

**ANNUAL REPORT FOR THE CENTER
FOR ENERGY AND COMBUSTION RESEARCH**

University of California, San Diego

July 1, 1991- June 30, 1992

1. Summary and Plans for the Coming Year

This center, previously known as the UCSD Energy Center, was given its new name in 1986 to underscore the close link on campus between energy and combustion research. Approximately twenty faculty and professional staff members are affiliated informally with CECR.

Since its origins, the center has focused on basic problems in finding new sources of energy and the social, environmental, economic, and political consequences of energy consumption, including combustion. Studies range from investigations into the fundamental nature of energy and combustion to practical applications in energy conservation and production, as well as pollution control.

Current research includes fundamental studies in combustion related to aerospace-plane propulsion, to power production and soot production by hydrocarbon fuels, and to use of boron fuels and sprays in combustion chambers. Two specific new grants are for Fundamentals of Acoustic Instability in Liquid-Propellant Rockets and Theories of Turbulent Combustion in High Speed Flows.

In one recent highlight, with support from General Atomics, undergraduate summer scholarship winners completed research projects on Reduced Chemical Kinetic Mechanisms for Heptane-Air Diffusion Flames and Offshore Compressed Air Energy Storage Ocean Wave Energy Conversion. In June of 1992, the Center hosted the annual Propulsion meeting of the Air Force Office of Scientific Research. It has brought together researchers from England, Spain, Germany, France, Poland, Mexico, Australia, Japan, and China for brief periods of study and of exchange of ideas.

Plans for the 1992-93 academic year include further emphasis on fluid dynamics of reacting and rarefied-gas flows relevant to propulsion. Two URI proposals have been submitted to the Air Force Office of Scientific Research on these subjects. In addition, renewed efforts in the areas of energy and of atmospheric air pollution are planned.

2. Advisory Committee

Mr. Neal Blue
Chairman and Chief Executive Officer
General Atomics

Mr. Gary D. Cotton
Senior Vice-President
Engineering and Operations
San Diego Gas & Electric

Dr. Edward A. Frieman
Director
Scripps Institution of Oceanography

Dr. Alan C. Kolb
Chairman and Chief Executive Officer
Maxwell Laboratories, Inc.

Mr. Mike Merlo
Manager of Research
Southern California Edison Company

3. Faculty and Researchers

Active faculty participants during the period 1990 - 92 included Director Forman A. Williams, Associate Director K. Seshadri, as well as Abraham L. Berlad, Robert J. Cattolica, Alvin S. Gordon, Juan C. Lasheras, Paul A. Libby, Stanford S. Penner, and Massoud T. Simnad.

Professional Researchers during the period 1991 - 92 included Jong Soo Kim, Shui-Chi Li, Gregory T. Linteris, and Kurt O. Lund.

4. Graduate and Postdoctoral Students

The number of graduate and post-doctoral students directly contributing to the unit who participated through assistantships, fellowships, or traineeships was 10, and the number of students otherwise involved in the unit's work was 4.

5. Instructional Programs

Undergraduate and graduate instruction were offered, as in prior years, on energy- and combustion-related topics within the Department of AMES and the Program on Science, Technology and Public Affairs.

The ORU sponsors a general series of seminars and public lectures in its areas of activities. A listing of these seminars is given in the following table.

| SEMINAR SPEAKER | DATE | TOPIC |
|--------------------|----------------|---|
| Xing Zhong Li | Feb. 4, 1991 | The Precursor of the "Cold Fusion" Phenomenon in Metal Deuterium Systems |
| C. K. Law | Feb. 7, 1991 | Stabilization, Extinction, and Flammability in Premixtures |
| A. K. Oppenheim | Feb. 14, 1991 | On the Mechanism of Turbulent Combustion |
| Edmund Storms | March 4, 1991 | Cold Fusion, Conflict Between Ego and Observation |
| Shunichi Tsugé | March 15, 1991 | The Premixed Turbulent Flame as a Solitary Wave |
| Tai-Kang Liu | July 1, 1991 | Effect of Boron Particle Surface Coating on Combustion of Solid Propellant for Ducted Rockets |
| Liya Regel | July 25, 1991 | Space Materials Research and Commercial Crystal Growth in Space |
| Irvin Glassman | Oct. 28, 1991 | Combustion of Metals Revisited Thermodynamically |
| Alvin S. Gordon | Oct. 30, 1991 | Alternative Fuels |
| Shunichi Tsugé | Nov. 22, 1991 | Solitary Wave Solution of Premixed Turbulent Flames and Turbulent Benard Convection |
| A. K. Oppenheim | Feb.2, 1992 | Future of Combustion in Engines |
| R. W. Bilger | April 20, 1992 | The CMC Method for Turbulent Non-premixed Combustion |
| S. S. Penner | June 5, 1992 | Energy Supplies with Sustainable Environmental Impacts |

6. Participation From Other Organizations

A number of specialists from other organizations working on energy and combustion research have been regular visitors to UCSD and have participated in campus programs through formal lectures and informal discussions. These include:

| | July 1, 1991- June 30, 1992 |
|---------------------|---|
| VISITOR | AFFILIATION |
| Shunichi Tsugé | University of Tsukuba, Japan |
| A. K. Oppenheim | University of California, Berkeley |
| Robert Bilger | University of Sydney, Australia |
| Amable Liñán | Departamento de Motopropulsion y Thermofluidodinamica, Universidad Politécnica de Madrid, Spain |
| Michal Cialkowski | Institute for Heat Engineering and Combustion Engines of Mosina, Poland |
| Dan Deitrich | Nasa Lewis Research Center, Cleveland |
| Irvin Glassman | Princeton University |
| Hideto Ikeda | IHI Research Institute, Japan |
| Masato Mikami | University of Tokyo, Japan |
| Jun'ichi Sato | IHI Research Institute, Japan |
| Tohru Mitani | Kakuda Research Center, National Aerospace Laboratory, Japan |
| Takashi Niioka | Tohoku University, Sendai, Japan |
| Dietmar Trees | Technische Hochschule, Aachen, Germany |
| Carlos Vasquez Espi | Escuela de Ingenieros Aeronauticos, Ciudad Universitaria, Madrid, Spain |
| Sun Yi | Energy Conservation Technology Center, Harbin, China |
| Tai-Kang Liu | Chung Shan Institute of Science and Technology, Taiwan, China |
| Liya Regel | Academy of Sciences, Moscow |
| William Wilcox | Clarkson University |
| Cesar Treviño | Facultad de Ingenieria, UNAM, Mexico |

7. Public Relations Activities

Faculty and staff members associated with the UCSD Center for Energy and Combustion Research continue to be involved in energy policy and analysis activities and studies at local, state, national and international levels. The editorial offices for Energy, The International Journal (published by Pergamon Press in London, England, since 1975) remain housed at the UCSD Center for Energy and Combustion Research. S.S. Penner is the Chairman of the Panel of Experts for the California Council on Science and Technology advising the Integrated Waste Management Board of the State of California.

8. Publications

1. H.K. Chelliah, C.K. Law, T. Ueda, M.D. Smooke and F. A. Williams, "An Experimental and Theoretical Investigation of the Dilution, Pressure and Flow-Field Effects on the Extinction Condition of Methane-Air-Nitrogen Diffusion Flames," Twenty-Third Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, PA, 1991, 503-511
2. E. Gutheil and F. A. Williams, "A Numerical and Asymptotic Investigation of Structures of Hydrogen-Air Diffusion Flames at Pressures and Temperatures of High-Speed Combustion," Twenty-Third Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, PA, 1991, 513-521.
3. W.T. Ashurst. and F. A. Williams, "Vortex Modification of Diffusion Flamelets," Twenty-Third Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, PA, 1991, 543-550.
4. S.C. Li and F. A. Williams, "Ignition and Combustion of Boron in Wet and Dry Atmospheres," Twenty-Third Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, PA, 1991, 1147-1154.
5. I.K. Puri, P.A. Libby and F. A. Williams, "Water-Gas Shift Reaction in Droplet Burning," Dynamics of Deflagrations and Reactive Systems: Heterogeneous Combustion (A.L. Kuhl, J.-C. Leyer, A.A. Borisov and W.A. Sirignano, editors), Vol 132 of Progress in Astronautics and Aeronautics, American Institute of Aeronautics and Astronautics, Washington, D.C., 1991, 150-163.
6. F. A. Williams, "Turbulent Reacting Flows," Chapter 8 of Fossil Fuel Combustion: A Source Book, (W. Bartok and A.F. Sarofim, editors), John Wiley and Sons, New York, 1991, 459-525.
7. S.B. Margolis and F. A. Williams, "Flame Propagation in Solids and High-Density Fluids with Arrhenius Reactant Diffusion," Combustion and Flame 83, 390-398 (1991).
8. F. A. Williams, "Turbulent Combustion," Recent Advances in Combustion Modelling (B. Larroutourou, editor), World Scientific, Singapore, 1991, pp. 221-231.
9. R.C. Aldredge III and F. A. Williams, "Influences of Wrinkled Premixed-Flame Dynamics on Large-Scale, Low-Intensity Turbulent Flow," Journal of Fluid Mechanics 228, 487-512 (1991).
10. F. A. Williams, "Overview of Asymptotics for Methane Flames," Chapter 4 of Reduced Kinetic Mechanisms and Asymptotic Approximations for Methane-Air Flames (M.D. Smooke, editor), Springer-Verlag, New York 1991, 68-85.
11. H.K. Chelliah, C. Treviño and F. A. Williams, "Asymptotic Analysis of Methane-Air Diffusion Flames," Chapter 7 of Reduced Kinetic Mechanisms and Asymptotic Approximations for Methane-Air Flames, (M.D. Smooke, editor), Springer-Verlag, New York, 1991, 137-158.

12. K. Saito, A.S. Gordon, W.F. Stickle and F. A. Williams, "A Study of the Early History of Soot Formation in Various Hydrocarbon Diffusion Flames," *Combustion Science and Technology* 80, 103-119 (1991).
13. G. Balakrishnan, A. Liñán and F. A. Williams, "Compressibility Effects in Thin Channels with Injection," *AIAA Journal* 29, 2149-2154 (1991).
14. G.T. Linteris, P.A. Libby and F. A. Williams, "Droplet Dynamics in a Non-Uniform Flow Field," *Combustion Science and Technology* 80, 319-335 (1991).
15. A. L. Berlad and V. Tangirala, "Particle Segregation Effects on the Combustion Safety of Dust-Containing Systems" in "Dynamics of Deflagrations and Reactive Systems: Heterogeneous Combustion". Eds.: A. L. Kuhl, et al. *Prog. in Astronautics and Aeronautics*, AIAA, Wahington, D.C., pp 59-72 (1991).
16. A. L. Berlad, V. Tangirala, H. Ross and L. Facca, "Radiative Structures of Lycopodium-Air Flames in Low Gravity," *J. Propulsion and Power* 7: 1 (1991), 5-8.
17. V. Tangirala, K. Seshadri, C. Trevino, and M. D. Smooke, "Analysis of the Structure of Counterflow Hydrogen-Air Diffusion Flames", *Dynamics of Deflagrations and Reactive Systems: Flames*, *Progress in Astronautics and Aeronautics* (Ed. Richard Seebass), Volume 131., 89-110 (1991).
18. K. Seshadri and J. Gottgens, "Structure of the Oxidation Layer for Stoichiometric and Lean Methane-Air Flames", in *Reduced Kinetic Mechanisms and Asymptotic Approximations for Methane-Air Flames* (Ed. M. D. Smooke), *Lecture Notes in Physics*, Vol 384, Chapter 6, 111-136 (1991).
19. M. Bui and K. Seshadri, "Comparisons Between Experimental Measurements and Numerical Calculations of the Structure of Heptane-Air Diffusion Flames", *Combustion Science and Technology* 79, No 4-6, 293-310 (1991).
20. M. B. Richards and S. S. Penner, "Oxidation of a Porous Graphite Cylinder with Airflow through a Coaxial Hole," pp. 223-247 in *Dynamics of Deflagration and Reactive Systems: Heterogeneous Combustion*, A. L. Kuhl, J. C. Leyer, A. A. Borisov, and W. A. Sirignano eds., vol. 132 of *Progress in Astronautics and Aeronautics*, AIAA, Washington, D.C. (1991).
21. S. S. Penner, C. P. Li, M. B. Richards, and D. F. Wiesenbahn, "A Model for De Novo Synthesis and Decomposition Rates of Dioxins and Furans in Municipal-Waste Incinerators," *The Science of the Total Environment* 104, 35-46 (1991).
22. S.S. Penner, "Fossil-Fuel Resources and CO₂ Production from Combustion", *Energy - The International Journal* 16, 1417-1419 (1991).
23. M. Champion and P. A. Libby, "Asymptotic Analysis of Stagnating Turbulence," *AIAA J.* 29 (1991), 16-14.

24. K. N. C. Bray, M. Champion and P. A. Libby, "Premixed Flames in Stagnating Turbulence. Part 1. General Formulation and Gradient Model for Counterflowing Streams," *Combust. Flame*, 84 (1991), 387-406.
25. I. Puri and P. A. Libby, "The Influence of Transport Properties on Droplet Burning," *Combustion Science and Technology* 76 (1991), 67-80.
26. T. R. Blake and P. A. Libby, "Combustion of a Spherical Carbon Particle in Slow Viscous Flow," *Combustion and Flame* Vol. 86 (1991), 147-161.
27. K. N. C. Bray and P. A. Libby, "Comment on 'Pressure-Containing Correlations in Variable Density and Turbulent Reacting Flows', by P. M. Campbell and A. K. C. Lau," *Combustion and Flame* Vol. 80 (1991), 108-109.
28. E. Meiburg, J. C. Lasheras and J. Martin, "Experimental and Numerical Analysis of the Three-dimensional Evolution of an Axisymmetric Jet". Turbulent Shear Flows 7., SpringerVerlag, (Berlin, Heidelberg. Germany). Durst, Launder, Schmidt Editors, pp 195-208, (1991).
29. J. C. Lasheras and E. Meiburg, "On the Three-dimensional Dynamics of the Coherent Vortical Structure Forming in Free, Shear Flows". Turbulence and Coherent Structures. Kluwer Academic Publishers, (Dordrecht, Holland). M. Lesieur and O. Metais Editors. pp 91-111, (1991).
30. E. Meiburg, J. Martin and J. C. Lasheras. "Three-dimensional Evolution of an Axisymmetric Jet". Separated Flows and Jets. Springer-Verlag, (Berlin, Heidelberg, Germany), Koslof and Dovgal Editors. pp 629-646, (1991).
31. J. C. Lasheras. "Topology of the Vorticity Field in Three-dimensional Co-flowing Forced Jets". The Global Geometry of Turbulence. Plenum Publishing Co. (New York). J. Jimenez Editor, Series B: Physics Vol 268, pp 95-104, (1991).
32. A. Ganan and J. C. Lasheras, "The Dynamics of Mixing of Small Spherical Particles in a Plane, Free Shear Layer". Physics of Fluids A, Vol 3, No 5-1, pp 1207-1302, (1991).
33. J. C. Lasheras. "Vortex Dynamics in Three-Dimensional Co-flowing Jets Under the Combined Effect of Axial and Azimuthal Forcing". Vortex Dynamics and Vortex Methods. AMS-SIAM Lectures in Applied Mathematics. Vol. 28, pp 403-422, (1991).
34. A. Lecuona, P. Rodriguez and J.C. Lasheras. "Three-Dimensional Structure of Strongly Forced Jets Diffusion Flames: Flow Visualization Studies". Combustion-Flow Diagnostics. Kluwer Academic Publishers, (Dordrecht, Holland). Durao, Eitor, Whitelaw and Witze Editors, (in press) (1991).

35. Kurt O. Lund, Anthony M. Colangelo and Gregory S. McKim. "Thermal-contact Electronic Packaging in Solar-Pointing Space Environment." *J. Solar Energy Engineering*, Vol. 113, No. 1, 42-50.(1991).
36. Kurt O. Lund, "Heat Rejection in High Temperature Phase-Change Space-Shuttle Experiment." *Solar Engineering - 1991, Proc. 2nd ASME-JSES-JSME International Solar Energy Conference*, 387-398, Reno, NV, (1991).
37. S. C. Li, "Optical Measurement of Size Histories of Boron Particles in Ignition and Combustion Stages," *Combustion Science and Technology*, Vol. 77 (1991), 149-169.
38. S. C. Li and F. A. Williams, "Ignition and Combustion of Boron Particles," *Second International Symposium on Special Topics in Chemical Propulsion: Combustion of Boron-Based Solid Propellants and Solid Fuel*, K. K. Kuo (Ed.), by Hemisphere Publishing Corporation, March, 1991, 24 pages.
39. L. Sinay and F. A. Williams, "An Analytical Approach to the Description of Nonadiabatic Cellular Flames Near Extinction," *Siam J. Applied Mathematics* 52, 416-427 (1992).
40. J.S. Kim, P.A. Libby and F. A. Williams, "Influences of Swirl on the Structure and Extinction of Strained Premixed Flames. Part II: Strong Rates of Rotation," *Physics of Fluids A* 4, 391-408, (1992).
41. M. Bui-Pham, K. Seshadri, and F. A. Williams, "The Asymptotic Structure of Premixed Methane-Air Flames with Slow CO Oxidation," *Combustion and Flame* 89, 343-362, (1992).
42. K. Seshadri, A. L. Berlad, and V. Tangirala, "The Structure of Premixed Particle Cloud Flames", *Combustion and Flame* 89, 333-342 (1992).
43. M. T. Simnad (ed.), A. Goodjohn and J. Kupitz (assoc. eds.), "High-Temperature Helium Gas-Cooled Reactors," *Special Issue of Energy - The International Journ.*, 16 (1/2), 1-601 (Jan./Feb. 1992).
44. M. T. Simnad, "The Early History of HTGR Nuclear Power Reactors," *Energy - The International Journ.*, 16 (1/2), 25-32 (Jan./Feb. 1992).
45. M. T. Simnad, "The Modular HTGR: Its Possible Role in the Use of Safe and Benign Nuclear Power," invited paper, p. 307-321 in *Proc. Conf. on Climate Change and Energy Policy*, Los Alamos, NM, Oct. 21-24, 1991, L. Rosen and R. Glasser (eds.), Amer. Inst. Phys., New York, 1992.
46. D. Czechowicz, J. Kaae, and M. T. Simnad, "Versatility of HTGR TRISO Nuclear Fuel for Space Applications," invited paper, p. 465-474, in *Proc. Conf. on Space Nuclear Power*, Jackson Hole, Wyoming, July 1-3, 1992, Amer. Nucl. Soc., (1992).

47. E. A. Early, M. T. Simnad, and M. B. Maple, "Properties of Alloy Precursors and the Resulting Superconducting YBaCuO-Ag Composite," *J. Appl. Phys.*, 71(3), 1327-1334 (1992).
48. M. T. Simnad, "Irradiation Effects on Nuclear Reactor Fuels and Fuel Elements for Advanced Nuclear Power Reactors," invited paper, Conf. on Irradiation Facilities: Applications to Nuclear Reactors, March 2-5, 1992, San Diego, CA, TMS/ASM Annual Meeting.
49. B. J. Lazaro and J. C. Lasheras, "Particle Entrainment and Turbulent Mixing in Free Shear-Flows: Part 1. The Naturally Developing Mixing Layer". *Journal of Fluid Mechanics*, Vol. 235, pp 143-178 (1992).
50. B. J. Lazaro and J. C. Lasheras, "Particle Entrainment and Turbulent Mixing in Free Shear-Flows: Part 2. The Forced Mixing Layer". *Journal of Fluid Mechanics*, Vol. 235, pp 179-221 (1992).
51. K. K. Tio, A. Linan and J. C. Lasheras. "Dynamics of Small, Heavy, Spherical Particles in a Periodic Stuart Vortex Flow". Submitted to *Physics of Fluids A*. (1992).
52. J.C. Lasheras, A. Linan, A. Lecuona and P. Rodriguez. "Vorticity Dynamics in Three Dimensional Pulsating Jet Diffusion Flames". 24th International Symposium on Combustion. The Combustion Institute ed, (Pittsburg, PA), (1992) In press
53. K.K. Tio, A. Linan and J. C. Lasheras and A. Ganan . "On the Dynamics of Buoyant and Heavy Particles in a Periodic Stuart Vortex Flow". Submitted for publication to the *Journal of Fluid Mechanics*, (1992).
54. Karl W. Baker and Kurt O. Lund, "Effects of Anisotropic Conduction and Heat-Pipe Interaction on Minimum-Weight Space Radiators." *Solar Engineering - 1992*, Vol. 2, Proc. ASME-JSES-KSES International Solar Energy Conf., 747-754. Maui, HI, (1992).
55. Kurt O. Lund, "FFT Analysis of Sensible-Heat Solar Dynamic Receivers." Proc. 27th Intersociety Energy Conversion Engineering Conf., Vol. 2, 2.359-2.367, San Diego, CA, (1992).
56. J. M. Card and F. A. Williams, "Asymptotic Analysis of the Structure and Extinction of Spherically Symmetrical n-Heptane Diffusion Flames." *Combustion Science and Technology*, Vol. 84, pp.91-119, 1992.
57. J. S. Kim, "A Formulation for Transverse Acoustic Instability in Liquid-propellant Rocket Motors." CECR Report 92-01, 1992.

9. Numbers of Full Time Employees

The number of full time administrative employees is 2, one university-supported and the other supported on extramural funds.

10. Space

The Center for Energy and Combustion Research occupied these rooms in Urey Hall: 6202, 6206, 6210, 6214, 6218, 6222, 6234, 6238, 6242, 6246, 6250, 6254, 6258, 6262, and 7230, and these labs in Urey Hall: 6106-6112, 6114, 6116-6120, 6124-6126, 6130 and 6132. In the Engineering Building, the Center occupied rooms 2208, 3205, and 6226.