DOE/ER-0158/3

Summaries of FY 1985 Engineering Research

December 1985

U.S. Department of Energy
Office of Energy Research
Office of Basic Energy Sciences
Division of Engineering and Geosciences

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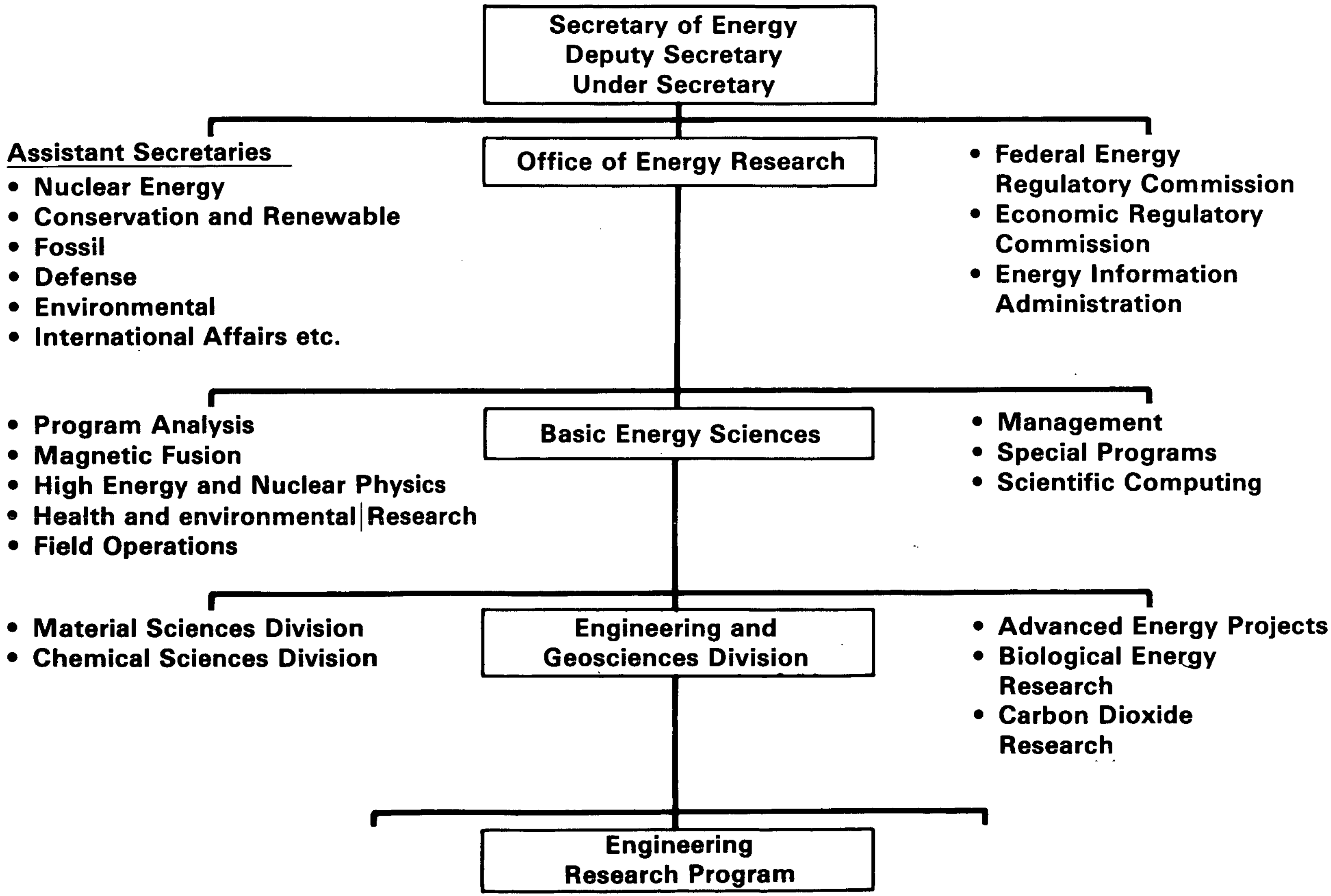
Washington, D.C. 20545

FOREWORD

This report documents the BES Engineering Research program for fiscal year 1985; it provides a summary for each of the program projects in addition to a brief program overview. The report is intended to provide staff of Congressional committees, other executive departments, and other DOE offices with substantive program information so as to facilitate governmental overview and coordination of Federal research programs. Of equal importance, its availability facilitates communication of program information to interested research engineers and scientists. The organizational chart for the DOE Office of Energy Research (OER) on the next page delineates the six Divisions within the OER Office of Basic Energy Sciences (BES). Each BES Division administers basic, mission oriented research programs in the area indicated by its title. The BES Engineering Research program is one such program; it is administered by the Engineering, and Geosciences Division of BES. Dr. Oscar P. Manley is technical manager of the Engineering Research program; inquiries concerning the program may be addressed to him, in writing or by phone at (301) 353-5822.

In preparing this report we asked the principal investigators to submit summaries for their projects that were specifically applicable to fiscal year 1985. The summaries received have been edited as necessary, but the press for timely publication made it impractical to have the investigators review and approve the summaries prior to publication. For more information about a given project, it is suggested that the investigators be contracted directly.

Engineering Research Program within DOE



INTRODUCTION

The individual project summaries follow the program overview. The summaries are ordered alphabetically by name of institution and so the table of contents lists all of the institutions at which projects were sponsored in fiscal year 1985.

The projects are numbered sequentially for individual identification in the indexes. Each project entry begins with a centered, institutional-departmental heading. The project number precedes the capitalized project title. The names of the investigators are listed immediately below the title. The funding level for fiscal year 1985 appears to the right of title; it is followed by the budget activity number (e.g., 01-A). These numbers categorize the projects for budgetary purposes and the categories are described in the budget number index. The year in which the project began and the anticipated duration in years are indicated respectively by the first two and last digits of the sequence directly below the budget activity number (e.g., 84-2). The summary description of the project completes the entry.

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PROGRAM REVIEW

BES ENGINEERING RESEARCH

The BES Engineering Research program is one of the component research programs which collectively constitute the DOE Basic Energy Sciences program. The DOE Basic Energy Sciences program supports energy related research in the physical and biological sciences, and in engineering. The chief purpose of the DOE Basic Energy Sciences program is to provide the fundamental scientific base on which identification and development of future, national energy options will depend. The major product of the program becomes part of the body of data and knowledge upon which the applied energy technologies are founded; the product is knowledge relevant to energy exploration, production, conversion and use.

The BES Engineering Research program was started 1979 to help resolve the numerous serious engineering issues arising from efforts to meet U.S. energy needs. The program supports fundamental research on broad, generic topics in energy related engineering--topics not as narrowly scoped as those addressed by the shorter term engineering research projects sponsored by the various DOE technology programs. Special emphasis is placed on projects which, if successfully concluded, will benefit more than one energy technology. During the first year several workshops were sponsored for the purpose of identifying energy related engineering research needs and initial priorities. Representatives from industry, academic institutions, national laboratories, and leading members of professional organizations (Engineering Societies Commission on Energy, American Society of Mechanical Engineers, Society of Automotive Engineers, and Joint Automation and Control Committee) participated in the workshops. In addition to the participants in the workshops, staff representatives from the DOE technology programs and other leading U.S. energy engineering experts made significant contributions to the setting of program priorities. There resulted from this process a strong confirmation of the need for a long-range, fundamental engineering research program with two major goals. The broad goals that were established by this process for the BES Engineering Research program are:

1) To extend the body of knowledge underlying current engineering practice so as to create new options for enhancing energy savings and production, for prolonging useful equipment life, and for reducing costs without degradation of industrial production and performance quality; and

2) To broaden the technical and conceptual base for solving future engineering problems in the energy technologies.

In this process, it was further established that to achieve these goals, the BES Engineering Research program should address the following topics identified as essential to the progress of many energy technologies:

1) Advanced industrial Technology -- improvement of energy conversion and utilization, opening new technological possibilities, and improvement of energy systems.

2) Fluid Dynamics and Thermal Processes -- broadening of understanding of heat transfer in non-steady flows, methodology for reducing vibrations and noise in heat exchangers, and engineering aspects of combustion.

3) Solid Mechanics -- continuum mechanics and crack propagation in structures.

4) Dynamics and Control of Processes and Systems -- development and use of information describing system behavior (system models), performance criteria, and theories of control optimization to achieve the best possible system performance subject to known constraints.

In addition to the above topics, Geotechnical Engineering (mining), Electric Power Technology, Reliability and Risk Analysis, and Novel Energy Related Engineering were endorsed as areas suitable for immediate initiation of engineering research projects. Because of budgetary limitations, the implemented BES Engineering Research program is somewhat less broad than the program envisioned above. At present, equal emphasis is being placed on three carefully selected, high priority research areas; namely,

1) Mechanical Sciences -- including tribology (basic nature of friction reduction phenomena), heat transfer, and solid mechanics (continuum mechanics and crack propagation).

2) System Sciences--including process control and instrumentation.

3) Engineering Analysis -- including non-linear dynamics, data bases for thermophysical properties of fluids, and modeling of combustion processes for engineering application.

These areas contain the most critical elements of the four topics enumerated above; as such they are of importance to energy technologies both in the short and long term, and therefore of immediate programmatic interest. It should be noted that other areas of basic research important to engineering are monitored elsewhere in BES. For instance, separation sciences and research on thermophysical properties, are among the responsibilities of the Chemical Sciences

Division, while microscopic aspects of fracture mechanics are in the domain of the Material Sciences Division. As resources permit, other high priority areas are being added to the Engineering Research program. Thus as a result of some growth in the program budget an important development has taken place in the Engineering Research Program: two major concentrations of research were initiated. First, a new program was organized at Oak Ridge National Lab dealing with intelligent machines in unstructured environment. It is expected that some resources will be available for coordinated, more narrowly focussed related, high quality research at universities and other research centers.

All such activities will be supported and administered directly by the Engineering Research Program, but some coordination of efforts with the ORNL program may prove useful. The research opportunities in this area of interest to the DOE - Engineering Research Program have been identified in a workshop held in November, 1983. Proceeding of the workshop entitled "Research Needs in Intelligent Machines" are available from the Center for Engineering Advanced Systems Research, Oak Ridge National Lab, Post Office Box X, Oak Ridge, TN, 37830.

Secondly in FY 1985 there has started a collaborative research effort between MIT and Idaho National Engineering Lab. At present, the collaboration is in four distinct areas: Plasma Process Engineering, Automated Welding, Fracture Mechanics, and Advanced Engineering Methods and Analysis.

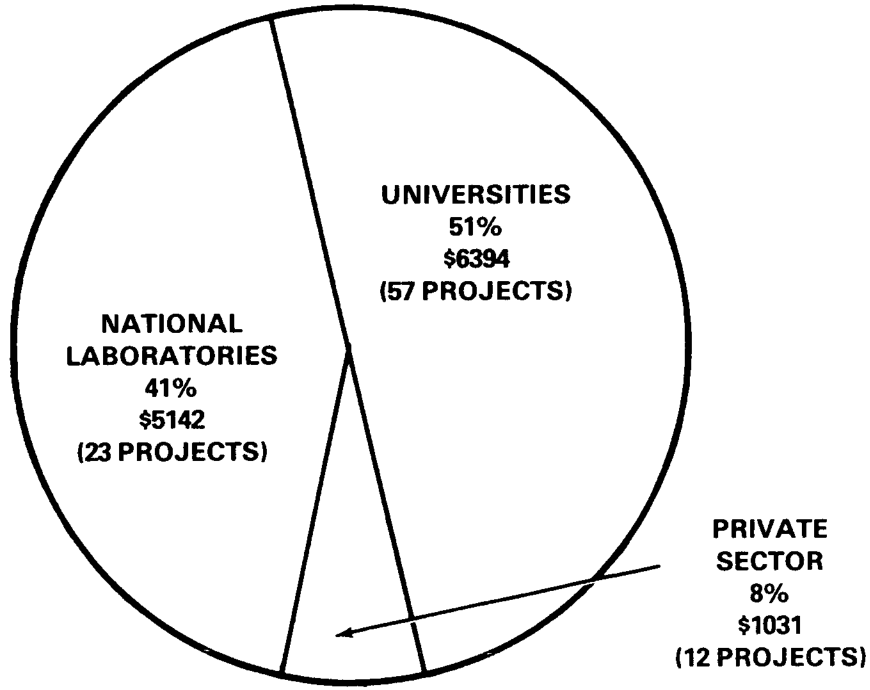
Again, it is expected that colateral, high-quality research efforts at other institutions will be supported by the Engineering Research program.

Finally, in the expectation of a future modest growth of this Program. These were held in September 1985 an International Workshop on Two-Phase Flow Fundamentals, and used at identifying basic research opportunities in that field. A summary report of the workshop will be available from the Program Office. The full proceedings will be published as a volume in the series "Advances in Heat and Mass Transfer" (Herrinsphere Publishing).

It should be mentioned too, that some very limited support is available for research on large scale systems. A report of a Workshop on Needs, Opportunities, and Options in this field is available from Professor G. L. Thompson, Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh, PA, 15213.

Research projects sponsored by the BES Engineering Research program are currently underway at universities, private sector laboratories, and DOE national laboratories. In fiscal year 1985 the program operating funds available amounted to about $13.5 million. The distribution of these funds among various institutions and by topical areas is illustrated on the next page. Project funding levels are mostly in the range of $50,000 to $150,000 per year. Typical duration of a project is three to four years, with some projects expected to last as long as ten years or more. The BES Engineering Research projects stem almost without expection from unsolicited proposals. Proposals which anticipate definite results in less than two years are usually referred to the appropriate DOE technology program for consideration. Anyone interested in submitting a proposal is encouraged to discuss his ideas with the technical program manager prior to submission of a formal proposal. Such discussion helps to establish whether or not a potential project has a reasonable chance of being funded. The primary considerations for possible support are the technical quality of the proposal and the professional standing of the principal investigators and staff. An effort is made to attract first rate, younger research engineers and energy oriented applied scientists. A high technical caliber of research is maintained by requiring that the projects supported have potential for a significant contribution to energy-related engineering science, or for an initial contribution to a new energy relevant technology. Sponsored projects are selected primarily for their relevance to DOE mission requirements; the contribution to energy related higher education is an important but secondary consideration. Thus projects sponsored at universities are essentially limited to advanced studies both theoretical and experimental usually performed by faculty members, staff research scientists, and doctoral candidates.

ENGINEERING RESEARCH PROGRAM
FY '85 BUDGET ($000's) BY INSTITUTIONAL TYPE



ENGINEERING RESEARCH PROGRAM
FY '85 BUDGET BY TECHNICAL AREAS

	($000 s)	%	NUMBER OF PROJECTS
MECHANICAL SCIENCES	3442	27	31
SYSTEMS SCIENCES	4957	40	27
ENGINEERING ANALYSIS	4168	33	34

AMES LABORATORY
Iowa State University
Ames, IA 50011

01. A COMPOSITE, MULTIVIEWING TRANSDUCER — $250,000
D. O. Thompson — 03-B
81-7

The objective of this project is to demonstrate a composite, multiviewing ultrasonic transducer suitable for detecting, characterizing, and reconstructing flaws in structural materials for various applications. Development of this transducer utilizes a combination of recent advances in ultrasonic scattering and inversion theories with new concepts in transducer configurations and excitation methods. An experimental model of a composite transducer has been used as an aid in developing the semi-automated data acquisition and protocol. It has been determined that seven transducer elements which are multiplexed using both pulse-echo and pitch-catch modes are sufficient to produce good flaw reconstructions. Effects of limited aperture on the reconstruction have also been examined. The reconstruction protocol fits the acquired data to an "equivalent" ellipsoid of general shape (3 axes, 3 angles), a shape that is compatible with a fracture mechanics description of growing flaws and thus suitable for failure prediction. Criteria have also been established for individual transducer selection using experimentally determined scattering results. It is suggested that this procedure may form an approach for the further development of new transducer standards.

ARGONNE NATIONAL LABORATORY
Components Technology Division
Argonne, IL 60439

02. THEORETICAL/EXPERIMENTAL STUDY OF STABILITY CONTROL — $130,000 — 01-C — 82-4

S. S. Chen, E. L. Reiss (Northwestern U), J. A. Jendrzejczyk

Theoretical and experimental studies are aimed at enhancing the understanding of nonlinear stability phenomena involving fluids, solids, and their coupling. The objective is to develop methods of controlling instability, and to explore the use of instability mechanics in engineering design. Studies of the mathematics of the modeled nonlinear systems are conducted at Northwestern University. Experiments and related analysis are performed at Argonne National Laboratory. Studies have been performed on the special fluidelastic stability problem of a slender elastic tube conveying fluid. In order to develop the required mathematical techniques and to understand the mathematical and physical phenomena that may occur, simpler oscillator problems have been studied. These include two simple, coupled nonlinear oscillators as a model to study nonlinear stability control by secondary bifurcation and to develop a technique to study subcritical bifurcation. In parallel with the theoretical study, experiments have been performed with a tube, fixed at the upstream end and supported at a downstream location by a knife-edge support whose distance from the end can be varied. A series of tests has been performed and reported. In addition, a numerical technique to predict large-amplitude oscillations above the critical flow velocity has been developed; numerical results agree well with experimental data. Further studies will focus on analytical methods for subcritical bifurcation and an experimental investigation of flow and flow-induced instabilities.

ARGONNE NATIONAL LABORATORY
Components Technology Division
Argonne, IL 60439

03. BOUNDS ON DYNAMIC PLASTIC DEFORMATION — $ 50,000
C. K. Youngdahl — 01-A
84-3

In many applications where load is transmitted to the structure through a fluid, details of the load history and spatial distribution affect significantly the final plastic deformation. The objective of this project is to devise load correlation parameters based on various weighted integrals of the time-space load distributions which can be used to characterize the effects of the load without resorting to detailed numerical analysis. These load correlation parameters have three important uses: to perform design loadings; to validate computer programs which have a nonlinear dynamic plasticity capability; and to correlate experimental simulations with actual or predicted events. The dynamic plastic deformation of some basic structural configurations will be analyzed for loadings which vary both in magnitude and region of application with time. Load correlation parameters will be hypothesized and their usefulness in predicting final plastic deformation will be determined. The analyses will be based initially on a rigid, perfectly plastic material model, but will be extended to include strain hardening and elastic effects if the work to determine load parameters is successful.

BATTELLE-COLUMBUS LABORATORIES
Physical Metallurgy Section
505 King Avenue
Columbus, OH 43201

04. DAMAGE ACCUMULATION BY CRACK GROWTH UNDER COMBINED CREEP AND FATIGUE — $ 56,000 — 01-A — 83-3

C. E. Jaske

The objective of this study is to develop and evaluate methods for assessing creep/fatigue crack growth under inelastic straining. A fracture-mechanics approach implementing the J integral for fatigue and the C* integral for creep is being employed. A crack-tip-zone interaction model is used to account for the interactions between creep and fatigue during crack growth at high temperatures. Experimental studies on Type 316 stainless steel at 593 and 649 C are continuing. Experiments similar to those previously performed on Type 316 stainless steel are being conducted on modified 9Cr-1Mo steel at 538 and 593 C. Four specimen configurations are being used: (1) low-cycle fatigue (LCF), (2) compact type (CT), (3) center-cracked tension (CCT), and (4) multiple-edge-notched tension (MENT). The LCF and MENT specimens have short (0.1 to 1.5 mm) cracks, and the CT and CCT specimens have long (25 to 35 mm) cracks. The range of the cyclic J integral has been shown to be a good parameter for characterizing fatigue-crack-growth rates when creep effects are negligible. The C* integral has been shown to be a good parameter for characterizing creep-crack-growth rates under static or slowly varying loading with steady-state creep across the remaining uncracked ligament. Transient effects during fatigue after a period of creep or vice versa can be interpreted in terms of the crack-tip-zone interaction model. Use of the MENT specimen configuration has been shown to provide a relatively simple and economic means of measuring creep-crack-growth at low propagation rates (near 1 mm per year). The general approach is being evaluated for cases where creep-fatigue damage may occur during dwell periods at some fraction (0 to 1.0) of the maximum cyclic load.

BRIGHAM YOUNG UNIVERSITY
Department of Chemical Engineering
Provo, UT 84602

05. MEASUREMENT AND PREDICTION OF LIQUID MIXTURE THERMAL CONDUCTIVITY AND VISCOSITY — $ 34,000, 06-A, 83-2

R.L. Rowley

In spite of the importance of liquid mixture thermal conductivities and viscosities in energy technology, existing models and correlations are either inaccurate and inadequate or require multiple adjustable parameters for each specific system. This project has led to the development of a new predictive method for liquid mixture thermal conductivities and shear viscosities, based on the local composition concept for nonrandom liquid mixtures, which permits accurate estimation of these properties from thermodynamic data with no adjustable parameters. A high-precision capillary viscometer has been used to study a wide range of binary and ternary viscosities over a moderately wide temperature range at ambient pressure. Additionally, a new transient hot-wire thermal conductivity apparatus capable of making rapid and accurate liquid mixture thermal conductivity measurements has been designed, constructed, and implemented in the measurement of binary and ternary liquid mixture values. These data have been used to test the newly developed model. Although the model contains only binary interaction terms obtained from equilibrium thermodynamic information, it is formally applicable to ternary mixtures as well. Test system emphasis has been on highly nonideal mixtures containing polar and associating components. Both binary and ternary viscosity predicted in this manner agree well with measured values. Binary thermal conductivity predictions are very accurate using this method. The objective of the current fiscal year is continued measurement of ternary mixture thermal conductivities and utilization of those values in further testing of the model.

BROWN UNIVERSITY
Division of Engineering
Providence, RI 02912

06. GEOMETRIC ANALYSIS OF THE ENSEMBLE OF SOLUTIONS IN TWO-PHASE FLOWS AND COMPLETE RESOLUTION OF THE PROBLEM OF CHOKING

$ 83,000
06-C
84-3

J. Kestin

The project studies a mathematical formalism for the qualitative analysis of the geometric-topological structure of all trajectories (solutions) of a two-phase model in a space formed with the state-velocity variables and physical distance. Such an analysis supplements the study of numerical solutions produced by an appropriate computer code. It serves to answer a number of questions of physics without actually solving the equations of the model, to establish a set of initial conditions for which the problem is well-posed, as well as that set for which no physically meaningful solutions exist. The most important advantage in carrying out such an analysis in detail is the fact that it provides us with a complete resolution of the problem of choking.

An analysis of a general form of the system of equations which govern steady-state multiphase flows shows that the state-velocity which exists at a choked section is idenpendent of the closure conditions (phenomenological assumptions), which, however, in the presence of appropriate inlet conditions, determine the location of the choked cross-section.

A method of determining the character of the singular points has been worked out.

CALIFORNIA INSTITUTE OF TECHNOLOGY
Department of Chemical Engineering
Pasadena, California

07. THE DEVELOPMENT OF PROCESS DESIGN AND CONTROL STRATEGIES FOR ENHANCED ENERGY EFFICIENCY IN THE PROCESS INDUSTRIES $ 71,000
03-A
84-2
M. Morari

The process industries are a major consumer of energy and the improvement of energy efficiency is an important goal. Process modifications aiming at a reduction of energy consumption tend to make a plant more integrated and thus more difficult to operate. In practice, the primary objective is not only steady state energy efficiency but that the plant is flexible, operable and controllable, i.e. resilient. The research goals are to develop design strategies for resilient processes and operating policies for highly integrated plants. The particular subtasks are: 1) Synthesis of resilient energy management network, 2) Development of control strategies for integrated distillation columns, and 3) Development of control and optimization procedures for systems with high parametric sensitivity (chemical reactors). The latter two tasks involve an entensive experimental verification phase. The development of interactive user-friendly CAD packages incorporating the fundamental theoretical developments are under way. This work is carried out in collaboration with, The University of Wisconsin.

UNIVERSITY OF CALIFORNIA, BERKELEY
Department of Mechanical Engineering
Berkeley, CA 94720

08. INVESTIGATION OF SECONDARY MOTIONS AND TRANSITION TO TURBULENCE IN BUOYANCY-DRIVEN ENCLOSURE FLOWS WITH STREAMLINE CURVATURE — $ 70,000 — 01-C — 85-3
J.A.C. Humphrey, R. Greif

A study is underway to clarify the role of secondary motions and transition to turbulence in buoyancy driven enclosure flows. Four flow modes will be investigated experimentally. The modes are determined by the boundary conditions imposed along the side walls of the enclosure. In three cases they include the unsteady two-dimensional collision of buoyancy driven, opposed, vertical boundary layer flows. The fourth case corresponds to the "classical" recirculating flow configuration with one side wall heated and the opposite wall cooled.

Preliminary experimentation suggests that centrifugal instabilities produced by steamline curvature may be expected to induce "Taylor-Gortler-Like" (TGL) vortex structures in the flows. The conditions for which the instabilities occur, and the characteristics of the flows before and after their appearance, are subjects for research.

Qualitative and quantitative flow visualization techniques under consideration include: (Qualitative) - the thymol blue electrochemical technique; suspensions of crushed mother of pearl; microspheres; and liquid crystals; (Quantitative) - liquid crystals; laser speckle photography (LSP); laser-Doppler velocimetry (LDV); and thermocouples. Difficulties related to variations in index of refraction can be minimized to yield results sufficiently accurate and precise for the purposes of this investigation.

Direct numerical simulations of the experimental conditions will be performed using a Navier-Stokes solver developed by us. The procedure solves 3-D, unsteady, variable property flows. Second and third order accurate differencing of the convective terms is under consideration.

The results of this work are expected to contribute directly to the basic understanding of transition to turbulence and turbulent flow, and the ability to model these flows mathematically.

UNIVERSITY OF CALIFORNIA, DAVIS
Department of Mechanical Engineering
Davis, CA 95616

09. STABILITY AND STABILIZATION OF PREMIXED FLAMES — $ 85,000
C. K. Law — 06-B — 84-2

The program aims to investigate effects of heat loss, aerodynamic stretching, and preferential diffusion on the limits and mechanisms for flame propagation and the generation, suppression, and sustenance of flame-front corrugations; to identify the influence of these phenomena on flame stabilization; and to explore possibilities of widening the stabilization limits. Experiments are being conducted by using a variety of laboratory-scale burners to systematically isolate and identify the importance of various system parameters on the phenomena of interest. Theoretical analyses using large-activation-energy asymptotics are performed for the various experimental flame configurations to provide guidance and confirmation. During the reporting period we have accurately determined the laminar flame speeds of methane/air and propane/air mixtures with hydrogen addition. The results show that the flame speed is significantly increased with hydrogen addition, and that it can be linearly correlated with the flame speed without hydrogen addition and a single parameter indicating the extent of hydrogen addition. Experiments have also been conducted to determine the extinction stretch rates of methane/air and propane/air flames. Results seem to imply that the stretch rate vanishes identically at the flammability limits. A theory describing the response of two interacting premixed flames has also been completed. The results show extended regimes of mixture combustibility due to flame interaciton and agree well with experimental data.

UNIVERSITY OF CALIFORNIA, BERKELEY
Department of Mechanical Engineering
School of Engineering and Applied Science
Los Angeles, CA 90024

10. BASIC STUDIES OF TRANSPORT PROCESSES IN POROUS MEDIA — $145,000
01-C
Ivan Catton — 82-6

The research covers two broad areas: 1) single-phase convection in porous media and 2) two-phase convection in porous media. The objective of this study is to develop physical understanding of the governing phenomena and models for prediction of transport processes by theoretical and experimental means.

Single phase buoyancy-driven flow through porous media was studied numerically using a general non-Darcian model. Emphasis was on boundary effects in a uniform porosity porous bed and on the importance of inertia terms. A two-dimensional analysis was applied to the simplest possible realization, i.e. horizontal and vertical porous layers of infinite extent. The boundary effect was found to be negligible for moderate or low permeabilities and the inertia terms were shown to always be important. For a vertical layer, inertia diminishes and destabilizes the basic shear flow. For the horizontal layer (porous Benard problem), inertia lowers the mean heat transport.

Two-phase flow through uniform and stratified porous media were studied. Pressure drop and void-fraction data were analyzed to establish microscopic flow equations. The resultant equations include models of capillary pressure, solid drag, and interfacial drag. Analyses of two-phase flow through stratified beds were performed to study the effects of medium stratification on the hydrodynamic behavior of flow. Experimental studies of counter-current flow of superheated steam and subcooled water in uniform beds are underway.

Transport phenomena associated with the heating of a stationary meniscus formed by an inclined partially submerged copper plate has been investigated experimentally and theoretically. For a near isothermal interline, the meniscus local heat transfer coefficient was evaluated using an integral method and compared against data obtained via laser holographic interferometry. The superheated interline lead to a wavy profile. A two dimensional linear stability analysis has predicted the frequency of oscillation measured.

UNIVERSITY OF CALIFORNIA, LOS ANGELES
School of Engineering and Applied Science
Department of Mechanical, Aerospace
and Nuclear Engineering Department
Los Angeles, CA 90024

11. ENHANCEMENT OF CRITICAL HEAT FLUX IN TUBES USING STAGED TANGENTIAL FLOW INJECTION — $ 59,000 — 01-B — 85-3
V.K. Dhir

The objectives of this work is to study experimentally and analytically the staged swirl flow concept for enhancing subcooled critical heat flux in tubes. In the staged swirl flow concept part of the coolant is injected tangentially at discrete locations along the tube axis. This method of injection not only results in a significant increase in the critical heat flux (CHF) but can also be used to shift the location at which CHF occurs. The shift is made possible by adjustment of flow rate through the injectors. The present study is divided into two main tasks:

The first task deals with optimization of the enhancement in subcooled critical heat flux with respect to diameter of the injectors, the angle subtended by the injectors with the tube axis and superposition of swirl created at different injection locations along the tube axis. The experimental study will be complemented with models for the swirl flow CHF and the two phase pressure drop.

In the second task basic understanding of heat transfer and pressure drop in swirling single and two phase flows will be developed. This task will include development of models for bubble detachment and motion under centifugal action and superposition and decay of swirl under single and two phase flow conditions.

Water and Freon-113 loops have been updated and are already operational. A few critical heat flux enhancement data with subcooled water at 2 atmosphere pressure have been obtained. Separate experiments to develop understanding of superposition and decay of swirl have been initiated.

UNIVERSITY OF CALIFORNIA, SAN DIEGO
Scripps Institution of Oceanography MC A-013
La Jolla, CA 92093

12. Nonlinear Dynamics of Dissipative Systems — $ 70,000
Henry D. I. Abarbanel — 06-C
84-2

This research involves investigating the mechanisms which make for efficient energy transfer from a slow, mean motion to a system characterized by high frequencies relative to the mean motion. The basic mechanism of viscosity in a fluid is an example of this. The goal is to learn how to quantitatively characterize the "effective" or "eddy" viscosities used in phenomenological studies of energy, momentum, and other transfers of a turbulent fluid. The work is proceeding by studying analytically and numerically the behavior of systems of a few degrees of freedom as a function of their coupling. The systems are known numerically and, in certain regimes using the Melnikov method, analytically to exhibit chaos. In regimes of parameter space where the motion is regular or laminar the energy transfers are weak; in regions of chaotic motion the rate of transfer can be given a quantitative interpretation in terms of phase space correlation functions. The exponential decay of these functions on a rapid time scale, possibly related to the nontrivial Liapunov exponents of the chaotic motion of the rapidly evolving system, gives an additional rapid rate scale for the transfer of energy to the coupled slow system. Applications to energy problems include all those setups where "friction" or dissipation of a slowly evolving flow are the result of its interaction with a higher frequency system.

UNIVERSITY OF CALIFORNIA, SAN DIEGO
Department of Applied Mechanics
and Engineering Sciences
La Jolla, CA 92093

13.	CHAOTIC ADVECTION AND EFFICIENT MIXING BY DETERMINISTIC FLOWS Hassan Aref	$ 59,000 01-C 85-3

This project is concerned with the kinematics of regions of fluid and/or individual particles being swept along by a flow. The focus is on those aspects of the flow that tend to enhance stirring and mixing quality, and the ultimate goal is to arrive at quantitative criteria that can be helpful in the design of devices where stirring and mixing are important. The research is of relevance to several aspects of chemical and mechanical engineering.

It has been known for some time that the kinematics of particles advected passively by a flow is formally a problem closely related to the phase space description used in the study of dynamical systems. This formal correspondence leads to the notion of "Lagrangian turbulence," a situation in which the trajectories of advected particles is extremely complicated although the advecting flow is relatively simple in the usual Eulerian description. Particle motions can be "chaotic," in the technical sense of the word, and such motions lead to highly efficient stirring. The main thrust of the research is to understand the applicability of chaotic dynamics to advection and to investigate certain model flows in detail using numerical simulation techniques.

The main novel insights produced so far pertain to time-dependent two-dimensional flows. The efficient stirring of very viscous fluids via the mechanisms mentioned is being investigated. Model flows pertaining to stirring in devices without moving parts and the rate at which material interfaces can be stretched are issues stated for investigation during the coming year.

UNIVERSITY OF CALIFORNIA, SANTA BARBARA
Department of Chemical and Nuclear Engineering

14. INVESTIGATION OF FLUID DYNAMIC PHENOMENA NEAR GAS-LIQUID INTERFACES — $81,000 — 01-C — 85-3
S. Banerjee
H. Fenech

The purpose of this project is to study the fluid dynamic phenomena near the interface of cocurrent and countercurrent gas-liquid stratified streams. Interfacial configuration, wave characteristics and turbulence structure will be measured experimentally using two different techniques. Hydrogen bubble tracers in water and high-speed motion photography will be used to follow the path of individual bubbles and obtain a statistical distribution of the turbulent velocity components and Reynolds stress at several distances from the interface in a region of fully developed flow. The alternate method consists in capturing photographically the development of dye streaks in an organic liquid seeded with a photochromic dye which is activated in streaks by a laser. Two separate experimental facilities have been constructed and tests are being conducted using each method.

UNIVERSITY OF CALIFORNIA, SANTA BARBARA
Department of Mechanical and Environmental Engineering
Santa Barbara, CA 93106

15. CONVECTION HEAT TRANSFER IN THE CRITICAL REGION OF FLUID MIXTURES — $ 43,000
E. Marschall — 01-B
83-2

The purpose of this project is to determine convective heat transfer rates in the vicinity of the critical point of liquid mixtures. The ability of pure liquids at critical or slightly super critical conditions to allow very large heat fluxes to occur at very small temperature differences has been established. It is the basic goal of this study to determine whether or not the same phenomenon exists for liquid mixtures. To accomplish this goal, heat transfer rates near the critical point of liquid mixtures are being measured depending on mixture concentrations, temperature differences, and material of heating surface. Emphasis is also placed on the study of the influence of azeotropic behavior and retrograde evaporation or condensation on the heat transfer characteristics. The overall result expected this work is a model for the prediction of heat transfer rates in the critical region of binary mixtures.

CARNEGIE-MELLON UNIVERSITY
Chemical Engineering Department
and
Graduate School of Industrial Administration
Pittsburgh PA 15213

16. STRATEGIES FOR OPTIMAL REDESIGN IN A CHANGING ENVIRONMENT — $150,000
03-A
85-4

L. T. Biegler, I. E. Grossmann, G. L. Thompson, A. W. Westerberg

The optimal redesign of existing processes is becoming a problem of great practical importance to the chemical industry and is expected to play a major role in the future. Redesign problems are heavily constrained and difficult to model since one must account for the performance of existing equipment under new process conditions. Therefore, determination of optimal modifications in an existing plant generally will be quite different from the optimal solutions governing a new plant.

This project will study and develop new strategies and methodologies that account for difficult features in optimal redesign problems. In particular, the following research areas will be addressed:

a) Long range planning for identifying redesign projects.

b) Optimal redesign of heat recovery networks and separation systems in chemical plants.

c) Integration of simulation and optimization tools for redesign calculations.

The proposed strategies will account for both economic and engineering considerations involved in optimal redesign problems, and will rely on concepts developed in the areas of process synthesis, mathematical programming and computer science. Most of the proposed techniques should be applicable to optimal re-design problems in other engineering disciplines.

UNIVERSITY OF CHICAGO
Enrico Fermi Institute
Chicago, IL 60637

17. FUNDAMENTAL AND TECHNIQUES OF NONIMAGING OPTICS FOR SOLAR ENERGY CONCENTRATION — $125,000 — 06-C — 81-6

R. Winston, J. J. O'Gallagher

Nonimaging optics departs from the methods of traditional optical design to develop instead techniques for maximizing the collecting power of concentrating elements and systems. Designs which exceed the concentration attainable with focusing techniques by factors of four of more and approach the theoretical limit are possible. This is accomplished by applying the concepts of Hamiltonian optics, phase space conservation, thermodynamic arguments, and radiative transfer methods. In the early nonimaging designs the mighty edifice of aberration theory was dismantled and replaced by a single key idea. According to this, maximum concentration is achieved by ensuring that rays collected at the extreme angle for which the concentrator is designed are redirected, after at most one reflection, to form a caustic on the absorber. This principle proved sufficiently elastic to accommodate most boundary conditions in two dimensions (i.e., linear geometry). However, the general problem of ideal concentration in three dimensions remains; its solution is a principal objective of current research. We are working on the relations between vector flux, radiance and electrodynamics in the expectation that a proper understanding of the connections between these concepts will lead to new optimized designs.

CLARKSON UNIVERSITY
Department of Chemical Engineering
Potsdam, NY 13676

18. NUMERICAL STUDIES OF COHERENT EDDIES IN WALL-BOUNDED FLOWS — $ 56,000 — 01-C — 82-6
J. McLaughlin

The objectives of the work are to obtain information about the origin of the "coherent" wall eddies which are responsible for the formation of "streaks" in the viscous wall region of turbulent shear flows and to obtain information about their importance in transport. The work involves pseudospectral simulations of channel flow and a three dimensional model of the viscous wall region. The unique feature of the studies lies in the choice of computer experiments which are employed in order to obtain information about the coherent eddies. These experiments can be divided into three groups (1) "wave break-up" experiments in which, after integrating sufficiently far in time to achieve statistical steady-state, certain spatial Fourier components of the velocity field are zeroed and then allowed to recover their energy by time-evolving the velocity field using the modified field as an initial condition; (2) studies in which steady, spanwise-modulated transpiration is applied at the walls in an attempt to modify streak spacings and to determine what effect such a modification has on the transport of energy and momentum; and (3) studies of the breakdown from transitional to turbulent flow with emphasis on the formation of coherent wall eddies.

COLORADO SCHOOL OF MINES
Department of Chemical Engineering
and Petroleum Refining
Golden, CO 80401

19. MEASUREMENT AND CORRELATION OF HEAT TRANSPORT PROPERTIES FOR MODEL COAL LIQUID COMPOUNDS USING AN EXISTING HOT WIRE INSTRUMENT $ 0

E. Dendy Sloan, Michael S. Graboski

The basic goal of this research is to determine some thermophysical properties of fluids encountered in the process of coal liquefaction. The research includes three major tasks. First, an expanded data base will be developed for coal liquids and model compounds. Second, these data will be tested against existing correlations for liquid thermal conductivity. Third, an instrument developed under a previous contract will be evaluated as a device for determining the thermal diffusivity of pertinent coal derived liquids.

COLORADO SCHOOL OF MINES
Department of Chemical Engineering
and Petroleum Refining
Golden, CO 80401

20. RADIATIVE HEAT TRANSFER IN OIL SHALE RETORTING — $ 0 / 01-B / 81-4
Michael C. Jones

Successful modeling of oil shale retorting and other fossil fuel conversion processes depends upon an accurate knowledge of the transport processes occurring. Among these are the transport of heat between combustion gases and rock particles and the axial transport of heat along the retort. At the temperatures of the combustion zone in a retort, the dominant mode of heat transport between combustion gases and solids is radiation. The objective of this project is to provide a basis for modeling by experimental measurements and by evaluation of models of the heat transfer processes. The experimental method is to observe the propagation down a packed bed of inlet gas temperature disturbances, and to infer interphase heat transfer coefficients and axial conductivities by comparison with the results of a differential equation model containing those parameters. The comparison may be made in time, Laplace, or frequency domains. The effect of gas radiation will be determined by performing the experiment with carbon dioxide rich mixtures and with non-radiating gas (nitrogen) as a control.

Frequency response experiments have been carried out on a 5" diameter packed bed of alumina spheres over a range of temperatures, flow rates and diameters. Measurements of both amplitude ratio and phase lag for thermometers at two different locations have allowed the testing of different models and the determination of model parameters. These measurements show good promise of allowing the separation of radiation and conduction effects.

CORNELL UNIVERSITY
Department of Mechanical and Aerospace Engineering
Ithaca, NY 14853

21. FUNDAMENTAL HIGH PRESSURE DROPLET COMBUSTION CHARACTERISTICS OF EMULSIONS AND MIXTURES — $ 14,000 — 06-B — 83-3

C. T. Avedisian

This work is designed to provide a fundamental understanding of the evaporation/combustion and internal boiling characteristics of droplets of mixtures and emulsions over a range of ambient pressures. Two principal experimental techniques are being used. In the first, the combustion of liquid droplets is to be studied in a drop tower. In this technique, the combustion chamber, test droplet, and associated instrumentation will be in free fall over a distance of about 30 ft., thus providing an experimental run time of about 1.3s. Measurements planned include the effects of ambient pressure and fuel composition on both the temporal variation of droplet diameter and vapor explosion intensity. This latter problem is being studied in more detail in the second principal experiment. The technique involves levitating light test droplets in a flowing stream of another heavier immiscible field liquid (glycerine) in a vertical chamber, the pressure of which can be controlled up to 20 atm at temperatures up to 250^{o} C. The intent of this experiment is to provide quantitative information on the specific mechanisms and parameters controlling the internal boiling characteristics of fuel droplets which are miscible mixtures of liquids.

CORNELL UNIVERSITY
School of Electrical Engineering
School of Mechanical and Aerospace Engineering
Ithaca, NY 14853

22. COMBUSTION CONTROL WITH SMART SENSORS $140,000
G. J. Wolga 03-B
F. C. Gouldin 82-3

The objective of this project is to develop and demonstrate a "smart" spectroscopic sensor suitable for monitoring gaseous combustion products by differential infrared absorption spectroscopy. The sensor is a computer controlled tunable acoustooptic infrared filter with sufficient resolution to resolve individual vibration-rotation absorption lines in the 5-6.5 micron spectral region. It will be self calibrating with respect to temperature changes and thus the sensor can operate unattended indefinitely. A tunable CO laser has been used to develop an accurate tuning curve for the filter in the 5 to 6.5 micron spectral region. Differential absorption spectra from CO and CO_2 spectrum are incompletely resolved due to the smaller rotational constant and overlapping hot bands. Thus, we use the CO spectrum to obtain the gas (rotational) temperature. Comparison of the observed spectrum with a synthesized spectrum permits a temperature determination which compares very favorably with thermocouple measurements within the exhaust plenum. Data analysis procedures for handling absorption integrated over a path length have been developed for conditions of cylindrical spatial symmetry and relatively small absorption. Current efforts concern: developing methods for determining gas concentration with resolved and unresolved spectra; introducing combustion particulates into the flow to determine the effects on signal to noise and consequently on the accuracy and precision of our measurements; modeling combustion exhaust gas flow in a power plant to select the best location for our sensor.

ELECTROCHEMICAL TECHNOLOGY CORP.
1601 Dexter Ave. N.
Seattle, WA 98109

23. ELECTROCHEMICAL WEAR MECHANISM AND DEPOSIT FORMATION IN LUBRICATED SYSTEMS — $ 92,633 — 01-D — 82-3

T. R. Beck

The objective of this research is to measure and determine the importance of electokinetic or zeta corrosion and deposit formation in lubricating rolling and sliding systems. Zeta corrosion is a phenomenon identified and modeled in 1968 for hydraulic servo control valves in commercial jet airplanes. This corrosive wear problem has now been solved by appropriate additives based on the theory. The approach of the present research is to compare measurements of wear for rolling and sliding lubricated systems to calculated zeta corrosion rates based on extensions of the valve wear model. Extensive electrokinetic and wear experiments have been carried out with nylon filaments or cloth rubbing on steel with lubricants of micron-filtered water or salt solutions. This system eliminates abrasive and adhesive wear. Use of aqueous solutions allows comparison to phenomena in the extensive corrosion literature for iron. Waveform of electrokinetic currents measured with an iron microelectrode rubbing transversely on a nylon filament on a shaft were in agreement with predictions of a model derived from hydrodynamics and electrical double layer theory. The measured currents were sufficient to account by Faraday's law for weight losses by wear of thin steel disks rubbing on aqueous lubricated nylon cloth. This wear is independent of oxygen partial pressure from 5 ppm to 5000 ppm, indicating a wear component not driven by oxygen reduction. The wear can be eliminated by cathodic protection and by well-known corrosion inhibitors, indicating that it is electrochemical in nature. The various measurements all indicate that zeta corrosion is responsible for the wear results.

FLOW INDUSTRIES, INC.
21414 68th Avenue South
Kent, WA 98032

24. DIRECT NUMERICAL SIMULATIONS OF TURBULENT HEAT TRANSFER — $160,000, 01-B, 84-3
R. Metcalfe

The purpose of this research is to apply the technique of direct numerical simulation to the study of turbulent heat transfer. Direct numerical simulation techniques have been applied successfully to such problems as the testing of turbulence theories, an examination of second order closure modeling assumptions, and addressing questions about the basic physics of turbulent diffusion, mixing layer control through forcing, homogeneous turbulence decay and the decay of turbulence in the presence of background stratification. There are some significant advantages to this approach. Since the flow field is known in detail at each time step, quantities which are difficult or impossible to measure in the laboratory can be computed. No closure modeling is done, so that no ad-hoc assumptions are introduced. The initial and boundary conditions as well as other critical parameters can be precisely controlled, permitting a systematic study of their effects on the evolution of the flow field.

GA TECHNOLOGIES INC.
10955 John Jay Hopkins Drive
San Diego, CA 92121

25. FLUID MECHANICS OF ACOUSTIC RESONANCE IN HEAT EXCHANGER TUBE BUNDLES — $112,870 — 01-C — 82-4

R. D. Blevins

The purpose of this study is to develop a predictive fluid mechanic model for acoustic resonance in shell and tube heat exchangers. Acoustic resonance in heat exchangers is the result of acoustic oscillations of gas in sympathy with periodic fluctuations in the flow over tubes. In the experimental phase of the program, a simulated tube bundle is being constructed which will be tested in air flow. Direct measurements of the onset of resonance, intensity and mode of acoustic pressure will made with microphones, and measurements of the exciting fluid dynamic fluctuations about the tube will be made with hot wire anemometers. Results will be processed on-line using fast Fourier transforms. In the theoretical phase of the program, a linear acoustic model for the phenomenon will be developed using acoustic source and dissipation terms and a calculated acoustic mode shape. The experimental results will then be used to refine the acoustic source and dissipation terms, develop a fundamental understanding of the fluid dynamic and acoustic interaction. A nonlinear model for the self-excitation will then be developed using Lighthill's formulation for aerodynamic sound in interaction with the coherent structures in the flow due to vortex shedding from the tubes.

GA TECHNOLOGIES INC.
P.O. Box 85608
San Diego, CA 92138

26. HIGHER DIMENSIONAL NONLINEAR DYNAMICS — $ 75,000
John M. Greene and Jin-Soo Kim — 06-C
85-3

The goal of this project is explore how the methods of nonlinear dynamics can be applied to ever more complex systems.

The modern theory of nonlinear dynamics is, to a large extent, the understanding of the way in which computational results can be used to gain insight into the nature of chaotic and turbulent systems. A property of such systems is that two different orbits that are crudely indistinguishable are generally quite different in their detailed behavior. Thus a single orbit, or realization, contains a confusing mixture of uninteresting detailed information, and usefully generalizable information. The most easily obtained, additional, exact, information that computers can provide comes from the solution of equations linearized around a given orbit. The objective of our program is a thorough understanding of the information available through linearization.

This information mostly falls under the key words of Lyapunov exponents and directions. That is, we will study the information available in the rates and directions of separation of nearby orbits, or realizations. The first phase will be a thorough analysis of some ordinary differential equations. Then we will undertake the study of some partial differential equations.

GEO-CHEM RESEARCH ASSOCIATES
400 East Third Street
Bloomington, ID 47401

27. PREDICTIVE MODELING OF URANIUM ROLL TYPE DEPOSITS — $100,000 — 06-A — 83-4
P. J. Ortoleva

Oxidizing meteoric waters percolating through a reduced sandstone aquifer can cause the accumulation of uranium and other ores at the redox interface. The oxidation of pyrite to hematite or geothite can lead to several instabilities underlying observed ore body properties. The existence (and in some cases non-uniqueness) of propagating redox fronts in ore-reductant systems (such as pyrite) was demonstrated and a general exact value for its speed was obtained for the lossless aquifer. The nonexistence of constant velocity redox fronts in multireductant systems was proven analytically and shown numerically to correspond to an accumulation of one mineral at the front of the other - the essential trapping process leading to redox deposits.

A class of instabilities was found when reaction-induced porosity variations were allowed to interact with the percolation flow through the porosity-dependent permeability of Darcy's law. The planar front of dissolution of soluble components in a sandstone aquifer (as pyrite in oxidizing inflow waters) was found analytically to be unstable to the formation of bumps. The range of wavelengths of the most rapidly growing array of bumps brackets the observed wavelengths in roll front deposits when geologically reasonable flow and porosity values were used in our expressions. Numerical simulations of the full nonlinear problem confirmed the linear analysis, and showed that, interestingly, a single bump (in the shape of the surface on which porosity changes) can branch into two fingers. Even very small changes in porosity across the redox front can lead to this fingering.

Nonlinear transport/reaction interactions underly the genesis of uranium roll-front deposits and directly control their geometry and quality. These insights are potentially very useful for exploration.

IDAHO NATIONAL ENGINEERING LABORATORY
Materials Science Division
Idaho Falls, ID 83415

28. ELASTIC-PLASTIC FRACTURE ANALYSIS EMPHASIS ON SURFACE FLAWS — $410,000 — 01-A
W. G. Reuter — 81-6

The objective is to improve design and analytical techniques for predicting the integrity of flawed structural components. The research is primarily experimental, with analytical evaluation guiding the direction of experimental testing. Tests are being conducted on a material (a modified ASTM A-710) exhibiting a range of fracture toughness but essentially constant yield and ultimate tensile strength. As the test temperature increases, the specimen configuration-fracture toughness relationship complies initially with requirements for linear elastic-fracture mechanics and eventually extends beyond the range of a J-controlled field. Presently, compact tension and 3-point bend specimens are being used to develop state-of-the-art fracture mechanics data on the lower shelf (K_{Ic}) and the transition zone and upper shelf (J_{Ic}, J-R, and CTOD). Materials such as Ti-15-3 and an aluminum base alloy are being used to obtain reduced fracture toughness in the absence of cleavage fracture. Results from the lower shelf and transition region are being used to predict failure conditions for specimens containg surface flaws. Predictions are then compared with experimental test data. These comparisons are presently underway for 6.4 and 12.7 mm thick surface-flawed specimens. Metallographic techniques are being used to measure crack tip opening displacement for comparison with analytical models. Moire interferometry and amplitude techniques have been developed for measuring in-plane displacement at the crack tip on tests conducted on a servohydraulic test machine and for field applications. Also, shadow moire techniques have been developed for out-of-plane measurements for quantifying changes in constraint. During the course of this development, capabilities have been developed for measuring dynamic events.

This project is one of six projects comprising a collaborative research program with MIT.

IDAHO NATIONAL ENGINEERING LABORATORY
Sensors and Diagnostics Division
Idaho Falls, ID 83415

29. IN-FLIGHT MEASUREMENT OF THE TEMPERATURE OF SMALL, HIGH VELOCITY PARTICLES — $125,000 — 06-A — 85-3
J. R. Fincke

Knowledge of in-flight particle temperature is fundamental to understanding particle/plasma interactions in the physical and/or chemical processing of fine powders. The measurement of in-flight particle temperature is based on a coincidence technique. A small measurement volume is defined by two independent lens/sensing systems. When a particle is present in the measurement volume, a signal will be observed and recorded simultaneously by each sensing system. Once a signal is recorded, the particle temperature may be deduced. The uncertainty in this temperature determination will be due to lack of information concerning the particle size, shape, and emissivity; and to the presence of an emitting, absorbing, and scattering medium. The proposed technique for backing out these effects is based on in situ estimation of the particle emissivity and the radiation emitted by the particle at several wavelenghs.

The program consists of three phases. Phase I is a basic study of particle emissivity and its relationship to light scattering by small particles in the visible and near infrared (IR). In the experimental portion of Phase I, individual particles will be electrostatically suspended, then heated by a laser beam. The particle temperature, emissivity, and reflectance (scattering) will be measured. Phase II will be the development of the in-flight coincidence technique. The major developmental problems in this phase are the signal processing techniques, rapid collection of spectral data, and the development of algorithms to deduce particle temperature and emissivity. Phase III will apply, and modify as necessary, these techniques to measure particle temperatures in a high temperature plasma. This phase of the program will address the problems associated with the presence of an emitting, absorbing, and scattering atmosphere.

This project is one of six projects comprising a collaborative research program with the Massachusetts Institute of Technology.

IDAHO NATIONAL ENGINEERING LABORATORY
Materials Science Division
Idaho Falls, ID 83415

30. EXPERIMENTAL MEASUREMENT OF THE PLASMA/PARTICLE INTERACTION — $335,000 — 06-A — 85-3

M. E. McIlwain, S. C. Snyder, L. D. Reynolds

The objective of this research is to quantitatively describe the heat, mass, and momentum transfer associated with metallic or oxide particles immersed in thermal plasma environments. In order to characterize the interaction between plasma constituents and particles, the development of new methods to determine plasma flow velocity and species compositons are being developed. Holographic interferometry is currently being considered for plasma flow velocity determination and planar laser induced fluorescence is being considered for compositional measurements adjacent to particle surfaces. Using these advanced techniques, temporal and spatially resolved distributions of the chemical and physical properties of the plasma/particle environment will be determined. Since this research is performed in collaboration with research at Massachusetts Institute of Technology, the resulting experimental data will be used to validate and correct theoretical models used for thermal plasma processing and for predictions relating to optimal torch and fixture design criteria. Experiments are currently being performed in two plasma torch designs, a constricted nozzle torch and an expanding nozzle torch. Input power dissipation levels ranging from 5 to 180 KW are being studied. These torch designs produce a representative plasma characteristic of those employed for industrial plasma processing.

IDAHO NATIONAL ENGINEERING LABORATORY
Materials Science Division
Idaho Falls, ID 83415

31. INTEGRATED SENSOR/MODEL DEVELOPMENT FOR AUTOMATED WELDING — $475,000 — 03-A
H. B. Smartt, L. A. Lott, J. O. Bolstad — 85-3

The objectives of this research are (1) to develop a model of the gas metal arc welding process suitable for real-time process control, (2) to develop an optical sensing system which provides critical weld bead geometry data, and (3) to develop an ultrasonic sensing system which can directly sense weld bead side-wall fusion and penetration. This project is part of a collaborative research program with the Massachusetts Institute of Technology.

A fundamental model of the gas metal arc welding process is being developed which considers wire melting, droplet detachment, droplet momentum, pool convection, and final weld pool geometry. Although iterative, numerical solution techniques are required, finite difference/finite element methods are not used. A computer controlled welding machine has been assembled for demonstration and verification of model and related sensor developments.

A pulsed laser enhanced, gated electro-optical sensor is being developed which suppresses most of the arc light, providing an image of the electrode wire, weld pool and surrounding base metal which is suitable for image processing. Required image processing techniques are also being developed.

Direct sensing of weld pool solid/liquid interface location is being developed using conventional pulse-echo ultrasonic transducers. Signal analysis/pattern recognition techniques are being developed for automated measurements.

IDAHO NATIONAL ENGINEERING LABORATORY
Advanced Methods Division
Idaho Falls, ID 83415

32. EXPERT SYSTEM AIDES FOR ANALYSIS CODES — $200,000 — 06-C — 85-3
V. H. Ransom, R. K. Fink
R. A. Callow, W. J. Bertch

The purpose of this research is to establish the impact that expert systems will have on the architecture of engineering analysis codes. A secondary purpose is to assess the benefits that are possible by employing expert systems as aides to engineering analysis codes. Expert systems are computer codes in which the knowledge of experts is codified and made readily accessible to others, in this case to the user of engineering analysis codes. Productivity can be enhanced by reducing the human effort and level of expertise necessary to complete analysis tasks, and by producing consistent high quality results.

The initial phase of this research has focused on the computer language and hardware communication issues, the best tools and architecture for expert system development, and the identification of the analysis code functions which could most benefit from expert system development. The general approach that is being taken is to select a representative analysis code for experimentation and the development of pilot expert systems for experimentation and assessment. The ATHENA code has been chosen for this purpose. ATHENA is an Advanced Thermal Hydraulic Energy Network Analyzer that is being developed for DOE and is fully operational. It is used for transient simulation of thermal hydraulic systems such as magnetic containment fusion reactors, light water reactors, and in general can be used for transient simulation of any single-phase or two-phase thermal hydraulic circuit.

IDAHO NATIONAL ENGINEERING LABORATORY
Materials Science Division
Idaho Falls, ID 83415

33. NONDESTRUCTIVE CHARACTERIZATION OF FRACTURE DYNAMICS AND CRACK GROWTH — $240,000 — 03-B — 83-5
J. A. Johnson and D. M. Tow

The purpose of this research is to develop instrumentation and models to measure and predict the interaction of ultrasound with cracks in engineering materials. An additional experimental program is concerned with measuring the properties of growing cracks, including crack-front geometry with advanced acoustic emission and radiographic techniques.

A model of the ultrasonic field/crack interaction is based on a numerical ray-tracing algorithm. An ultrasonic transducer, operating in the pulse-echo mode is assumed to be equivalent to a large number of spherical sources spread uniformly over the face of the transducer. The total field in the region of a crack is calculated as the sum of the fields from all these sources. The reflected and diffracted fields from the crack are calculated from the incident field from the transducer. These fields are traced back to the transducer face and the integrated field across the face is determined. This can then be directly compared with experiment to investigate the validity of various field/crack interaction models.

They dynamic crack growth measurements have used ultrasonic techniques to attempt to measure the crack-front position and the plastic zone size around the crack tip. An advance acoustic emission (AE) detection system is being developed which will be capable of detecting and digitizing AE signals at much higher frequencies than used in conventional systems. This will allow improved resolution in detecting the source of the emissions and in discriminating between types of sources. The capability of microfocus x-ray techniques for detecting a moving crack front will be investigated. Real-time video recording or high-speed x-ray cinematography will be used to record the dynamic events.

UNIVERSITY OF ILLINOIS AT CHICAGO
Energy Resources Center
Chicago, IL 60680

34. BOILING OF AQUEOUS POLYMER SOLUTIONS $70,000
J. P. Harnett 06-A
85-2

The goal of this research is to study the pool boiling behavior of aqueous polymer solutions, both purely viscous and viscoelastic with the objective of providing accurate boiling measurements using well-defined fluids. Detailed measurements of the transport and rheological properties of the test fluids will be carried out prior to and following the experiments. The direct measurements of the boiling heat flux and surface and fluid temperatures will be supplemented by photographic studies to provide additional insight into the boiling process.

Measurements of free convection heat transfer from horizontal platinum wires to surrounding purely viscous and viscoelastic non-Newtonian fluids have been carried out prior to the boiling experiment. For free convection to purely viscous non-Newtonian fluids at Rayleigh number of the order of 10^{-2} to 1 it is found that the Nusselt number decreases with decreasing power law index values are found to be in agreement with values predicted for Newtonian fluids provided that the zero shear rate viscosity is used for the viscoelastic fluid viscosity.

UNIVERSITY OF IILINOIS AT CHICAGO
Department of Civil Engineering,
Mechanics and Metallurgy
Chicago, IL 60680

35. CONTINUOUS DAMAGE THEORY $ 43,000
Dusan Krajcinovic 01-A
83-3

The study focuses on the establishment of a phenomenological theory consistent with the geometry of the microscale and its changes. In case of a solid weakened by an ensemble of flat, penny-shaped cracks its diminished capacity to transmit loads can be adequately described by a set of doublets defining the void area density and the normal of the observed plane. The continuum damage model formulated along these lines has the essential structure of the slip theory. The kinetic equations are derived assuming the existence of a flow potential in the space of affinities. The application of the developed model to brittle materials clearly demonstrates its ability in replicating salient trends of mechanical response observed in experiments.

Aware of a certain degree of arbitrariness with regard to the determination of kinetic equations (governing the damage growth) inherent to all phenomenological models the attention was lately shifted to some extent to micromechanical considerations. The initial, rather promising results, offer considerable hope for the resolution of some very important problems such as softening, size effect, etc.

The present plans are to develop further the micromechanical model and review a host of existing phenomenological theories to assess their relation to actual microstructural kinetics.

ILLINOIS INSTITUTE OF TECHNOLOGY
Department of Chemical Engineering
Chicago, IL 60616

36. METHOD OF VIBRATIONAL CONTROL IN THE PROBLEM OF STABILIZATION OF CHEMICAL REACTORS — $ 82,000
03-A
84-3

Ali Cinar

The objective of this project is to develop a vibrational control technique for complex nonlinear dynamic systems with multiple steady states and limit cycles. From the mathematical standpoint, the goal of this research is to analyze the effects of fast parametric oscillations on the dynamics of the systems studied. During the second period of the project the tasks were:

1. To conduct further experiments in vibrational control of a CSTR with homogeneous liquid phase exothermic reaction,

2. To construct a catalytic exothermic CSTR system and to develop the reactor model,

3. To model a packed-bed tubular reactor system.

The models developed in tasks 2 and 3 will be used by the research group at the University of Michigan (S. M. Meerkov, PI) for theoretical studies in vibrational control.

ILLINOIS INSTITUTE OF TECHNOLOGY
Department of Mechanical Engineering
Chicago, IL 60616

37. INTERFEROMETRIC MEASUREMENTS IN DOUBLE-DIFFUSIVE SYSTEMS — $ 74,000
03-B
84-3

William M. Worek
Zalman Lavan

The objective of the project is to develop an experimental technique to measure two scalar variables in double-diffusive or other two component systems. The two frequency optical decomposition technique uses a dual frequency Mach-Zehnder Interferometer to simultaneously determine the local gradients of two scalar variables in the test system. Interferograms taken at the two different frequencies are analyzed using index of refraction data which is a function of temperature and concentration. The experimental program will be integrated with an analytical approach in an attempt to identify and assess the potential application of such a technique and the impact on stability studies in double-diffusive systems.

JET PROPULSION LABORATORY
California Institute of Technology
Pasadena, CA 91109

38. BASIC DATA FOR THE DEVELOPMENT OF MOLECULES AS THRESHOLD ELECTRON DETECTORS — $ 75,000 — 03-B — 82-3

A. Chutjian, S. Alajajian

Measurements are being made of, at high electron energy resolution, lineshapes and cross sections for attachment of thermal electrons to a number of perfluorinated and chlorohalocarbon compounds. These molecules have been shown to be viable candidates for use as molecular detectors for extremely low-energy (0-20 millielectron volt) electrons. In particular, the molecules c-C_6F_{10} have extremely large cross sections, and narrow wings, and are well-suited to use as electron detectors in an appropriate collision geometry. In parallel, theoretical calculations are carried out to understand observations in terms of the molecular potential energy surfaces involved, and to explain temperature dependence observed in other experiments.

JET PROPULSION LABORATORY
California Institute of Technology
Pasadena, CA 91109

39. THIN FILM CHEMICAL SENSORS BASED ON ELECTRON TUNNELING — $ 106,000 — 03-B — 83-4

J. Lambe, S.K. Khanna

The objective of this three year program is to understand the physical mechanism of detection underlying a totally new chemical detection concept which utilized electron tunneling as the sensing mechanism. The technical approach involves investigations of the tunneling spectrum (second derivative of current with respect to voltage versus voltate) of metal-metal oxide-metal (e.g., aluminum-aluminum oxide-gold) tunnel junctions which are exposed to chemicals such as halogens. Some of the other key questions to be addressed in this project are: 1) what are the ultimate sensitivity and selectivity, and 2) what are the contributions of the insulating layer and the top porous metal electrode. These electrical measurements, in addition to surface and interface studies, should help us to understand the detection mechanism. A successful program can pave the way for the development of a compact thin film electronic chemical sensor for use in the automation of the chemical processes, and hence, to increase reliability and productivity.

LAWRENCE BERKELEY LABORATORY
Physics Division and
Accelerator and Fusion Division
University of California
Berkeley, CA 94720

40. STUDIES IN NONLINEAR DYNAMICS — $150,000
Allan N. Kaufman, Robert G. Littlejohn — 06-C
80-6

This project involves studies of fundamental properties of nonlinear dynamical systems which arise in physical situations of importance to energy research. Four main subjects are being explored. First, theoretical studies to generalize the WKB representation of wave phenomena are in progress. In this work, caustics are avoided by working in ray-phase space. The Maslov concept is generalized by utilizing Heisenberg and metaplectic operators to represent phase space translations and rotations. In this way, WKB eigenfunctions are obtained in symplectically covariant form, exhibiting no caustic singularities. Second, modern Hamilionian concepts are applied to deal with classical perturbation theories, in particular averaging methods based on slow and fast space-time scales. Reduction techniques yield systematic Hamiltonization of many models in current use, e.g., guiding-center motion and wave modulation. Third, action principles are being used to imbed single-particle Lie-transform perturbation methods in collective models, such as Vlasov-Maxwell systems. Nonlinear phenomena (e.g., ponderomotive forces) are thus dealt with self-consistently. Fourth, a new formulation of conservative dissipative processes is being explored, in which the entropy and energy functionals jointly generate the time-evolution of the system.

LAWRENCE BERKELEY LABORATORY
Energy and Environment Division
University of California
Berkeley, CA 94720

41. CONTROLLED COMBUSTION $160,000
A. K. Oppenheim 06-B
79-8

The principal objective of this study is the acquisition of fundamental knowledge required for the development of controlled combustion systems. Such systems offer the prospect of maximizing thermal energy conversion efficiency, minimizing pollutant emissions, and optimizing the tolerance to a wide variety of fuels. A thorough understanding of ignition--the initiation of a self-sustained exothermic process of combustion--is for this purpose of essential importance. The major objective of the experimental program is the establishment of a fundamental background for the design of enhanced ignition systems. Of prime significance in this respect is the determination of the role of active radicals. This is accomplished by the use of a high frequency response molecular beam mass spectrometer that has been designed and built especially for this purpose. The corresponding theoretical approach is based on an extended thermo-chemical analysis for auto-ignition in a closed system, following the method of approach developed by Semenov and Frank-Kamenetskii. This is supplemented by numerical modeling of jets and flame propagation in turbulent flow.

LAWRENCE LIVERMORE NATIONAL LABORATORY
Department of Electronics Engineering
P. O. Box 808 L-97
Livermore, CA 94550

42. DESIGN AND APPLICATION OF ADAPTIVE CONTROL SYSTEMS — $100,000
03-A
D. T. Gavel, A. N. Payne, and K. D. Young — 82-4

The objective of this project is to develop design techniques for adaptive control systems to achieve specific engineering performance requirements. During the past year, it was recognized that one of the important research directions in adaptive control was in the incorporation of decentralized information constraints. In the modeling and design of controllers for large-scale systems, the decentralized approach has proven advantageous over a more traditional 'all in one' view. Decentralization allows the modeler to view small subsystems separately, thereby reducing considerably the modeling and control design effort. The many issues that we have encountered in doing research in decentralized adaptive control have stimulated other research tasks in the decentralized control and large-scale system area.

LOS ALAMOS NATIONAL LABORATORY
Electronics Division
Los Alamos, NM 87545

43. DEVELOPMENT OF THERMIONIC INTEGRATED CIRCUITS (TICs) — $200,000 — 03-B — 82-6

B. McCormick, D. Wilde, R. Lemons, M. MacRoberts, D. Lynn, R. Dooley, D. Brown

The object of this project is to develop electronics that are capable of operating in both high-temperature and high-radiation environments while maintaining levels of circuit sophisitcation, integration, and reliability demanded of modern electronics. The approach taken for these active electronic-gain devices has been to use the intrinsically high-temperature phenomenon of thermionic emission in conjunction with the thin-film technology of integrated circuits to produce microminiature vacuum triodes. High-temperature tests have been conducted at 500 ^{o}C with no degradation in device characteristics. Current research is focused on improving cathode lifetime, emission, and geometry to ensure the reliability and functionality of TIC technology in high-temperature and high radiation environments.

UNIVERSITY OF MARYLAND
Department of Mechanical Engineering
College Park, MD 20742

44. NUMERICAL MODELLING ENERGY RELATED FLOWS $ 20,000
B.S. Berger 01-C
85-1

The objective of the current study is the numerical determination of the motion of elastic tubes oscillating in a crossflow. A computer program has been written and fully tested which calculates the transient two dimensional motion of an unconstrained circular cylinder which is restrained by a spring and damper. The fully coupled Navier Stokes rigid body equations are solved. Extensive numerical tests have been performed for Re=400 which are in agreement with experimental results. Solutions for the static case have been found for Re=1000 and 2000.

The model of the vibrating tube as a rigid circular cylinder restrained by a spring and damper has been replaced in a second computer simulation by a continuous model. The linear partial differential equations describing the motion of a slender beam have been coupled with the two dimensional Navier Stokes equations. This approximation is currently under test for Re=400. It is anticipated that higher values of Reynold's number will be attained.

THE UNIVERSITY OF MARYLAND
Department of Mechanical Engineering
College Park, MD 20742

45. AN INVESTIGATION OF THE ENERGY AND VORTICITY DYNAMICS OF TURBULENT SHEAR FLOWS — $ 20,000 — 01-C — 85-3

Peter S. Bernard

A description of the dynamics of the vorticity field is central to an understanding of the physics of turbulent shear flows. This follows both from the ubiquitous presence of coherent vortical structures in turbulent flows as well as from the role played by vortex stretching in energy transference and the establishment of local dissipation rates. The MVC (Mean Vorticity and Covariance) closure allows for a connection to be made between phenomenological events occurring in shear flows and the overall balance of the vorticity field. The objective of this research effort is to use these properties of the MVC theory to formulate a complete model of the energy and vorticity dynamics of turbulent shear flows. This is to be carried out by seeking numerical solutions to the closure equations in the context of channel and zero pressure gradient turbulent boundary layer flows. To aid in the analysis of the boundary layer as well as for comparison, purposes, experimental measurements of terms in the vorticity and energy equations taken by a nine-sensor vorticity probe are also being obtained.

UNIVERSITY OF MARYLAND
Department of Electrical Engineering
College Park, MD 20742

46. STUDY OF MAGNETOSTATIC PROBLEMS IN NONLINEAR MEDIA WITH HYSTERESIS — $ 56,000
06-C
83-4

I. C. Mayergoyz

This project has two main research objectives: (1) to develop boundary Galerkin's approach and its quasi-finite-element realization in order to circumvent the difficulties which are related to the unbounded regions of field distribution, and (2) to investigate mathematical models of hysteresis and develop the methods for the calculation of magnetostatic problems in media with hysteresis.

As far as the first objective is concerned, the calculation of magnetic in unbounded regions will be reduced to coupled boundary/volume Galerkin's forms and a new quasi-finite-element projection technique will be developed on this basis. The problems concerning convergence of the quasi-finite-element methods, existence and uniqueness of the solution of simultaneous nonlinear quasi-finite-element equations and global iterative methods of the calculation of the solution of these equations will be the focus of this research.

For the second objective, mathematical models of hysteresis as continuous superposition of rectangular hysteresis nonlinearities will be investigated. Special attention will be paid to the solution of identification problems and to the generalization of these models for the case of vector hysteresis. The application of continuation methods to the calculation of magnetostatic fields in media with hysteresis will be studied.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
The Energy Laboratory
Cambridge, MA 02139

47. TURBULENT PREMIXED FLAME STUDY — $132,000 — 06-B — 83-3

Wai Cheng, James Keck
Steve Pope, (Cornell University)

This program is a combined experimental and theoretical study of premixed turbulent flames. The primary aim of the experiment is to study the gross behavior and some detailed properties of statistically spherical flames. The theoretical part of the program centers on the description of the flame behavior using the pdf formulation. In both efforts, the primary variables are the turbulent Reynolds number (based on the integral scale), and the Damkohler number (based on the ratio of the eddy turn over time to the chemical reaction time). The flame propagation characteristics were recorded by high speed Schlieren photography and the results interpreted in terms of the turbulence characteristics obtained from hot wire measuremnets. A large number of flame records had been collected to examine the statistical behavior of the flame ball. A model based on conditional velocity /flame progress variable joint pdf was developed.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Energy Laboratory
Cambridge, MA 02139

48. A PARITY SIMULATOR FOR NUCLEAR POWER PLANT DYNAMICS — $151,000
K.F. Hansen — 06-C, 85-3

The simulation of the behavior of dynamic systems is an important part of the computer field. The great advances in digital electronics are such that most simulation is done digitally. However, problems unique to the use of digital computers, such as computer languages, numerical algorithms, and computer/user interfaces have made simulation of engineering systems difficult and/or awkward. This is particularly true with regard to transient analysis of nuclear power plants.

One area of analog simulation that has remained in widespread use is that of "breadboard" circuits to simulate electric electronic networks. Recent developments have led to a very flexible and convenient breadboard technique called parity simulation, where individual integrated circuits in the simulator behave as individual circuit elements. The system is also user friendly in that the analyst communicates in his own engineering language.

It is well-known that electric analogs can be constructed to other physical systems such as mechanical, thermal, fluid, magnetic, or acoustic systems. Research in this project is aimed at developing integrated circuit analogs to plant components, such as pipes, reactor cores, heat exchangers, pumps, etc. The IC elements will solve the conservation equations of mass, energy, and momentum. Thus far elements have been developed for single phase compressible and incompressible flow.

This is one of several projects carried out in cooperation with Idaho National Engineering Laboratory/EG&G.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Materials Science and Engineering
Cambridge, MA 02139

49. PLASMA REDUCTION OF METALLIC OXIDE PARTICLES — $ 90,000
T.B. King — 06-A
85-3

The objective of this research is to characterize the reduction to metal of oxide particles injected into the tail flame of an arc plasma. At the present time it is not known if a significant degree of reaction occurs in flight or if such reduction processes require a molten bath and, hence, a transferred arc plasma. The experimental method involves injecting mixtures of carbon and metallic oxide particles, in the size range 20 to 100 microns, into an arc plasma just beyond the point of initial generation and sampling downstream, at various distances with a simple, watercooled suction cup. The particles thus removed from the plasma may be examined by microscopy and electron microanalysis to determine the extent of reduction.

Preliminary work has been concerned with injection and collection methods using a 50kw transferred arc plasma torch and furnace. This system was originally designed to study gas-metal kinetics and is not well adapted to particle injection. A new system capable of both transferred and non-transferred modes operation in a cold wall reactor is being constructed.

This work is closely coordinated with research at the Idaho National Engineering Laboratory in which particle trajectories and temperatures are to be measured. Such information is necessary to specify the time-temperation history of individual particles.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Plasma Program
Cambridge, MA 02139

50. HIGH TEMPERATURE GAS-PARTICLE REACTIONS $257,000
Prof. John F. Elliott 06-A
Prof. R. Erik Spjut 85-3
Dr. Pedro Bolsaitis

The research is directed to the study of the kinetics of gas-particle reactions at high temperatures with the aim of simulating the behavior of particles exposed to arc plasmas. The experimental system consists of an electrodynamic balance in which a particle (dia. is 10 to 150 microns) is suspended by an electrostatic field and is heated by a laser beam. The composition of the atmosphere in the chamber of the balance is controlled, and the physical and chemical interactions between the gas and the particle can be followed with a time resolution of 10 to 15 milliseconds. The experimental system has been manufactured and assembled, and the computer system and programs for weighing the particle and controlling its temperature have been placed in operation. The laser heating system with the necessary safety equipment is installed. Preliminary tests with a 7 microns tungsten particle have shown that the design of the balance is satisfactory. Preliminary experiments on the evaporation of silica and alumina particles are underway.

This work is closely coordinated with the experimental program at Idaho National Engineering Laboratory.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Materials Science and Engineering
Cambridge, MA 02139

51. TRANSPORT PHENOMENA IN PLASMA SYSTEMS $ 71,000
J. Szekely 06-A
85-3

The purpose of this research is the development of a comprehensive mathematical model of plasma systems and the verification and updating of this model in the light of experimental measurements to be obtained at the Idaho National Engineering Laboratory. At the present time there exists a two dimensional representation of plasma jet systems and relatively simple models of plasma -- particle and plasma -- surface interactions.

The specific objective of the research program is to refine the existing two dimensional models, by allowing for the presence of swirl, to refine the representation of plasma -- particle interactions and finally to evolve a full, three dimensional representation of these systems.

This work is closely coordinated with the experimental program at the Idaho National Engineering Laboratory. In addition it hoped to compare the theoretical predictions with the experimental measurements generated at the University of Limoges.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
The Energy Laboratory
Cambridge, MA 02139

52. ENERGETICS OF COMMINUTION — $124,000
Terry Ring, Carl Peterson — 06-C
85-3

This program is central to a broader program of comminution research that includes basic studies on the behavior of single particles, particulate beds, and the design and testing of a novel coal crushing concept.

Single particle work has progressed the furthest. A very rigid miniature compression testing device has been fabricated and data generation has just begun. Behavior of the device is satisfactory and computer data acquisition is being installed to permit routine testing of a statistically significant number of particles. This device will provide information on force and energy requirements for particle fracture as a function of particle size and material properties. A new theory of comminution has been proposed which seems to explain the shift in energies required for failure as size decreases for uniform materials. More complex materials such as particles with voids and composite materials will be examined next. The increased difficulty to fracture a particle of smaller size has a practical significance in the crushing behavior of particulate beds.

Particulated bed work will include both analytical and experimental studies, seeking the combination of bed stress and strain required to cause individual particle fracture within some zones of the bed. These studies will ultimately tie back to the individual particle failure studies when computer simulations are used to predict particle movements and forces acting on the particles.

A novel comminution mill has been designed which uses particle-to-particle shear to cause particle failure.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Ocean Engineering
Cambridge, MA 02139

53. IN-PROCESS CONTROL OF RESIDUAL STRESSES AND DISTORTION IN AUTOMATIC WELDING — $195,000
03-A
85-3

Koichi Masubuchi

The objective of this research program is to develop the technology of in-process control of residual stresses and distortion in automatic welding. The program consists of the following three phases:

Phase 1: In-process control of residual stresses and distortion in some weldments.

Phase 2: Development of technologies for minimizing and eliminating, if possible, tack welds.

Phase 3: Plans for future advancement of the technology of in-process control of residual stresses and distortion.

The effort during the first year covers primarily Phases 1 and 2.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
The Energy Laboratory
Cambridge, MA 02139

54. INVESTIGATION OF VISIBLE AND NEAR VISIBLE LIGHT EMISSIONS AS SENSORS FOR CONTROL OF ARC WELDING PROCESSES — $ 58,000
03-B
85-3

Thomas W. Eagar

The present research is part of a cooperative program among faculty at MIT and staff at INEL to develop a sound understanding of the arc welding process, and to develop sensing and control methods which can be used to automate the process.

The current research is attempting to map the light emissions spatially, temporally, and spectrally, from gas tungsten welding arcs. The experimental method makes use of a somewhat unique subtractive double monochromator, which provides a two dimensional image of the arc while filtering out all but a specific range of light wavenumbers. With it, it is possible to photograph the distribution of relatively weak elements in the arc without the disturbance of the strong argon or helium background spectra. By studying the emission of Mn or Cr on stainless steels, it is possible to see clearly the anode spot on the weld surface. Video movies of the spot movement are being made and will be analyzed to determine the true heat distribution on the weld surface. Spectra from arcs on several different materials are being measured to determine regions in the frequency spectrum which are relatively free of light. It is hoped that such regions will identify windows where it will be best to utilize the laser weld pool sensor being developed by INEL.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Laboratory for Manufacturing and Productivity
Cambridge, MA 02139

55. MULTIVARIABLE CONTROL OF THE GAS-METAL ARC WELDING PROCESS — $ 95,000 — 03-B — 85-3

David E. Hardt

The process of Gas Metal Arc Welding (GMAW) involves many process control variables such as arc voltage, current, travel speed, wire feed rate, and voltage pulsing profile. These multiple inputs to the weld cause changes in multiple outputs such as weld width, depth, reinforcement height and thermal effects in the weldment. All existing work in closed-loop control of welding, however, has treated this highly coupled, multiple input-multiple output system as a single variable control problem, concentrating, for example, on controlling just the weld width or depth.

The objective of this work is to cast the GMAW control problem in its most general sense and then examine the use of advanced mutlivariable control methods. We have begun this work at two extremes, one starting from a specific two-variable problem in GMAW for which models and measurements exist, and the other from a more basic, but idealized perspective. The former will allow us to quickly identify where gaps in our knowledge of the process and the characterization of the measurements exist, and allow us to perform initial experiments in within the first year of the project. The latter will begin building a comprehensive framework for the solution of the complete control problem, defined as independent regulation of all relevant outputs while rejecting a significant range of system disturbances.

This project is coordinated with the experimental work at Idaho National Engineering Laboratory.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Energy Laboratory
Cambridge, MA 02139

56. MODELING OF GMA WELD POOL GEOMETRY AND METAL TRANSFER — $ 84,000
William Unkel — 03-B — 85-3

Realtime control of weld parameters such as weld pool geometry can reduce welding flaws and therefore increase the productlvity of producing welded structures. One important component to achieving online control is a physically based-model of the welding process. For a complex process such as welding, models play several roles including:

a) interpreting noisy and often indirect measurement data;

b) identifying process modifications that make multivariable control easier; and,

c) providing a component of the actual control algorithm.

Previous modeling efforts have concentrated on the Gas Tungsten Arc Welding (GTAW) Process and have laid the groundwork for the present work on the Gas Metal Arc Welding (GMAW) Process.

The principal goal of the present work is to develop physically based, but computationally simple models for the GMAW situation and to use these models to identify process modifications to allow a more effective multivariable control system to be implemented. Those models will be confirmed by comparison with experimental data and will also be considered for use in online interpretation of sensor data.

This research is coordinated with the experimental work at Idaho National Engineering Laboratory.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mechanical Engineering
Cambridge, MA 02139

57. MODELING AND ANALYSIS OF SURFACE CRACKS — $185,000 — 01-A — 85-3
David M. Parks
Frank A. McClintock

This research focuses on the analysis of ductile crack initiation, growth and instability in part-through surface-cracked plates and shells. The overall approach consists of determining parametric limits of applicability of the "dominant singularity" formalism at nonlinear fracture mechanics in these crack configurations as they are influenced (principally) by material strain hardening, load biaxiality, and crack geometry. When such single-parameter dominance is obtained, correlations of crack response with J-integral or related measures may be justified. The analysis requires detailed finite element computations which are too costly for routine applications, so further development of simplified analytical models such as the so-called "line-spring" model is underway. Exploratory experiments are also being undertaken to probe effects of asymmetry of loading, prior plastic strain history, and other factors on subsequent ductile fracture. Load biaxiality effects have been simulated for axial tension and internal pressure loading on pipes containing a circumferential crack. Accepted solutions for J derived for tension alone can underestimate fully plastic biaxial J-values by up to an order of magnitude.

Recent developments have resulted in marked improvement in agreement between calculations and experimental data obtained in a parallel effort at INEL.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Energy Laboratory
Cambridge, MA 02139

58. DEVELOPMENT OF AN EXPERT SYSTEM TO SYNTHESIZE HEAT AND WORK INTEGRATION SYSTEMS FOR PROCESS PLANTS — $ 86,000 — 06-C — 85-3

L. B. Evans

The goal of this research is to develop a prototype expert system for the synthesis of heat and work integration systems in process plants. This is an important problem in the design of new plants and the retrofitting of existing plants for energy conservation.

The expert system will assist the process engineer in designing heat and work integration systems. A scientific approach to the design of such systems based upon sound thermodynamic principles has emerged within the past decade, so there is now an accepted set of design rules or heuristics that is a prerequisite for an expert system.

The development of a prototype system seeks to answer many open questions, such as: What is the appropriate architecture fot the system? How should the knowledge base be represented; What is the best strategy for generating and evaluating alternative solutions; Are standard tools of artificial intelligence suitable for this problem or must we develop specialized procedures? Is an expert system useful either as an aid or alternative to the solution of the problem by a human designer?

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Laboratory for Manufacturing and Productivity
Cambridge, MA 02139

59. A STUDY OF REDUCED ORDER MODEL REFERENCE ADAPTIVE CONTROL FOR IMPROVED MANUFACTURING PROCESS CONTROL — $ 0 — 03-B — 82-4

David E. Hardt

This research deals with the application of adaptive control methods to problems typical of manufacturing process control. The basic form under investigation is the Model Reference Adaptive control method, which involves adapting the system gains to force the physical system performance to match that of a reference model. To insure global stability the physical system and reference plant must be of identical dynamical order, also implying that the physical process is essentially linear and quasi-stationary. However, when many manufacturing processes, such as welding or metal forming, are considered, these restrictions become unrealistic, yet the need for adaptive controller is evident from the highly variabls parameters associated with these processes. Accordingly, this research has concentrated on examining MRAC and now other associated methods with respect to their suitability and designability for such applications.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
The Energy Laboratory
Cambridge, MA 02139

60. PISTON RING FRICTION AND VEHICLE FUEL ECONOMY — $115,000
D. P. Hoult, J. M. Rife — 01-D, 80-6

The purpose of this research is to study the friction mechanism in automotive engines, in particular the components of frictional losses which arises due to the interaction between the piston rings and the piston liner. It is believed that this is the largest single component of friction in a typical automotive engine. The research underway comprises modelling and measuring the motion of each degree of freedom model of piston ring as it moves up and down in the piston groove has been completed and modifications necessary for the theory have been described. The next steps of this project, which are underway, are to study the ring twist and radial motion of rings in a experimental lubrication engine. The theory has suggested a novel concept for a gas lubricated ring which may greatly reduce engine friction.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mechanical Engineering
Cambridge, MA 02139

61. THE DEVELOPMENT OF A FRICTION MODEL PREDICTING THE SLIDING BEHAVIOR OF MATERIAL PAIRS, ESPECIALLY AT LOW TEMPERATURES — $ 58,000 — 01-D — 85-2

Yukikazu Iwasa

The principal objectives of this research program are 1) to develop a friction model which predicts correctly whether a system sliding at low speeds will give steady or unsteady sliding behavior and 2) to advance basic understanding of the friction process.

The program consists of experimental and analytical studies. Experimental work includes collection of data on creep properties of the two contacting materials, namely bulk creep behavior in tension and interface creep data in shear. The interface creep takes place when one material is pressed against the other by a constant force and a shear force insufficient to produce gross sliding is applied. The extent to which the bulk creep properties determine the interfacial creep behavior both at room temperature and at cryogenic temperatures will be determined, and this knowledge should lead to better models of the friction process. In turn, such knowlege will contribute to a more reliable operation of superconducting magnets.

UNIVERSITY OF MASSACHUSETTS
Chemical Engineering Department
Goessmann Laboratory
Amherst, MA 01003

62. A DESIGN AND SYNTHESIS PROCEDURE FOR HOMOGENEOUS AND HETEROGENEOUS AZEOTROPIC DISTILLATIONS — $ 33,000 — 06-A — 85-3

M. F. Doherty

New techniques are being developed to aid in the design and synthesis of multicomponent, nonideal and azeotropic separation systems. The synthesis problem is a difficult one for it not only entails choosing the optimal column configuration and processing conditions, but also involves choosing the optimal entrainer. The problem is compounded by the presence of distillation boundaries in azeotropic mixtures which put severe constraints on the feasible class of column sequences. At present there is no systematic method available in the literature for solving this synthesis problem.

The technique being developed is based on the concept of a residue curve map. These maps represent the fundamental phase-equilibrium behavior of the mixture in a way which is uniquely suited for separation-system studies. The maps provide information for discriminating between feasible and infeasible column sequences. New design tools have also been developed for calculating such quantities as minimum reflux ratios for azeotropic mixtures. The ultimate aim of this research program is to develop a comprehensive body of theory which will result in automatic computer procedures for synthesising optimal separation sequences for multicomponent azeotropic mixtures.

UNIVERSITY OF MASSACHUSETTS
Chemical Engineering Department
Goessmann Laboratory
Amherst, MA 01003-0011

63. A HIERARCHICAL PROCEDURE FOR FLOWSHEET, CONTROL SYSTEM, AND RETROFIT DESIGN FOR CHEMICAL PROCESSES — $115,000 — 03-B — 83-6
J. M. Douglas, M. F. Malone

New short-cut models for the energy integration of distillation sequences show that the total entropy of separation can be used to select the best sequence. A computer code based on this procedure runs essentially instantaneously, so that the use of heuristics for selecting distillation sequences can be avoided. Current efforts are to include complex columns, multiple feeds and sloppy spits into the code.

The new separation system selection procedure is also being incorporated into the "Expert System" for developing base-case designs and evaluating process alternatives. In addition, the "Expert System" is being modified so that it will run "instantaneously." Moreover, systematic procedures for the retrofitting and steady state control of complete plants, which will serve as the knowledge base for "Expert Systems" have been developed and are being tested.

UNIVERSITY OF MASSACHUSETTS
Chemical Engineering Department
Goessmann Laboratory
Amherst, MA 01003-0011

64. MIXING: STRETCHING, BREAKUP, AND CHAOTIC DISPERSION OF IMMISCIBLE LIQUIDS — $ 52,000
J. M. Ottino — 01-C
85-3

This project involved experimental and theoretical studies of mixing and dispersion of immiscible fluids, particularly high viscosity liquids such as polymer solutions and melts. The objective is the understanding of the process leading to stretching, breakup, and chaotic dispersion of one fluid in the bulk of another in deterministic flows. Breakup is studied at a local scale, where velocity gradients are linear and possibly time dependent, dispersion is studied at larger scales where the flow is non-linear and possibly chaotic.

UNIVERSITY OF MASSACHUSETTS
Chemical Engineering Department
Goessman Laboratory
Amherst, MA 01003

65. MULTIVARIABLE & DISTRIBUTED CONTROL OF NON-LINEAR SYSTEMS — $ 60,000
E. Ydstie — 03-B, 85-3

The objective of this work is to develop a methodology for nonlinear, adaptive control of chemical and petroleum processes. The algorithm we investigate is suited for implementation in a distributed network of computers and it is amenable for complete plant control and optimization. The approach is motivated by the many recent successful applications of linear adaptive control theory. However, our approach rely on physically based process models and the maximum use of prior information about system characteristics. Our investigation will include:

- -alogorithmic development and stability analysis.
- -application to a distributed control of pilot process.
- -simulation and optimization of a complete plant.

UNIVERSITY OF MICHIGAN
Department of Mechanical Engineering and Applied Mechanics
Ann Arbor, MI 48109

66. LOSS CHARACTERISTICS OF CORD-RUBBER COMPOSITES $ 75,000
S. K. Clark 01-D
83-3

The research to be carried out under this contract is divided roughly into two phases. The first is completion of data acquisition on the loss characteristics of cord-rubber composites under both uniaxial and multiaxial stress states. This effort will utilize information currently available as well as measurements made here. The effects of prestrain, frequency, strain amplitude and temperature will be included in the assessment of the viscoelastic properties of these materials.

The major activity during the latter part of the work will be analysis and measurement of the rolling loss of a relatively simple pneumatic tire. The tire geometry will be essentially cylindrical in form, similar to the type of tire used in vehicles traversing soft or marshy terrain. These are essentially cylindrical rollers, but with end closures making it possible to inflate them. Analysis will be carried out using the viscoelastic material properties previously obtained, as well as finite element codes suitable for this type of problem. Comparison of calculated and measured rolling resistance values will give valuable insight into the types of finite element models best suited for this computation, and should give confidence to the tire industry in its efforts to apply finite element techniques to the calculation of tire operating properties.

Since tire rolling resistance represents a major component in the vehicular fuel consumption, minimization of it represents an important part of the overall national energy consumption effort.

UNIVERSITY OF MICHIGAN
Department of Electrical Engineering
and Computer Science
Ann Arbor, MI 48109

67. METHOD OF VIBRATIONAL CONTROL IN THE PROBLEM OF STABILIZATION OF CHEMICAL REACTORS — $ 97,000 — 03-B — 85-2
Semyon M. Meerkov

The objective of this research project is to develop a new control technique, referred to as vibrational control, and apply it to systems where traditional approaches, based on the feedback or feedforward principles, are not applicable. From the mathematical standpoint, the goal of the project is to analyze the effects of fast parametric oscillations on the dynamics of nonlinear systems with multiple steady states and limit cycles. The approach used in the research is based on asymptotic analysis (averaging theory) of deterministic and stochastic,ordinary and partial differential equations. The results obtained or being currently developed include: (i) theory of vibrational control for nonlinear systems; (ii) theory of vibrational-feedback control; (iii) vibrational control of distributed parameter systems; (iv) vibrational control of stochastic systems. The main application considered is in the area of exothermic and catalytic CSTR's and tubular reactors. The obtained theoretical results and their implementation in terms of chemical reactors have been utilized by the research group at the Illinois Institute of Technology (A. Cinar, PI) in experimental studies on vibrational control.

UNIVERSITY OF MINNESOTA
Department of Mechanical Engineerihg
Minneapolis, MN 55455

68. FLOW AND HEAT TRANSFER WITH IMPINGING JETS AND WALL JETS — $178,000 — 01-B — 81-6
R.J. Goldstein

This project is directed toward providing information on the flow and heat transfer characteristics of impinging jets and wall jets, and related phenomena in separated flows. Measurements of the heat transfer in the region of impingement are obtained for single jets entering a still ambient, for jets entering a crossflow, and for various one- and two-dimensional arrays of jets. In addition to quantitative heat transfer measurements for these flows, visualization techniques are used to provide insight into the mechanisms for interaction between the jets and the surrounding fluid. Important phenomena related to separation in curved flows are observed. A laser-Doppler anemometer was developed to provide detailed measurements of velocity distributions, velocity fluctuations, and Reynolds stresses in a plane wall jet. The measurements can be used to check the validity of turbulent transport models that have been suggested. Data has also been taken for a two-dimensional array of small jets impinging on a heat transfer surface; during these studies, a liquid crystal system was developed for examining the features of single and multiple jet impingement on a flat surface. The liquid crystal technique and measurement of the pressure distribution near individual jets on an impinging jet plate are being applied to inclined impinging jets. Related experiments on separated flows include the characteristics of horseshoe vortices as examined using a mass transfer system.

UNIVERSITY OF MINNESOTA
Department of Mechanical Engineering
Minneapolis, MN 55455

69. THERMAL PLASMA PROCESSING OF MATERIALS $142,000
E. Pfender 06-A
85-3

A combined analytical/experimental program is carried out directed towards a better understanding of the interaction of particulate matter with thermal plasmas. One of the major objectives of the work is the development and diagnosis of a new plasma reactor which should solve the problems of particle injection, particle confinement, and particle dwell time in the plasma. Finally, it is intended to use this reactor for materials studies involving superconducting alloys.

The modeling work is primarily concerned with a detailed assessment of the relative importance of the numerous effects which determine heat, momentum, and mass transfer to and from particles injected into thermal plasmas. Diagnostic methods for the plasma include emission spectroscopy, laser Doppler anemometry, current, voltage, and calorimetric heat transfer measurements. Product powders will be analyzes using scanning and transmission electron microscopy, x-ray and electron diffraction, and measurements of the transition temperature for superconducting compounds.

NATIONAL BUREAU OF STANDARDS
Tribology Group
Institute for Materials Science & Engineering
Gaithersburg, MD 20899

70. A STUDY OF THE CHEMICAL MECHANISM IN LUBRICATION $ 60,000
S. M. Hsu 01-D
84-4

The chemical mechanisms responsible for lubrication in concentrated tribological contacts are not well understood. The project is examining systematically both the nature and extent of the influence of chemical reactions on friction and wear in the contact zone. Advances have been made in theoretical modeling of the temperature profiles in a four-ball contact; modeling of elastohydrodynamic film at concentrated contacts; analytical characterization of model structures; and the investigation of interactions between naturally occurring polar species and antiwear additives. Pure model structures are being used as lubricants to test the effects of chemical functional groups on friction and wear. Chemical kinetic studies on tribochemical reaction rates for various classes of compounds under wearing conditions will be compiled. The topography of worn surfaces will be characterized to predict oil film thickness under different speed and load combinations using the NBS six-microliter four-ball wear tester. Micro-asperity and contact zone temperatures will be studied and computations will be made using Archard-Jaeger equations as well as finite element analysis. A theoretical model linking elastohydrodynamic theories to tribochemical rate constants with material properties will be attempted to predict lubrication effectiveness a priori.

NATIONAL BUREAU OF STANDARDS
Office of Standard Reference Data
Gaithersburg, Md. 20899

71. SUPPORT OF CRITICAL DATA COMPILATIONS — $450,000
David R. Lide, Jr. — 06-A, 80-6

The Office of Standard Reference Data administers a collaborative interagency program for preparation of compilations of physical and chemical reference data. Each project supported is expected to lead to a publishable data compilation containing recommended values and accuracy estimates for the data set in question. Projects funded during fiscal year 1985 include work on photochemistry of transition metal coordination complexes; soft x-ray interactions with matter; atomic transition probabilities of highly ionized atoms; thermodynamic tables for hydrocarbon isomer groups; ceramics phase diagrams; alloy phase diagrams; thermophysical properties of fluids; fatigue properties; and ductile fracture toughness of high-strength steels.

This project is included in the BES ENGINEERING RESEARCH program for administrative convenience. Coordination with NBS is accomplished in collaboration with several BES programs. BES FY 1985 funds for the project were provided by the Chemical Sciences and Materials Sciences divisions, and the Division of Engineering and Geosciences.

NATIONAL BUREAU OF STANDARDS
Thermophysics Division
Gaithersburg, MD 20899 and Boulder, CO 80303

72. THERMOPHYSIGAL PROPERTY MEASUREMENTS IN FLUID MIXTURES — $520.000 — 03-B — 84-3

N.A. Olien, J.M.H. Levelt Sengers

The project aims at the development of accurate measurement capabilities for the thermophysical properties of complex, multiphase, fluid mixtures containing hydrocarbons. The research is being done jointly by two research groups within the Thermophysics Division of the NBS Center for Chemical Engineering. One group is located at the Gaithersburg, MD laboratories and the other at the Boulder, CO laboratories. The properties involved are PVT (pressure-volume-temperature), PVTx (pressure-volume-temperatures-composition), phase equilibria (liquid-vapor and liquid-liquid equilibria), phase behavior in interfaces, and transport properties (viscosity, thermal conductivity, and diffusion coefficient). The apparatus will be designed for use in corrosive, highly corrosive, and sometimes toxic and flammable fluids with measurements extending to high temperatures (800K) and high pressures (30 PMa and in some cases 70 MPa). Also under study are methods for evaluating supercritical solvent mixtures and related fluid mixtures.

CITY UNIVERSITY OF NEW YORK
The City College
Department of Chemical Engineering
New York, NY 10031

73. TOPICS IN PHYSICO-CHEMICAL HYDRODYNAMICS — $250,000
06-A
Benjamin G. Levich — 80-8

This research comprises two main directions:

(i) Fully Developed Turbulence (FDT). We aim at the entirely novel understanding of the nature of FDT. We assert that the structure of FDT is determined by a foam-like topology of the vorticity field lines where the prime role is played by the hierarchy of helical fluctuations. The active production of turbulence in this picture proceeds outside of these fluctuations and concentrates in space of fractal dimensionality. Presently, we have extensive experimental data to support our view. Further experiments are underway.

(ii) Interfacial Mechanics.

(a) A mechanism for the development of the deformation patterns commonly observed on the surfaces of biological cell plasma membranes was suggested. In this mechanism, the membrane is treated as a viscoelastic continuum and a chemical reaction network on the surface of the membrane regulates the membrane elasticity.

(b) Hydrodynamic waves induced by chemical reactivity waves was studied. Results indicate that a wave of chemical reactivity derived from a multistable chemical reaction on the surface of a thin liquid film is able to induce a hydrodynamic wave in the film through the Marangoni tractions due to the reactivity wave.

(c) The classical linear capillary instability of a thin fluid filament surrounded by a bulk fluid was investigated for the case in which the filament is in steady shear flow. Results indicate that a nonlinear interaction between the shear flow and the capillary forces can, under certain conditions, stabilize the developing linear instability.

NORTHWESTERN UNIVERSITY
Department of Civil Engineering
Evanston, IL 60201

74. EFFECTS OF CRACK GEOMETRY AND NEAR-CRACK MATERIAL BEHAVIOR ON SCATTERING OF ULTRASONIC WAVES FOR QNDE APPLICATIONS — $ 55,000, 03-B, 83-3
J. D. Achenbach

Among the methods of quantitative non-destructive evaluation of structural elements, the method based on scattering of ultrasonic (elastic) waves by flaws is particularly useful. The work on this project is concerned with applications of the scattered field approach to the detection of a cracklike flaw, and to the determination of its location, size, shape, and orientation. Interior, as well as surface-breaking and near-surface cracks are considered. The usual mathematical modeling of ultrasonic wave scattering by cracks is adjusted to account for several typical characteristics of fatigue and stress-corrosions cracks, and the environment of such cracks. Effects due to crack-face roughness, crack-closure and crack-face interactions are considered, as well as global anisotropy. Local anisotropy and inhomogeneity due to near-tip voids, and the effect of a zone of plastic deformation near a crack tip will also be investigated. Parametrical studies are expected to display the masking of characteristic "crack-like" features of the scattered field by a spectrum of signals due to deviations from an idealized crack geometry and idealized material behavior. Progress has been made on the effects of crack-face interactions and global anisotropy.

OAK RIDGE NATIONAL LABORATORY
Engineering Physics and Mathematics Division
Oak Ridge, TN 37830-2008

75.	CENTER FOR ENGINEERING SYSTEMS ADVANCED RESEARCH (CESAR)	$925,000
		03-C
	C. R. Weisbin	84-10

The Center for Engineering Systems Advanced Research (CESAR) conducts interdisciplinary long-range research and concept demonstration related to intelligent machines. CESAR provides a framework for merging concepts from the fields of artificial and machine intelligence with advanced control theory. There are two primary themes; (1) robotic systems for identification, navigation, and manipulation in unstructured environments, and (2) multi-purpose plant management and maintenance.

Emphasis in FY 85 was directed toward automated planning for navigation and manipulation, concurrent algorithm development for real-time systems, robot dynamics for rigid and flexible structures, and sensitivity uncertainty analysis for decision making.

UNIVERSITY OF PENNSYLVANIA
Department of Mechanical Engineering
and Applied Mechanics
Philadelphia, PA 19104

76. CRACK-TIP FIELDS FOR MATERIALS WITH EXPONENTIAL-LAW-CREEP BEHAVIOR AT HIGH STRESS — $ 0 — 01-A — 83-3

John L. Bassani

This research is concerned with elastic-viscoplastic analyses of cracks under creep conditions, with particular emphasis on the influence of the assumed stress dependence on the creep strain rate. Around the tip of a sharp notch in a material described by the assumed law the creep strain-rates are much greater than the elastic ones. The spatial asymptotic analysis based upon a hodograph transformation demonstrates that the notch-tip stress intensification is weaker and the strain-rate intensification is stronger than for a power-law creeping material.

PHYSICAL SCIENCES INC.
Research Park, P.O. Box 3100
Andover, Massachusetts 01810

77. EXPERIMENTAL AND THEORETICAL STUDIES OF CONDENSATION IN MULTICOMPONENT SYSTEMS — $155,000, 06-A, 84-4
M. B. Frish, G. Wilemski

This research program comprises experimental and theoretical studies of nucleation and condensation in multicomponent gas mixtures. The program goals are: 1) to improve basic understanding of binary nucleation and droplet growth, 2) to stringently test theories of binary nucleation at high nucleation rates and under nonisothermal conditions, 3) to develop improved theories where needed, 4) to enlarge the data base for systems of both fundamental and practical interest, and 5) to provide reliable means for predicting the behavior of mixtures used in practical applications such as turbo-machinery. Experimentally, gas mixtures will be cooled in a supersonic nozzle to obtain much higher binary nucleation rates than have previously been studied. The nozzle is designed to insure that steady state nucleation occurs and to give satisfactory spatial resolution of the temperature profile. Laser light scattering is the primary means of detecting nuclei as small as 10A in radius and of monitoring droplet growth. Interferometry is used to diagnose the temperature profile within the nozzle. By varying the amount of inert carrier gas used, both isothermal and nonisothermal nucleation will be studied. Construction of the flow and optical systems is complete, and data collection has begun. A new thermodynamic theory of binary cluster composition has been developed. Calculations with this theory have established the feasibility of using bulk liquid mixture surface tensions to compute nucleation onset (for small rates) in aqueous alcohol and acetone mixtures, thus removing a severe deficiency of classical binary nucleation theory.

PURDUE UNIVERSITY
School of Mechanical Engineering
West Lafayette, IN 47907

78. HEATING AND EVAPORATION OF TURBULENT LIQUID FILMS — $115,000 — 01-B — 85-4
Issam Mudawwar

The purpose of this project is to investigate turbulent activity in freely-falling films. During the first two years of the project, emphasis will be placed on obtaining heat transfer data for turbulent falling films subjected to sensible heating or to surface evaporation. General correlations of the data will be developed, and attempts will be made to predict the results in terms of an empirical turbulence model. Special efforts will be made to cover the widest possible ranges of Reynolds, Prandtl, and Kapitza numbers. During the later stages of the project, the eddy-viscosity profile across freely-falling films will be correlated experimentally using a Laser-Doppler Velocimeter (LDV) system. Simultaneous measurements of the instantaneous longitudinal and transverse velocity components, and of the film thickness will be used to correlate the turbulent shear stress in the presence of surface waves. Based on these results, a new empirical turbulence model will be developed. Predictions based on this model will be compared to heat transfer results obtained during earlier stages of the project.

The final outcome of the proposed project will be a new turbulence model which accounts for the effects of waves and surface tension damping forces on the free interface of freely-falling films.

ROCKEFELLER UNIVERSITY
Department of Physics and Mathematics
1230 York Avenue
New York, NY 10021

79. SOME BASIC RESEARCH PROBLEMS RELATED TO ENERGY — $ 73,000
06-C
81-6

Kenneth M. Case, E.G.D. Cohen

This project is concerned with investigations of three specific areas: 1) the prediction and evaluation of thermophysical data of fluids and fluid mixtures, and 2) study of the applications of nonlinear evolution equations. Work is underway to construct a model which can give a first approximation to the transport properties of fluid mixtures in their dependence on size and mass of the constituent particles. The nonlinear evolution equations being investigated describe a very large number of energy related processes. One such equation, the so-called Sine-Gordon equation, has been under study and a number of previously unknown results for the equation have been found.

SANDIA NATIONAL LABORATORIES
Device Research Division
Albuquerque, NM 87185

80. HIGH-TEMPERATURE ELECTRONICS — $120,000
R. J. Chaffin, L. R. Dawson, — 03-B
D. R. Myers, T. E. Zipperian — 80-7

The project addresses fundamental engineering questions relevant to the development of high-temperature (up to 500^{o}C) electronics for energy technologies. Included are sensors, passive components, and active semiconductor devices which provide electronic gain or control. The FY-85 work has concentrated on electronic devices formed from heterojunctions of gallium arsenide and aluminum gallium arsenide, and heterojunctions formed from gallium phosphide and aluminum gallium phosphide. Mesa-isolated, liquid-phase epitaxial, heterojunction bipolar transistors and heterojunction, semiconductor controlled rectifiers have been fabricated. High-temperature evaluation of these devices is currently in progress. Future studies include optimization of these structures for high-temperature service as well a development of stable metallization systems for these devices. An ultimate goal is the development of a viable high-temperature integrated circuit technology.

SANDIA NATIONAL LABORATORIES
Combustion Research Facility
Thermofluids Division
Livermore, CA 94550

81. DYNAMICAL PERCOLATION PROCESSES AND APPLICATIONS $ 50,000
A. R. Kerstein, B. F. Edwards 06-C
85-3

The technical goal of this project is to develop a unified framework for predicting and interpreting phenomena in combustion and fracture mechanics which are strongly influenced by underlying spatial random processes. The underlying processes for coal combustion are those determining macromolecular chemical structure and pore morphology. For combustion of heterogeneous propellants or fracture of heterogeneous solids, the underlying process determines the spatial distribution of phases or structural defects within the material. For these applications and others, explicit models of the underlying spatial random processes will be formulated and their observable consequences will be predicted by means of computer simulations and analytical methods. Special emphasis will be placed on "percolation threshold" effects associated with loss of global connectedness.

SANDIA NATIONAL LABORATORIES
Combustion Research Facility
Thermofluids Division
Livermore, CA 94550

82. DYNAMICS OF MULTICOMPONENT LIQUID FUEL DROPLETS — $170,000
B. R. Sanders, H. A. Dwyer — 06-B, 81-7

The overall objective of this program is the development of a comprehensive model of multicomponent liquid fuel droplet vaporization and combustion. In particular, we will numerically solve for the two-dimensional, unsteady behavior of multicomponent liquid fuel droplets in a strong convective environment representative of typical combustion systems. Experimental evidence has shown that multicomponent liquid fuels can undergo disruptive behavior and micro-explosive combustion; however, there is no detailed model available to explain such dynamic events. Disruptive behavior and microexplosion phenomena are of intense practical interest as a secondary atomization method to provide rapid fuel droplet disintegration, vaporization and combustion.

SCIENCE APPLICATIONS, INC.
1200 Prospect Street, P. O. Box 2351
LaJolla, California 91038

83. ASPECTS OF TURBULENCE IN NONLINEAR SYSTEMS $101,000
E. Frieman 06-C
84-3

The basic goal of this program is to advance the understanding of flow and transport in turbulent systems. A central strategy is to exploit the distinct sets of temporal and spatial scales exhibited by most physical systems. The plasma system is chosen as a specific example in which to develop and demonstrate these methods.

The program has been broken down into five tasks: (1) The first task is to understand the relation between the various gyroradius kinetic theories. (2) The second task is to derive these gyrokinetic equations from the viewpoint of contemporary Hamiltonian dynamics. The relation between divergencies in the generating functions (for Lie transform theory) and resonances in the solutions to the nonlinear perturbative equations of motion will also be explored in this task. (3) The third task involves application of modern procedures to the resulting nonlinear systems arrived at in the first two tasks. Field theoretic techniques will lead to expansions which might be parameterized in terms of the linearization amplitude and ratio of Larmor theory. (4) The fourth task involves the investigation of applying renormalization group theories to these equations to yield nonperturbative relations among correlation functions. The nature and distinction between intrinsic and extrinsic stochasticity will also be examined. (5) Lastly, application of the concepts and lessons learned to a broader class of turbulent systems will be considered.

SCIENTIFIC SYSTEMS, INC.
54 Ringe Avenue Extension
Cambridge, MA 02140

84. CHAOTIC DYNAMICS IN FEEDBACK SYSTEMS $ 0
J. Baillieul, R. W. Brockett 03-A
N. Kopell 82-4

The objective of this research effort is to study chaotic motions occuring in certain classes of dynamical systems which arise in the study of feedback control systems, electric power conversion circuitry and various other engineering applications. Part of the effort is focused on a simple class of differential equations whose coefficients depend piecewise linearly on the state. Because this is a simpler class of dynamical systems than others which have been widely studied recently, it is possible to obtain especially accurate simulations of system trajectories. On the other hand, numerical simulations that have been carried out indicate very interesting qualitative features of the dynamics of such systems, and there is evidence of a strange attractor in a very simple third order system. Specific research is aimed at these and other classes of models in three areas: (i) the use of singular perturbations techniques to analyze first return maps, (ii) the use of difference equations to study to qualitative behavior of "chaotic" differential equations, and (iii) the use of input/output analysis (particularly various control theoretic techniques involving Nyquist plots, describing functions, etc.) to study the qualitative behavior of feedback models.

SKF INDUSTRIES, INC.
1100 First Avenue
King of Prussia, PA 19406-1352

85.	MECHANICAL INTERACTIONS OF ROUGH SURFACES J. I. McCool	$ 80,000 01-D 82-5

This program is aimed at developing fundamental information and resolving a number of issues that impact the design of mechanical systems in which surface microtopography per se or events which occur on the microgeometric scale play a critical role.

The work is organized into two distinct tasks:

In Task I, a rig designed and built by SKF is being used to provide optical interferograms of the lubricated contact of rough surfaces along with measurements of the traction transmitted under conditions of combined rolling, sliding and spinning. These tests will serve to explore the limitations of predictive models of film thickness, traction, and the frequency of asperity contact interactions and micropitting in the so-called partial EHD regime wherein the thickness of the lubricant film separating the bodies is of the same order as the surface roughness amplitudes.

The objective of Task II is to develop guidelines and techniques for the digital processing of surface roughness data generated in analog form by a stylus profile instrument.

Issues to be addressed are: filter bandpass selection, record length, and sample spacing, spatial vs. frequency domain estimation, type of digital filtering and the effects of preprocessing.

SOLAR ENERGY RESEARCH INSTITUTE
Thermal Sciences Research Branch
1617 Cole Blvd.
Golden, CO 80401

86. SHEAR-INDUCED INSTABILITIES IN A DOUBLE-DIFFUSIVE PARTIALLY STRATIFIED FLUID — $ 75,000 — 01-C — 85-3

F. Zangrando

This basic experimental study concentrates on mixing mechanisms in a double-diffusive, stratified fluid subjected to the combined effects of bottom heating and horizontal flow. The fluid contains two components (in this case, heat and salt) that contribute in opposing manner to the fluid density and that have significantly different diffusivities (ratio of order 100). The tasks proposed emphasize qualitative and quantitative observation of the behavior of the interfacial layer between a double-diffusive stratification and an initially well mixed region, both of arbitrary thickness, in the presence of buoyancy driven convection due to bottom heating and of shear flow imposed on the mixed region. The effect of each destabilizing component, including line jet discharge and flow into a sink, will be first studied separately and compared with results obtained with single-component stratifications. The combined effect of buoyancy driven convection with a superposed lateral flow (recirculation) will then be studied in order to compare the various mixing mechanisms under similar experimental conditions and to determine the entrainment at the interfacial boundary layer.

UNIVERSITY OF SOUTHERN CALIFORNIA
Department of Physics
University Park
Los Angeles, CA 90089

87. A STUDY OF GAS-SURFACE ENERGY EXCHANGE PROCESSES — $ 0, 06-A, 83-3

J. A. Kunc, D. E. Shemansky

The objective of this theoretical research program is to study the fundamental characteristics of gas-surface energy exchange reactions. The interaction process refers to low density conditions in the gas component and therefore has general application to a number of disparate disciplines, including the maintenance of clean high vacuum systems for research in subjects such as fusion reactions, and many other important areas in engineering and technology. The approach to the calculations is to construct accurate theoretical models of the solid structure on a miscroscopic scale, and account for the many body gas surface physical interaction using Monte Carlo techniques. One of the fundamental questions to be examined is the relationship between the physical scale interaction potential of the individual gas atom - solid atom pair and the effective mean potential of the gas - surface interaction mny body system.

STANFORD UNIVERSITY
Department of Chemical Engineering
Stanford, CA 94305

88. TRANSPORT CHARACTERISTICS OF CONCENTRATED SLURRIES — $ 68,000
Andreas Acrivos — 01-C
85-3

The aim of this research is to study the flow behavior of concentrated suspensions from a fundamental point of view. The work to date has uncovered a host of seemingly unrelated phenomena pertaining to the rheology of concentrated suspensions, to which explanations have been provided that have shed new light on the understanding of such systems. The principal phenomena in question are: a) the observed resuspension of a settled bed of particles in a viscous fluid upon being sheared, b) the existence of a shear-induced anisotropy in a concentrated suspension which manifests itself in measurable normal stresses; and c) the slow decay with time of the effective viscosity of a concentrated suspension, as measured in a Couette viscometer, together with a shear thinning behavior in such systems. Evidence has been provided that many of these phenomena arise as a result of the existence of a shear-induced diffusion mechanism which produces a flux of particles from regions of high particle concentration to low, or from regions of high shear to low.

The current research has the following aims: a) to study the resuspension mechanism in detail experimentally and to develop a reliable theory which would account for the experimental observations; b) to measure the shear-induced diffusion coefficient by a novel technique over a wide range of particle sizes, particle concentrations and degrees of polydispersity, and to construct a theory for determining this coefficient; c) to examine in depth the shear-induced anisotropy, as inferred from our normal stress measurements, and determine to what extent it can lead to a drift of particles in concentrated suspensions; and d) to identify the mechanism responsible for the observed shear thinning behavior in concentrated suspension, an experimental fact which at present is unexplained.

The overall goal of this combined experimental and theoretical program is to develop a theoretical framework, currently lacking, for modelling quantitatively the flow behavior of concentrated suspensions.

STANFORD UNIVERSITY
Department of Mechanical Engineering
Stanford, CA 94305

89. HEAT TRANSFER EFFECTS OF LONGITUDINAL VORTICES EMBEDDED IN A TURBULENT BOUNDARY LAYER — $52,000 — 01-B — 83-3
John Eaton

Large-scale longitudinal vortices can be developed in a turbulent boundary layer by a variety of mechanisms. Such vortices can cause significant local augmentation of the heat-transfer rate. The objectives of the present study are (i) to examine the effects of an isolated vortex independent of other interfering phenomena and (ii) to determine what physical mechanisms are responsible for the heat-transfer augmentation. Experiments are being conducted in a two-dimensional, boundary-layer wind tunnel. The vortex is formed by a half delta wing attached normal to the test wall and at an angle of attack to the oncoming flow. The spatially resolved heat-transfer coefficient is measured using a constant-heat-flux foil surface with 160 thermocouples for surface-temperature measurements. All three components of the mean velocity are measured using a four-hole pressure probe, and turbulent stresses are measured using hot wires. A typical vortex decays very slowly in a zero pressure gradient flow and causes a peak heat-transfer augmentation of around 25%. The heat transfer behavior is a weak function of the Reynolds number and the vortex size and strength when normalized by flat plate values. Velocity data show that the augmentation is associated with local thinning of the boundary layer by the vortex. The boundary layer profiles imply that at a given spanwise position the flow behaves like a two-dimensional turbulent boundary layer, at least through the log region.

STANFORD UNIVERSITY
Department of Mechanical Engineering
Division of Applied Mechanics
Stanford, CA 94305

90. ENERGY CHANGES IN TRANSFORMING SOLIDS $330,000
George Herrmann, David M. Barnett 01-A
82-4

A variety of processes occuring in stressed deformable solids, such as void formation, void growth, motion of dislocations and point defects, grain boundary sliding, etc., are accompanied by energy changes. It is these energy changes which give rise to the concept of generalized configurational (or material) forces and provide a most promising way to characterize state changes and the processes in question. During the past year we have examined material forces associated with solids containing a specified distribution of dislocations and disclinations. Furthermore, a remarkably simple formula has been derived for calculating the hoop stress distribution along the boundary of a circular cavity in an infinite sheet containing arbitrary sources of internal stresses; the calculation can be made without solving an elastic boundary value problem. As several specific examples show, this formula is most useful for calculating energy release rates. Work on generalizing this approach to cavities of arbitrary shape is currently in progress.

STANFORD UNIVERSITY
Department of Aeronautics/Astronautics
Stanford, Ca 94305-2186

91. TOMOGRAPHIC OPTICAL DATA ACQUISITION SYSTEMS FOR COMBUSTION RESEARCH — $ 70,000
L. Hesselink — 03-B, 85-3

The objective of the research is to study a coflowing combusting jet using high speed optical tomography.

The approach involves development of a unique optical data acquisition system which incorporates holographic optical elements (HOE's) for making rapid holographic interferometry measurements from a large number of directions about the object (projections). Subsequent data analysis allows 3-D reconstruction of the density or species concentration field. Algebraic reconstruction and convolution backprojection techniques are evaluated for this application. Holographic interferometry projections are recorded on a high speed motion film and after development film is digitized for further processing. Nonlinear regression methods and Fourier techniques are studied for fringe readout. The measurements yield density maps in the cold coflowing jet and temperature distributions in the combusting jet.

STANFORD UNIVERSITY
W.W. Hansen Laboratories of Physics
Stanford, CA 94305

92. NONDESTRUCTIVE TESTING $110,000
G. S. Kino 03-B
81-6

A new type of acoustic transducer, operating at frequencies in the 1-8 MHz range in air, has been investigated. Focused 2 MHz transducers, unfocused 1 and 8 MHz transducer, and resonant 800 kHz proximity sensors have been constructed. The devices have been used as range sensors suitable for measuring distances in the 1-14 cm range with accuracies as good as 40 microns. They have also been applied to imaging cirucit board profiles and measuring the thickness of films a few micrometers thick.

Perhaps the most important application is as a photoacoustic sensor in air. At 2 MHz, the sensitivity of these devices is fifty times better than an infrared sensor. They have been used as photoacoustic sensor for measuring the film thickness of silicon dioxide on silicon in the 1000-3000 A range, and of ferrite-filled epoxy layers, of the order of 1 micron thick, laid down on magnetic recording discs. The transverse resolution is a few micrometers. They have also been applied to imaging regions of high surface recombination in silicon, where carriers are generated by an incident laser beam modulated at 2 MHz; the recombination causes surface heating, which is detectable by acoustic wave generation in air.

STANFORD UNIVERSITY
Department of Mechanical Engineering
Stanford, CA 94305

93. FLEXIBLE AUTOMATED OPTICAL SENSING SYSTEMS FOR THE STUDY AND CONTROL ENERGY CONVERSION PROCESSES — $200,000, 03-B, 85-3

C. H. Kruger, G. Kychakoff

The integration of optical sensors with computers is needed for the study and control of energy conversion processes. The aim of this program is to develop systematic methods for combining the capabilities of optical sensors and computers, and to apply these methods to generate a family of advanced optical sensing systems.

In order to implement this scheme, a number of components are being developed:

(1) Optical waveguide tranducers have many attractive features for our application, including ease of optical alignment, insensitivity to electrical interferences, durability, and low cost. New transducers to sense parameters such as electric fields in a low pressure plasma, chemical species in a liquid, temperature in the range 10-200K, solid body curvature and pattern misalignment are being developed.

(2) Optical signal analysis devices are needed to implement the multiplexing and optical preprocessing parts of our sensing system. A number of devices exploiting novel schemes to carry out elementary signal analysis functions such as switching, multiplication, division, subtraction, and addition are being developed. These devices will subsequently be assembled into analog optical circuits which will be used in our hybrid optical/electronic signal analysis modules.

(3) Computer software is needed for data acquisition, interpretation and control. Specific software modules being developed initiate data acquisition, control the multiplexer and signal analysis modules, control data transfer and convert data from numerical to symbolic representation--the most useful form for interpretation and control purposes. Subsequent work will focus on the relationship between this representation and process models.

STANFORD UNIVERSITY
Department of Chemistry
Stanford, CA 94305

94. EFFICIENCY OF CHEMICAL AND THERMAL ENGINES — $102,000
J. Ross — 06-C
82-4

Research is concerned with the issue of the enhancement of power output in thermal and chemical engines by means of external perturbations of constraints coupled to nonlinearities of the mechanism of the engine. The possibility has been shown of the increase in power output of the thermal engine driven by a chemical reaction by means of external periodic variation of pressure, temperature and mass flux for the same average chemical throughput as the unperturbed (steady or periodic) state. Since the power output of an engine is necessarily accompanied by dissipation due to irreversible processes essential for power production, an increase in the power output by means of external perturbations is accompanied by a decrease in the rate of entropy production. There exists particular frequencies of external perturbations at which resonance effects lead to enhancement of power output. A linear analysis is possible by analytic methods but the full nonlinearities need to be treated by numerical methods. Research is in progress on optimization of cycles for combined thermal and chemical engines, and the search for upper limits of the efficiency of chemical engines with non-zero throughput (reaction rates) of monotonic and oscillatory reactions.

STANFORD UNIVERSITY
Department of Civil Engineering
Stanford, CA 94305

95. MOMENTUM AND HEAT TRANSFERS IN A COMPLEX, BUT WELL-DEFINED TURBULENT FLOW — $113,000 — 01-B — 84-3
R. L. Street

A basic study of a three-dimensional, variable density, recirculating flow is being conducted in a lid-driven cavity. A unique facility has been created to provide an extremely well-regulated flow. Water is the working fluid. The objectives of the research are to provide 1) a complete data base for a range of conditions (laminar, turbulent, forced convection, etc.) in a complex recirculating flow, 2) deeper insight into the physical processes governing heat and momentum transport in such flow, and 3) a critical evaluation of the performance of numerical simulation models in predicting the experimental results. Flow and temperature visualization has been carried out for 1) homogeneous, 2) stably stratified and 3) naturally buoyant flow conditions. General flow features have been established for Reynolds numbers up to 10,000, e.g., the number of identifiable eddy structures, the presence of Taylor-Gortler vortices, and the strength and the development of the thermocline in the stratified cases. LDA velocity measurements have been obtained and compared with both two- and three-dimensional numerical codes. Several codes simulate the experimental results for laminar flows quite well except for the Taylor-Gortler vortices, which have been reproduced successfully so far by only two three-dimensional codes with fine grids. Turbulent flow cases and code modifications are to be examined. Temperature and heat flux measurements are being made. Temperature and velocity correlation data will be obtained for turbulent flow cases using LDA and the temperature rig simultaneously.

STEVENS INSTITUTE OF TECHNOLOGY
Department of Physics and Engineering Physics
Hoboken, NJ 07030

96. INVESTIGATIONS OF TRANSITIONS FROM ORDER TO CHAOS IN DYNAMICAL SYSTEMS — $ 35,000
George Schmidt — 06-C — 83-3

The transition from order to chaos in dynamical systems of few degrees of freedom are studied, using theory, numerical computation, and a laboratory experiment as tools of this investigation. The first phase of the program is now completed.

We have performed a laboratory experiment studying the orbit of a magnetic dipole in an oscillating magnetic field, with controlled dissipation. Period doubling bifurcation sequences leading to chaotic motion have been observed, as well as period three orbits. For sufficiently large dissipation, chaotic motion takes the form of a strange attractor.

While the transition to chaos in low dimensional Hamiltonian systems is by now well understood, there is no comprehensive theory for dissipative systems. We established a basis for such a theory by studying the dissipative standard map numerically. It was found that all studied stable periodic orbits of the Hamiltonian map turn into attractors for all values of the dissipation parameter. As the dissipation parameter is reduced strange attractors are gradually wiped out so that none exists for the Hamiltonian system. These results are likely to apply to a large variety of dynamical systems.

The next stage of this work involves the detailed study of the disappearance of strange attractors. In all systems, we have studied the one piece strange attractor disappears first, then the two, four, eight, etc. piece attractors. Furthermore, the dissipation parameter values where these transitions occur seem to follow a geometric progression that appears to be universal, leading to a new universal constant. We plan to apply renormalization theory to find this constant and demonstrate the universal character of the process.

UNIVERSITY OF TEXAS AT AUSTIN
Center for Studies in Statistical Mechanics
Austin, TX 78712

97. THE BEHAVIOR OF MATTER UNDER NONEQUILIBRIUM CONDITIONS: FUNDAMENTAL ASPECTS AND APPLICATION IN ENERGY-ORIENTED PROBLEMS — $100,000 — 06-C — 81-6
I. Prigogine

This research aims at new fundamental developments in the area of non-equilibrium phenomena, as well as at various applications to disciplines in which complex systems giving rise to instabilities and bifurcations are of current and primary concern. Special emphasis is being placed on three principal directions. First, the methods of nonlinear dynamical systems will be applied to investigate the transition phenomena occuring in physico-chemical problems such as atmospheric dynamics, the Belusov-Zhabotinski reaction and the oxidation of hydrocarbons an gaseous phase. both perturbative and global techniques will be applied, since current experimental evidence suggests that some of these transitions involve chaotic dynamics and homoclinic orbits. Second, problems arising in connection with selection of nonequilibrium states will be analysed. In particular, the effect of extremely small influences in the selection of symmetry-breaking states -- which are realized in chemical, electronic, and other systems -- will be studied, taking both additive and multiplicative fluctuations into consideration. The implication of the results for the origin of biomolecular chirality will be assessed. Colaborative experiments are planned to substantiate the theoretical developments. Third, special attention will be focused on the problem of combustion. A fundamental analysis of this phenomenon, from both the stand point of the theory of dynamical systems and the stand point of stochastic theory, is still lacking. In the proposed research, the effect of stochastic perturbations, of inhomogeneities and of internal fluctuations during the process of ignition, in which the system is expected to present a high sensitivity, will be analysed using Semenov's model for combustion as well as more realistic models. A fundamental theory of nucleation of flame fronts is expected to be one of the outcomes of these developments.

UNIVERSITY OF TEXAS AT AUSTIN
Department of Physics
Austin, TX 78712

98. PERTURBATION AND CHARACTERIZATION OF NONLINEAR PROCESSES — $125,000 — 06-C — 83-4

Harry L. Swinney and J. Swift

In this study techniques are being developed to characterize regular and chaotic behavior in nonlinear systems. Although recent theoretical and experimental studies have shown that nonlinear nonequilibrium processes often exhibit nonperiodic behavior, it is difficult to relate these results to nonlinear systems in industry and in nature because research thus far has concerned primarily deterministic systems with no perturbations, while noise is alsays present for real systems. Moreover, the observed nonperiodic behavior has not been quantified, so experiments cannot be easily compared with one another and with theory. In this research, we are addressing these problems by (1) conducting experiments on the Belousov-Zhabotinskii reaction in a well-stirred flow reactor with imposed computer-controlled perturbations, and (2) developing a method to determine from experimental data the Lyapunov exponents that characterize a nonperiodic process. Methods will also be developed for determining from laboratory data other quantities including the fractal dimension and the metric entropy.

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Depts. of Engineering Science and Mechanics and Mechanical Engineering
Blacksburg, VA 24061

99. HEAT TRANSFER IN OSCILLATORY FLOW — $101,000
D. P. Telionis, T. E. Diller — 01-B
82-4

The objective has been to study the response of the velocity field and heat transfer of a single cylinder and bundles of cylinders to forced oscillations of the fluid crossflow. Experiments were conducted in a wind tunnel with an emphasis on the heat transfer, and a water tunnel where the flow was examined in detail via Laser-Doppler Velocimetry and Flow Visualization. Both tunnels were modified to provide a well-controlled pulsating flow. Analytical efforts were based on numerical integrations of boundary layer equations and special mathematical tools for modeling the flow and heat transfer in the wake of the cylinders.

UNIVERSITY OF WISCONSIN
Department of Chemical Engineering
Madison, WI 53706

100. THE DEVELOPMENT OF PROCESS DESIGN AND CONTROL STRATEGIES FOR ENHANCED ENERGY EFFICIENCY IN THE PROCESS INDUSTRIES — $101,000 — 03-A — 80-6
W. H. Ray, D. F. Rudd

The process industries are a major consumer of energy and the improvement of energy efficiency is an important goal. Process modifications aiming at a reductino of energy consumption tend to make a plant more integrated and thus more difficult to operate. In practice, the primary objective is not only steady state energy efficiency but that the plant is flexible, operable, and controllable, i.e. resilient. The research goals are to develop design strategies for resilient processes and operating policies for highly integrated plants. The particular substances are: 1) Synthesis of resilient energy management network, 2) Development of control strategies for integrated distillation columns, and 3) Development of control and optimization procedures for systems with high parametric sensitivity (chemical reactors). The latter two tasks involve an extensive experimental verification phase. The development of interactive user-friendly CAD packages incorporating the fundamental theoretical development are under way.

This work is carried out in collaboration with California Institute of Technology.

BUDGET NUMBER INDEX

MECHANICAL SCIENCES:

01-A Solid Mechanics: macroscopic aspects of elastic and plastic deformations, and crack propagation

01-B Heat Transfer

01-C Fluid Mechanics

01-D Tribology

CONTROL SYSTEMS AND INSTRUMENTATION:

03-A Control systems, large scale systems

03-B Instrumentation for hostile environment, and NDE

03-C Intelligent systems

ENGINEERING DATA AND ANALYSIS:

06-A Thermophysical properties and processes

06-B Combustion

06-C Non-linear dynamics and engineering analysis

PROJECT TITLES

PROJECT TITLES

Budget Number		Project Number

PROJECT TITLES

Budget Number | Project Number

03-B

03-C

06-A

06-B

PROJECT TITLES

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06-C

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