FIVE-YEAR SUMMARY REPORT ON THE UCSD ENERGY CENTER (EC)/ CENTER FOR ENERGY AND COMBUSTION RESEARCH (CECR)

(July 1, 1984 to June 30, 1989)

TABLE OF CONTENTS

Tables

FIVE-YEAR SUMMARY REPORT ON THE UCSD ENERGY CENTER (EC)* / CENTER FOR ENERGY AND COMBUSTION RESEARCH (CECR)**

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HISTORY

The UCSD Energy Center commenced operation informally during the fall of 1972 and was designated an organized research unit at UCSD as of July 1, 1974. The goals in establishing the Energy Center are well defined by the following statement abstracted from the October 1973 draft proposal to establish this ORU:

> The purpose of a UCSD Energy Center is to strengthen interdisciplinary programs of research and teaching, as well as to provide graduate and post-doctoral students with added research opportunities, facilities and assistance.
>
> The establishment of a UCSD Energy Center will serve important educational, research, and public-service functions which are not satisfactorily met by the existing departments or other organized research units at UCSD. An opportunity exists in the San Diego area to solve fundamental problems deriving from the interrelated physical, biological, economic, political, and social consequences of man's need for energy. The importance of energy problems arises from factors which include: (i) the key role of energy supply in the functioning and growth of industrial society, (ii) the finite supply of fossil-fuel resources, (iii) the environmental side effects of energy production and use (air, water and thermal pollution), (iv) risks associated with nuclear-energy production (radioactive release, diversion of fissionable material for military use), (v) the danger that planning in the energy area, which has a controlling effect on many other areas of planning, will be ruled by considerations which are too narrow or biased to reflect the public interest.

S. S. Penner, Professor of Engineering Physics in the Department of Applied Mechanics and Engineering Sciences, was asked to assume overall responsibility for coordination and development of the UCSD Energy Center plan. Since its inception, there have been no budgetary allocations made for the support of faculty, senior research staff or graduate students associated with EC/CECR. Instead, involvement in studies has followed

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* Prior to September 1986.

** Since September 1986.

the principle that faculty participation is only effective when it is accomplished in accord with individual preferences, competence and availability, depending on the subject matter under investigation. A loosely-knit group of EC/CECR participants was created (see Appendix I) by soliciting expressions of interest and involvement by faculty members and research personnel whose activities and areas of competence were consonant with the purposes, public-service activities, teaching functions, and research programs performed at EC/CECR.

The development of the UCSD Energy Center was greatly aided by a program-initiation grant, which was received from the Gulf Oil Foundation during 1973. A number of graduate fellowships were established by grants received from the High Temperature Reactor Associates, the San Diego Gas and Electric Company, and the Shell Oil Foundation.

INSTRUCTIONAL PROGRAMS

Early emphasis of Energy Center efforts was placed on course development.

Since the beginning of the 1974-75 academic year, the following courses have been offered intermittently (courses taught during the last five years are identified by asterisks):

AMES 34: A Freshman-level course dealing with Energy: Demands, Resources, Technology and Policy. This is a survey course on energy stressing the following topics: the manner in which our energy demands are defined at the local, regional, national and international levels; the total (currently used and potential) resources available for satisfying energy demands; highlights of technological challenges concerning new energy-production and utilization techniques; energy policy, with emphasis on potential environmental and economic impacts.

AMES/FS 119A*: An interdisciplinary, upper-division course on Energy: Demands, Resources, Technology and Policy. This course includes the following topics: past and estimated future energy demands; renewable and non-renewable energy resources; economic impact of energy use; environmental impact of energy use; energy conservation in manufacturing, transportation, home use; energy policies.

AMES/FS 119B*: An interdisciplinary, upper-division course on Energy: Non-Nuclear Energy Technologies. This course includes the following topics: oil recovery from tar sands and oil shale; coal production, gasification, liquefaction, and utilization; the hydrogen economy; energy-storage systems; techniques for direct energy conversion;

solar-energy utilization; energy from windmills; tidal and wave-energy utilization; hydroelectric power generation; hydrothermal energy; geothermal energy from hot rocks; electrical power production, transmission and distribution.

AMES/FS 119C*: An interdisciplinary, upper-division course on Energy: Nuclear Energy Technologies and Energy Policies. This course includes the following topics: a brief survey of energy demands and resources; available nuclear energy (physical background, thermal dynamics, atomic and nuclear physics; fission and fusion processes); physics of fission reactions; engineering aspects, safety and environmental effects of fusion; scaling laws and start-up criteria; laser fusion; magnetic confinement; equilibrium; instability; nuclear energy policies.

In addition, a one-quarter course per year has typically been offered at the advanced graduate level on selected energy technologies (e.g., coal gasification and liquefaction, solar energy, geothermal energy, fusion power, fault-tree analysis of nuclear reactor safety, etc.). Faculty members from several departments have been regular participants in these interdisciplinary offerings. The course material that has been used in AMES/FS 119A, 119B and 119C prior to 1984 is described in the following publications:

Energy, Volume I: Demands, Resources, Impact, Technology, and Policy, 373 pages, by S.S. Penner and L. Icerman, Addison-Wesley Publishing Company, Reading, Mass., 1974; reprinted in 1976 and 1979; a second edition was published in 1981.

Energy, Volume II: Non-Nuclear Energy Technologies, 673 pages, by S.S. Penner and L. Icerman, Addison-Wesley Publishing Company, Reading, Mass., 1975; reprinted with revisions in 1977; reprinted in 1979; a second edition was published in 1984 (by Pergamon Press, Inc.).

Energy, Volume III: Nuclear Energy and Energy Policies, 713 pages, by S.S. Penner, K.A. Brueckner, R.J. Cerbone, A. Hochstim, J.P. Howe, L. Icerman, M.Z. Nagel, W.B. Thompson, and B.J. West, Addison-Wesley Publishing Company, Reading, Mass., 1976.

Extensive revisions and updating of these books has been done during the last five years for these scheduled courses, although the books have continued to serve as useful source materials.

A regular schedule of undergraduate and graduate instruction on combustion is offered by EC/CECR participants. The following courses have been offered at least once in two years.

AMES 211: Introduction to Combustion. In this course, the students are exposed to a systematic development of the theory of chemical reactions in fluid flows. An attempt is made to cover the entire field, although emphasis is placed on the theoretical aspects of the subject. Topics include relevant thermodynamics, chemical kinetics, fluid mechanics, applied mathematics, and transport processes. Other topics include deflagrations, detonations, diffusion flames, premixed flames, ignition and extinction processes, and turbulent combustion.

AMES 213: Mechanics of Propulsion. In this course, students are exposed to the fluid mechanics, thermodynamics, and combustion processes involved in the propulsion of aircraft by use of air-breathing engines, as well as space-vehicle propulsion using solid- and liquid-propellant rocket engines. Topics include discussions on the operations of diffusers, compressors, combustors, turbines, pumps, and nozzles. Other topics include combustion instability, spray combustion, and combustion of solid propellants.

The following textbooks have been used for instruction in combustion and propulsion:

Combustion Theory (Second Edition), 680 pages, by F.A. Williams, Benjamin/Cummings Publishing Co., Inc., Menlo Park, CA (1985).

Mechanics and Thermodynamics of Propulsion, 563 pages, by P.A. Hill and C.R. Peterson, Addison-Wesley Publishing Company, Reading, Massachusetts (1965).

The UCSD Energy Center/CECR does not accept or process applications for graduate students. All inquiries concerning admission to graduate work are submitted directly to the responsible UCSD departments.

RESEARCH

Although there is considerable overlap between combustion and energy research, we will distinguish between these two areas on the basis of the primary funding authorities and purposes of the studies.

A great deal of the research in the physical, engineering, biological, and social sciences is energy-related. In this sense, investigations performed by many UCSD faculty members under their own grants and contracts are important in furthering the objectives of

EC/CECR. The following examples of these studies will serve to indicate the scope of activities with readily identifiable bearing on important energy issues:

Predictive air-quality models for land use, transportation and energy planning; physico-chemical models of regional air pollution; short-term statistical predictions; air-basin time-response studies.

Measurements of rate constants for elementary chemical reaction steps.

Development of superconducting materials for use at elevated temperatures.

Possible "fusion" at low temperatures.

Hydrogen storage in rare-earth metals.

The use of biological systems for the direct production of hydrogen on exposure of water to solar radiation.

Development of new insulating materials.

Geophysical aspects of energy utilization.

Escalating atmospheric CO_2 levels and the greenhouse effect.

During prior five-year periods and with support from the San Diego Gas and Electric Company and from the U.S. Department of Energy, associates of the UCSD Energy Center developed integrated programs dealing with energy conservation, which included the following topics: systems management of passive energy-conserving devices in residential units, fenestration devices for energy conservation, passive solar energy technologies in energy conservation, ceiling insulation in energy conservation, control of infiltration to reduce energy use, improved lubrication for energy conservation, electric load management, and life-cycle costing in energy conservation. These programs involved experimental measurements on components, field measurements on model homes, field evaluations and data analyses of consumer acceptance, as well as analyses, evaluation, and publication of results.

Energy- and combustion-related publications by faculty members associated with EC/CECR during the last five years are summarized in Tables 1 and 2.

Among energy-related studies performed during the last five years, the following may be singled out as indicative of major research thrusts:

(i) An assessment of "Developing Coal Combustion Technologies" for the U.S. Department of Energy. The resulting multi-author publication of this lengthy manuscript was first published in Energy and then reprinted in the review journal Progress in Energy and Combustion Science at the request of the Editor of the latter journal. This episode provides an excellent example of the close linkage between the fossil-fuel part of energy research and combustion research.

(ii) An assessment of Research Needs for Advanced Fuel Cells was performed for the U.S. Department of Energy and published as a book-length (229 pages) manuscript in a special issue of Energy in 1986; this special issue was reprinted for sale also as a hard-cover book.

(iii) An assessment of Coal Gasification: Direct Applications and Syntheses of Chemicals and Fuels was performed for the U.S. Department of Energy and published first by NTIS (300 pages) and then as a special issue of Energy (288 pages) and as a hard-cover book in 1987.

(iv) Two assessments were performed for the National Science Foundation during 1988 on incineration of municipal, hazardous and biomedical wastes. Both of the resulting reports were distributed by NSF with UCSD Energy Center covers. The first of these studies dealt with combustion research and led incidentally to the first published resource assessment (about 10,000 MWe) for steady-state incineration of usable wastes in the U.S. [see Penner et al, Energy 13, 845-851 (1988)]. The second study dealt with "Diagnostics of Gaseous Emissions from Waste Incinerators" and is currently (1989) in press (29 pages) in Energy.

(v) Extensive studies on utility-load forecasting have been performed by R. Ramanathan and his colleagues in the Department of Economics for the Electric Power Research Institute and the Wisconsin Electric Power Company.

(vi) Numerous studies have been carried out by M.T. Simnad and his colleagues at General Atomics on all aspects of the development and commercialization of the high-temperature gas-cooled reactor, with emphasis on nuclear fuels and improved materials.

(vii) Numerous studies by M.T. Simnad and colleagues in the Department of Physics deal with the developments of high-temperature superconducting materials.

(viii) An analysis has been completed by M.T. Simnad of how one trillion dollars was wasted on nuclear power, with 500 billions of dollars lost in the U.S. alone.

(ix) A detailed investigation was conducted of systems for thermal energy storage by G. Arrhenius and A.G. Tsai.

(x) Other energy-related publications are listed in Table 1. Here, it suffices to note recent and current emphasis on oxidation of nuclear-grade graphite, which may become a key technical and policy issue if efforts to commercialize a new,

"passively safe" generation of nuclear reactors (such as GA's high-temperature, gas-cooled nuclear reactor or HTGR) come to fruition.

E.D. Goldberg, who has served as an Associate Director of CECR since 1986, has continued an active research program on environmental issues. His energy-related studies are listed in Table 1 as Nos. 34-41 and deal especially with waste disposal in the oceans and carbon in the environment.

COMBUSTION RESEARCH

Combustion research at EC/CECR covers an especially wide range of fundamental and applied topics, including each of the following: laser diagnostics of combustion systems, structures of adjacent laminar diffusion flames, mechanisms for the formations of dioxins and furans in municipal-waste incinerators and the development of procedures for minimization of their production, structures of stretched laminar premixed flames, description of the asymptotic structure of laminar premixed flames and diffusion flames using reduced chemical kinetic mechanisms, turbulent flames, and combustion under reduced gravity. Publications dealing with combustion research are summarized in Table 2. The following are examples of current studies.

Experimental, numerical and analytical studies are in progress to clarify the mechanisms of propagation of flames in particle clouds under microgravity conditions. This research is being performed by A.L. Berlad and V. Tangirala in collaboration with scientists at the NASA Lewis Research Center (LeRC). Studies of flame propagation and extinction for premixed flames have occupied a position of central interest in combustion science. Despite the substantial body of experimental and theoretical work achieved to date, experiments aimed at determining these properties for quiescent premixed particle clouds in a gaseous oxidizer suffer from a number of serious deficiencies. The principal difficulty in performing experiments on particle clouds under normal gravity is caused by sedimentation of particles of significant size, thereby rendering spatial and temporal

uniformity of a quiescent reactive particle cloud impossible. The principal objectives of this experimental microgravity program are to obtain flame-propagation rates and flame-extinction-limit data for several important premixed, quiescent particle-cloud combustion systems under near-zero-gravity conditions. The data resulting from these experiments are needed for utilization with currently available and tractable flame propagation and extinction theory. These data are also expected to provide new standards for the evaluation of fire hazards in particle suspensions for both earth-based and space-based applications. Both terrestrial and space-based fire-safety criteria require the identification of the critical concentrations of particulate fuels, inerts, and other critical conditions that specify flame-existence limits. Novel combustion phenomena have been observed during recent microgravity experiments. "Chattering" particle-cloud flame-data have required new theoretical formulations. Current and future μg particle-cloud experiments may be expected to provide other data which are not only essential to implementation of current theory but also stimulate the creation of new theoretical structures. Previous and ongoing UCSD – NASA LeRC collaborative efforts have been concerned with needed experimental developments for the design and utilization of microgravity particle-cloud experiments. The supportive experimental studies at UCSD include particle-cloud preparation and flame-observation techniques, developments of measures for the suppression of particle-particle and particle-wall attachments, optical methods for deduction of optical absorption-emission properties of individual particles and of clouds of particles, and measurements of vaporization-pyrolysis kinetics for specific particulate types (e.g., lycopodium). General scientific support for all elements of the ongoing microgravity particle-cloud experiments has been derived from close collaborative interaction between UCSD and NASA LeRC personnel. The results of many of these efforts are reflected in the findings detailed under selected references.

K. Seshadri and F.A. Williams have been actively pursuing basic research concerning the structure of laminar flames. Gaseous fuels, liquid fuels and also solid fuels

have been considered in these studies. The liquid fuels include homogeneous solutions of hydrocarbons and alcohols. Since combustion of diesel fuel resembles the processes occurring in diffusion flames and because turbulent, nonpremixed combustion may be considered as a statistical collection of strained, laminar flamelets, studies have been performed on the structures and mechanisms of extinction of strained, laminar diffusion flames and strained, laminar, partially-premixed diffusion flames. The use of alternate fuels often results in soot formation. Therefore, studies were also performed to clarify the chemical mechanisms of soot formation in diffusion flames. For a well-controlled laboratory experiment, it is essential that the composition of the fuel be known. Petroleum-based fuels are often blends of aromatics and aliphatics. For this reason, experiments were performed on such representative fuels as homogeneous solutions of heptane, toluene and methanol. The results have been analyzed by the use of asymptotic theories.

Combustion processes involve a complex interaction of fluid dynamics, chemical kinetics and transport processes, and analytical studies must properly account for these interactions. To clarify the structures of these flames, detailed numerical calculations were performed by M. Smooke at Yale University (working with K. Seshadri and M. Bui at UCSD). The results of these calculations were then compared with experimental measurements. K. Seshadri and F.A. Williams, in collaboration with N. Peters (RWTH, Aachen, FRG), C. Treviño (UNAM, Mexico), and H. Chelliah (Princeton) have developed asymptotic descriptions for the structures of methane air-flames using reduced chemical kinetic mechanisms. The techniques developed show considerable promise of yielding accurate descriptions of the structures of practical flames. Recently, K. Seshadri and F.A. Williams organized a workshop to discuss developments on asymptotic descriptions of methane-air flames. A list of presentations at the workshop and a list of participants are shown in Table 5.

P. A. Libby has presently four research activities dealing with combustion. (i) The first relates to premixed turbulent combustion, which he has carried out for many years in

collaboration with K.N.C. Bray (Cambridge University) and, more recently, with M. Champion (Université de Poitiers). Bray and Champion frequently visit La Jolla for extended periods of time in order to collaborate with P.A. Libby. This research has resulted in the Bray-Moss-Libby model for premixed turbulent combustion, which is generally recognized as providing a useful description for the processes involved. Work is presently underway to extend this theory to premixed flames in stagnating turbulence, which is of great fundamental interest. (ii) Another research program is carried out in collaboration with F.A. Williams and deals with the structure and extinction characteristics of premixed laminar flames for various geometric configurations. Particular attention has been devoted initially to planar flames. More recently, other configurations, such as cylindrical flames and flames subject to both rates of strain and swirl, have been considered. A study of the influence of swirl on premixed laminar flames is currently in progress. (iii) Matched asymptotic expansions have been applied to the equations arising in moment descriptions of turbulent flows. Since many turbulent flows involve multiple length scales, their analyses lend themselves naturally to asymptotic methods. Turbulent channel- and boundary-layer flows have been treated by these methods. In collaboration with Champion, stagnating turbulence, i.e., turbulence which encounters a bluff body such as a circular cylinder, is being investigated. Three distinct regions may be identified: a region far from the body, another close to the body where a shear layer involving all of the processes of convection, diffusion and dissipation exists and, finally, a viscous sublayer immediately adjacent to the body. At high Reynolds numbers, these three regions involve significantly different length scales, and asymptotic methods are therefore applicable. (iv) The behavior of droplets in nonuniform flow fields is the subject of the fourth research area. In collaboration with I. Puri, experiments involving the photographic tracking of droplets in well defined, nonuniform flows are being carried out. Counterflowing isothermal streams, laminar counterflowing nonpremixed flames and Poiseuille flows are being studied. The purpose of this research is to assess the validity of the various empirical

formulas used to describe droplet drags and the rates of mass loss in highly nonuniform flows. Recently obtained results indicate significant shortcomings for these formulas. In addition, the droplets are found to experience significant lift. The mechanism for the generation of this lift is presently being investigated.

PUBLIC SERVICE FUNCTIONS

In accord with the principle that public-service functions constitute an important focus for faculty effort, very many of the UCSD faculty members serve on advisory boards of national, statewide and regional governmental agencies. Examples of these activities are the following: membership on the National Science Board; advisory committees of the U.S. Department of Energy and of the congressional Office of Technology Assessment; State of California committees dealing with energy and resources; the Quality of Life Board of the City of San Diego; the EPRI Advisory Committee; the U.S. Advisory Committee for the International Institute of Applied Systems Analysis; energy advisory committees for senior congressional, senatorial, and administration committees; etc.

The performance of research assessments for the U.S. Department of Energy and NSF under contracts awarded to the Regents of the University of California has been noted. Related to this type of activity is a study on "Research Priorities for Advanced Fossil Fuel Technologies" prepared by the Committee on Advanced Fossil Energy Technologies (S. S. Penner, Chairman), Energy Engineering Board, Commission on Engineering and Technical Systems, National Research Council, published by the National Academy Press, Washington, D.C. (1986).

Among the scientific journals edited by UCSD faculty members (the Editor and two Associate Editors are at UCSD) is Energy, The International Journal (Pergamon Press), now in it thirteenth year of publication. EC/CECR participants serve on the Editorial Boards of numerous international journals dealing with combustion research.

The UCSD campus has served as a regional focus for professional seminars, special lectures, and symposia dealing with important public issues such as energy, as well as with combustion research. Representative seminars held at UCSD EC/CECR during the last five years are summarized in Table 3.

FUTURE DIRECTIONS

The instructional, public service functions and research contributions of the UCSD Energy Center have had significant impacts. Without university support for staff and without redirection of research activities by faculty members, the research activities must remain of a type that can pass peer review on the campus, support graduate research of a classical variety in well defined disciplinary fields, and satisfy customers whose time scales are generally incommensurate with established university proceedings.

Participants in the activities of the UCSD Energy Center have selected for past emphasis energy conservation, passive solar technologies, selected costing studies, the development of new fossil-fuel technologies, and waste incineration. Nuclear energy and its problems for U.S. applications have concerned a number of UCSD faculty members on a continuing basis (M. Simnad, W.B. Thompson and J.P. Howe). Novel programs (e.g., OTEC bottoming cycles in San Diego County, novel versions of OTEC, and other unconventional programs) have been assessed periodically but the time for implementation has not been judged appropriate.

A major redirection of research and instructional activities was implemented in 1986 with the redesignation of the ORU as a Center for Energy and Combustion Research. In view of the primary research interests of the majority of CECR participants, it may be anticipated that combustion-research activities will assume much greater relative significance in the future than in the past, which should not be interpreted to mean that the total output of energy-related programmatic activities is destined to decline. On the contrary, as near-term preoccupation in the U.S. shifts again to shortages and excessive

costs for transportation fuels, new directions in fossil-fuel utilization and syntheses will follow. Environmental issues associated with the energy technologies are certain to assume a much larger and more critical role in the future than in the past. A return to nuclear energy in the form of "passively safe" systems appears to be likely. A new generation of renewables, especially in the form of economically advantageous solar technologies, should be ready for the markets during the next decade. Finally, there may be room for additional energy savings through improved technologies, leading to additional energy conservation, which has constituted the most important gains during the last decade in response to escalating prices and economic pressures.

Accompanying future research activities, we may anticipate continuing updating of instructional programs, as well as growth in the number of post-doctoral participants and graduate students. With the initial receipt in 1989 of a $10,000 grant from GA to establish a competitive senior summer-research program, increased involvement in CECR programs by undergraduates may be anticipated.

FUNDING FOR RESEARCH

A summary of contractual support received during the period 1984-89 is given in Table 6.

Table 1. Energy-related publications during the period July 1, 1984 to June 30, 1989.

1. S.S. Penner, S.B. Alpert, J.M. Beér, C.R. Bozzuto, I. Glassman, R.B. Knust, W. Markert, Jr., A.K. Oppenheim, L.D. Smoot, R.E. Sommerlad, C.L. Wagoner, I. Wender, W. Wolowodiuk, and K.E. Yeager, "Developing Coal-Combustion Technologies," Energy 9, 361-418 (1984); also published in Progress in Energy and Combustion Science 10, 87-144 (1984).

2. M.R. Brambley, E.M. Kennedy, S.J. Romelczyk, and S.S. Penner, "Field Study of the Effect of Low-Cost Weatherstripping Devices on Energy Use in Single Family (San Diego) Residences," Energy 9, 465-476 (1984).

3. S.S. Penner and D.F. Wiesenhahn, "Stability of Growth Rates in Energy Technologies," Energy 10, 983-986 (1985).

4. "Research Priorities for Advanced Fossil Energy Technologies," a report prepared by the Committee on Advanced Fossil Energy Technologies, S.S. Penner, Chairman, Energy Engineering Board, Commission on Engineering and Technical Systems, National Research Council, National Academy Press, Washington, D.C. (1986).

5. S.S. Penner, S.B. Alpert, J.M. Beér, M. Denn, W. Haag, R. Magee, E. Reichl, E.S. Rubin, P.R. Solomon, I. Wender, and K. Woodcock, Coal Gasification: Direct Applications and Syntheses of Chemicals and Fuels, 300 pp., Pergamon Press, NY (October 1987) and Energy 12, 623-903 (1987); see also Publication DOE/ER-0326, Dist. Category UC-109, 506 pages, National Technical Information Service, U.S. Dept. of Commerce, Springfield, VA 22161 (June 1987); see also the book by the same title, Pergamon Press, 288 pp., London and New York (1987).

6. S.S. Penner, "Coal Gasification: Direct Applications and Syntheses of Chemicals and Fuels," Fourth Annual Pittsburgh Coal Conference, pp. 493-496, University of Pittsburgh, Pittsburgh, PA (September 28 - October 2, 1987).

7. S.S. Penner, "Research Recommendations on Incineration of Municipal-, Hazardous- and Biomedical-Wastes," 33 pp., NSF, Washington, D.C. (July 1988).

8. S.S. Penner et al, "Research Recommendations on Diagnostics on Gaseous Emissions from Waste Incinerators," 35 pp., NSF, Washington, D.C., November 1988; Energy (in press, 1989).

9. S.S. Penner, D.P.Y. Chang, R. Goulard, and T. Lester, "Waste Incineration and Energy Recovery," Energy 13, 845-851 (1988).

10. S.S. Penner and M.B. Richards, "Oxidation of Nuclear-Reactor-Grade Graphite," Energy 13, 461-468 (1988).

11. M.B. Richards and S.S. Penner, "Pore-Structure-Independent Combustion in Porous Media," Casci Anniversary Volume, Springer (in press, 1989).

12. M.B. Richards and S.S. Penner, "Oxidation of a Porous Graphite Cylinder with Airflow through a Coaxial Hole," to be presented at the Eleventh International Colloquium on Gasdynamics of Explosions and Reactive Systems, The University of Michigan, Ann Arbor (July 1989).

13. R. Ramanathan, C.W.J. Granger and R. Engle, "Two-Step Modeling for Short-Term Forecasting," pp. 131-158 in Comparative Models for Electrical Load Forecasting, D.W. Bunn and E.D. Farmer, eds., J. Wiley & Sons, New York (1985).

14. R. Ramanathan et al, "Weather Normalization of Residential Electricity Sales," EPRI Report EA-4080, Palo Alto, CA (June 1985).

15. "Forecast Master Program Case Studies," R. Ramanathan, ed., EPRI Report EM-5114, Palo Alto, CA (April 1987).

16. R. Ramanathan, "Weather Normalization of WEPCO's Peak Loads," Wisconsin Electric Power Co., Milwaukee, WI (January 1989).

17. M.T. Simnad, "Review of Corrosion, Water Treatment, and Materials in Water-Cooled Nuclear Reactor Steam Generators," General Atomic Report GA-A16330, 142 pp., La Jolla, CA (1984).

18. I. Maya, K.R. Schultz, J.M. Battaglia, L.C. Brown, E.T. Cheng, R.L. Creedon, D.R. Engler, W.G. Homeyer, M.T. Simnad, P.W. Trester, C.P.C. Wong, R.W. Goodrich, B.K. Jensen, and R. Krauss, "Chemical Production Utilizing Fusion Energy," GA-Technologies Report GA-A16813, 140 pp., La Jolla, CA (1984).

19. M.T. Simnad, "Materials for Nuclear Reactors," invited Section in Encyclopedia of Materials Science, pp. 1780-1786, M.C. Beaver, ed., Pergamon Press, London (1986).

20. M.T. Simnad, "Solid Moderator and Reflector Materials for Nuclear Reactors," invited Section in Encyclopedia of Materials Science, pp. 1779-1786, M.C. Beaver, ed., Pergamon Press, London (1986).

21. M.T. Simnad and G.B. West, "TRIGA-LEU Reactor Fuel Irradiation Tests to High Burnup in the ORR," Proceedings of the European Nuclear Society Conference, Geneva (June 1986).

22. M.T. Simnad, "Materials and Fuels Selection and Development Program for the Star-C Space Nuclear Thermionic Power Reactor," section of "GA-Technologies Report to DOE/DOD/NASA," La Jolla, CA (November 1986).

23. M.T. Simnad, "Materials and Fuels for Nuclear Power Reactors," invited contribution to Encyclopedia of Physical Science and Technology, vol. 9, pp. 343-388, Academic Press, New York (Spring 1987).

24. G.B. West, M.T. Simnad, and G.L. Copeland, "Final Qualification Testing Results for TRIGA-LEU Fuel," Trans. Am. Nuc. Soc. 55, 276-277 (1987).

25. E.A. Early, C.L. Seaman, M.B. Maple, and M.T. Simnad, "Preparation and Properties of High-T_c Superconducting Oxide-Silver Composites by Oxidation of a Ductile Alloy Precursor," Physica C 153-155, 1161-1162 (1988).

26. E.A. Early, C.L. Seaman, M.T. Simnad, and M.B. Maple, "Fabrication of High-T_c Superconducting Oxides by Oxidation of Ductile Alloy Precursors," Proc. TMS Symposium on High Temperature Superconducting Oxides, the Metallurgical Society of the AIME, Las Vegas, Nevada (February 27 - March 2, 1989).

27. E.A. Early, C.L. Seaman, M.T. Simnad, and M.B. Maple, "Properties of High-T_c Superconducting Oxide-Silver Composites from Oxidation of Precursor Alloys," Proc. Materials Research Society Annual Meeting, San Diego (April 1989).

28. M.T. Simnad, "Construction Materials for Coal Gasification," Energy 12, 247-261 (1987).

29. M.T. Simnad, "Highlights of Fifty Years of Nuclear Fuels Developments," invited paper in Proc. Conf. Fifty Years with Nuclear Fission, Washington, D.C. (April 26-28, 1989).

30. M.T. Simnad, "History of the Development of the HTGR," in Proc. Conf. on Gas-Cooled Nuclear Reactors, M.T. Simnad, ed., Energy (in press, 1990).

31. M.T. Simnad, "Fuel and Fuel Element Developments for Water-Cooled Nuclear Power Reactors," International Atomic Energy Agency Monograph Series, IAEA, Vienna (1989).

32. M.T. Simnad, "Analysis of the Factors Contributing to the One Trillion Dollars Wasted on Nuclear Power," Energy (in press, 1989).

33. A.G. Tsai, "Thermal Energy Storage," Ph.D. Thesis performed under the supervision of G. Arrhenius, UCSD, La Jolla, CA (1986).

34. E.D. Goldberg, "Information Needs for Ocean Waste Disposal," La Mer, 241-247 (1984).

35. M. Koide and E.D. Goldberg, "The Historical Record of Artificial Radioactive Fallout from the Atmosphere in Polar Glaciers," in Greenland Ice Core: Geophysics, Geochemistry and Environment, C.C. Langway, Jr., H. Oeschger and W. Dansgaard, eds., American Geophysical Monograph 33, 95-100 (1985).

36. E.D. Goldberg, "The Oceans as Waste Space," in Ocean Yearbook 5, pp. 150-161, E.M. Borgese and N. Ginsburg, eds., The University of Chicago Press, Chicago, IL (1985).

37. M. Koide and E.D. Goldberg, "Determination of Tc-99, Ni-63 and Sn-121m+126 in the Marine Environment," J. Environ. Radioactivity 2, 261-282 (1985).

38. E.D. Goldberg, "The Mussel Watch Concept (translation from Russian into English," Environmental Monitoring and Assessment 7, 91-103 (1986).

39. E.D. Goldberg, Black Carbon in the Environment, 197 pp., John Wiley Interscience, New York, NY (1985).

40. E.D. Goldberg, "Acceptable Environmental Change from Waste Disposal," pp. 19-26, in The Role of the Oceans as a Waste Disposal Option, G. Kullenberg, ed., D. Reidel Publishing Co. (1986); also in Public Waste Management and Ocean Choice, K.D. Stolzenbach, J.D. Kildow and E.T. Harding, eds., MIT Sea Grant College Program, MITSG 85-86, pp. 15-24, Cambridge, MA (1986).

41. E.D. Goldberg, "The Assimilative Capacity of the Oceans for Wastes," in Strategies and Advanced Techniques for Marine Pollution Studies,

42. K.K. Bertine, J. Chow, M. Koide and E.D. Goldberg, "Plutonium Isotopes in the Environment: Some Existing Problems and Some New Ocean Results," J. Environ. Radioactivity fI3, 189-201 (1986).

43. E.D. Goldberg, "Black Carbon in the Environment: Records of Historic and Prehistoric Burning," in Dating Young Sediments, pp. 127-137, A.J. Hurford, E. Jager and J.A.M. Ten Cate, eds., CCOP Technical Publication 16, Bankok, Thailand (1986).

44. A. Bard, E.D. Goldberg and D.W. Spencer, "Modern Chemistry and Chemical Technology Applied to the Oceans and Its Resources: Introduction," Applied Geochem. 3, 3-8 (1988).

Table 2. Combustion publications from EC/CECR during the period July 1, 1984 to June 30, 1989.

A. L. Berlad:

1. A.L. Berlad, "Gravitational Effects on the Extinction Conditions for Premixed Flames," XXXV IAF Congress, Lausanne (October 1984); also, Acta Astronautica 12, 539 (1985).

2. A.L. Berlad, "On Characterization and Mitigation of Combustion Hazards Involved in the Handling of Particulate Materials," invited Review, Drying Technology 3, 123 (1985).

3. A.L. Berlad, "Gravitational Effects on Stabilized Lycopodium-Air Flames," Combustion Science and Technology 47, 55 (1986).

4. A.L. Berlad, "Structure and Stability of Premixed Flames," Proc. Fall Meeting, Western States Section, The Combustion Institute (1985).

5. A.L. Berlad, "Combustion Studies in Microgravity," invited paper, Proceedings of the NSF Workshop on Opportunities for Academic Research in a Low Gravity Environment (1985). Also Progress in Astronautics and Aeronautics 108, 201 (1986).

6. A.L. Berlad, "Particle Cloud Kinetics in Microgravity," AIAA paper No. 87-0577.

7. A.L. Berlad, "Autoignition of Fuel-Oxidizer Mixtures in Microgravity," Proc. Int'l Astronautical Federation Congress, Paper No. 87-385 (October 1987). Also Acta Astronautica (November 1988).

8. A.L. Berlad, "Spontaneous Ignition Phenomena in Two-Phase Mixtures with Heterogeneous Processes," Proc. Western States Section, The Combustion Institute, Paper No. 61 (November 1987).

9. A.L. Berlad, "Particle Cloud Mixing in Microgravity," AIAA Paper 88-0453 (January 1988).

10. A.L. Berlad, "Particle Cloud Combustion in Low Gravity," invited Review in Materials and Fluid Science in Low Gravity, J.N. Koster, ed. (to appear, 1989).

11. A.L. Berlad, "Radiative Structure of Lycopodium-Air Flames in Low Gravity," AIAA Paper No. 89-0500.

12. A.L. Berlad, "Particle Cloud Flames in Acoustic Fields," Combustion and Flame (accepted for publication, 1989).

13. A.L. Berlad, "Reduced Gravity Particle Cloud Experiment," in "Selected Papers: Microgravity Science and Applications Flight Programs," NASA TM 4069, Vol. 2 (October 1988).

14. A.L. Berlad, "Feasibility of Reduced Gravity Experiments Involving Quiescent, Uniform Particle Cloud Combustion," NASA-TM No. 101371 (October 1988).

15. A.L. Berlad, "Combustion in Low Gravity: Historical Overview," invited Plenary Lecture, International Microgravity Combustion Workshop, Cleveland, Ohio (January 1989), Proceedings (in press, 1989).

A. S. Gordon

16. K. Saito, F.A. Williams, and A.S. Gordon, "Anomalous Quenching of Hydrogen Diffusion Flames in Coflow Configurations," Combust. Sci. Technol. 36, 285-299 (1984).

17. K. Saito, F.A. Williams, and A.S. Gordon, "Effects of Oxygen on Soot Formation in Methane Diffusion Flames," Combust. Sci. Technol. 47, 117-138 (1986).

18. K. Saito, F.A. Williams, and A.S. Gordon, "Structure of Laminar Coflow Methane-Air Diffusion Flames," J. Heat Transfer 108, 640-648 (1986).

19. A. Hamins, A.S. Gordon, K. Saito, and K. Seshadri, "Acetone Impurity in Acetylene Tanks," Combust. Sci. Technol. 45, 309-310 (1986).

20. A. Hamins, A.S. Gordon, K. Seshadri, and K. Saito, "The Structure of Coflowing, Laminar C_2 Hydrocarbon-Air Diffusion Flames," Twenty-First Symposium (International) on Combustion, pp. 1077-1085, The Combustion Institute, Pittsburgh, PA (1986).

21. K. Saito, F.A. Williams, and A.S. Gordon, "A Study of the Two-Color Soot Zone for Small Hydrocarbon Diffusion Flames," Combust. Sci. Technol. 51, 285-305 (1987).

P. A. Libby:

22. P.A. Libby and F.A. Williams, "Strained Premixed Laminar Flames with Two Reaction Zones," Combust. Sci. Technol. 37, 221-252 (1984).

23. M. Champion and P.A. Libby, "Turbulent Premixed Combustion in a Boundary Layer," Combust. Sci. Technol. 38, 267-291 (1984).

24. G. Masuya and P.A. Libby, "Further Developments of a Nongradient Theory of Premixed Turbulent Flames," Technical Report of National Aerospace Laboratory, 11 pp., TR-802T, National Aerospace Laboratory, Chōfu, Tokyo, Japan (March 1984).

25. K.N.C. Bray, P.A. Libby, and J.B. Moss, "Flamelet Crossing Frequencies and Mean Reaction Rates in Premixed Turbulent Combustion," Combust. Sci. Technol. 41, 143-172 (1984).

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27. K.N.C. Bray, P.A. Libby, and J.B. Moss, "Unified Modeling Approach for Premixed Turbulent Combustion. Part I: General Formulation," Combust. Flame 61, 87-102 (1985).

28. P.A. Libby, "Theory of Normal Premixed Turbulent Flames Revisited," Prog. Energy Combust. Sci. 11, 86-96 (1985).

29. K.N.C. Bray, P.A. Libby, and J.B. Moss, "Scalar Length Scale Variations in Premixed Turbulent Flames," pp. 421-427, Twentieth Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, Pennsylvania (1985).

30. K.N.C. Bray, M. Champion, N. Dave, and P.A. Libby, "On the Thermochemistry of Premixed Turbulent Combustion in Variable Enthalpy Systems," Combust. Sci. Technol. 46, 31-43 (1986).

31. K.N.C. Bray and P.A. Libby, "Passage Times and Flamelet Crossing Frequencies in Premixed Turbulent Combustion," Combust. Sci. Technol. 47, 253-274 (1986).

32. A. Hamins, M. Heitor, and P.A. Libby, "Gravitational Effects on the Structure and Propagation of Premixed Flames," IAF '86, 37th Congress of the International Astronautical Federation, Innsbruck, Austria, Pergamon Press (October 1986), also Acta Astronaut. 17, 503-514 (1988).

33. D.-G. Xie and P.A. Libby, "The Burning of Graphite Spheres with Gas-Phase Equilibrium," Combust. Flame 67, 37-54 (1987).

34. P.A. Libby, S. Sivasegaram, and J.H. Whitelaw, "Premixed Combustion," Prog. Energy Combust. Sci. 12, 393-405 (1986).

35. K.N.C. Bray, M. Champion, and P.A. Libby, "The Turbulent Premixed Boundary Layer with Variable Enthalpy," Combust. Sci. Technol. 55, 139-162 (1987).

36. P.A. Libby and F.A. Williams, "Premixed Laminar Flames with General Rates of Strain," Combust. Sci. Technol. 54, 237-273 (1988).

37. K.N.C. Bray, M. Champion, and P.A. Libby, "The Correlation Functions for Flamelet Crossings in Premixed Turbulent Flames," Combust. Sci. Technol. 59, 463-369 (1988).

S. S. Penner:

38. S.S. Penner, C.P. Wang, and M.Y. Bahadori, "Laser Diagnostics Applied to Combustion Systems," Twentieth Symposium (International) on Combustion, pp. 1149-1176, The Combustion Institute, Pittsburgh, PA (1985).

39. S.S. Penner, C.P. Wang, and M.Y. Bahadori, "Laser Diagnostics for Particle-Laden Flames," JQSRT 33, 293-296 (1985).

40. M.Y. Bahadori, C.-P. Li, and S.S. Penner, "Two Adjacent, Coupled Laminar Diffusion Flames with Cylindrical Symmetry," paper presented at the 10th International Colloquium on Dynamics of Explosions and Reactive Systems, Berkeley, CA (August 1985); Progress in Astronautics and Aeronautics, Vol. 105, pp. 192-207, AIAA, NY (1986).

41. C.-P. Li, D. Wiesenhahn, and S.S. Penner, "Multiple Diffusion Flames with Rectangular Symmetry," Combustion and Flame 65, 215-225 (1986).

42. S.S. Penner, D.F. Wiesenhahn, and C.-P. Li, "Incinerator Production, Fate and Health Effects of Polychlorinated Dioxins and Furans," Energy 12, 33-43 (1987).

43. S.S. Penner, D.F. Wiesenhahn, and C.-P. Li, "Mass Burning of Municipal Wastes," Annual Reviews of Energy 12, pp. 415-444, J.M. Hollander, H. Brooks and D. Sternlight, eds., Annual Reviews, Inc., Palo Alto, CA (1987).

44. D.F. Wiesenhahn, C.-P. Li, and S.S. Penner, "A Simplified Model for Dioxin Formation in Municipal Waste Incinerators," Energy 13, 225-237 (1988).

45. C.-P. Li, D.F. Wiesenhahn, and S.S. Penner, "Production of Toxic Equivalents to 2,3,7,8-TCDD in Municipal Waste Incinerators (MWIs)," Energy 13, 217-223 (1988).

46. S.S. Penner, C.-P. Li, and D.F. Wiesenhahn, "A Model for Dioxin and Furan Production in Municipal Waste Incinerators," in 11th International Colloquium on Gasdynamics of Explosions and Reactive Systems, Dynamics of Reactive Systems, Part II: Heterogeneous Combustion Applications, pp. 343-362, A.L. Kuhl, J.R. Bowen, J.C. Leyer, and A. Borisov, eds., Progress in Astronautics and Aeronautics, Vol. 113, AIAA, Washington, D.C. (1988).

47. S.S. Penner, "Relation Between Toxic Inputs and Dioxin and Furan Outputs for Municipal-Waste Incinerators (MWIs)," Energy 13, 389-391 (1988).

K. Seshadri:

48. K. Seshadri and D.E. Rosner, "Optical Methods of Dew Point and Deposition Rate Measurement in Salt/Ash-Containing Combustion Gases. Part I. $B_2O_{3(l)}$ Deposition Rates by the Interference Method," AIChE Journal 30, 187-196 (1984).

49. A. Hamins and K. Seshadri, "Prediction of Overall Chemical Kinetic Rate Parameters for Extinction of Diffusion Flames Above Multicomponent Fuels," Combust. Sci. Tech. 38, 89-104 (1984).

50. A. Hamins and K. Seshadri, "Structure of Counterflow Diffusion Flames Burning Multicomponent Fuels," Twentieth Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, Pennsylvania, 1905-1913 (1984).

51. K. Seshadri, I. Puri, and N. Peters, "Experimental and Theoretical Investigation of Partially Premixed Diffusion Flames at Extinction," Combust. Flame 61, 237-249 (1985).

52. K. Seshadri and D.E. Rosner, "Optical Methods of Dew Point, Deposition Rate, and Evaporation Rate Measurements in Salt/Ash-Containing Combustion Gases. Part II. $B_2O_{3(l)}$ Deposition Rates by the Polarization (Ellipsometric) Method," Combust. Flame 61, 251-260 (1985).

53. A. Hamins, H. Thridandam, and K. Seshadri, "Structure and Extinction of a Partially Premixed Diffusion Flame," Chem. Eng. Sci. 40, 2027-2038 (1985).

54. A. Hamins and K. Seshadri, "The Influence of Alcohols on the Combustion of Hydrocarbon Fuels in Diffusion Flames," Combust. Flame 64, 43-54 (1986).

55. A. Hamins, A.S. Gordon, K. Saito, and K. Seshadri, "Acetone Impurity in Acetylene from Tanks," Combust. Sci. Tech. 45, 309-310 (1986).

56. I. Puri and K. Seshadri, "Extinction of Diffusion Flames Burning Diluted Methane and Diluted Propane in Diluted Air," Combust. Flame 65, 137-150 (1986).

57. M.D. Smooke, I.K. Puri, and K. Seshadri, "A Comparison Between Numerical Calculations and Experimental Measurements of the Structure of a Counterflow Diffusion Flame Burning Diluted Methane in Diluted Air," pp. 1783-1792, Twenty-First Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, Pennsylvania, (1986).

58. A. Hamins, A.S. Gordon, K. Seshadri, and K. Saito, "The Structure of Coflowing, Laminar, C_2 Hydrocarbon-Air Diffusion Flames," pp. 1077-1085, Twenty-First Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, Pennsylvania (1986).

59. A. Hamins and K. Seshadri, "The Structure of Diffusion Flames Burning Pure Binary and Ternary Solutions of Methanol, Heptane, and Toluene," Combust. Flame 68, 295-307 (1987).

60. I. Puri and K. Seshadri, "Mechanisms of Extinction of Counterflow Premixed Flames Burning Lean Mixtures of Methane-Air and Propane-Air," Combust. Sci. Tech. 53, 55-65 (1987).

61. I. K. Puri, K. Seshadri, M.D. Smooke, and D.E. Keyes, "A Comparison Between Numerical Calculations and Experimental Measurements of the Structure of a Counterflow Methane-Air Diffusion Flame," Combust. Sci. Tech. 56, 1-22 (1987).

62. K. Seshadri and N. Peters, "Asymptotic Structure and Extinction of Methane-Air Diffusion Flames," Combust. Flame 73, 23-44 (1988).

63. M.D. Smooke, K. Seshadri, and I.K. Puri, "The Structure and Extinction of Partially Premixed Flames Burning Methane in Air," Twenty-Second Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, Pennsylvania, (to appear, 1988).

64. K. Seshadri, C. Treviño, and M.D. Smooke, "Analysis of the Structure and Mechanisms of Extinction of a Counterflow Methanol-Air Diffusion Flame," Combustion and Flame (to appear, 1989).

65. K. Seshadri and C. Treviño, "The Influence of Lewis Number of the Reactants on the Asymptotic Structure of Counterflow Diffusion Flames," Combustion Science and Technology (to appear, 1989).

66. K. Seshadri and N. Peters, "The Inner Structure of Methane-Air Flames," Combustion and Flame (to appear, 1989).

F. A. Williams:*

67. F.A. Williams, "Influences of Detailed Chemistry on Asymptotic Approximations for Flame Structure," in Mathematical Modeling in Combustion and Related Topics, pp. 315-341, C.-M. Brauner and C. Schmidt-Lainé, eds., Martinus Nijhoff Publishers, Dordrecht, The Netherlands (1988).

68. A.R. Kerstein, W.T. Ashurst, and F.A. Williams, "Field Equation for Interface Propagation in an Unsteady Homogeneous Flow Field," Physical Review A Rapid Communications 37, 2728-2731 (1988).

69. F.A. Williams, "Asymptotic Methods for Flames with Detailed Chemistry," Mathematical Modeling in Combustion Science, pp. 44-51, J.D. Buckmaster and T. Takeno, eds., Springer-Verlag, New York (1988).

70. F.A. Williams, "Asymptotic Approach to Analysis of Propellant Combustion," Mathematical Modeling in Combustion Science, pp. 160-162, J.D. Buckmaster and T. Takeno, eds., Springer-Verlag, New York (1988).

71. S.B. Margolis and F.A. Williams, "Diffusional/Thermal Coupling and Intrinsic Instability of Solid Propellant Combustion," Combustion Science and Technology 59, 27-84 (1988).

72. B.D. Shaw, F.L. Dryer, N. Gat, and F.A. Williams, "Interactions Between Gaseous Electrical Discharges and Single Liquid Droplets," Combustion and Flame 74, 233-254 (1988).

73. C. Treviño and F.A. Williams, "Asymptotic Analysis of the Structure and Extinction of Methane-Air Diffusion Flames," Dynamics of Reactive Systems Part I: Flames, pp. 129-165, A.L. Kuhl, J.R. Bowen, J.-C. Leyer and A. Borisov, eds., Vol. 113 of Progress in Astronautics and Aeronautics, American Institute of Aeronautics and Astronautics, Washington, DC (1988).

74. B.D. Shaw, F.L. Dryer, J.B. Haggard, Jr., and F.A. Williams, "Sooting and Disruption in Spherically Symmetrical Combustion of Decane Droplets in Air," Acta Astronautica 17, 1195-1202 (1988).

75. P.A. Libby, N. Peters, and F.A. Williams, "Cylindrical Premixed Laminar Flames," Combustion and Flame 75, 265-280 (1989).

76. F.A. Williams, "Structures of Flamelets in Turbulent Reacting Flows and Influences of Combustion on Turbulence Fields," Turbulent Reactive Flows, pp. 195-212, R. Borghi and S.N.B. Murthy, eds., Springer-Verlag, New York (1989).

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* Only papers published since his return to UCSD in 1988 are listed for F.A. Williams.

Table 3. Seminars Presented at the Center for Energy and Combustion Research

Date	Speaker	Topic
January 8, 1985	G. Anastas, San Diego Gas and Electric Company	Emerging Energy Technologies
January 29,1985	A.L. Berlad, University of California, San Diego	Combustion under Microgravity Conditions
April 16, 1985	J. Steible, GA Technologies	Fluidized Bed Combustion Application to Waste Treatment
April 29, 1985	K. Saito, National Bureau of Standards	Upward Turbulent Flame Spread
March 12, 1986	M. Smooke, Yale University	Comparison between Numerical Calculations and Experimental Measurements of the Structure of Laminar Flames
October 9, 1986	A. Fontijn, Rensselaer Polytechnic Institute	High-Temperature Reactor Studies of Homogeneous Elementary Reactions
November 13, 1986	A. Baxter, GA Technologies	The Chernobyl Disaster
January 29, 1987	D.F. Wiesenhahn and C.P. Li, University of California, San Diego	Municipal Waste Incinerator Modeling, Designs and Toxic-Pollutant Production
February 20, 1987	A.R. Kâragozian, University of California, Los Angeles	Vortex Modeling of Reacting Flow Processes in Hazardous Waste and Other Combustion Systems
March 6, 1987	C. Treviño, University National Autonoma de Mexico	Asymptotic Analyses of the Structure and Extinction of Methane-Air Diffusion Flames
March 12, 1987	C.F. McDonald, GA Technologies	Advanced, Very High Temperature Gas-Cooled Reactor Concepts for the 21st Century
March 21, 1987	K.C. Smyth, National Bureau of Standards	Chemical Growth in Hydrocarbon Diffusion Flames
April 3, 1987	K. Seshadri, University of California, San Diego	Experimental and Theoretical Combustion Studies with Realistic Kinetics
April 10, 1987	A.L. Berlad, University of California, San Diego	The NASA Program on Low-Gravity Combustion
April 17, 1987	A.C. Fernandes-Pello, University of California, Berkeley	Fire Research

Table 3. Continued

Date	Speaker	Topic
April 22, 1987	B. Butler, SAIC	Recent Developments in High Power Density Sodium/Sulfur Batteries
April 27, 1987	O.I. Smith, University of California, Los Angeles	Experimental and Numerical Investigations of Flames of Interest in Propellant Applications
May 1, 1987	W. Heiser and D.T. Pratt, Aero-Jet General	The Aerospaceplane and Propulsion by Supersonic Combustion or Oblique Detonation
May 8, 1987	R. Cattolica, Sandia/Livermore	Recent Developments in Combustion Diagnostics
May 15, 1987	S. Warnatz, Heidelberg	Kinetic Modeling in Combustion Systems
May 21, 1987	K. Kedward, Alcoa Defense Systems	The Impact of Materials Research on Composite Structures Development
May 22, 1987	R. Sawyer, University of California, Berkeley	Engine Combustion
May 29, 1987	D. Smooke, Yale University	Numerical Analysis of Combustion Systems
June 2, 1987	B. Butler, SAIC	Advances in Solar Energy Materials
June 5, 1987	J. Tishkoff, AFOSR	AFOSR Program in Supersonic Combustion
June 12, 1987	W. Kollmann, University of California, Davis	Combustion in Turbulent Flows
October 20, 1987	A.K. Oppenheim, University of California, Berkeley	Strive for Controlled Combustion Engines
November 9, 1987	E. Oran, NRL, Washington, D.C.	Numerical Calculations of Combustible Flows
November 17, 1987	B. Krahl-Urban, Kernforschungsanlage, J lich, FRG	The Forests: An Eco-System in Danger
November 20, 1987	A. Hamins, National Bureau of Standards	Soot Production in Diffusion Flames
December 2, 1987	W. Wittemore, GA Technologies	Neutron Radiography Facilities at GA Technologies

Date	Speaker	Topic
January 14, 1988	M. Sichel, University of Michigan	Oblique Detonation-Shock Wave Interactions in the Supersonic Flow of Combustible Mixtures
January 28, 1988	I. Kennedy, University of California, Davis	Particle Formation in Reacting Mixing Layers
February 4, 1988	S.S. Penner, University of California, San Diego	Models for Toxic Compound Productions in Municipal Waste Incinerators
February 11, 1988	K. Seshadri, University of California, San Diego	Asymptotic Structure of Methane-Air Diffusion Flames
February 18, 1988	S. Sohrab, Northwestern University	Laminar Flames in Rotating Flows
February 25, 1988	F. Williams, Princeton University	Structure of Wet Carbon Monoxide Flames
March 2, 1988	J. Cervantes de Gortari, Universidad Nacional de México	Heat Transfer in Combustion Systems
March 3, 1988	W. Sirignano, University of California, Irvine	Turbulent Reacting Flows
March 10, 1988	J.O.L. Wendt, University of Arizona, Tuscon	Mechanisms Governing Transients from the Batch Incineration of Liquid Wastes in Rotary Kilns
April 6, 1988	J. Corey, Corey Labs	Nitinol Heat Engines
August 3, 1988	J.O. Olsson, Chalmers University of Technology	Computational Study of Low Pressure Premixed Formaldehyde Flame
August 25, 1988	B.N. Raghunandan, Indian Institute of Science	Recirculating Flow over a Burning Surface—Flame Structure and Heat Transfer Augmentation
September 28, 1988		Graduate Student and Faculty Get-Together
October 19, 1988	H.B. Stewart, Nutevco	Recollecting the Future: A Preview of Technology, Business, and the Economy in the Next Thirty Years
November 9, 1988	A. Berlad, University of California, San Diego	Particle Cloud Flame Structure in Reduced Gravity

Table 3. Continued

Date	Speaker	Topic
February 22, 1989	B.D. Shaw, University of California, San Diego	Reduced-Gravity Combustion of Unsupported Heptane and Decane Droplets
March 13, 1989	M. Smooke, Yale University	Results of Numerical Calculations on Methane-Air Flames
March 13, 1989	S.H. Lam, Princeton University	Construction of Reduced Chemical Kinetic Mechanism for Methane-Air Reaction System Using the CSP Method
March 13, 1989	B. Rogg, Cambridge University	Asymptotic Structure of Weakly Strained Methane-Air Flames
March 13, 1989	K. Seshadri, University of California, San Diego	The Inner Structure of Methane-Air Flames
March 13, 1989	N. Peters, Tech. Hoch. Aachen	Asymptotic Structure of Lean Methane-Air Flames
March 13, 1989	N. Peters, Tech. Hoch. Aachen	Planar Flame with Newtonian Heat Loss
March 14, 1989	C. Treviño, UNAM	Time-Dependent Perturbation of Steady Diffusion-Flame Structure
March 14, 1989	H. Chelliah, Princeton University	Aspects of the Structure and Extinction of Diffusion Flames in Methane-Oxygen-Nitrogen Systems
March 14, 1989	R.W. Bilger, Sydney University	On Reduced Mechanisms for Methane-Air Combustion in Nonpremixed Flames
March 14, 1989	J.Y. Chen, Sandia, Livermore	Application of Reduced Mechanisms for Predicting Turbulent Flames
April 5, 1989	C.F. Melius, Sandia, Livermore	Ignition and Combustion of Nitramine Propellants
April 19, 1989	F.L. Dryer, Princeton University	Some Further Observations on Hydrocarbon Combustion Chemistry and Modeling
May 10, 1989	S. Vosen, Sandia, Livermore	Liquid Propellant Combustion
May 15, 1989	P. Clavin, Universite de Provence-Centre Saint Jerome	Vibrating Flame Instability in Tubes
May 17, 1989	M.C. Branch, University of Colorado	Structure and Kinetics of Laminar Premixed Flames of CH_4 and CH_2O with NO_2 and N_2O

Date	Speaker	Topic
May 31, 1989	M. Richards, GA Technologies/University of California, San Diego	A Pore Structure—Independent Combustion Model for Porous Media with Application to Graphite Oxidation

Table 4. Ph.D.s and post-doctoral collaborators of PIs working in energy or combustion research during the period July 1, 1984 – June 30, 1989.

A.L. Berlad:

Post-Doctoral Collaborators
N. Joshi
V. Tangirala

P. A. Libby:

Doctoral Students
D.-G. Xie
Nikhil Dave

Post-Doctoral Collaborators
Ishwar Puri

K. Seshadri:

Ph.D. Students
Anthony Hamins
Ishwar Puri

F.A. Williams:

Ph.D. Students
Ralph Aldredge
John Card
Balakrishnan Ganeshan
Jong-Soo Kim
Shui-Chi Li
Benjamin Shaw

Representative Post-Doctoral Collaborators:
Harsha Chelliah
Suk-Ho Chung
Eva Gutheil
Julio Hernandéz
Amable Liñán
Norbert Peters
Jun'ichi Sato
Cesár Treviño
Shunichi Tsugé

S. S. Penner:

Doctoral Students:

M. Y. Bahadori
M. R. Brambley
E. M. Kennedy
C. P. Li
M. B. Richards
D. F. Wiesenhahn

Post-Doctoral Collaborators:

C. P. Wang and approximately 50 senior scientists and engineers who participated in evaluations for DOE, NSF, and NRC.

Table 5. List of presentations and participants at a workshop dealing with recent developments on aymptotic descriptions of methane-air flames.

WORKSHOP ON REDUCED KINETIC MECHANISMS AND ASYMPTOTIC APPROXIMATIONS FOR METHANE-AIR FLAMES

Meeting Location: Ida and Cecil Green Faculty Club
University of California, San Diego
La Jolla, California 92093
Meeting Dates: March 13, 14, and 15, 1989

PROGRAM

Monday, March 13, 1989

Prof. M. Smooke Yale University	Results of Numerical Calculations on Methane-Air Flames
Prof. S. H. Lam Princeton University	Construction of Reduced Chemical Kinetic Mechanism for Methane-Air Reaction System Using the CSP Method
Prof. B. Rogg Cambridge University	Asymptotic Structure of Weakly Strained Methane-Air Flames
Prof. K. Seshadri UCSD	The Inner Structure of Methane-Air Flames
Prof. N. Peters Tech. Hoch. Aachen	Asymptotic Structure of Lean Methane-Air Flames
Prof. N. Peters Tech. Hoch. Aachen	Planar Flame with Newtonian Heat Loss

Tuesday, March 14, 1989

Prof. C. Treviño UNAM, Mexico City	Time-Dependent Perturbation of Steady Diffusion-Flame Structure
Dr. H. Chelliah Princeton University	Aspects of the Structure and Extinction of Diffusion Flames in Methane-Oxygen-Nitrogen Systems
Prof. R. W. Bilger Sydney University	On Reduced Mechanisms for Methane-Air Combustion in Nonpremixed Flames
Dr. J. Y. Chen Sandia, Livermore	Application of Reduced Mechanisms for Predicting Turbulent Flames

Wednesday, March 15, 1989

General Discussion, Evaluation of Status, Plans for Publication.

Attendees

R. W. Bilger	Sydney University
H. Chelliah	Princeton University
J. Y. Chen	Sandia, Livermore
R. W. Dibble	Sandia, Livermore
F. Hernandéz	UCSD
R. Greene	Sydney University
A. S. Gordon	UCSD
E. Gutheil	UCSD
S. H. Lam	Princeton University
P. A. Libby	UCSD
N. Peters	Tech. Hoch. Aachen
B. Rogg	Cambridge University
M. Smooke	Yale University
S. Starner	Sydney University
C. Treviño	UNAM, Mexico City
F. A. Williams	UCSD

Plus UCSD Graduate Students

Table 6. Summary of contractual support received during the period 1984-89.