet Distortion Generator System: A New Tool for Aircraft Turbine Engine Testing. General Discussion. Summary and Recommendations.

4.2.5 Turbulence in Internal Flows

- a) Chairman: S.N.B. Murthy, Purdue University, West Lafayette, Indiana.
- b) Sponsored by: Naval Air Systems Command and the Office of Naval Research (Fluid Dynamics Program and Power Program)
- c) Date: June 14-15, 1976.
- d) Place: Airlie House, Warrenton, Virginia.
- e) References to Proceedings:
 - 1. Report No. PU-RI-77. Proceedings of Workshop on Turbulence in Internal Flows.
Edited by S.N.B. Murthy. Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1976. Reference No. AD A040966.
 - 2. Turbulence in Internal Flows.
Edited by S.N.B. Murthy, Hemisphere Publishing Corporation, Washington, D.C., 1976.
- f) Contents of Proceedings:

Preface. Thirty years of Research. Welcoming Remarks.

Introduction. Preliminary Report on Sheared Cellular Motion as a Qualitative Model of Homogeneous Turbulent Shear Flow.

Interacting Shear Layers in Turbomachines and Diffusers. Some Preliminary Observations on the Effect of Initial Conditions on the Structure of the Two-Dimensional Turbulent Mixing Layer.

On the Developing Region of a Plane Mixing Layer. The Effects of an External Turbulent Uniform Shear Flow on a Turbulent Boundary Layer. The Effect of Swirl on the Turbulence Structure of Jets. Implications of the Structure of the Viscous Wall Layer. Further Investigation of the Linear and Nonlinear Theory for Constant-Temperature Hot-Wire Anemometers. Results of a Two Equation Model for Turbulent Flows and Development of a Relaxation Stress Model for Application to Straining and Rotating Flows. Application of the

Turbulence-Model Transition-Prediction Method to Flight-Test Vehicles. A Second Moment Turbulence Model Applied to Fully Separated Flows. The Modelling of a Turbulent Near Wake Using the Interactive Hypothesis. Some Important Physical Phenomena in Flows with Separated Turbulent Boundary Layers. Turbulence Velocity Scales for Swirling Flows. Effect of Freestream Turbulence and Initial Boundary Layers on the Development of Turbulent Mixing Layers. Measurements in Curved Flows. Small Disturbances in a Compressor with Strong Swirl. Wake Cutting Experiments. Some Turbulence and Unsteadiness Effects in Turbomachinery. Visual Study of Oscillating Flow over a Stationary Airfoil. Generation, Measurement and Suppression of Large Scale Vorticity in Internal Flows. Panel Discussion. Summary Report. Index.

4.2.6 Transonic Flow Problems in Turbomachinery

- a) Chairmen: T.C. Adamson, Jr., Department of Aerospace Engineering, The University of Michigan, and M.F. Platzer, Department of Aeronautics, Naval Postgraduate School, Monterey, California.
- b) Sponsored by: Office of Naval Research (Project SQUID), the Naval Air Systems Command, and the Air Force Office of Scientific Research.
- c) Date: February 11-12, 1976.
- d) Place: Naval Postgraduate School, Monterey, California.
- e) References to Proceedings:
 - 1. Report No. MICH-16-PU: Proceedings of Workshop on Transonic Flow Problems in Turbomachinery.
Edited by T.C. Adamson, Jr. and M.F. Platzer, Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, 1976. Reference No. A 037 060.
 - 2. Transonic Flow Problems in Turbomachinery
Edited by T.C. Adamson, Jr. and M.F. Platzer, Hemisphere Publishing Corporation, Washington, D.C., 1976.
- f) Contents of Proceedings

Preface. Thirty Years of Research. Welcoming Remarks. Analysis: Basic Formulation for Transonic Flow Problems in Rotors. Introductory Remarks for Session on Basic Formulation for Transonic Flow Problems in Rotors. Basic Formulation for Transonic Flow Problems in Rotors. Three-Dimensional Inviscid Flow Through a Highly-Loaded Transonic Compressor Rotor. Calculation of 3-Dimensional Choking Mass Flow in Turbomachinery with 2-Dimensional Flow Models. Three Dimensional Transonic Shear Flow in a Channel. Some Formulation Considerations in 3-D Transonic Flow Computation. Computation of Steady and Periodic Two-Dimensional Nonlinear Transonic Flows in Fan and Compressor Stages. Analysis: Computational Methods. Computation of

Transonic Potential Flows in Turbomachinery. Finite Difference Procedure for Unsteady Transonic Flows: A Review. Four Issues in the Computation of Transonic Flows in Turbomachinery. Comparison of a Finite Difference Method with a Time-Marching Method for Blade to Blade Transonic Flow Calculations. Rotational Transonic Internal Flows. Application of a Multi-Level Grid Method to Transonic Flow Calculations. Application of Time-Dependent Finite Volume Method to Transonic Flow in Large Turbines. Finite-Difference Calculations of Three-Dimensional Transonic Flow Through a Compressor Blade Row, Using the Small-Disturbance Nonlinear Potential Equation. Transonic Relaxation Methods. Calculation of Transonic Potential Flowfields About Complex, Three-Dimensional Configurations. Calculation of Supercritical Flow Past a Double Wedge by Telenin's Method. Supercritical Cascade Design. A Navier-Stokes Solution of the Three-Dimensional Viscous Compressible Flow in a Centrifugal Compressor Impeller. Shock-Fitting in Transonic Flow Computation. Efficiency Gains of Second Order Accurate Methods with Shock Fitting. Solutions to Internal Transonic Flows via Parametric Differentiation. Perturbation Solutions for Blade-to-Blade Surfaces of a Transonic Compressor. Viscous Effects in Transonic Flows. On the Prediction of Viscous Phenomena in Transonic Flows. Normal Shock Wave-Turbulent Boundary Layer Interactions in Transonic Flow Near Separation. Interactions of Normal Shock Waves with Turbulent Boundary Layers at Transonic Speeds. Coupled Inviscid/Boundary-Layer Flow Field Predictions for Transonic Turbomachinery Cascades. Experiment. Review of Experimental Work on Transonic Flow in Turbomachinery. Flow in a Transonic Compressor Rotor. Comparison of Prediction of Transonic Flow in a Fan with Flow Measurements Taken Using a Laser Doppler Velocimeter. Nonintrusive Measurements of the Flow Vectors Within the Blade Passages of a Transonic Compressor Rotor. A Transonic/Supersonic Smoke Tunnel for the Investigation of Cascade Loss Models. A Laser Velocimeter

System for Small Radial Turbomachinery. Laser Doppler
Velocimeter Measurements in a Two-Dimensional Transonic Flow.
Real Time Measurements in a Transonic Compressor. A Comparative
Evaluation of Numerical and Experimental Cascade Data. The
Effect of Leading-Edge Thickness on the Bow Shock in Transonic
Rotors. Review and Discussion. Review of Session I, Review of
Session II, Discussion, Sessions I and II, Review of Session III,
Discussion, Session III, Review of Session IV, Discussion,
Session IV. Concluding Remarks. Concluding Remarks. Some Remarks
On Present and Future Research Tasks in Fluid Mechanics.
Workshop Participants. Index.

4.2.7 Combustion Measurements

- a) Chairman: R. Goulard, The George Washington University, Washington, D.C.
- b) Sponsored by: Office of Naval Research (Project SQUID), and the Air Force Office of Scientific Research.
- c) Date: May 22-23, 1975.
- d) Place: Purdue University, West Lafayette, Indiana.
- e) References to Proceedings:
 - 1. Report No. PU-RI-76. Proceedings of Workshop on Combustion Measurements.
Edited by R. Goulard, Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1975. Reference No. ADA 020 386.
 - 2. Combustion Measurements
Edited by R. Goulard, Hemisphere Publishing Corporation, Washington, D.C., 1976.
- f) Contents of Proceedings
Preface. Thirty Years of Research. Needed Measurements in Combustor Technology. New Directions in Combustion Research. Combustion Models. Combustion Modeling (an APS summer study assessment). Elementary Combustion Reaction Kinetics Measurements at Realistic Temperatures. Some Conclusions Regarding Combustion Measurements Reached at the SAI/NSF (RANN) Workshop on the Numerical Simulation of Combustion. Combustor Design and Phenomenology. Phenomenology and Design of Jet Engine Combustors. Laser Velocimetry. Laser Velocimetry for Combustion Measurements in Jet Propulsion Systems. Laser Velocimeter Measurements of a Confined Turbulent Diffusion Flame Burner. Problems of Laser Velocimeter Application. Laser Anemometry in High Velocity, High Temperature Boundary Layers. Absorption-Emission and Resonance Techniques. Absorption-Emission Measurements in

Jet Engine Flows. Absorption-Emission Spectroscopy Applied to the Study of Pollutant Kinetics and Reaction Intermediates in High-Intensity Continuous Combustion. **Boundary** Layer Measurements of Temperature and Electron Number Density Profiles in a Combustion NHD Generator. Concentration Measurements by Fluorescence. Local Species Concentration Measurement by Resonance Scattering Technique. Discussion (session on absorption-emission and resonance techniques) Scattering Measurements. Raman Scattering Studies of Combustion. Application of Laser Diagnostics to Combustion. Gas Concentration and Temperature Measurements by Coherent Anti-Stokes Raman Scattering. Coherent Anti-Stokes Raman Spectroscopy (CARS) in Liquids and NRL's Program on Gases. Comparison of Density and Temperature Measurement Using Raman Scattering and Rayleigh Scattering. Laser Modulated Particulate Incandescence Noise Effects in Laser Raman Scattering Diagnostics. Raman Measurements of Specie Concentration and Temperature in an Aircraft Turbine Exhaust. Raman Scattering from Laminar and Turbulent Flame Gases. Interferometry. Interferometric Flame Temperature Measurements. Progress on Improved Flow Visualization by Resonance Refractivity. Holography and Holographic Interferometry. Measurement of Asymmetric Temperature Fields by Holographic Interferometry. Experimental Capabilities of Holographic Interferometry in Combustion. Holographic Two-Wavelengths Interferometry for Measurement of Combined Heat and Mass Transfer. Probe Methods and Special Techniques. Probe Measurements in Laminar Flows. Probe Measurements in Laminar Combustion Systems. New Results of Studies of Combustion Flows Obtained at the ONERA. In Situ Optical Versus Probe Sampling Measurement of NO Concentration in Jet Engine Exhaust. Probe Measurements in Turbulent Flows. Probe Measurements in Turbulent Combustion. Modeling of Combustion Phenomena with Large Rates of Heat Release. Turbulent Mixing. Particulate

Measurements in Combustion. Particulate Measurement in the Exhaust of Gas Turbine Engines. Optical Methods for In Situ Determination of Particle Size-Concentration-Velocity. Distributions in Combustion Flows. Laser Scattering from Moving, Polydisperse Particle Systems in Flames. Particulate Measurements in Combustion. Burning Spray Measurements. Droplet Effects in Combustion. Discussion (session on particulates). Forum. Introduction. Velocity. Concentrations. Temperature. The Spray Region and the Combustor Environment. Turbulence. Review and Suggested Experiments. Introduction. Measurement Techniques. Combustion Measurements. References. Conclusions and Recommendations. Workshop Participants. Index.

4.2.8 Unsteady Flows in Jet Engines

- a) Chairman: F.O. Carta, Purdue University, West Lafayette, Indiana.
- b) Sponsored by: Office of Naval Research Program.
- c) Date: July 11-12, 1974.
- d) Place: United Aircraft Research Laboratories.
- e) Reference to Proceedings:
 - 1. Report No. UARL-3-PU: Proceedings of Workshop on Unsteady Flows in Jet Engines.
 Edited by F.O. Carta, Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1974. Reference No. ADA 003 853.
- f) Contents of Proceedings
 Welcoming Comments. Foreword. Introduction. Compressor-Diffuser Interaction with Circumferential Flow. Aircraft. Discussion. The Response of an Axial Compressor to Unsteady Disturbances. Unsteady Fluid Dynamic Response of an Isolated Rotor with Distorted Inflow. Laboratories. Discussion. Short Talks. On-Rotor Studies of Rotating Stall. Polytechnic Institute and State University. Discussion. Unsteady Flows in an Annular Supersonic Blade Cascade. J. Fabri, ONERA. Discussion. Effect of Blade Row Geometry on Axial Flow Rotor. Unsteady Response to Inflow Distortion. Pennsylvania State University. Discussion. Dynamic Stall Detection and Design Aids for Distortion Tolerant Compressors Using Quasi-Steady Actuator Disc Analysis. Motoren- und Turbinen- Union. Discussion. Unsteady Response of Compressor Rotors to a 90° Circumferential. Pressure Distortion. Technology. Discussion. Short Talks. The Basis of a Field Method for the Calculation of Unsteady Flow in Cascades. Unsteady Supersonic Flow Around an Airfoil. The Unsteady Supersonic Flow Downstream of an Oscillating Airfoil. Unsteady Airloads on a Cascade of Staggered Blades in

Incompressible Flow. W.H. Heiser, Air Force Aero-Propulsion Laboratory, Chairman. Invited papers. Rotating Stall Research at Calspan. Some Comparisons of the Flow Characteristics of a Turbofan Compressor System with and without Inlet Pressure Distortion. Short talk. Experimentally Observed Three-Dimensional Effects of Circumferential Distortion: Invited papers. Air Force Overview. A Cascade in Unsteady Flow - A Progress Report. Prediction of Maximum Time-Variant Inlet Distortion Levels. Linearized Theory of Nonstationary Cascades at Part-Stalled Conditions. Oscillating Boundary Layers with Large Amplitude: Short Talks. Techniques for the Experimental Study of Unsteady Flow Effects in Turbomachines. The Need for and Future Direction of Research in Determining a Circumferential Inlet Pressure Distortion Index for Axial Flow Compressors. Influence of Loading on the Unsteady Aerodynamics of Turbomachine Blades. Rotating Stall in a 5-Stage Transonic Compressor. Panel Discussion. List of Participants.

4.2.9 Turbulent Mixing in Non-Reactive and Reactive Flows

- a) Chairman: S.N.B. Murthy, Purdue University, West Lafayette, Indiana.
- b) Sponsored by: Office of Naval Research (Project SQUID), and the Air Force Office of Scientific Research.
- c) Date: May 20-21, 1974.
- d) Place: Purdue University, West Lafayette, Indiana.
- e) References to Proceedings:
 - 1. Report No. PU-R2-74: Proceedings of Workshop on Turbulent Mixing in Non-Reactive and Reactive Flows.
Edited by S.N.B. Murthy, Published for the ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, 1974. Reference No. ADA 006 322.
 - 2. Turbulent Mixing in Non-Reactive and Reactive Flows
Edited by S.N.B. Murthy, Plenum Press, New York, 1974.
- f) Contents of Proceedings
Introduction. Turbulent Mixing in Non-Reactive and Reactive Flows: A Review. Turbulent Modelling: Solved and Unsolved Problems. On the Modelling of the Scalar-Correlations Necessary to Construct a Second-Order Closure Description of Turbulent Flow. Computational Studies of Turbulent Flows with Chemical Reaction. Recent Advances in Theoretical Descriptions of Turbulent Diffusion Flames. Turbulent Mixing in Systems with Simple Reactions. Turbulent Mixing Studies in a Chemical Reactor. Comments on Unmixedness. Velocity and Pressure Characterization of Coaxial Jets. A Probability Distribution Function for Turbulent Flows. Mixing in "Complex" Turbulent Flows. Coherent Structures in Turbulence. Large Scale Motion in Turbulent Boundary Layers. Some Remarks on Synthetic Turbulent Shear Flows. Progress and Problems in Understanding Turbulent Shear Flows. Ensemble-Averaged Large Scale Structure in the Turbulent Mixing Layer. Some Observations on the Mechanism of Entrainment. Supersonic Free Turbulent Mixing Layers. Studies Related to Turbulent Flows Involving Fast

Chemical Reactions. Diffusion-Limited First and Second Order
Chemical Reactions in a Turbulent Shear Layer. On Turbulence
Structure and Mixing Mechanism in Free Turbulent Shear Flows.
Conditional (Point-Averaged) Temperature and Velocities in a
Heated Turbulent Plane. Diffusion from a Periodically Heated
Line-Source Segment and its Application to Measurements in
Turbulent Flows. General Discussion.

4.2.10 Laser Raman Gas Diagnostics

- a) Chairmen: Marshall Lapp and C.M. Penney, General Electric Company, Schenectady, New York.
- b) Sponsored by: Office of Naval Research (Project SQUID), the Air Force Aero Propulsion Laboratory, and the General Electric Co.
- c) Date: May 10-11, 1973.
- d) Place: Schenectady, New York.
- e) References to Proceedings:
 - 1. Laser Raman Gas Diagnostics, Edited by Marshall Lapp and C.M. Penney. Reference No. Ad 782 652.
 - 2. Laser Raman Gas Diagnostics
Edited by Marshall Lapp and C.M. Penney, Plenum Press, New York, 1973.
- f) Contents of Proceedings

Foreword. Introduction. Session I - Introduction; Density Measurements. Laser Raman Scattering Applications. Analysis of Raman Contours in Vibration-Rotation Spectra. Measurement of Aircraft Turbine Engine Exhaust Emissions. The Use of a Fabry-Perot Interferometer for Studying Rotational Raman Spectra of Gases. Gas Concentration Measurement by Coherent Raman Anti-Stokes Scattering. Session II - Temperature Measurements; Chemistry. Flame Temperatures from Vibrational Raman Scattering. Measurement of Vibrational and Rotational-Translational Temperatures Independently from Pure Rotational Raman Spectra. Raman Scattering and Fluorescence Studies of Flames. Measurement of Rotational Temperatures by Raman Spectroscopy: Application of Raman Spectroscopy to the Acquisition of Thermodynamic Values in a Chemical System. Transient Flow Field Temperature Profile Measurement Using Rotational Raman Spectroscopy. Low Temperature Measurements by Rotational Raman Scattering. Session III - Resonance Effects:

Remote Probes; Experimental Advances. Light-Scattering and Fluorescence in the Approach to Resonance- Stronger Probing Processes. Observation of S-Band Heads in the Resonance Raman Spectrum of Iodine Vapor. Remote Raman Scattering Probes. Rapid and Ultra Rapid Raman Spectroscopy. Electronic Signal Processing for Raman Scattering Measurements. Session IV - Technology Applications. Introductory Remarks for Session on Technological Applications of Raman Scattering, with Emphasis on Fluid Mechanics and Combustion. Laser Raman Scattering - A Technique for Arc-Tunnel Flow Calibration. Results of Recent Applications of Raman Scattering to Research Problems at NASA Langley Research Center. Raman Scattering Measurements of Mean Values and Fluctuations in Fluid Mechanics. Raman Gas Mixing Measurements and Ramanography. Raman Scattering with High Gain Multiple-Pass Cells. Preliminary Results of Raman Scattering Diagnostics of Expansion Flows. Study of Reactions Producing Vibrationally-Excited Nitrogen. Application of Raman Scattering to Gasdynamic Flows. Remote Raman Temperature Measurement with a Dye Laser. Raman Spectroscopy of Some Hydrocarbons and Freons in the Gas Phase. The Possible Application of Raman Scattering Measurements to Turbulent Mixing Layers. Fourier Transform Raman Spectroscopy. List of Attendees. Author Index. Subject Index.

4.2.11 Aeroelasticty in Turbomachines

- a) Chairman: S. Fleeter, Purdue University, West Lafayette, Indiana.
- b) Sponsored by: Detroit Diesel Allison, Division General Motors Corporation.
- c) Date: June 1-2, 1972.
- d) Detroit Diesel Allison
- e) References to Proceedings:
 - 1. Aeroelasticity in Turbomachines, Edited by S. Fleeter. Reference No. AD 749 680.
- f) Contents of Proceedings

Introduction. Acknowlegments. List of Participants. PART I - MAIN PRESENTATIONS, AEROELASTICITY IN TURBOMACHINES. Perspectives in Aeroelasticity. On the Unstalled, Subsonic, Sonic and Supersonic Aerodynamic Coefficients Necessary for Aeroelastic Calculation. Unsteady Cascade Flow--A Schlieren Study. Unsteady Forces Acting on Turbomachine Blades. Unsteady Cascade Aerodynamics Including Compressibility Effects. Torsional Flutter of Unstalled Blades at High Subsonic Mach Numbers. Supersonic Unstalled Torsional Flutter. Unsteady Transonic and Supersonic Cascade Flows. Semi-Empirical Analysis of Stall Flutter. Flutter of Cylindrical Shells Exposed to a Swirl Type of Flow. Flutter of a Cylindrical Shell in a Swirling Flow. Determination of Turbine Blade Damage from Noise Spectrum Measurements. PART II - PANEL DISCUSSION, RESEARCH NEEDS. Questions and Answers.

4.2.12 Fluid Dynamics of Unsteady, Three-Dimensional Separated Flows

a) Chairmen: D.E. Abbott and J.C. WU, Purdue University, West Lafayette, Indiana.

b) Sponsored by: Office of Naval Research Program.

c) Date: June 10-11, 1971.

d) Place: The Georgia Institute of Technology.

e) References to Proceedings:

1. Fluid Dynamics of Unsteady, Three-Dimensional Separated Flows, Edited by F.J. Marshall. Reference No. AD 736 248.

f) Contents of Proceedings

Introduction. Acknowledgements. List of Participants. Part I - Main Presentations. Dynamic Flow in Engine Air Inlets for Subsonic Aircraft. Behavior of Diffusers with Distorted and Unsteady Inlet Conditions. Analysis of Non-Linear, Unsteady, Inviscid Flows Including Blade to Blade Interactions. An Analysis of the Unsteady Compressible Turbulent Boundary Layer. A Generalized Method for the Calculation of Three-Dimensional Turbulent Boundary Layers. General Analysis of Unsteady Boundary Layers, Laminar and Turbulent. An Analysis of Laminar Separation-Bubble Flow Using the Navier-Stokes Equation. Numerical Solution of Unsteady, Three-Dimensional Navier-Stokes Equations. Unsteady Boundary Layer Separation. Panel Discussion. Part II - 10 Minute Presentations. Dynamic Stall on a Helicopter Rotor Blade. Numerical Solutions of Unsteady Inviscid Flow Problems. Short Unseparated Diffuser. Numerical Calculation of the Three-Dimensional Turbulent Boundary Layer on a Sharp Cone at Incidence in a Supersonic Flow. Calculation of Turbulent Separation in Adverse Pressure Gradients. Numerical Solutions of the Compressible Boundary Layer Equations for Laminar, Transitional, and Turbulent Three-Dimensional Flows. Unsteady Velocity Field Near the Leading Edge of a Flat Plate. A

Theoretical Study of the Effect of Unsteady Pressure Gradient Reduction on Dynamic Stall Delay. Steady and Nonsteady Potential Flow Methods for Airfoils with Spoilers. Recombination of Turbulent Free Shear Layer and Base Pressure Problems. Unsteady Boundary Layer Separation over Oscillating Airfoils. Velocity Amplification in Forward Stagnation Flow. The Wave Type Vortex Generator. Numerical Solution of the Time Dependent Navier-Stokes Equations. The Case for Extended Boundary-Layer Equations. Laminar Supersonic Flow over a Small Rearward Facing Step. Experimental Investigation of Turbulent Transonic Separated Flows.

4.2.13 Research in the Gas Dynamics Of Jet Engines

- a) Chairmen: R. Goulard and M. L'Ecuyer, Purdue University, Indiana.
- b) Sponsored by: Office of Naval Research Program.
- c) Date: December 4-5, 1969.
- d) Place: Squid Workshop, Chicago, Illinois.
- e) References to Proceedings:
 - 1. Research in the Gas Dynamics of Jet Engines, Edited by R. Goulard and M. L'Ecuyer.
- f) Contents of Proceedings

Introduction and Acknowledgments. List of Participants. Some Thoughts About Possible Directions of Future Research In Jet Engine Technology. Performance of Propulsion Systems. Some Objectives in Jet Engine Research. The NASA Ad-Hoc Committee on Fluid Mechanics Problems in Aircraft Gas Turbine Engines. Fluid Dynamic Analysis for Blade Design. The Dynamic Simulation of Turbine Engine Compressors. Some Current Areas of Interest in Air-Breathing Propulsion Research. Turbine Cooling. Turboblade Vibrations. Small Gas Turbine Engine Problems. Fluid Dynamic Problems of Exhaust Systems. Areas of Needed Research.

4.3 Colloquia

4.3.1. Gas Turbine Combustor Modeling

- a) Chairman: S.N.B. Murthy, School of Mechanical Engineering, Purdue University, West Lafayette, Indiana 47907.
- b) Sponsorship: Air Force Office of Scientific Research and Office of Naval Research (Power Program).
- c) Date: September 5 and 6, 1979.
- d) Place: Purdue University, West Lafayette, Indiana.
- e) Reference to Proceedings:
 - (1) Report No. PU-R1-79: Summary Report DOD Colloquium on Gas Turbine Combustor Modeling. September 1979. Published for ONR by School of Mechanical Engineering, Purdue University, West Lafayette, Indiana 47907. November 1979.
- f) Contents: Introduction. Discussion of Objectives. Outline of the Report. Status of Modeling. Current Models. General Discussion. Specific Models. Recommendations. Applied Research Needs. Fundamental Research Needs in Advanced Detailed Modeling. Numerical-Computation. Model Validation. Role of Modeling.

PRECEDING PAGE BLANK-NOT FILMED

4.3.2. Flow Separation

a) Chairman: Roger L. Simpson, Southern Methodist University,
Dallas, Texas 75272.

b) Sponsorship: Office of Naval Research (Power Program)

c) Date: January 18 - 19, 1979.

d) Place: Southern Methodist University, Dallas, Texas.

e) Reference to Proceedings:

Report No. SMU-3-PU: Summary Report on Colloquium on Flow
Separation (January 1979).

Published for ONR by School of Mechanical Engineering.

Purdue University, West Lafayette, Indiana 47907.

August 1979.

f) Contents: Preface. Introduction. Terminology. Flow Theory.
Flow Modeling. Measurements and Techniques. Methods of Flow Control.
Control of Separated Flow. Concluding Remarks. References.
Appendix I.

4.3.3. Raman Techniques for Measurements in Reactive Gaseous Environments

- a) Chairman: S.N.B. Murthy, School of Mechanical Engineering.
Purdue University, West Lafayette, Indiana 47907.
- b) Sponsorship: Office of Naval Research (Power Program).
- c) Date: January 12 - 13, 1978.
- d) Place: Sandia Laboratories, Livermore, California.
- e) Reference to Proceedings: A summary report on the Colloquium
submitted by S.N.B. Murthy.

5. SPECIAL SERVICES

5.1. International Colloquium on Gas Dynamics of Explosions and Reactive Systems

5.1.1. Fourth International Colloquium, La Jolla, California

Proposal from Dr. S.S. Penner, University of California - San Diego, La Jolla, for funding of publication of proceedings was funded through Project SQUID.

Proceedings appeared in Acta Astronautica, Vol. 1.

5.1.2. Fifth International Colloquium, Stockholm, Sweden

Proposal from Dr. A. K. Oppenheim, University of California - Berkeley, Lawrence Livermore Laboratory, for funding of publication of proceedings was funded through Project SQUID.

Proceedings appeared in Acta Astronautica, Vols. 3 and 4.

5.1.3. Sixth International Colloquium, Gottingen, Germany

Proposal from Dr. A.K. Oppenheim, University of California - Berkeley, Lawrence Livermore Laboratory, for funding of publication of proceedings was funded through Project SQUID.

Proceedings appeared in Acta Astronautica, Vols. 5 and 6.

5.2. International Workshop on Laser Velocimetry

Proposals received from Purdue University, West Lafayette, Indiana, for the support of the following Workshops were funded by the ONR through Project SQUID.

- 1) First International Workshop on Laser Velocimetry, held at Purdue University, March 9 - 10, 1972.
- 2) Second International Workshop on Laser Velocimetry, held at Purdue University, March 27 - 29, 1974.

In both cases, Dr. W.H. Stevenson and Dr. H.D. Thompson were the persons who requested funding, as Co-Chairmen of the Workshop and editors of Proceedings of Workshops.

Proceedings of the Workshops have been published as follows.

- 1) The Use of the Laser Doppler Velocimeter for Flow Measurements, Proceedings of a Workshop Co-sponsored by Project SQUID (ONR) and the U.S. Army Missile Command, March 9-10, 1972. W.H. Stevenson and H.D. Thompson. Reference No.: AD-753243.
- 2) Proceedings of the Second International Workshop on Laser Velocimetry, vols. I and II, March 27-29, 1974. W.H. Stevenson and H.D. Thompson. Published by Purdue University, West Lafayette, Indiana. Reference No.:

It may be noted that the Third International Workshop on Laser Velocimetry and Particle Sizing was held at Purdue University, July 11-13, 1978 and co-sponsored by the ONR Power Program, although not through Project SQUID. The proceedings of that Workshop is available as follows.

Laser Velocimetry and Particle Sizing, edited by Doyle Thompson and W.H. Stevenson, Hemisphere Publishing Corporation, Washington: 1979.

5.3. Consulting Services of Dr. Gordon and Dr. Tardy on Special Projects
of ONR (Power Project)

Funding for the Consulting Services was provided by the ONR through Project SQUID.

Certification was received from the Office of Naval Research that consulting services had been performed satisfactorily along with submission of required report to the ONR.

6. DISCUSSION

6.1. Thrust Areas

It can be observed from Section 2 that the thrust areas in the period October, 1967 through December, 1979, have changed as follows.

- 1) 1967 - 1969
 - a) Fluid mechanics and MHD
 - b) Atomic and molecular collisions
 - c) Chemi-ionization and ion-molecule reactions
 - d) Combustion and chemical rate processes
- 2) 1970 - 1972

Same as the period 1967 - 1969 except that research in the area of MHD was not funded directly.
- 3) 1972 - 1973
 - a) Fluid mechanics
 - b) Combustion and molecular processes
 - c) Measurement techniques
- 4) 1974 - 1979
 - a) Aerodynamics and turbomachinery
 - b) Turbulence
 - c) Combustion and molecular processes/chemical kinetics
 - d) Measurements

Subjects such as MHD-applications, chemi-ionization, ion-molecule reactions and properties of gases have become de-emphasized since 1972.

Fluid mechanics has always included some aspects of turbulence and measurement techniques, but since 1974, turbulence has been identified

as a distinct thrust area, especially chemically-reactive turbulent flows.

Measurement techniques, their development and application, have been identified as a thrust area since 1972 and has generally concentrated on optical/non-intrusive techniques for diagnosis and measurement.

Various aspects of the fluid mechanics and chemical kinetics of combustion have always been recognized as a thrust area, with emphasis recently on advanced and alternative fuels.

6.2 Possible Thrust Areas

The broad thrust areas of aerodynamics and turbomachinery, combustion and molecular processes, and measurements appear to be useful in the next five to seven year period.

Investigations in turbulent combustion per se may need further discussion.

Under aerodynamics, additional emphasis seems useful in engine-airframe integration related topics. In general, these problems involve "complex flows" or "complex interactions of flows".

In the area of fluid mechanics, one may particularly note the needs in these areas:

- a) rotational internal flows,
- b) fine passage flows,
- c) multi-phase flows,
- d) transitory flows, and
- e) aero-elastic interactions.

In each of the foregoing, measurements will play a significant role.

Numerical-computer experiments indicate a further direction for research.

Regarding development of diagnostic and measurement techniques, some caution is required in regulating sporadic and unproductive research. Understanding of phenomena, generation of data especially from the point of view of modeling processes and uncovering easily-applicable and reliable techniques should continue to be the goals of work in this area.

6.3. Workshops and Colloquia

Project SQUID has organized a series of workshops and colloquia. They have proved extremely effective in the evolution of fruitful areas of research, in generating interest in the community in various technical areas and, most significant of all, in focussing research on recognizable goals.

This important activity of Project SQUID should be continued.

The ONR role in the workshops and colloquia, other than as the sponsoring agency, has consisted in the past in active participation through providing guidance and clarifications. In general, a workshop or colloquium has been conducted by a chairman, selected by the ONR from the university-research community, so that a free exchange of views is assured.

The publication of proceedings of workshops and colloquia, so that it is available to the public, has been much appreciated.

6.4 Project Organization

6.4.1. Project SQUID, devoted to basic research needs in propulsion of

long-range relevance to the Navy, has developed over the years a strong university involvement in (a) identifying research areas, (b) encouraging development of proposals, (c) reviewing proposals, on-going contractual research and technical reports and (d) providing assistance to the ONR in the development of a well-synthesized program by conducting workshops and colloquia.

Such an involvement is extremely useful, and in many respects necessary, in the organization of basic research in an advanced technology area such as propulsion which is inter-disciplinary in various engineering and applied sciences.

6.4.2 Project SQUID research may prove even more effective, particularly in its translation into "exploratory development", if "Centers of Project SQUID" are organized in addition to "Individual Research Projects".

A Center of Project SQUID can be located at an Institution where Propulsion has become established as a "thrust-area" with adequate personnel and facilities. A Center of Project SQUID should conduct research in a selected broad area with the participation of a number of investigators. Funding may be assured over a pre-determined period of years, subject to annual review. A Center for Project SQUID should be encouraged to work closely with an industrial organization wherever possible.

In the broad area of jet propulsion related to aircraft and missiles, the following are of primary interest: (a) variable cycle and geometry engines; (b) modular construction of engines; (c) engine-airframe/vehicle integration; (d) fuels and combustion; and (e) diagnostics and measurement. Whether one is considering rockets, air-breathing missiles, V/STOL systems, supersonic military aircraft or hypersonic air-breathing engines, the afore-mentioned five broad areas will prove of basic significance. In each of those areas, one can again recognize certain smaller subject areas

for concentrated effort, either from considerations of priority or from considerations of the length of time required for useful results to accrue. Such a subject area then will become the research subject-area for a Center for Project SQUID.

Some examples of broad areas of basic research related to Navy interest in propulsion are as follows: (1) Alternative fuels, physical, chemical and combustion characteristics, (2) Measurements in hostile engine environments, (3) Heat and mass transport processes in combustors and turbines, (4) Advanced turbo-machinery aero/mechanical design, (5) Small scale fluid dynamics, (6) Modeling of complex and interacting flows.

6.4.3. Project SQUID has been a unique example of organizing basic research related to an area of advanced technology, where industry itself is endeavoring continuously through internal development efforts to meet international competition both in basic and operational costs of the product, namely jet propulsion engines. The particular organization of Project SQUID, under which work reported here has been performed, has been extraordinarily successful as is evidenced by this report. The possibility of publication of research activities under the project in a single report is in itself a feature of the project.

Project SQUID research has had continuous impact on engine technology, not in terms of specific improvement in one or other component or aspect of performance, but in two extremely important respects: (a) demonstrating the importance and benefit of obtaining basic understanding of various phenomena in universalizing the results of ad hoc investigations and (b) creating a climate for utilizing results of research as an important contributor to life cycle improvement and total cost reduction.

Such objectives have been met through several features of the organization itself:

- (1) Designated funding that has not been changed due to ordinary exigencies of circumstances.
- (2) Detailed and open review of proposals and on-going contracts.

- (3) Reporting of results of research through designated technical and semi-annual reports.
- (4) Sponsoring Workshops and Colloquia from time to time for synthesizing and assessing research activity in various subject-areas.
- (5) Association of an active researcher in the area with the technical evaluation of research projects on a continuous basis and of selected consultants as and when desirable.

The third of the above has been appreciated very greatly by the investigators from the point of view of scientific/technical developments. The outside "Technical Director" has, without any managerial or executive authority, performed a complementary role to that of the ONR Director of the Project in the evolution of Project activities. It has been an invariably successful, and in several respects necessary, addition to the management of this type of research activity.

Planning of basic research is in some respects a contradiction in terms. On the other hand, sustained support for basic research requires recognition of schools of approach to various problems and continuous review of research directions. Project SQUID operation - its assessment, review and reporting processes - has been uniquely successful in providing both continuity and critical evaluation in each of the subjects it has concentrated on at any given time.

