

Steven A. Lottes, Ph.D.

Mechanical Engineer
Energy Systems Division
Argonne National Laboratory

Professional Experience

Transportation Research and Analysis Computing Center

Computational Fluid Dynamics, Simulation, Modeling, and Analysis Leader
March 2008 – present

- Reviewed the state of the art in hydraulics engineering for river flows with focus on flooding conditions and multiphase erosion of river beds at bridge structures under flood conditions.
- Currently planning and pursuing the establishment of a growing set of capabilities, services, and users at TRACC in the area of computational fluid dynamics (CFD) for hydraulic and aerodynamic research for transportation infrastructure and system research.
- Managed and collaborated with Northern Illinois University in the bridge hydraulics research program to apply advanced CFD techniques to evaluate risks to bridges due to scour and hydrodynamic forces during floods.
- Developing CFD training materials for hydraulics engineering applications at TRACC
- Developed CFD brochure and advertising booth materials for conferences and meetings to promote awareness of the advanced analysis capabilities at TRACC that are available to members of the hydraulics and transportation communities.
- Recruited new users and provided technical support in the use of TRACC facilities.

Process Technology Research Section

Computational Fluid Dynamics, Simulation, Modeling, and Analysis Leader
June 1988 – March 2008

- Developed four copyrighted CFD codes for application in the areas of glass and aluminum furnace modeling, commercial fluid catalytic cracker (FCC) modeling for petroleum refining, MHD combustor modeling, and fuel processor catalytic reactor modeling.
- Developed and implemented new theory in CFD analysis software in both numerical techniques and the physical processes that govern multi-phase reacting flow systems. This work included the development of models and algorithms to couple petroleum spray vaporization with disperse phase heat carrier catalyst particle flows, multi-stage algorithms to compute detailed chemical kinetics coupled to CFD computation with reduced chemistry models that use integral methods to bridge the kinetic and flow time scales, and other models and methods to compute interfacial phenomena and reaction in multiphase CFD software.
- Planned and developed research partnerships with industry and universities to conduct research and advance the state of the art in a wide variety of applications in the areas of multiphase and reacting flows applied to chemical reactor design and furnaces in the chemical process industry and energy and energy systems research in general.
- Applied commercial CFD and multi-physics software to the design and optimization of a variety of chemical reactors and combustors.
- Published extensively and presented results of research at conferences and meetings.

AT&T Bell Telephone Laboratories

Member of Technical Staff
Switching System Design and Development Facility
June 1973 – September 1980

- Conducted computer systems software design, development, and trouble shooting in the data base area of the No. 1 ESS switching system, which was the primary interface to the customer in AT&T's telecommunications system in the 1960s through the 1980s. Led host database software development for the Remote Switching System (RSS) project and others.

- Developed and conducted training courses on database systems for the No. 1 ESS switching system. The courses were eventually video taped for use by others.

Education

Ph.D. Mechanical Engineering, University of Illinois at Chicago, Chicago, Illinois, 1989
M.S. Mechanical Engineering, University of Illinois at Chicago, Chicago, Illinois, 1984
M.S. Computer Science, Purdue University, West Lafayette, Indiana, 1973
B.S. Mathematics with High Honors, University of Illinois, Urbana-Champaign, Illinois, 1971

Awards

2004 R&D100 Award, Golchert, B., S.A. Lottes, M. Petrick, C.Q. Zhou, and S.L. Chang, **GFM: Glass Furnace Model**, "Through the Looking Glass," R&D Magazine, Vol. 46, No. 9, 2004.

Patents

Chang, S.L., S.A. Lottes, and C.Q. Zhou, *Methodology for Extracting Local Constants from Petroleum Cracking Flows*, ANL Invention Report, ANL-IN-97-074 (1997), U.S. Patent No. 6,013,172, January 11, 2000.

Ahmed, Shabbir, Lee, Sheldon H., Calderone, Steven G., Kao, Richard L., Camara, Elias H., Lottes, Steven A., Krumpelt, Michael, Harvey, Todd L., *Dynamic Fuel Processor with Controlled Declining Temperatures*, U.S. Patent Application No. 112,684, Publication No. 20030188475, October 9, 2003.

Software Copyrights

Lottes S.A., Chang, S.L., B. Golchert, S.A. Lottes, M. Petrick, and C.Q. Zhou, **GFM 4.0**, *Glass Furnace Model*, Computer Software Copyright, Energy Science & Technology Software Center, ANL-SF-01-030c, 2006.

Lottes, S.A., **PARMFLO**, *Parallel Reacting Multiphase Flow*, Computer Software Copyright, Energy Science & Technology Software Center, ANL-SF-03-066, 2003.

Chang, S.L., B. Golchert, S.A. Lottes, M. Petrick, and C.Q. Zhou, **GFM 2.0**, *Glass Furnace Model*, Computer Software Copyright, Energy Science & Technology Software Center, ANL-SF-01-030b, 2002.

Chang, S.L., B. Golchert, S.A. Lottes, M. Petrick, and C.Q. Zhou, **GFM**, *Glass Furnace Model*, Computer Software Copyright, Energy Science & Technology Software Center, ANL-SF-01-030 Package ID 001355MLTPL00 GFM, 2001.

Chang, S.L. and S.A. Lottes, **ICRKFLOW**, *Version 2.0 - Two-Dimensional Multiple Phase Integral Petroleum Cracking Flow Computer Code*, Computer Software Copyright, ANL-SF-97-082 (1997)

Chang, S.L. and S.A. Lottes, **ICRKFLOW** - *Two-Dimensional Multiple Phase Integral Petroleum Cracking Flow Computer Code*, Computer Software Copyright, ANL-SF-95-138 (1996).

Chang, S.L. and S.A. Lottes, **ICOMFLO2** - *Two-Dimensional Multiple Phase Integral Combustion Flow Computer Code*, Computer Software Copyright, ANL-SF-93-109 (September 11, 1995).

Publications: Journal Articles and Refereed Papers

S.A. Lottes, R.W. Lyczkowski, C.B. Panchal, and R.D. Doctor, *Modeling and Analysis of Calcium Bromide Hydrolysis*, International Journal of Hydrogen Energy, HE3733, article in press, October, 2008.

S. Ahmed, R. Ahluwalia, S.H.D. Lee, and S. Lottes, *A Gasoline Fuel Processor Designed to Study Quick-Start Performance*, Journal of Power Sources, 154, 214-222, 2006.

Lottes, S.A., *Computational Modeling of Industrial Scale Reactor System Components Using Parallel Processing on a Networked Cluster of Computers*, paper IMECE2003-42705, Fuels and Combustion Technology topic area of the 2003 International Mechanical Engineering Congress and Exposition.

Chang, S.L., S.A. Lottes, C.Q. Zhou, B.J. Bowman, and M. Petrick, *Numerical Study of Spray Injection Effects on the Heat Transfer and Product Yields of FCC Riser Reactors*, Journal of Heat Transfer, Vol. 123, No. 3: 544-555 (June, 2001).

Chang, S.L., C.Q. Zhou, S.A. Lottes, and M. Petrick, *Numerical Evaluation of Advanced Multi-Stage FCC Units*, Proceedings of the International Mechanical Engineering Congress and Exposition, Orlando, FL (November 5-10, 2000).

Lottes, S.A., C.Q. Zhou, S.L. Chang, and B.J. Bowman, *Computational Study of the Effects of Spray Injection Parameters on Mixing, Vaporization, and Reaction in a Three Phase Flow*, Proceedings of the 33rd National Heat Transfer Conference, Albuquerque, NM (August 15-17, 1999).

Chang, S.L., C.Q. Zhou, S.A. Lottes, B. Golchert, and M. Petrick, *A Numerical Investigation of the Scaled-Up Effects on Flow, Heat Transfer, and Kinetics Processes of FCC Units*, HTD-Vol. 361, Proceedings of the ASME Heat Transfer Division 2:73-81, the 1998 International Mechanical Engineering Congress and Exposition, Anaheim, CA (November 15-20, 1998).

Chang, S.L., S.A. Lottes, C.Q. Zhou, and M. Petrick, *A Numerical Study of Short Residence Time FCC Riser Flows with a New Flow/Kinetics Modeling Technique*, HTD-Vol. 361, Proceedings of the ASME Heat Transfer Division 2:83-90, the 1998 International Mechanical Engineering Congress and Exposition, Anaheim, CA (November 15-20, 1998).

Chang, S.L., S.A. Lottes, C.Q. Zhou, B. Golchert, and M. Petrick, *Interactions of Multi-Phase Hydrodynamics, Droplet Evaporation, and Chemical Kinetics in FCC Riser Reactors*, HTD-Vol. 357, Proceedings of the ASME Heat Transfer Division 1:261-269, the 7th AIAA/ASME Joint Thermophysics and Heat Transfer conference, Albuquerque, NM (June 15-17, 1998).

Chang, S.L., S.A. Lottes, C.Q. Zhou, and M. Petrick, *A Hybrid Technique for Coupling Chemical Kinetics and Hydrodynamics Computations in Multi-Phase Reacting Flow Systems*, HTD-Vol. 352, Proceedings of the ASME Heat Transfer Division 2:149-158, the 1997 International Mechanical Engineering Congress and Exposition, Dallas, TX (November 16-21, 1997).

Chang, S.L., S.A. Lottes, C.Q. Zhou, B. Golchert, and M. Petrick, *CFD Code Development for Performance Evaluation of a Pilot-Scale FCC Riser Reactor*, Proceedings of the ASME 1997 International Mechanical Engineering Congress and Exposition, Dallas, TX (November 16-21, 1997).

Chang, S.L., S.A. Lottes, C.Q. Zhou, and M. Petrick, *Evaluation of Multiphase Heat Transfer and Droplet Evaporation in Petroleum Cracking Flows*, HTD-Vol. 335, Proceedings of the ASME Heat Transfer Division 4:17-27, International Mechanical Engineering Congress and Exposition, Atlanta, GA (November 17-22, 1996).

Chang, S.L., C.Q. Zhou, S.A. Lottes, J. X. Bouillard, and M. Petrick, *A Sectional Coupling Approach for the Simulation of Multi-Phase Reacting Flow in a Bent Reactor*, HTD-Vol. 335, Proceedings of the ASME Heat Transfer Division 4:361-373, International Mechanical Engineering Congress and Exposition, Atlanta, GA (November 17-22, 1996).

Chang, S.L. and S.A. Lottes, *Characteristics of Multiphase Flow with Particle Evaporation in a Combustor with Counter-Flow Injection*, Energy Conversion and Management, 36(11):1031-1045, (1995).

Lyczkowski, R.W., J.X. Bouillard, S.L. Chang and S.A. Lottes *State-of-the-Art Review of Computational Fluid Dynamics Modeling for Fluid-Solids Systems*, the International Symposium on Parallel Computing in Multiphase Flow Systems Simulations, 1994 ASME Winter Annual Meeting, Chicago, IL (November 6-11, 1994).

Chang, S.L., and S.A. Lottes, *Integral Combustion Simulation of a Turbulent Reacting Flow in a Channel with Cross-Stream Injection*, Numerical Heat Transfer Part A, 24(1):25-43 (1993).

Chang, S.L., and S.A. Lottes, *Simulation of a Particle-Laden Combustion Flow in an MHD Second Stage Combustor*, Proceedings of the ASME Winter Annual Meeting, HT-12C, Anaheim, CA, (November, 1992).

Chang, S.L., S.A. Lottes, and G.F. Berry, *Computation of Two-Dimensional Non-Reacting Jet/Main Flow Mixing in an MHD Second Stage Combustor*, Numerical Heat Transfer, Part A, 20(2):223-236 (1991).

Roquemore, W.M., R.S. Tankin, H.H. Chiu, and S.A. Lottes, *A Study of a Bluff-Body Combustor Using Laser Sheet Lighting*, Experiments in Fluids, 4, 205-213 (1986).

Publications: Conference Papers

Panchal CB, Lyczkowski RW, Lottes SA, Yang J, Doctor RD, *Analysis of kinetics of CaBr₂ hydrolysis in a direct steam sparging contactor*. Paper 532f, presented in the Session Developments in Thermochemical and Electrolytic Routes to Hydrogen. American Institute of Chemical Engineers Annual Meeting, Salt Lake City; November 4–9, 2007.

S.A. Lottes and R.W. Lyczkowski, *Modeling and Analysis of CaBr₂ Hydrolysis*, COMSOL User's Conference 2006, October 22-24, 2006.

Panchal, C.B., Lottes, S.A., Petrick, M., *Two-phase pipe side model for fired heaters*, AIChE 2006 Spring National Meeting; Orlando, FL, April 23-27, 2006.

S. Ahmed, R. Ahluwalia, S.H.D. Lee, S.A. Lottes, D. Papadimas, K. Liao, S. Calderone, T. Harvey, *Time and Fuel Consumed in Start-up of a Gasoline Fuel Processor*, 2004 Fuel Cell Seminar, November 1-5, 2004, San Antonio, TX (poster session).

Lottes, S.A., P.F. Fischer, and S.L. Chang, *Development of a Dual Serial-Parallel Multiphase CFD Code for Application to Industrial Combustor/Reactor Systems*, Proceedings of the 8th International Energy Forum, Energy 2000: 26-31, Energex 2000, Las Vegas, NV (July 23-28, 2000).

Egelja, A. and S.A. Lottes, *Computational Fluid Dynamics Simulations of a Glass Melting Furnace*, Proceedings of the 8th International Energy Forum, Energy 2000: 3-8, Energex 2000, Las Vegas NV (July 23-28, 2000).

Bowman, B.J., C.Q. Zhou, S.L. Chang, and S.A. Lottes, *A Study of the Spray Injection Reynolds Number Effects on Gasoline Yields in an FCC Riser Reactor*, Proceedings of the 2000 Technical Meeting of the Central States Section of the Combustion Institute, Indianapolis, IN (April 16-18, 2000).

Bowman, B.J., C.Q. Zhou, S.L. Chang, and S.A. Lottes, *Comparison of Asymmetric with Symmetric Feed Oil Injection Parameters in a Riser Reactor*, Proceedings of the 15th International Conference on Advanced Science and Technology, Argonne, IL (April 2-3, 1999).

Bowman, B.J., C.Q. Zhou, S.L. Chang, and S.A. Lottes, *Effects of Feed Injection Parameters on Gasoline Yields in an FCC Riser*, Proceedings of the First Joint Meeting of the Combustion Institute, Washington, D.C. (March 15-17, 1999).

Chang, S.L., S.A. Lottes, C.Q. Zhou, B. Golchert, and M. Petrick, *A General Kinetics-Flow Coupling Model for FCC Riser Flow Simulation*, Proceedings of 1998 Conference of Combustion Fundamentals and Applications, Lexington, KY, (June 6-7, 1998).

Chang, S.L., S.A. Lottes, C.Q. Zhou, B. Golchert, and M. Petrick, *A Numerical Investigation of Scale-Up Effects on Coke Yields of a Thermal Cracking Riser Reactor*, Proceedings of the Second International Symposium on Scale Modeling, Lexington, KY, pp. 299-306 (June 23-27, 1997).

Chang, S.L., C.Q. Zhou, S.A. Lottes, B. Golchert, and M. Petrick, *Methodologies of Extracting Kinetic Constants for Multiphase Reacting Flow Simulation*, Proceedings of 1997 Conference of Combustion Fundamentals and Applications, Point Clear, AL, pp. 348-353 (April 27-29, 1997).

Chang, S.L., S.A. Lottes, C.Q. Zhou, and M. Petrick, *A Coke/Soot Formation Model for Multiphase Reacting Flow Simulation*, Proceedings of 1997 Conference of Combustion Fundamentals and Applications, Point Clear, AL, pp. 354-359 (April 27-29, 1997).

Chang, S.L., S.A. Lottes, C.Q. Zhou, B. Golchert, and M. Petrick, *Visual Display of FCC Flow Simulation*, Presented at the 2nd Industrial Energy Efficiency Symposium & EXPO, Crystal City, VA (February 24-27, 1997).

Chang, S.L., S.A. Lottes, and M. Petrick, *Development of a Three-Phase Reacting Flow Computer Model for Analysis of Petroleum Cracking*, Proceedings of 1995 Mid-America Chinese Professional Annual Convention, Itasca, IL, pp. 281-288 (June 23-25, 1995).

Wu, B., S.L. Chang, S.A. Lottes, and M. Petrick, *An Investigation of Computational Modeling on Phase Distribution Phenomena in Vertical Pipes*, presented at the 2nd International Symposium on Multiphase Flow, Kyoto, Japan (April 3-7, 1995).

Wu, B., Chang, S.L., Lottes, S.A., Petrick, M., *A New Model for Gas/Solid Pipe Flow*, International symposium on two-phase flow modeling and experimentation, 9-11 Oct 1995, Rome (Italy), 1995.

Chang, S.L., S.A. Lottes, and M. Petrick, *Simulation of Three-Dimensional Multiphase Flow Characteristics in the De-swirl Section of the CDIF MHD Power Train*, Proceedings of the 32nd Symposium on Engineering Aspects of Magnetohydrodynamics, Pittsburgh, PA, pp.9.1-10 (June 27-30, 1994).

Chang, S.L., S.A. Lottes, J.X. Bouillard, and M. Petrick *Study of Multiphase Flow Characteristics in an MHD Power Train*, Proceedings of 31st Symposium of Engineering Aspects of Magnetohydrodynamics, Whitefish, Montana, pp. Vb.2.1-12 (June 29-July 1, 1993)

Chang, S.L. and S.A. Lottes *Computer Simulation of an Advanced Combustor for Clean Coal Technology*, International Symposium on Energy, Environment, and Information Management, Argonne, IL, pp. 2.8-2.18 (September 15-18, 1992)

Chang, S.L., S.A. Lottes, and J.X. Bouillard *Dispersion of Seed Vapor and Gas Conductivity in an MHD Second Stage Combustor*, Proceedings of 30th Symposium of Engineering Aspects of Magnetohydrodynamics, Baltimore, MD, pp. VI.3.1-11 (June 29-July 2, 1992)

Lottes, S.A., and S.L. Chang *Particle-Jet Interactions in an MHD Second Stage Combustor*, Proceedings of 30th Symposium of Engineering Aspects of Magnetohydrodynamics, Baltimore, MD, pp. VI.4.1-12 (June 29-July 2, 1992)

Lottes, S.A., and S.L. Chang *Interactions of Turbulent Eddies and Combustion in an MHD Second Stage Combustor*, Proceedings of the 26th Intersociety Energy Conversion Engineering Conference, Boston, MA, 3:69-74 (August 4-9, 1991).

Berry, G.F., S.L. Chang, S.A. Lottes, and W.A. Rimkus, *Multi-Dimensional Computer Simulation of MHD Combustor Hydrodynamics*, AIAA 22nd Fluid Dynamics, Plasma Dynamics & Lasers Conference, Honolulu, Hawaii, AIAA 91-1511 (June 24-26, 1991)

Lottes, S.A., and S.L. Chang *Simulation of Combustion Processes in an MHD Second Stage Combustor*, Proceedings of 29th Symposium of Engineering Aspects of Magnetohydrodynamics, New Orleans, LA, pp. III.4.1-11 (June 17-21, 1991)

Chang, S.L., and S.A. Lottes, *Effect of Copper Catalytic Reactions on the Kinetics of Supersonic Hydrogen Flames*, Proceedings of the 7th International Conference on Advanced Science and Technology, ANL, IL, pp. 150-160 (March 30, 1991)

Lottes, S.A., and S.L. Chang, *Computer Simulation of Jet Penetration and Fluid Mixing in a Channel with Cross-Stream Jets*, Proceedings of the 7th International Conference on Advanced Science and Technology, ANL, IL, pp. 188-198 (March 30, 1991)

Chang, S.L., S.A. Lottes, and G.F. Berry, *Copper Contamination Effects on Hydrogen-Air Combustion under Scramjet Testing Conditions*, Proceedings of the 27th Joint Army-Navy-NASA-Air Force Combustion Meeting, Cheyenne, Wyoming (November 5-9, 1990)

Lottes, S.A., S.L. Chang, and G.F. Berry, *Effects of Jet Port Arrangement on Three-Dimensional Non-Reacting Jet-Gas Mixing in an MHD Second Stage Combustor*, Proceedings of 25th Intersociety Energy Conversion Engineering Conference, Reno, Nevada, 2:468-473 (August 12-18, 1990).

Chang, S.L., S.A. Lottes, and G.F. Berry, *Two-Dimensional Non-Reacting Jet-Gas Mixing in an MHD Second Stage Combustor*, Proceedings of 28th Symposium of Engineering Aspects of Magnetohydrodynamics, Chicago, IL, pp. V.3.1-V.3.10 (June 26-28, 1990).

Chang, S.L., S.A. Lottes, and G.F. Berry, *Three-Dimensional Computer Simulation of Non-reacting Jet Gas Flow Mixing in an MHD Second Stage Combustor*, Proceedings of 28th Symposium of Engineering Aspects of Magnetohydrodynamics, Chicago, IL, pp. IV.24.1-IV.24.9 (June 26-28, 1990).

Roquemore W.M., Tankin R.S., Chiu H.H., and Lottes S.A., *The role of vortex shedding in a bluff-body combustor*. In So R.M.C., Whitelaw J.H., and Lapp M., editors, *Experimental Measurement and Techniques in Turbulent Reactive and Nonreactive Flows*, volume 66. American Society of Mechanical Engineers AMD, New York NY, 1984.

Lottes, S.A., and H.H. Chiu, *Resonant Combustion of Single Droplet and Droplet Clouds with Application to Turbulent Internal Group Flame*, Proceedings of the AIAA 22nd Aerospace Sciences Meeting, Reno, NV, 84-0128, (January 9-12, 1984).

Lottes, S.A., and H.H. Chiu, *Unsteady Spray Group Combustion*, Proceedings of the Central States Section of the Combustion Institute 1987 Spring Technical Meeting, Argonne, IL (May 11-12, 1987).

Lottes S.L., and H.H. Chiu, *Group Combustion of Unsteady Sprays*, Proceedings of 23rd Joint Propulsion Conference, San Diego, CA, 87-1956 (June 29-July 2, 1987).

Lottes S.L., and H.H. Chiu, *Anatomy of Group Combustion Burning Mode Transitions in Spray Group Combustion*, Proceedings of 24th JANNAF Combustion Conference, Monterey, CA (October 5-9, 1987).

Publications: Reports

S.A. Lottes and M. Petrick, *Glass Furnace Model (GFM) Development and Technology Transfer Program Final Report*, ANL-07/28, Nov. 2007.

R.D. Doctor, M. Henry, Y. Lin, S.A. Lottes, R.W. Lyczkowski, C.B. Panchal, and J.W. Weidner, *Nuclear Hydrogen Initiative Calcium-Bromine Cycle: Feasibility of a Calcium-Bromine Thermochemical Cycle for Nuclear Hydrogen Production*, Argonne National Laboratory Report (2006).

S.L. Chang, S.A. Lottes, J.X. Bouillard, and M. Petrick, *Flow Simulation of the CDIF MHD Power Train System*, ANL Report, ANL/MHD-97/02, (Nov., 1997)

S.L. Chang, S.A. Lottes, and M. Petrick, *Multiphase Integral Reacting Flow Computer Code (ICOMFLO): User's Guide*, ANL Report, ANL/MHD-97/01 (Nov. 1997)

Chang, S.L., J. X. Bouillard, S.A. Lottes, M. Petrick, and Q.C. Zhou *Evaluation of the ANL ICRKFLO Code for Simulation of a Fluid Catalytic Cracking Reactor*, ANL LDRD Report, (April 1996).

Chang, S.L., S.A. Lottes, and M. Petrick, *Heavy Crude Oil Pretreatment via Fluidized-Bed and Hydrogenation Processing of Midway Sunset Crude Oil*, Final Report to Bartlesville Project Office, DOE and Santa Fe Energy Resources, Inc., Houston, Texas, ANL/SF-93-109 (September, 1995)

Chang, S.L. and S.A. Lottes, *Effects Of Copper-Catalytic Reactions On The Kinetics Of Hydrogen Flames And A Preliminary Study Of Two-Dimensional Interfacial Combustion*, Final Report to Arnolds Engineering Development Center, DoD (February, 1993)

Coffey H.T., J.L. He, S.L. Chang, J.X. Bouillard, S.S. Chen, Y. Cai, L.O. Hoppie, S.A. Lottes, D.M. Rote, Z.Y. Zhang, G. Myers, A. Cvercko, and J.R. Williams, *Preliminary Design for a Maglev Development Facility*, ANL Report ANL/ESD-14 (October, 1991)

Lottes, S.A., and H.H. Chiu, *Dynamics of Large Scale Vortex Structures and the Quasi-Large Scale Structures in the Wake of a Splitter Plate. Part I – Structure of Steady Base Flow*, Report submitted to the Air Force Office of Scientific Research (May, 1986)

Lottes, S.A., *Dynamic Flow Structures in a Bluff Body Combustor*, Final Report to USAF-SCEEE Graduate Student Summer Support Program, Contract No. F49620-82-C-0035, (August, 1984)