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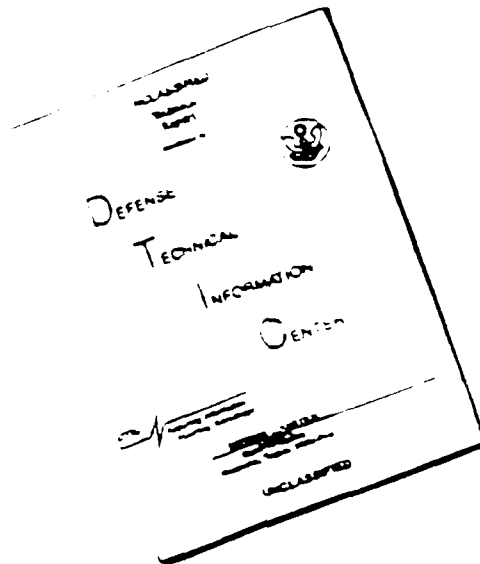
cc. Dr. X B Reed

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Report on the
Twelfth Symposium on Turbulence
September 24-26, 1990

X B Reed, Jr.
Professor of Chemical Engineering
University of Missouri-Rolla
Symposium Director and Chairman

Sponsored by
Office of Naval Research

and

University of Missouri-Rolla's
Department of Chemical Engineering
and Continuing Education

April 1992

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TWELFTH SYMPOSIUM ON TURBULENCE

The Twelfth Symposium on Turbulence was held at the University of Missouri-Rolla (UMR), with the technical sessions beginning on Monday morning, September 24, 1990, and ending at midday Wednesday, September 26, 1992; registration and a social get-together on Sunday evening preceded the technical program.

The Twelfth Turbulence Symposium was sponsored by the Office of Naval Research, without whose support it would not have been held. Dr. L.P. Purtell and Dr. Spiro Lekoudis shared the responsibility for this, with Pat attending the Turbulence Symposium and serving on the Steering Committee. The PI expresses his appreciation for ONR's support over the years when he has been responsible for the Turbulence Symposium.

The facilities of the University of Missouri-Rolla are made available for the Turbulence Symposium, with the Chemical Engineering Department and Continuing Education providing secretarial and other help. The Turbulence Symposia of 1983, 1984, 1986, 1988, and 1990 have been directed by X B Reed, Jr. of the University of Missouri-Rolla, with the assistance of his co-chairmen, G. K. Patterson, now Associate Dean of Engineering, University of Missouri-Rolla, and J. L. Zakin, Chairman of Ohio State University's Chemical Engineering Department. Because of the reduced funding, Drs. Patterson and Zakin will become Honorary Co-chairmen.

The highlights of the technical program were:

"Vortical Structures and Their Central Role in Boundary Layer Turbulence"
by Stephen K. Robinson
NASA Langley Research Laboratory
Hampton, VA

"The Models of Free Shear Dynamics"
by Larry Redekopp
University of Southern California
Los Angeles, CA

"PDF Methods for Turbulent Flows"
by Steve Pope
Cornell University
Ithaca, NY

and

"New Developments in Understanding Supersonic Turbulent Boundary Layers"
by A. J. Smits
Princeton University
Princeton, NJ

There were 64 contributed papers distributed among eleven technical sessions. The full program follows (see Appendix A).

One of the features of the UMR Turbulence Symposium which has long been felt to be desirable (highly desirable, very important) by most attendees, as well as by the Steering Committee, has been the intimate nature of the Turbulence Symposium, especially its opportunities for technical discussions outside the formal Q&A/Comments interludes following each presentation. Until the 1988 Turbulence Symposium, simultaneous sessions had been avoided. With the advent in the late '70's and early '80's of decreased funding from federal agencies and of decreased funding for travel in universities, federal laboratories, and industrial R&D, attendance at the Turbulence Symposium began to decline. The trend has continued and has had especially deleterious effects for those not presenting papers. Efforts to halt the attendance erosion culminated in the 1988 Turbulence Symposium being characterized by simultaneous sessions for the entire Symposium, aside from the invited lecturers. That continued in the 1990 Turbulence Symposium and will doubtless continue into the foreseeable future. Simultaneous sessions have been apportioned, very roughly speaking, into fundamental versus applied sessions in an attempt to minimize conflict and in particular to continue to provide a full Turbulence Symposium of activity for attendees who want it to remain one emphasizing fundamental developments, while at the same time connecting them with strong applications.

There continue to be certain, not necessarily major, problems with having the manuscripts from the Turbulence Symposium published in the archival literature. There has been a relatively high rejection rate, but authors now rightly blame the journals, not the PI, the Turbulence Symposium, or the Steering Committee. Rather than appearing in a single issue of the journal, papers appear over a period of time, and worse, attribution to the Turbulence

Symposium is not always made. There were no papers from the 1990 Turbulence Symposium published in Computers and Fluids, so this journal is not a problem; but those from 1988 and 1990 published in Physics of Fluids often lacked the Turbulence Symposium designation.

The continued support of ONR by encouraging its funded (and proposal submitting) investigators to present papers at the Turbulence Symposium is an important ingredient in maintaining and increasing quality and attendance. It also provides ONR personnel additional first-hand opportunities to see the work of many of their past, present, and future supported investigators "in action" and to hear, as well as participate in, their evaluation during the Steering Committee discussions, as well as in the Q&A following presentations.

Participant Response

One-hundred participants attended the Twelfth Turbulence Symposium, with seventy-two from universities (up from 67 in '90), seventeen from governmental laboratories (up from 10), and eleven from industry (up from 10). There was, as is customary, a significant international contingent present, with Australia (1), Canada (1), Federal Republic of Germany (2), France (1), Netherlands (4), Switzerland (1), Hong Kong (1), India (1), Japan (1), United Kingdom (1), and Republic of China (3), represented. The list of participants appears in Appendix B.

Equipment Exhibits

Each Symposium, ample space is made available for vendors of turbulence measurement, data acquisition, and analysis equipment, and various companies are invited. TSI and DANTEC, as always, brought large demonstration teams. They also provide tangible support, including underwriting the social hour, which we appreciate. New personnel from DANTEC expressed the strong opinion that they were not sufficiently given the opportunity to sell their wares.

Banquet

Zeno's Restaurant hosted the Turbulence Symposium banquet, and the excellent midwestern steaks at a modest price (banquet costs were \$19) were widely complimented. The Collegium Musicum provided after-dinner entertainment. Mr. Basil Moore was the after-dinner speaker, and "The humor of Abe Lincoln" was indeed humorous.

APPENDIX A

Program Announcement

with Symposium on Turbulence



September 24-26, 1990
Rolla, MO U.S.A.

Twelfth Symposium on Turbulence

Day, September 23, 1990

8-10 p.m. Registration and Social Hour, Zeno's Motel and Steak House

Day, September 24, 1990

8:45-9:30 a.m. Registration—Miner Lounge, University Center-East, UMR

10-3:45 a.m. Symposium Opening—Welcoming Remarks—Centennial Hall-West

3:45-3:00 a.m. Announcements and General Information

Symposium Sponsors

Office of Naval Research
University of Missouri-Rolla

Symposium Chairmen

B. Reed, Jr.
University of Missouri-Rolla
Chairman

Garv K. Patterson
University of Missouri-Rolla
Co-Chairman

Jacques L. Zakin
Ohio State University
Co-Chairman

Organizing Committee

Dr. R. J. Adrian
Professor of Theoretical and Applied
Mechanics
University of Illinois
Dr. R. S. Brodkey
Professor of Chemical Engineering
Ohio State University
Dr. R. J. Hansen
Naval Research Laboratory
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Associate Dean of Engineering
University of Missouri-Rolla
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Professor of Chemical Engineering
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Professor of Mechanical and Aerospace
Engineering
Princeton University
Dr. C. G. Speziale
ICASE
NASA Langley Research Center
Dr. D. E. Stock
Professor of Mechanical Engineering
Washington State University
Dr. W. G. Tiederman
Professor of Mechanical Engineering
Purdue University
Dr. J. L. Zakin, Co-Director
Professor and Chairman of Chemical
Engineering
Ohio State University

Monday Morning, September 24, 1990

9:00 a.m. Invited Lecture, Centennial Hall-West, "Vortical Structures and Their Central Role in Boundary Layer Turbulence," Stephen K. Robinson, NASA Langley Research Laboratory, Hampton, Va.
10:00 a.m. Coffee Break

A

Coherent Turbulence Structure—Centennial Hall-West
Chairmen: R. S. Brodkey and A. K. M. F. Hussain

- 20 a.m. "The Characteristics of Spiral Waves in An Axially Rotating Pipe Flow," S. Imao, M. Iton, Y. Yamada, and Q. Zhang, Nagoya Institute of Technology
40 a.m. "Transition, Turbulence, and Oscillating Flow in a Pipe—A Visual Study," L. S. Fisher and R. S. Brodkey, Ohio State University
1 a.m. "Interaction of Coherent Structures within a Coaxial Jet," S. K. Tang and N. W. M. Ko, University of Hong Kong

B

Jets and Wakes—Mark Twain Room
Chairman: S. Lekoudis

- 10:20 a.m. "Characteristics of 3D Turbulent Jets in Crossflow," A. O. Demuren, NASA Lewis Research Center
10:40 a.m. "The Development of Twin-Jets Issuing into a Crossflow," P. J. Disimile, R. G. DiMicco, University of Cincinnati; N. Toy and E. Savory, University of Surrey
11:00 a.m. "Unified Theory for Turbulent Shear, Jet and Wake Flows," W. C. Mui, Washington State University

- 20 a.m. "On Instabilities and Large Structures in Reattaching Boundary Layers," P. R. Sandhyapathy, NASA Langley Research Center
40 a.m. "Effect of Adverse Pressure Gradient on the Turbulence Burst Structure of Low Reynolds Number Equilibrium Boundary Layers," J. B. White and W. G. Tiederman, Purdue University

12:00 noon Lunch—Centennial Hall-East

Monday Afternoon, September 24, 1990

1:00 p.m. Invited Lecture, Centennial Hall-West, "The Models of Free Shear Dynamics," Larry Redekopp, Professor and Chairman, Aerospace Engineering, University of Southern California, Los Angeles, Calif.

A

Coherent Turbulence Structures (cont.)—Centennial Hall-West

B

Coherent Turbulence Structures—Eduction and Dynamics—Mark Twain Room
Chairmen: R. J. Adrian and X B Reed, Jr.

- 10 p.m. "Pattern Recognition, VITA, U-Signal Slope, and Quadrant Splitting: A Comparison for Channel Flow." Y. G. Aouad and R. S. Brodkey, Ohio State University
- 11 p.m. "Quadrant Analysis of Fluctuating Turbulent Velocity Components in a Two-Dimensional Fully-Developed Turbulent Channel Flow Using a Triple Wire Probe." S. Yavuzkurt, Stanford University

2:40 p.m.

Coherent Structures, Boundary Layer Control, Drag Reduction—Continental Hall-West

Chairmen: W. G. Tiederman and J. McMichad

- 12 p.m. "Coherent Structures over Drag Reducing Surfaces." A. D. Schwarzman Manen, R. Hoogsteen, J. C. Stouthart, K. Krishna Prasad, Eindhoven University of Technology; and F. T. M. Nieuwstadt, Technical University of Delft
- 13 p.m. "Jet Vortex Generators for Turbulent Flow Separation Control." G. V. Seiby, Old Dominion University; J. C. Lin and F. G. Howard, NASA Langley Research Center

- 2:00 p.m. "Pseudo-Dynamic Reconstruction of the Structure of Turbulent Boundary Layers." T. Giesseke and Y. G. Guezennec, Ohio State University

- 2:20 p.m. "Experiments on the Nonlinear Spectral Dynamics of Planar Jet Transition in Wavenumber Domain." F. O. Thomas and H. C. Chu, University of Notre Dame

Break

Coherent Turbulence Structures—Eduction and Dynamics (cont.)—Mark Twain Room

- 3:00 p.m. "Experiments on the Effect of Mean Flow Unsteadiness on the Subharmonic Generation in Plane Mixing Layers." M. R. Haig, R. W. Miksad, and E. J. Powers, University of Texas at Austin

- 3:20 p.m. "Plane Waves and Structures in Turbulent Channel Flow." L. Sirovich, Brown University; K. S. Bail, University of Texas at Austin; and R. A. Handler, Naval Research Laboratory

- 3:40 p.m. "Diffusion of Slot Injected Drag Reducing Polymer Solution in a LESU Modified Turbulent Boundary Layer." S. T. Sommer and H. L. Petne, Pennsylvania State University

- 4:00 p.m. "Structure of Reynolds Stress Near the Wall in Aqueous Polymer Solutions." B. Gampert and Ch. K. Yong, Universität Essen, Essen, West Germany

- 4:20 p.m. "The Interaction of Polymer Additives with Vorticity—A Case Study on Vortex Rings." A. Gyr, Federal Institute of Technology, Switzerland

- 4:40 p.m. "Unsteady Flow in a Three-Dimensional Rectangular Cavity Immersed in a Turbulent Boundary Layer." R. G. DiMicco, P. J. Disimile, University of Cincinnati; and N. Toy, E. Savory, University of Surrey

- 3:40 p.m. "Computational and Experimental Observations on Near Field Characteristics of an Excited Free Shear Layer." A. B. Cain, F. W. Roos, and J. T. Kegeles, McDonnell Douglas Research Laboratories

- 4:00 p.m. "Nonlinear Processes of an Axisymmetric Circular Jet under Quasi-Mode Quasi-Frequency Excitations." Y. T. Lin, M. R. Wang, and F. B. Hsiao, National Cheng-Kung University

- 4:20 p.m. "Observed Development Details for Laminar Flow Instabilities and Small-Scale Turbulence Within Low-Speed, Two-Dimensional Wall Jet Flows." S. S. Fisher and B. H. Mughal, University of Virginia

Tuesday Morning, September 25, 1990

8:20 a.m. Invited Lecture, Centennial Hall-West, "PDF Methods for Turbulent Flows," Steve Pope, Mechanical and Aerospace Engineering, Cornell University, Ithaca, N.Y.

A

Scalar Transport—Centennial Hall-West
Chairmen: J. C. Hill and G. K. Patterson

- 8 a.m. "Use of a PDF Method in the Modeling of Turbulent Reacting Flow in a Jet-Stirred Reactor," D. Roekaerts, Koninklijke/Shell-Laboratorium, Amsterdam
- 9 a.m. "Optical Measurement of the Turbulent Scalar Field in a Gas Flow With and Without Combustion," K. Oberster-Lenn and W. Merzkirch, Universität Essen, West Germany
- 10 a.m. "Turbulent Transport of a Passive Scalar," R. C. Sanderson, A. D. Leonard, and J. C. Hill, Iowa State University

B

New Measurement Methods—Mark Twain Room
Chairmen: M. M. Reischman and R. J. Adrian

- 9:20 a.m. "High-Speed Particle Image Velocimetry Interrogations Using Coarse Image Arrays," A. Prasad, R. J. Adrian, C. C. Landreth, and P. Offutt, University of Illinois, Urbana
- 9:40 a.m. "The Development of a System for Real-Time, Full-Field Surface Shear Stress Measurements Using Liquid Crystals," N. Toy, E. Savory, and S. Paskin, University of Surrey
- 10:00 a.m. "Investigating the Use of Stereoscopic Particle Streak Velocimetry for Measuring the Three-Dimensional Vorticity Field," S. K. Sinha, University of Mississippi, and P. S. Khatman, University of Nebraska-Lincoln

10:20 a.m. Coffee Break

- 10:40 a.m. "Kinematics of the Reaction Zone in Homogeneous Turbulence," A. D. Leonard and J. C. Hill, Iowa State University
- 11:00 a.m. "Direct Numerical Simulation of a Parallel-Consecutive Reaction Pair in Homogeneous Turbulence," M. Chakraborti and J. C. Hill, Iowa State University
- 11:20 a.m. "Large-Eddy Simulation of Turbulent Reacting Plumes," R. I. Sykes, D. S. Henn, W. S. Lewellen, and S. F. Parker, ARAP Division of California Research and Technology, Inc.
- 11:40 a.m. "Numerical and Experimental Investigations of Temperature Distribution in Aluminum Pots with Prescribed Boundary Conditions," F. A. Elrefaie, H. A. Ahmed, and E. E. Khalil, Cairo University

- 10:40 a.m. "Flow Velocity Measurements by Digital Imaging Pulsed Laser Velocimetry," Y. A. Hassan and R. Cannan, Texas A&M University
- 11:00 a.m. "Flow Gradient Corrections on Hot-Wire Measurements as Applied in a Two-Dimensional Turbulent Wake," J. H. M. Goorden, National Aerospace Laboratory, the Netherlands; and M. van Lent, Fokker Aircraft B.V.
- 11:20 a.m. "A New Approach to Non-Invasive Flow Measurements in Complex Flows," R. K. Menon and J. D. Miller, TSI Incorporated
- 11:40 a.m. "Visualization of Regular Structures in a Triple Jet by Laser Induced Fluorescence," G. Völmerbaumer and G. Schweiger, Universität Duisburg

12:00 noon Lunch—Centennial Hall-East

Tuesday Afternoon, September 25, 1990

1:00 p.m. Invited Lecture, Centennial Hall-West, "New Developments in Understanding Supersonic Turbulence Boundary Layers," A. J. Smits, Mechanical and Aerospace Engineering, Princeton University, Princeton, N.J.

A

B

- Supersonic and Supersonic Turbulence—Centennial Hall-West**
Chairmen: A. J. Smits, R. B. Miles, and C. G. Speziale
- 1:00 p.m. "Convection Velocity in Supersonic Turbulent Boundary Layers," E. F. Spina, Syracuse University; J. F. Donovan, McDonnell Douglas Research Laboratory; and A. J. Smits, Princeton University
- 1:20 p.m. "Compressibility and Mixing in Turbulent Free Shear Layers," J. C. Dutton, R. F. Burr, S. G. Goebel, and N. L. Messersmith, University of Illinois-Urbana
- 1:40 p.m. "Sound Propagation Issues in Compressible Turbulence," D. Papamoschou, University of California, Irvine

- Lagrangian Turbulence—Mark Twain Room**
Chairmen: D. E. Stock and G. S. Jones
- 2:00 p.m. "On the Role of Accelerating Particles in the Generation of Reynolds Stress," R. A. Handler and J. D. Swearingen, Naval Research Laboratory; P. S. Bernard, University of Maryland
- 2:20 p.m. "Stochastic Trajectory Models Applied to Turbulent Diffusion: Monte-Carlo Process versus Markov Chain," L. Wang and D. E. Stock, Washington State University
- 2:40 p.m. "A Study on Turbulent Diffusion and Deformation of Material Interface in a Pipe Flow with Hydrogen Bubble Method," Y. Hirata, H. Adachi, and R. Ito, Osaka University

- 3:00 p.m. Break
- 3:20 p.m. "On the Particle Motion in a Homogeneous Isotropic Turbulence," U. Lei and F. G. Yen, National Taiwan University
- 3:40 p.m. "Turbulent Deposition and Trapping of Aerosols at a Wall," J. W. Brooke, K. Kontomaris, and T. J. Hanratty, University of Illinois; and J. B. McLaughlin, Clarkson University
- 4:00 p.m. "Dispersion by Irregular Surface Waves in Stratified One-Dimensional Channel Flows," B. Jong, University of Twente
- 2:00 p.m. "Exploratory Study of In-plane Streamline Curvature Effects on a Supersonic Turbulent Boundary Layer," C. B. McGinley, NASA Langley; and S. M. Bogdonoff, Princeton University
- 2:20 p.m. "Exploratory Study of Turbulent Structure in Compressible Shear Layers Using Fluctuating Pitot Pressure Measurements," Y. R. Shau and D. S. Dilling, University of Texas at Austin
- 2:40 p.m. "Compressible Free Shear Layers," M. Samimy, G. S. Elliott, and M. F. Reeder, Ohio State University
- 3:00 p.m. "Hot Wire Measurement Method for Temperature and Velocity Fluctuations from Transonic to Supersonic Range in Heated Flows at Low Reynolds Number," P. Dupont and J. F. Debieve, Institut de Mecanique Statistique de la Turbulence, Marseille
- 3:20 p.m. "Imaging Turbulent Structure in High-Speed Air by Filtered Rayleigh Scattering," R. Miles, W. Lampert, and J. Forkey, Princeton University

9 a.m. "Second-Order Closure Models for High-Speed Compressible Turbulent Flows." C. G. Speziale and S. Sarkar, NASA Langley Research Center

6:15 p.m. Social Hour—Zeno's Motel and Steak House

Courtesy of Dantec Electronics; TSI, Inc.; and Aerometrics, Inc.

7-10 p.m. Banquet Dinner

Wednesday Morning, September 26, 1990

Local Turbulence Structure—Centennial Hall-West

Chairmen: R. J. Hansen and S. Lekoudis

9 a.m. "Locally Axisymmetric Turbulence." W. K. George, University of Buffalo, SUNY; and H. J. Hussein, Vanderbilt University

10 a.m. "A Comparative Study of Three Techniques for Estimation of Turbulence Energy Spectrum." P. K. Rajan and S. S. Munukutla, Tennessee Technological University

Complex Turbulent Flows—Mark Twain Room

Chairmen: J. L. Zakin and M. McMichael

8:20 a.m. "Quantitative Determination of the Evolution of the Wake Behind and Impulsively Started Circular Cylinder." C. Chu and Y. Liao, National Taiwan University

8:40 a.m. "Visual Study on Vortex Developments over Lifting Surfaces After Impulsive Start." F. Finaish, University of Missouri-Rolla

10 a.m. "Turbulence Wavenumber Spectra in Fully-Developed Smooth Pipe Flow." J. C. S. Lai, University of New South Wales; K. J. Bullock and P. Hollis, University of Queensland

10:20 a.m. "Energy and Scalar Variance for Turbulence: Velocity and Scalar Bispectra." J. R. Hennig, National Center for Atmospheric Research; and C. Metals, Institut de Mecanique de Grenoble

10:40 a.m. "Bispectral Behavior of Large Ensembles of Exact Solutions to Burgers' Equation for Random Initial Conditions—A Preliminary Report." W. Zheng and X. B. Reed, Jr., University of Missouri-Rolla

11:00 a.m. "The Effect of Streamline Curvature on Decaying Grid Turbulence." P. L. Johnson and J. P. Johnston, Stanford University

9:00 a.m. "Vortex Shedding and Karman Street Development Downstream of Single and Tandem Airfoils." M. P. Liandrat, Old Dominion University; and R. D. Watson, NASA Langley Research Center

9:20 a.m. "Vortex Street in a Confined Slurry Flow." C. O. Popiel and D. F. Van Der Merwe, Energy Laboratory, South Africa

9:40 a.m. "Turbulence Measurements in an Atomizing Jet." H. J. Hussein and J. Stone, Vanderbilt University; and B. E. Ank, Dantec Electronics

10:00 a.m. "Effect of Turbulence Measured by Low Inertia Gill Anemometer on Droplet Coagulation." R. Hopkins and J. Podzimek, University of Missouri-Rolla

Adjournment

Equipment Exhibit

Suppliers of equipment for turbulence measurements and analysis are invited to demonstrate their equipment during the Symposium. TSI, TSI, and Aerometrics will be present.

Registration

All attendees are urged to return the registration form to allow an estimate of attendance. A registration fee of \$225 is being charged. A special rate of \$100 is available for graduate students if accompanied by a letter from their faculty adviser. It includes coffee breaks but does not cover the cost of the lunches or the banquet on Tuesday evening. Attendees who preregister will receive a local map of the UMR campus and motel locations with telephone numbers in order to make their own lodging arrangements.

Transportation

Bus pickup will be provided at major motels in Rolla.

Proceedings for Former Symposia

The proceedings of the 1971, 1973, 1975, 1981, 1983 and preprints of the 1984, 1986 and 1988 Symposia on Turbulence are available for purchase by use of the application blank.

Meeting Places

University Center-East, University of Missouri-Rolla, for lectures and luncheons; Zeno's Motel and Steak House for social hours and banquet.

For Further Information

Waiter Ries, Coordinator
Continuing Education
119 Mechanical Engineering Annex
University of Missouri-Rolla
Rolla, MO 65401-0249
Phone (314) 341-4132 or
1-800-752-5057

Continuing Education
University of Missouri-Rolla

REGISTRATION CARD September 24-26, 1990

SYMPOSIUM ON TURBULENCE

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Registrants: (Please Check)

☐ Registration Fee	\$225
☐ Registration Fee less \$100 deposit	\$125
☐ Graduate Student Registration Fee	\$100
☐ Monday Luncheon	\$ 8
☐ Tuesday Luncheon	\$ 8
☐ Banquet Dinner	\$ 19
☐ 1971 Proceedings	\$ 11
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☐ 1983 Proceedings	\$ 40
☐ 1984 Preprints	\$ 25
☐ 1986 Preprints	\$ 30
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☐ *Overseas Mailing Charge	\$ 25

Total Enclosed

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or airways serve St. Louis (100 miles east of Rolla). Car rentals may be made at the airport.

round buses leave the airport each day bound for Rolla and vice versa. The Greyhound schedule is:

(central daylight savings time)

St. Louis Airport to Rolla
Departure times:

Daily
8:10 a.m.
2:30 p.m.
7:05 p.m.
8:20 p.m.
11:20 p.m.

Rolla to St. Louis Airport
Departure times:

Daily
3:05 a.m.
9:50 a.m.
12:30 p.m.
1:20 p.m.
3:25 p.m. (Mon.-Fri.)
6:45 p.m.
10:00 p.m.

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