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Summaries of FY 1982 Engineering Research

December 1982

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

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Office of Energy Research
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Division of Engineering, Mathematical
and Geosciences
Washington, D.C. 20545

FOREWORD

This report documents the BES Engineering Research program for fiscal year 1982; 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, Mathematical 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. The Division phone number is (301) 353 5822. Dr. Manley can be contacted by phone at this number.

In preparing this report we asked the principal investigators to submit summaries for their projects that were specifically applicable to fiscal year 1982. 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 contacted directly.

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Office of Basic Energy Sciences

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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 1982.

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 1982 appears to the right of the title; it is followed by the budget activity number (e.g., 01-03). 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., 80-2). The summary description of the project completes the entry.

TABLE OF CONTENTS

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, engineering, and applied mathematics. 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 in 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.

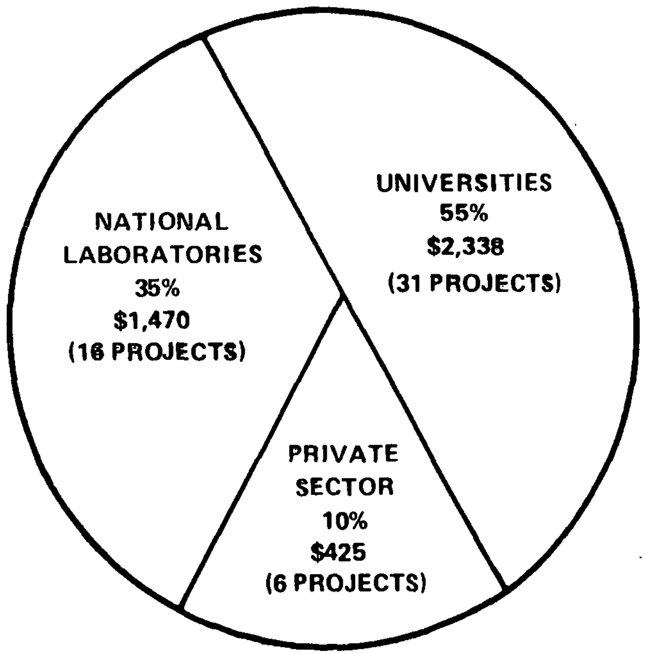
These areas contain the most critical elements of the four topics enumerated above; as such, they are of importance to energy technologies both in the short and long term, and therefore of immediate programmatic interest. It should be noted that other areas of basic research important to engineering are monitored elsewhere in BES. For instance, fluid mechanics, especially turbulence 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 in fiscal year 1983, a significant portion of the real increment in available funds will be used to fill a widely perceived gap between research on advanced control systems and the developments in artificial intelligence as they apply to energy systems. Further in the future as funds become available, the program will address the development of methodologies for simulating the scale-up of process plants. With the availability of an increasing data base, new concepts in the mathematical theory of non-linear systems offer opportunity for rapid advances in this relatively unexplored engineering field.

Research projects sponsored by the BES Engineering Research program are currently underway at universities, private sector laboratories, and DOE national laboratories. In fiscal year 1982 the program operating funds available amounted to about $4 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 $100,000 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 exception 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

ENGINEERING RESEARCH PROGRAM
FY '82 BUDGET ($000's)
BY INSTITUTIONAL TYPE



ENGINEERING RESEARCH PROGRAM
FY '82 BUDGET
BY TECHNICAL AREAS

	($000's)	%	NUMBER OF PROJECTS
MECHANICAL SCIENCES	1,556	37%	24
SYSTEMS SCIENCES	1,510	36%	18
ENGINEERING ANALYSIS	1,167	27%	10

limited to advanced studies both theoretical and experimental usually performed by faculty members, staff research scientists, and doctoral candidates.

AMES LABORATORY
Iowa State University
Ames, Iowa 50011

01.	A COMPOSITE, MULTIVIEWING TRANSDUCER James Corones, D. O. Thompson, R. B. Thompson	$150,000	01-03 81-3

The objective of this project is to demonstrate a first breadboard model of a multiviewing ultrasonic transducer suitable for detecting and characterizing flaws in structural materials in various applications. The successful development of the device depends upon the combination of recent advances in ultrasonic scattering and inversion theories with new concepts in transducer configurations and excitation methods. An experimental composite transducer simulator has been used as an aid in developing the data acquisition and analysis protocol. It has been determined that seven transducer elements which are multiplexed using both pulse-echo and selected pitch-catch modes are sufficient to produce good flaw reconstructions. The data protocol fits the inverted data to an ellipsoid of general shape (3 axes, 3 angles). Results obtained indicate that this combination produces a good reconstruction of a flaw's size, shape, and orientation. Work is currently in progress on a self-contained composite transducer and automated data protocol software.

ARGONNE NATIONAL LABORATORY
Components Technology Division
Argonne, Illinois 60439

02.	THEORETICAL/EXPERIMENTAL STUDY OF STABILITY CONTROL	$30,000	01-02 82-3

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 analyses are performed at Argonne National Laboratory. The studies have been initiated with the special fluid-elastic 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, a simpler oscillator problem has been analyzed in detail. 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. The transition from one instability to another has been identified as a function of the ratio of the downstream support location (distance from fixed end) to the total tube length. In addition, tube natural frequency and damping were measured as a function of flow velocity.

ARGONNE NATIONAL LABORATORY
Components Technology Division
Argonne, Illinois 60439

03. ENGINEERING MODELS IN DYNAMIC PLASTICITY — $50,000 — 01-04 80-3

G. S. Rosenberg, H. C. Lin, C. A. Kot

The objective is to develop a rational continuum basis for describing the dynamic plastic deformation of materials subjected to short duration, high intensity loading. A phenomenological approach coupled with irreversible thermodynamics guides the derivation of constitutive representations. Constitutive equations based on the endochronic theory of viscoplasticity with an improved intrinsic time measure and including strain-rate effects have been derived for one-dimensional and bixial (tension-torsion) stress states. Applications of these constitutive formulations to one-dimensional wave propagation problems in thin-wall tubes show good agreement with experimental data both during loading and unloading. A critical review of endochronic formulations, their applications, and some of the criticisms of the theory have also been completed. The analytical and numerical studies indicate that the improved formulations widen the predictive scope of endochronic theory, while preserving its advantages, i.e., not having to define a yield surface and reducing computational effort.

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

04.	DAMAGE ACCUMULATION BY CRACK GROWTH UNDER COMBINED CREEP AND FATIGUE C. E. Jaske	\$ 0	01-04 80-2

The objective of this study is to develop and evaluate methods for assessing creep/fatigue crack growth under inelastic straining. A fracture-mechanics approach using the J-integral for fatigue and the C* integral for creep is being employed. A computer program has been developed to calculate creep/fatigue crack growth in laboratory specimens. A crack-tip-zone interaction model was developed to account for interaction between creep and fatigue during crack growth at high temperature. Experimental work is being carried out on solution annealed Type 316 stainless steel in air at 593 and 649 C. Cyclic-crack-growth-rate behavior has been characterized both under continuous cycling conditions and under conditions of hold times up to 1-hour long at peak tensile load during each fatigue cycle. It has been found that ΔJ can be used to characterize the fatigue-crack growth rate for surface flaws in low-cycle fatigue specimens that are in the range of 0.05 to 1.5 millimeters. Creep-crack-growth behavior has been characterized for rates between 10^{-10} and 10^{-7} meters per second using the C* integral. Transient fatigue-crack-growth rates after periods of creep have been characterized and the behavior explained in terms of the crack-tip-zone interaction model that has been developed. The initial results indicate that the approach being used is a quite promising one. Further verification of the validity of this approach at lower cyclic and creep-crack-growth rates that are particularly relevant to practical engineering problems needs to be evaluated in further work.

BIPHASE ENERGY SYSTEMS
2800 Airport Avenue
Santa Monica, CA 90405

05.	TWO-PHASE FLOW RESEARCH D. M. Rovner	$63,000	01-02 80-3

This project is planned as a three year effort to carry out research on two-phase nozzles and the interaction of the flow from such a nozzle with a rotating separator. During the second phase, which was completed in July of 1982, an investigation was conducted to determine the efficiency of momentum transfer from the two-phase jet to a rotating separator. Nozzle-thrust and separator-torque measurements were used to determine the momentum transfer. Nozzle/separator geometric parameters and nozzle-flow parameters were varied and the effects on momentum transfer were measured. The effect of the geometric parameters was well-predicted by a control-volume analysis. The most important nozzle-flow parameter appeared to be the slip velocity between the two phases. In addition, measurements made at low mass ratios of water-to-air revealed that there was transfer of momentum to the separator wheel from the gaseous phase. In a typical case it was shown that up to 30% of the torque the gaseous phase exerted on the separator wheel was measured. (The uncertainty is due to the unknown velocity slip between the phases). During the third phase of the project, interactions between a pickup and the rotating liquid film on a separator will be studied. The focus will be on measurement of drag exerted on the separator and minimization of harmful wakes.

BROWN UNIVERSITY
Division of Engineering
Providence, Rhode Island 02912

06. IMPROVEMENT IN THE DESIGN AND EXTENSION OF OPERATING RANGE OF VISCOMETERS AND THERMAL CONDUCTIVITY CELLS — $96,000 — 01-03 81-3
J. Kestin

This project continues the development of measurement of two important transport properties, the viscosity and the thermal conductivity. Work is underway on the modification of existing instrumentation to extend the ranges of pressure and temperature and to make measurements at combined high temperatures and pressures (300-400 C and 30-40 MPa) while retaining the accuracy of 0.1-0.5% which is the state-of-the-art for more modest conditions. Working simultaneously in the same carefully staged way, the goal for thermal conductivity measurements is to develop instrumentation that will cover the range up to 50 MPa and 600 C. With each staged increase in capability, extensive measurements are being made on selected substances to secure results before the instruments are exposed to increased risk. New measurements on the viscosity of H_2O and D_2O were performed up to 200 C to create a basis for the search for a law of corresponding states. Preliminary calculations seem to point to the existence of such a law with appropriately chosen reference values. In the thermal conductivity instrument measurements on the mixtures of $Ar-CH_4$ have been completed. The next step consists of a series of measurements on mixtures involving two gases of nearly identical molecular weight but different structure. Measurements on N_2-CO show that the mixtures have the same viscosity as N_2 or CO (both nearly equal), but significantly different thermal conductivity. This may prove of theoretical interest in statistical mechanics. The selected substances are chosen to make a contribution to the national energy program as well as to the development of methods of calculation for use in science and industry.

UNIVERSITY OF CALIFORNIA, LOS ANGELES
School of Engineering and Applied Science
Department of Mechanics and Structures
Los Angeles, California 90024

07.	FLOW AND HEAT TRANSFER IN UNIFORM AND NON-UNIFORM POROUS BEDS Ivan Catton	$55,000	01-02 82-3

The research, covers two broad areas: 1) single-phase convection in porous media and 2) two-phase convection in porous media. The two areas of study are further sub-divided into a) forced convection, b) free convection, c) free/forced convection, d) fluidization under two-phase flow conditions and e) effects of bed non-uniformities. Layered porous media with intervening liquid regions as well as layers with no through flow will be part of the study. The objective of this research is to develop physical understanding of the governing phenomena and models for prediction of heat transfer by theoretical and experimental means. Current experimental and theoretical studies address single-phase natural convection. The Prigogine approach using non-equilibrium thermo-hydrodynamic stability theory has been used to predict the Nusselt number for a porous layer heated from below. The experimental data confirm the predictions.

CALSPAN ADVANCED TECHNOLOGY CENTER
Aerodynamic Research Department
Buffalo, New York 14225

08. THE EFFECT OF AIR FLOW INSIDE A PNEUMATIC TIRE ON TEMPERATURE BUILDUP AND ROLLING RESISTANCE — $ 110,000 — 01-01 81-3

William J. Rae, George T. Skinner

The objective of this study is to quantify the effects of air flow and heat transfer inside a pneumatic tire on the temperature buildup and rolling resistance of the tire. The approach being followed has three phases: in the first, detailed measurements are being made of the flow velocities inside a tire under typical operating conditions. The principal experimental apparatus being used in these experiments is a set of hot-wire anemometers. In addition, pressures and temperatures will be measured at selected points. In the second phase, a computer program for predicting this flow will be developed, and its results compared with the experimental data. During the third phase, an energy-balance model will be developed, by means of which the flow and heat-transfer information developed in the first two phases will be translated into quantitative knowledge about energy losses due to the air flow. The overall result expected from this work is a method for assessing quantitatively the energy balance of the tire, as affected by load, road speed, inflation pressure, and other parameters.

CALSPAN ADVANCED TECHNOLOGY CENTER
Environmental Sciences Department
Buffalo, New York 14225

09.	MITIGATION OF BIOFOULING USING SURFACE COATINGS R. E. Baier, A. E. Meyer, R. W. King M. S. Fornalik H. Gucinski	$ 62,000	01-02 80-3

Surface-energy-control coatings on sensitive analytical plates are being used inside novel flow cells, at known shear rates, to evaluate the hypothesis that biofouling films on energy-transfer equipment might be suppressed without the use of toxicants. Laboratory trials identified coatings with usefully long lifetimes when subjected to flowing artificial seawater. Experimental data show a possible minimum biofouling condition for surface layers with 20-30 mN/m critical surface tensions. An apparently universal pattern of microfouling was observed on all test materials. The sequence of events occurs within the well known "induction period" before deterioration of fluid friction factors or heat exchange are noted by conventional measurements, but a heat-exchange version of the test flow cells shows evidence of improved sensitivity to these critical early events. In field tests biofouling films with secondary silicate overlayers formed on all test surfaces. However unlike unheated steel surfaces these films could be easily removed from heat exchanger grade stainless steel to about 22 mN/m. It was noted that iron carbonate and iron hydroxide components served as "transition" layers from the biofouling precursor films to the glassy outermost deposits, suggesting a new plan of attack for fouling control additives. Field studies are in progress at the coal-fired Niagara Mohawk power plant on the Niagara River, confirming and extending the data base for fresh Great Lakes quality water.

UNIVERSITY OF CHICAGO
Enrico Fermi Institute
Chicago, Illinois 60637

10.	FUNDAMENTALS AND TECHNIQUES OF NONIMAGING OPTICS FOR SOLAR ENERGY CONCENTRATION R. Winston, J. O'Gallagher	$ 95,000	01-06 81-3

Nonimaging optics has led to the development of solar concentrators which have greatly relaxed optical tolerances and in many cases do not need to track the sun. The objectives of this research are further development of the theoretical formalism and its application to useful new concentrator designs such as improved solutions for minimizing or eliminating intercept losses in cases where the energy absorber must be isolated from the concentrator and in studies of nonimaging elements for hybrid systems. Of particular significance is recent work which shows explicitly that the brightness theorem in geometrical optics (the analogue of Liouville's theorem) applies in the physical optics domain as well. Thus it can be shown that the claims advanced for several proposed unconventional concentrator designs involving holographic elements must be carefully evaluated and in many cases cannot be true. Theoretical work is continuing in an effort to derive a general expression for the energy flow inside a concentrator from boundary conditions imposed by the location of reflecting and refracting surfaces.

CLARKSON COLLEGE OF TECHNOLOGY
Department of Chemical Engineering
Potsdam, New York 13676

11. BURSTING IN STEADY AND PULSATING TURRBULENT PIPE FLOW — $ 66,000 — 01-02 82-3
J. B. McLaughlin, R. J. Nunge

The objectives of the research project are: (1) to gain an understanding of the effects of externally imposed pressure pulsations on turbulence structure and momentum, heat, and mass transfer in turbulent pipe flow; and (2) to determine the feasibility of exploiting such effects to increase the efficiency of heat exchangers and similar devices. A combination of computer modelling and laboratory experiments is pursued. The computer modelling involves the numerical simulation of a nonlinear, three-dimensional, time-dependent model of the Navier-Stokes equation in which a plug flow condition is imposed on the axial component of the velocity in the core of the pipe. The model predicts the effects of pulsations on the time-averaged transport and on the wall-region eddies. Some of the predictions will be tested in laboratory experiments on a fully developed turbulent pipe flow. The experiments involve measurements of flow rates, pressure gradients, local pressures, and local wall shear stresses.

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

12. RADIATIVE HEAT TRANSFER IN OIL SHALE RETORTING — $ 45,000 — 01-02 81-2
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 or argon) as a control. Preliminary measurements on a two inch diameter bed led to the conclusion that heat loss at that diameter may predominate. Therefore a larger diameter bed with improved insulation is being constructed for this project. It aims at a temperature capability exceeding two thousand degrees Fahrenheit in order to guarantee the predominance of radiative transfer and to provide much needed high temperature interphase heat transfer data. This apparatus is now undergoing preliminary testing and methods of parameter evaluation for frequency response experiments are being tested.

CORNELL UNIVERSITY
College of Engineering
Ithaca, New York 14853

13. COMBUSTION CONTROL WITH SMART SENSORS — $ 115,000 — 01-03 81-2

G. J. Wolga, F. C. Gouldin

The objective of this project is to develop a "smart" spectroscopic sensor suitable for monitoring gaseous combustion products by differential infrared absorption spectroscopy and to use the sensor to demonstrate closed loop combustion control of a two-burner furnace. 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 filter obtained from Westinghouse is currently being tested using a single frequency CO laser to calibrate the tuning curve of the filter and to determine the temperature dependence of the tuning curve. Subsequently, infrared differential absorption spectroscopy will be demonstrated in an absorption cell; a flat flame burner; a turbulent, swirl burner; and, finally, on the combustion products of a two-burner furnace. This furnace will be fueled through control valves adjusted by a computer with the spectroscopic sensor providing quantitative information on combustion product concentrations sufficient to optimize furnace efficiency. Design and construction of the test burners is underway.

GENERAL ATOMIC COMPANY
10955 John Jay Hopkins Drive
San Diego, California 92121

14. FLUID MECHANICS OF ACOUSTIC RESONANCE IN HEAT EXCHANGER TUBE BUNDLES — $ 75,000 — 01-02 82-2
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. The 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.

IDAHO NATIONAL ENGINEERING LABORATORY
Materials Technology Division
Idaho Falls, Idaho 83415

15.	NDE IMAGING RESEARCH D. D. Keiser, J. A. Seydel, B. A. Barna, J. A. Johnson	$ 50,000	01-03 79-3

This project encompasses the development of data acquisition and processing techniques for improved ultrasonic imaging of reflectors in structural materials. The approach is to develop image processing computer codes that correct artifacts arising from interface variations and transducer field effects. Work to date has successfully integrated surface mapping algorithms and synthetic aperture techniques to provide images that significantly improve both positional accuracy and image resolution over unprocessed images. The processing algorithms have not only been applied to longitudinal ultrasonic waves but also to shear wave or angle beam data where the phase history of the signal is more complex. Subtle variations in the phase and frequency behavior across the sonic aperture have been related to reflector and sound field characteristics. A more complete understanding of the mechanisms of this behavior is being pursued and should provide information that will better characterize the reflectors. The increased accuracy in location and resolution that is the objective of this research will provide an optimum basis for fracture mechanics evaluations and resultant improvement in the safety of structural components.

IDAHO NATIONAL ENGINEERING LABORATORY
Materials Technology Division
Idaho Falls, Idaho 83415

16. ENGINEERING ANALYSIS OF ELASTIC-PLASTIC FRACTURE — $100,000 — 01-04, 81-3

D. D. Keiser, V. W. Storhok
W. G. Reuter

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 exhibiting a range of fracture toughness but essentially constant yield and ultimate tensile strength. As test temperature increases, the specimen configuration-fracture toughness relationship will comply initially with requirements for linear elastic-fracture mechanics and eventually extend beyond the range of a J-controlled field. Presently, compact tension (3-point bend specimens will also be used in the future) are being used to develop state-of-the-art fracture mechanics data on the lower shelf (K), transition zone (J , J-R curves, etc.), and on the upper shelf (J , J-R curves, etc.). Results from the lower shelf and transition region are being used to predict failure conditions for specimens containing surface flaws. Predictions are then compared with experimental test data. These comparisons are presently underway for the first series of 6.4 mm thick surface-flawed specimens. Fabrication of additional surface-flawed specimens of 6.4 and 12.7 mm thickness is in progress.

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
Department of Chemical Engineering
Urbana, Illinois 61801-3791

17. CONDITIONS FOR DROPWISE CONDENSATION ON ELECTROPLATED GOLD — $ 53,000 — 01-02 80-3
J. W. Westwater

This research is concerned with the use of thin coatings of gold, or possibly other noble metals, to produce dropwise condensation of steam on copper. Dropwise condensation is preferred to filmwise condensation, because it has much larger heat transfer coefficients. Numerous tests have been done with gold surfaces deposited by electroplating and by vacuum deposition. Analyses of the surface was by Auger spectroscopy and by electron microscopy. Success with gold has led to extension of the research to silver coatings. Distinct differences have been discovered. The minimum thickness of gold required for good dropwise condensation is 100 nm, whereas for silver it is 150 nm. A gold thickness of 200 nm will produce dropwise condensation for 12,000 hr. before deterioration of the surface is noted. With silver, a thickness of 300 nm begins to deteriorate in 200 hr., and a thickness of 3000 nm is required to achieve 1200 hr. To date the tests support a hypothesis that the role of the noble metal layer is to provide an oxide-free surface to which a trace of organic material can adhere firmly. The work is being directed to identify the source of the organic absorbent.

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

18.	INTERACTIONS BETWEEN FRICTION-INDUCED VIBRATION AND WEAR V. Aronov, A. F. D'Souza S. Kalpakjian	$79,000	01-02 82-2

The objective of this project is to improve our understanding of the influence of system rigidity and vibrations on friction and wear. There is increasing evidence, both from our previous studies and from the very limited literature available, that in addition to the role of various physical, chemical and mechanical parameters, the dynamic characteristics of the equipment or machinery involved also have a significant influence on wear. This project involves an interdisciplinary study to investigate the interactions between friction-induced vibration and wear. The major experimental parameters are the normal and tangential rigidity in a sliding system and different lubricating conditions, with observations and analysis of wear surfaces and particles with scanning electron microscopy. Among the subjects being studied are the regimes of load and speed at which transitions from mild to severe wear occur with self-excited vibrations. A stability theory is being developed to explain the onset of different types of vibrations. Physical and mathematical models of oscillations are also being developed, including the effects of surface alterations due to wear.

ILLINOIS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering
Chicago, Illinois 60616

19. METHOD OF VIBRATIONAL CONTROL IN THE PROBLEM OF STABILIZATION OF CHEMICAL REACTORS — $ 74,000 — 01-03 80-3

S. M. Meerkov

The objective of this research is to develop the vibrational control technique for complex nonlinear dynamic systems with multiple steady states and limit cycles. From the mathematical point of view, the goal of the project is to analyze the effects of fast parametric oscillations on the system's dynamics. During the second year of the project, the vibrational control theory was extended to a broad class of nonlinear systems. This extension was based on the reduction of a nonlinear system with fast parametric oscillations to a so called standard form through a substitution, generated by an auxiliary differential equation. The resulting averaged equation is shown to characterize properly the original dynamics if the small parameter (a ratio of the period of parametric oscillations to the rise time of the system) is less then 0.16. The developed theory was applied to the sensitivity analysis of the vibrationally controlled Continuous Stirred Tank and Catalytic reactors. It was shown that fast oscillations of any parameter lead to a positive vibrational control effect.

THE UNIVERSITY OF IOWA
Division of Energy Engineering
Iowa City, Iowa 52242

20. CONVECTIVE AND RADIATIVE TRANSFER FOR TURBULENT FLOW IN ENERGY SYSTEMS — $ 0 — 01-02 79-3
T. F. Smith, C. J. Chen

The overall objective of this research is an examination of the interaction of convective and radiative heat transfer for turbulent flow of a radiatively participating gas through circular ducts. Within this objective, the specific aims are: 1) formulation of the conservation equations for mass, momentum, and energy transport in a manner suitable for the intended applications and for solution on a digital computer, 2) identification and development of appropriate models to describe turbulent and radiative transport properties, 3) development of solution techniques which are efficient, convenient, and accurate, 4) acquisition and analysis of velocity, temperature, and heat flux results in order to identify the contribution and significance of the various transport mechanisms, and 5) development of limiting cases and simplified models which would be suitable for engineering design studies. The past year's efforts have been concerned with formulation of the radiative energy exchange model, acquiring results for laminar flow of a radiatively participating gray gas, and testing of the finite analytic numerical scheme for flows in circular ducts and cavities. Current research addresses radiative transfer in real gases and incorporation of turbulent models in the numerical scheme.

JET PROPULSION LABORATORY
California Institute of Technology
Pasadena, CA 91109

21. THIN FILM CHEMICAL SENSORS BASED ON ELECTRON TUNNELING — $30,000 — 01-03 82-3
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 utilizes electron tunneling as the sensing mechanism. The technical approach involves investigations of the tunneling spectrum (second derivative of current with respect to voltage versus voltage) of metal-metal oxide-metal (e.g., Al-Al 0 -Au) 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 (SIMS, LEEDS) 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. An oil free ultra high vacuum system (10 Torr) was assembled and made operational to fabricate tunnel junctions and an inelastic electron tunneling spectrometer is being constructed to measure the tunneling spectrum of the tunnel junctions.

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

22. CONTROLLED COMBUSTION $150,000 01-05
A. K. Oppenheim 79-6

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. For this purpose 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 to determine the role of active radicals played in the course of ignition. 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 results will be interpreted on the basis of a thermo-chemical analysis as set forth by Semenov and Frank-Kamenetskii for ignition in a closed system. This is supplemented by numerical modeling of flame propagation in turbulent flow. The experimental testing program is in progress with flash photolysis of NO used to ignite a helium diluted hydrogen-oxygen mixture. In the concomitant analytical studies we have been able to deduce the classical first and second ignition limits by appropriate scaling of the thermal relaxation time.

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

23. STUDIES IN NONLINEAR DYNAMICS $ 75,000 01-06
Allan N. Kaufman, Henry D. I. Abarbanel 80-3

This project involves studies of fundamental properties of non linear dynamical systems which arise in physical situations of importance to energy research. Three 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 a space of enlarged dimensionality. Propagation of short wave length signals is then treated in a regular, non-linear fashion in phase space. Second, the transport properties of conservative and dissipative non-linear systems described by systems of ordinary differential equations are investigated. Transport equations have been derived and the transport coefficients expressed as integrals over correlation functions of state space. Transport properties of fluids which allow a reasonable mode truncation (Galerkin approximation) are given by these methods. Current work is focused on evaluating the asymptotic attractors and computing physically important correlation functions on the attractor. Third, investigations of analytic techniques for determining the position in parameter space and nature of bifurcations from periodic orbits are underway. Analytic methods based on center manifold theory and Poincare normal forms are being developed to study the stability of limit cycles which arise in a Hopf bifurcation from steady orbits. Applications to fluid flow and oscillations in non-linear phenomena of importance to energy systems are the testing grounds for the mathematical techniques.

LAWRENCE LIVERMORE NATIONAL LABORATORY
P. O. Box 808 L-311
Livermore, California 94550

24. AUTOMATIC CHARACTERIZATION AND CONTROL OF COMPLEX SYSTEMS — $ 100,000 — 01-03 79-3

Jack W. Frazer,
David J. Balaban, Hal R. Brand,
Stanley M. Lanning, Julia L. Wang

Significant progress has been made on all of the major goals of the program. Many graphic representations necessary for data interpretation and to support modeling have been developed including among others, 4-D representations of chemical reactions, splines-under-tension for sparce data surface representation, 3-D color level surfaces with advanced lighting models, and quantitative color representations for chemical vapor deposition processes. Parameter estimation efforts includes both linear and non-linear estimation as applied to the study of complex chemical reactions where the study was conducted entirely under computer control. Much has been learned about the indentifiability problem for non-linear chemical systems. Preliminary results leads us to question much of the published kinetic data. A good LISP interpreter for utilization on LSI-11 computers has been developed. To date there has been completion of one expert system and near completion on a second. Artificial intelligence was thus used to solve two practical problems in chemical experimentation. In the area of control strategies, non-linear chemical models of the process in a specific control algorithm have been included. This demonstrates the use of chemical models in the Smith predictor control strategies. New effort is being directed to more advanced uses of artificial intelligence in control of experimentation, data analysis, parameter estimation, process control, and for automatic code generation.

LAWRENCE LIVERMORE NATIONAL LABORATORY
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Livermore, CA 94550

25. PROCESSING AND CHARACTERIZATION OF SCATTERED SIGNALS FROM ACOUSTIC TARGETS — $100,000 — 01-03 82-4
B. Maxfield, E. Miller

We have begun in FY 1982 a study to develop a fundamental understanding of acoustic scattering from targets having relevance to material strength, for example flaws in metal components and welding faults, and to process such target signatures for possible automatic material characterization in nondestructive evaluation (NDE). This work is related to instrumentation development for NDE and more specifically with electromagnetic/acoustic scattering, and signal processing research. LLNL is currently involved in both areas using internal funds (engineering research) as well as reimbursable support (from various DOD agencies, and NRC).

LOS ALAMOS NATIONAL LABORATORY
Electronics Division
Los Alamos, New Mexico 87545

26. DEVELOPMENT OF INTEGRATED THERMIONIC CIRCUITS — $100,000 — 01-03 82-3
B. McCormick, D. Wilde,
D. Lynn, R. Dooley

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 sophistication, 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 C for approximately 13,000 hours with no degradation in device characteristics. Devices have been subjected to total radiation doses of 10 neutrons/cm and 2.5 x 10 rad and radiation pulses of 1.4 x 10 neutrons/cm /s and 1.2 x 10 rad/s with no upset or damage. The onset of device upset occurs at 10 rad/s, but the devices recover immediately. These tests have been conducted up to 10 rad/s, and the devices in all cases display immediate recovery. It was determined that the source of resistive leakage between elements was due to the reduction and deposition of hydrocarbons present in the photoresist used to define the cathode pattern. The cathode development process and the cathode coating are being changed to reduce the hydrocarbons present resulting in a leakage reduction (two orders of magnitude) to a level acceptable for circuit development.

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

27. NUMERICAL MODELING OF TURBULENT ENERGY RELATED FLOWS — $ 40,000 — 01-02 81-2
B. S. Berger, P. S. Bernard

The objective of this research effort is computational modeling of turbulent energy related fluid flows with a view to the calculation of the lift and drag forces acting on the individual tubes of a heat exchanger tube bank. The MVC turbulence closure has served as the basis for the computation. Results derived from the previous year's research have appeared in four journal publications. The first two pertain to the derivation of the closure field equations in 3-D and their specialization to cylindrical geometries. The second two are studies of dissipation in the boundary layer involving microscales, correlation tensors and the balance of turbulent energy in the linear wall region. Current efforts have concentrated on the numerical aspects of the application of the MVC closure to cross flows over circular cylinders. In this regard the computation of velocity correlations from vorticity correlations is of particular importance and has led to successful theoretical and computational studies of the symmetry of correlation functions, the numerical integration of Green's functions and the computation of velocity fluctuations from vorticity fluctuations. These results have been incorporated in a computer code which is undergoing numerical verification for the crossflow problem.

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

28.	SHORT-CUT PROCEDURES FOR THE SIMULTANEOUS DESIGN OF A PROCESS AND ITS CONTROL SYSTEMS J. M. Douglas, M. F. Malone	$ 65,000	01-03 81-2

The economic impact of disturbances and the steady-state operability of several chemical processes has been analyzed. The short-cut design and performance models compare well with more accurate computer aided designs. Therefore, this methodology is well-suited for use in preliminary design and process development. Sensitivity and approximate optimal designs in the presence of disturbances indicate that cost savings can be significant (e.g. in the manufacture of benzene from toluene or acetone from isopropanol). Steady-state optimal designs indicate that complex distillation column arrangements, such as sidestream columns with or without strippers or multiple feeds can be more economical than traditional designs. An operability and control analysis of processes which use these complex columns is therefore desirable. Short-cut models for these separations for use in whole-plant models are being developed.

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

29. A STUDY OF REDUCED ORDER MODEL REFERENCE CONTROL SYSTEMS FOR IMPROVED PROCESS CONTROL — $ 45,000 — 01-03 82-3
David E. Hardt

The objective of this research is to provide a method for easy design of control systems when the plant involved is highly variable in both structure and parameter values. This typifies many manufacturing processes, which in general are highly sensitive to intrinsic properties of the infeed material, have poorly understood or controlled boundary conditions, and often have highly non-linear characteristics. In addition, the disturbances most frequent in a manufacturing process are best characterized as parameter changes rather than state variable changes. The choice of a parameter adaptive control paradigm is obvious since it has the property of optimizing system response characteristics in the face of wide plant parameter variations. Model Reference Adaptive Systems enjoy an ease of design and performance specification, and again seem applicable; however, there is a restriction within current theory that the plant be characterized in its structure well enough to have a reference model of identical order. This restriction implies a static plant structure and more *a priori* knowledge than is often present. In this research the implication of a reduced order (or mis-matched) reference model is being investigated. Initial work has involved looking at the effect of mismatch and the extent to which non-perfect model following can be quantified. Some preliminary experimental work has also been done on a welding control system to test the robustness of various existing forms of model reference controller design.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Nuclear Engineering
Cambridge, Massachusetts 02139

30. HYDRODYNAMIC PREDICTION OF MULTIDIMENSIONAL SINGLE- AND TWO-PHASE FLOW IN ROD ARRAY — $ 54,000 — 01-02 82-3

N. E. Todreas, D. B. Ebeling-Koning, J. T. Robinson

The objective of this research is to develop basic constitutive laws for the hydrodynamics of flow oblique to rod arrays. A thorough knowledge of the flow field within heat exchanging components comprised of rod arrays (i.e., heat exchangers, steam generators, nuclear reactor cores, condensers) is of primary importance to maintaining a high component efficiency, lifetime, and operational performance. Much thermal-hydraulic design and operational performance analysis of these energy components is being performed with discretized computer models. The recent advancements in high-speed digital computers and numerical computational methods have facilitated the expansion of these thermal-hydraulic codes from one- to two- and three-dimensional multiphase flow analysis. These new codes require as input constitutive laws of multidimensional, single- and two-phase flow fields within rod arrays such as those being developed in this project. Specifically, constitutive relations for single-phase flow resistance, two-phase flow resistance, and relative phasic motion (slip) will be developed based on pressure, velocity, and void fraction profile measurements using atmospheric air/water within vertical test sections comprised of rod arrays inclined at 0, 30, 45, and 90 degrees to the direction of flow. The sensitivity of component performance to the improved constitutive laws will also be assessed. Tasks completed this year have been (1) the design and construction of the test loop and instrumentation; and (2) completion of preliminary single-phase flow measurements and two-phase flow field observations.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Center for Advanced Engineering Study
Cambridge, Massachusetts 02139

31. FURTHER DEVELOPMENT OF THE METHODS OF THERMOECONOMICS — $ 0 — 01-06 79-3
Myron Tribus, Yehia M. El-Sayed

Thermoeconomics is the combination of "second law analysis" (thermodynamics) with the methods of engineering economy to improve energy intensive systems. The method originated about 25 years ago in the design of sea water demineralization systems. According to the method fluxes of thermodynamic value (essergy) and economic value (money) are traced from the boundaries to the interior where the tradeoffs between irreversibility and amortization may be studied with greater clarity. The purpose of this project was to develop the method in its greatest generality, apply it to practical industrial problems and disseminate the results. The project is now in the final year of a three year program. During the first year the methods were re-formulated and a few industrial problems were solved. During the second year three publications were prepared and accepted. A keynote address was given for a conference devoted to Thermoeconomics. Informal talks were given to several industrial groups. During the third year consultation and advice were given to Sandia Laboratories regarding a central receiver solar system. Contracts were negotiated with three industrial companies. It was our hope that the solutions to their problems could form the basis for publications but now we find they object to even revealing their sponsorship! Two reports are now in preparation. The first deals with an extension of our use of Lagrange multipliers through the use of "constraint modifiers". A second report develops the principles behind "costing equations". Their release is planned for early 1983. Last year, as a result of our lectures and publications, we had several inquiries regarding how best to introduce these methods to industrial personnel. Proposals for continuing the work are now before two corporations.

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

32. IMPROVEMENT OF RELIABILITY OF WELDING BY IN-PROCESS SENSING AND CONTROL $ 0 01-03 79-3

Koichi Masubuchi, Henry M. Paynter, David E. Hardt, William C. Unkel

The ultimate objective of this research effort is to improve the reliability of welding by developing "smart" welding machines. A smart welding machine is equipped with sensors, artificial intelligence, and actuators for reducing welding errors by one or two orders of magnitude. These results are obtained by achieving closed-loop control of the weld itself, thereby insuring consistent quality despite variations in preparation, thermal environment, and joint geometry. The current three-year project, which can be regarded as Phase 1 of the overall program, consists of two major tasks as follows: 1) development of a fundamental understanding of welding arcs and basic control strategies, and 2) development of prototype smart welding machines. Significant developments during the first two years include the ability to manipulate the momentum of the arc plasma so as to control the mechanical and thermal input, and the concept of weld puddle mechanical impedance to control penetration. Current work focuses on using these concepts to develop a prototype smart welder.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
The Energy Laboratory
Cambridge, Massachusetts 02139

33. PISTON RING FRICTION AND VEHICLE FUEL ECONOMY — $125,000 — 01-01 / 80-3
D. P. Hoult, J. M. Rife

This project addresses the development of a physical model for piston ring-lubricant system design. The experimental base will come from a series of experiments to be conducted in a high speed photographic rig, a friction engine, and from flow visualization models. During the first year, a theoretical model was developed to describe the motion of the piston ring in a groove during the operation of a four cycle engine. This model is based conceptually on the work of Rangert, and is three dimensional with three degrees of freedom. The model predicts oil film thickness, oil consumption and friction throughout the cycle. At present the calculations have been in the quasi-steady regime. The turning points of the ring motion, when it changes orientation, remain to be studied in detail. The second major area of research was the design and construction of a test facility for the visualization of piston ring motion. Preliminary runs have been made to develop the experimental methodology. During the next year experiments will be used to evaluate, calibrate and extend the model.

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

34. LOSS CHARACTERISTICS OF CORD RUBBER COMPOSITES — $ 0 — 01-01 80-2

S. K. Clark, Farhad Tabaddor*

The general objective of this work is to develop analytical methods suitable for the prediction of the hysteretic loss characteristics of textile cord-rubber composites commonly used in industrial products, with particular reference to pneumatic tires. The theories presently available for the prediction of composite elastic moduli have been modified for the viscoelastic case by inclusion of complex material properties, and the results have been used to predict loss characteristics of such composite materials under cyclic stressing. These analytical predictions are now being compared with experimental data obtained from tubular specimens covering a wide range of geometric and material construction variables. One summary of the present status of this work is being published under the title "Viscoelastic Loss Characteristics of Cord Rubber Composites" in the Proceedings of the Fourth International Congress on Vehicle Structural Mechanics, by the Society of Automotive Engineers. Further comparisons of experimental data with calculation will be published at the International Symposium on Constitutive equations to be held at the University of Arizona January 11-12, 1983. Test work is still continuing on both torsion and bending effects.

*B. F. Goodrich Tire Company

UNIVERSITY OF MINNESOTA
Department of Mechanical Engineering
Minneapolis, Minnesota 55455

35. FLOW AND HEAT TRANSFER WITH IMPINGING JETS AND WALL JETS — $ 72,000 — 01-02 81-3
R. J. Goldstein

This project is planned to provide information on flow of impinging jets and wall jets. Measurements of the heat transfer in the region of impingement will be obtained for single jets entering a still ambient, for jets entering a crossflow, and for various two-dimensional arrays of jets. In addition to quantitative heat transfer measurements for these flows, visualization techniques will be used to provide insight into the mechanism of the interaction of the jets and the local wall shear. A laser-Doppler anemometer is being developed to provide detailed measurements of velocity distributions, velocity fluctuations, and Reynolds stresses in a plane wall jet. Design of this system is complete and construction is nearing completion. Such measurements should provide precision data for testing the validity of turbulent transport models that have been suggested. To date, significant data have been obtained with a single jet; the results of several series of tests have been correlated with equations for both the peak heat transfer coefficient and the average heat transfer coefficient over various regions from the center of impingement. Also, some data have been taken for a two-dimensional array of small jets impinging on a heat transfer surface. During these latter studies, a liquid crystal system was developed for studying the features of single and multiple jet rows on a flat surface. Development of the liquid crystal technique and study of the pressure distribution near individual jets on an impinging jet plate is a new element introduced into the project as the effort got underway. It should add significantly to the initially planned scope of the project.

NATIONAL BUREAU OF STANDARDS
Office of Standard Reference Data
Washington, D.C. 20234

36. SUPPORT OF CRITICAL DATA COMPILATIONS — $400,000 — 01-05 80-6
David R. Lide Jr.

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 active during fiscal year 1982 include work on thermophysical properties of air and its components; high temperature vaporization of metal oxides; electrochemical equilibrium data on iron-water systems; thermodynamic properties of vanadium-niobium alloys; and refractive indices of optical materials; thermodynamic properties of ethylene; properties of non-aqueous solvents for battery development; solubility of coal-derived compounds; limit of superheat of liquids; chemical kinetics of excited species; atomic transition probabilities of highly ionized atoms; X-ray production cross sections; and alloy phase diagrams for systems of copper, alkali metals, and rare earths.

This project is included in the BES ENGINEERING RESEARCH program for administrative convenience. Coordination with NBS is accomplished in collaboration with the BES Chemical Sciences and Materials Sciences divisions. BES FY 1982 funds for the project were provided by the Chemical Sciences and Materials Sciences divisions.

NATIONAL BUREAU OF STANDARDS
Thermophysics Division
Washington, D.C. 20234

37. THERMOPHYSICAL PROPERTIES OF HYDROCARBON MIXTURES — $200,000 — 01-03 80-6
H. J. Raveche, N. Olien

This 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 the Thermophysical Properties Division, at the NBS-Boulder facility and the Thermophysics Division at NBS-Gaithersburg, both within the NBS Center for Chemical Engineering. The properties involved are PVT (pressure-volume-temperature), phase equilibria (liquid-vapor and liquid-liquid equilibria) and transport properties (viscosity and thermal conductivity). The apparatus will be designed for use in corrosive, highly corrosive, and sometimes toxic and flammable fluids with measurements extending to high temperatures (900 K) and high pressures (30 MPa and in some cases 70 MPa). Current work involves: 1) construction of a constant-flow phase equilibria apparatus covering the range 300-800 K with pressures to 30 MPa or more; 2) construction of a multicomponent-multiphase non-sampling cell for temperatures to 470 K and pressures to 10 MPa; 3) design and construction of new phase equilibria apparatus to cover the range 250-350 K with pressures to 20 MPa; 4) automation of an existing Burnett PVT apparatus for the range 270-470K; 5) construction of a magnetic balance densimeter for the range 270-470 K with pressures to MPa; 6) design of a torsional crystal viscometer for the range 300-750 K with pressures to 50 MPa or more; and 7) initiate design of high temperature thermal conductivity apparatus. Future work will include completion of the apparatus, performance testing, and the start of measurements on systems relating to long-term energy needs, such as polar-nonpolar mixtures found in the reaction products of the conversion of solid fuels to liquid and gaseous fuels and chemical feedstocks. In addition, other measurement techniques will be explored such as acoustic properties, light scattering, etc.

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

38. TOPICS OF INTERFACE MECHANICS $200,000 01-06
Benjamin Levich 81-3

This project is planned as a three-year, systematic investigation in the field of interface mechanics. The work has encompassed two principal efforts: one is concerned with transport and stability problems of interface mechanics; the other is concerned with the theory of turbulence and its applications. Studies of transport and stability problems are continuing and include: 1) Interface stability of thin liquid films, 2) Transport and dynamical properties of a fluid-solid interface, 3) Spreading of the films of insoluble, surface-active substances on a liquid surface, 4) Interfacial instability of an interface in the presence of an oscillatory pressure gradient, and 5) Noise and fluctuation phenomena in chemically reactive mixtures near critical points. Six studies dealing with problems involving the theory of turbulence and its applications have been undertaken: 1) Small scale, high frequency properties of a randomly stirred fluid, 2) The Hamiltonian formulation of the Euler equation and subsequent constraints on the properties of randomly stirred fluids, 3) Interaction of surface and internal waves in the theory of weak turbulence, 4) Bifurcation of wave patterns in reaction-diffusion systems, 5) A modified amplitude equation of Rayleigh-Benard convection, and 6) Nonlinear instability in a rotating fluid with a horizontal temperature gradient. A number of papers reporting results have been prepared and submitted for publication.

NORTHWESTERN UNIVERSITY
Chemical Engineering Department
Evanston, Illinois 60201

39. CONVECTIVE BOILING HEAT TRANSFER IN NARROW ANNULAR GAPS — $50,000 — 01-02 81-2
S. G. Bankoff, R. S. Tankin, M. C. Yuen

Commercial nuclear steam generators are subject to accelerated stress-corrosion due to thermal cycling in the crevices between the boiler tubes and tubesheets, probably resulting from periodic rewetting and dryout. The objective of this research is to study boiling heat transfer in these short narrow gaps, using a two-loop system, with a primary water side operating at 17 bars, and the secondary steam-water side up to 7 bars. Heat transfer coefficients over the full range of conditions, from subcooled nuclear boiling to dispersed droplet-flow conditions, will be measured. Improved correlations, taking into account the crevice L/D effect, will be thus obtained. A theoretical analysis of the periodic dryout and rewet phenomenon is also planned.

PACIFIC NORTHWEST LABORATORY
Engineering Physics Department
Richland, Washington 99352

40. AUTOREGRESSIVE MODELING FOR NONDESTRUCTIVE TESTING — $ 50,000 — 01-03 79-3
R. B. Melton

The objective of this project is to develop improved nondestructive testing (NDT) techniques by using digital signal processing and pattern recognition. A recent accomplishment was the development of a new approach for classifying NDT waveforms by modeling the waveforms using techniques from modern spectrum analysis. It was then shown that these models can be used to construct digital filters that are spectrally matched to each category of data. These matched filters can in turn be used to classify data from unknown sources. This technique is an improvement over conventional pattern recognition in that the matched filters are realized as recursive digital filters which are easily implemented in hardware. Future work will extend the use of parametric modeling and establish a general procedure for generating inverse filters to deconvolve system characteristics from observed data.

PACIFIC NORTHWEST LABORATORY
Engineering Physics Department
Richland, Washington 99352

41.	HOLOGRAPHIC INVESTIGATION OF THERMAL-NONEQUILIBRIUM VAPOR GENERATION IN TWO-PHASE FLOWS J. M. Creer, J. M. Bates, B. B. Brenden, J. L. Daniel	$100,000	01-02 81-3

The principal objective of the research is to gain a basic understanding of the thermal nonequilibrium vapor generation process. Nonequilibrium vapor generation is known to have major implications in the analysis of postulated Loss of Coolant Accidents (LOCA) for light water nuclear reactors as well as being important to the analysis and development of alternate energy sources such as geothermal, liquified natural gas, and solar. Single and double pulse holographic optical recording techniques and associated image analysis capabilities are being utilized to permit detailed three-dimensional characterization of two-phase flow fields in regions of thermodynamic nonequilibrium. Two-phase flow fields will be formed in rapidly depressurizing, recirculating flow through a specially designed convergent-divergent nozzle assembly. The first two years of the proposed three-year project have been devoted to optimizing holocamera systems, developing appropriate software for a semiautomated contrast scanner/image analysis system, and designing and procuring hardware for FY 1983 tests in a closed loop high pressure/temperature thermal hydraulic facility.

UNIVERSITY OF PENNSYLVANIA
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Engineering and Science
Philadelphia, PA 19104

42. HIGH TEMPERATURE CHEMICALLY SENSITIVE ELECTRONIC DEVICES — $100,000 — 01-03 82-3
J. N. Zemel, I. R. Lauks,
S. Yuen, J. Wei

Monitoring the chemical environment in an aqueous saline solution is a major problem in geothermal environments. Additionally, the kinetic behavior of aqueous solutions in the temperature range from 0-250 C and pressures from 0-5000 psi have not been fully investigated. The purpose of this program is to develop the scientific and technological knowledge which will permit real time analysis of the chemical behavior of aqueous saline solutions in this temperature and pressure regime.

The approach adopted has been to develop a chemically sensitive electronic device based on a specially designed and constructed gate controlled diode (ICD). These devices have been demonstrated to operate up to 200 C. IrO reactively sputtered films have been shown to survive 200 C at 4000 psi in distilled water for periods in excess of four hours without any observable degradation.

In the past six months, a four element (ion) structure has been designed and preliminary data obtained on its operation. Continuing measurements on IrO stared in water for a year showed that the layers would survive with a pH response that was reproducible to better than 10mV. Continued efforts are planned on characterizing the IrO layers and completing the four element sensor.

PENNSYLVANIA STATE UNIVERSITY
Department of Mechanical Engineering
University Park, Pennsylvania 16802

43.	THE OFFSET STRIP FIN-- A GENERALIZED UNDERSTANDING OF ITS PERFORMANCE CHARACTERISTICS Ralph L. Webb	$ 10,000	01-02 79-3

This research is concerned with developing a generalized method to predict the friction factor of the offset-strip-fin that is used in compact heat exchangers. Data on eight geometrical arrays has been completed. The major work completed in the past year is the development of a theoretical model to predict the friction factor. This model assumes laminar flow on the fin surface, and in the wake region. The model predicts the low Reynolds number data of the eight test arrays within 12%. The model underpredicts the data in the higher Reynolds number region, because the assumption of laminar flow is violated. A semi-empirical correlation was developed to allow prediction of the friction factor over a wide range of Reynolds numbers. The theoretical model and correlation were shown to do a good job of predicting the friction factor in actual heat exchanger geometries. After completing several sets of data, the program will be done.

RICE UNIVERSITY
Department of Chemical Engineering
Houston, Texas 77251

44. MEASUREMENT AND PREDICTION OF LIQUID MIXTURE THERMAL CONDUCTIVITY AND VISCOSITY — $ 41,000 — 01-05 82-3
R. L. Rowley

Accurate liquid mixture thermal conductivities and shear viscosities will be measured in binary and ternary liquid mixtures as a function of temperature and composition with emphasis on those systems containing at least one polar component. The experimental data will be used to develop further, test and refine a local compositional model for prediction of multicomponent liquid mixture transport properties that properly accounts for the observed composition and temperature behavior. In spite of the importance of these mixture properties in energy technology, existing models and correlations are either inaccurate and inadequate or require multiple adjustable parameters on each specific system. A high-precision capillary viscometer is now in operation. Binary and ternary viscosity studies are being conducted over a wide temperature and pressure range to test a newly developed local composition model for shear viscosity. In particular, ternary predictions are being compared to experimental data to test the use of binary interaction terms in ternary systems. A new parallel plate, steady state, thermal conductivity cell capable of making rapid and accurate determinations of liquid mixture thermal conductivity is in the final stages of design. This apparatus will allow accumulation of heretofore almost nonexistent ternary mixture data for refinement of the local composition model already developed and tested on binary mixtures.

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

45.	SOME BASIC RESEARCH PROBLEMS RELATED TO ENERGY Kenneth M. Case, E.G.D. Cohen, Mark Kac	$ 61,000	01-06 81-2

This project is concerned with investigations of three specific areas: 1) The prediction and evaluation of thermophysical data of fluids and fluid mixtures, 2) The statistical problems which arise in oil exploration, and 3) 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. Work is also underway to develop and test various methods of estimating the number of oil pools in an area from a number of random drillings. 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.

RUTGERS UNIVERSITY
Department of Mechanics and Materials Science
Piscataway, New Jersey 08854

46. STRESS CREEP OF STRUCTURAL METALS G. J. Weng	$ 33,000	01-04 81-2

The project is concerned with the study of creep behavior of structural metals at elevated temperature. Traditionally, creep deformation has been studied exclusively either from the phenomenological standpoint without looking into the properties of microstructure, or from the metallurgical standpoint without much concern with the macroscopic behavior under combined stress. This project, taking the physics of microscopic deformation as the basis, but aim at the overall macroscopic behavior to provide a physically consistent theory to describing the creep deformation under practical working conditions. The first result established a theory capable of describing the unified time-independent plastic deformation and time-dependent creep deformation for structural metals under relatively high stress at an elevated temperature. Another result is directed toward the elucidation and prediction of enhanced tensile creep deformation of structural metals when a cyclic torsional strain is also acting on the material. This consequence of creep acceleration is particularly relevant to design. The study of relaxation behavior is currently underway.

SANDIA NATIONAL LABORATORIES
Device Research Division
Albuquerque, New Mexico 87185

47. HIGH TEMPERATURE ELECTRONICS $ 45,000 01-03
R. J. Chaffin, L. R. Dawson, 80-3
D. R. Myers, T. E. Zipperian,

This project addresses fundamental engineering questions relevant to the development of high temperature (up to 500 C) electronics for energy technologies. Included are sensors, passive components, and active semiconductor devices which provide electronic gain. The work has concentrated on gallium phosphide (GaP) and aluminum gallium arsenide (AlGaAs) semiconductor diodes and on gallium phosphide/aluminum gallium phosphide (GaP/AlGaP) heterojunctiondiodes and bipolar transistors. An ion-implanted, p n homojunction diode was successfully fabricated in GaP. A heterojunction GaP/AlGaP biolar transistor has shown useful transistor action from -195 C to 550 C. Initial results from this project have shown that it is possible to build active semiconductor devices for very high temperatures. Future plans include developing stable metallization systems for these devices and developing device geometries and processing techniques compatible with a high-temperature integrated circuit technology.

SANDIA NATIONAL LABORATORIES
Combustion Sciences Directorate
Thermofluids Division
Livermore, California 94550

48. CONVECTIVE DROPLET VAPORIZATION AND COMBUSTION — $100,000 — 01-05 81-3
B. R. Sanders, H. A. Dwyer,
A. R. Kerstein,

The technical goal of this project is to develop a complete analysis of liquid droplet vaporization and combustion processes through single droplet modeling and a statistical approach to multidroplet interactions. First, an analysis of liquid droplet vaporization and combustion will be developed by solving the coupled shear-driven recirculation flow within the droplet and the external convective gas-phase flow past the droplet, where a differential velocity exists between the droplet and free stream. Second, a statistical approach will be developed to study the combustion of a large ensemble of droplets whose locations and sizes are randomly distributed. The detailed solution of individual droplet heating and vaporization will be used as empirical inputs to the statistical spray combustion model. The single droplet numerical model has been extended to include variable transport properties in liquid and gas phases, complete separated fluid mechanics, and mass transport at the droplet surface. Additionally, a combusting spray was modeled where droplet interactions influence the connectedness of the flame zone (localized pockets of flame vs. a single connected continuum). Percolation theory has been used to identify the transition between these regimes, and to derive the dynamics of this transition as burnout proceeds in a simple spray geometry. This is the first known application of statistical methods to the problem of flame zone connectedness, a previously unresolved question of long standing.

SCIENTIFIC SYSTEMS, INC.
54 Rindge Avenue Extension
Cambridge, Massachusetts 02140

49.	ELECTRICAL COMPONENTS MODELING TECHNIQUES FOR EFFICIENCY AND STABILITY ANALYSIS J. Baillieul, R. B. Washburn	$ 0	01-03 80-2

The objective of this research project is to develop a theoretical framework for the design and control of pulse-modulated energy conversion systems, and to identify and analyze stability problems for such systems. A particular kind of instability which has been shown to occur in nonlinear feedback models of pulse-modulated energy conversion networks involves bounded, aperiodic, non-asymptotically stable motions. This type of chaotic behavior has been the primary focus of the first year research effort. While a complete theory of chaotic dynamics does not currently exist, a large body of literature is now available in prominent mathematics and physics journals. Work is being done to extend existing theory, and to find ways to tailor new and classical results to the nonlinear feedback models which describe energy conversion circuits. Both continuous and discrete time models are being considered, and the connections with classical problems in ergodic theory are being explored.

SKF INDUSTRIES, INC.
Technology Services Division
1100 First Avenue
King of Prussia, Pennsylvania 19406

50.	LUBRICATION OF ENGINEERING SURFACES - II J. I. McCool	$ 0	01-01 80-2

The objective is to study on the characterization of bearing surfaces for applications in the design of high performance traction drives, gears, bearings, etc.. Software developed in a previous project uses a simulation model to determine the real contact area, load, and asperity pressure when two microscopically rough surfaces are brought into contact. These values measure the severity of the contact and hence the propensity for wear and surface fatigue. The model is driven by nine parameters (bispectral moments) which describe the statistical microgeometry of a general anisotropic surface. The model assumes that the surface heights, shapes, and curvatures follow a multidimensional gaussian distribution and that the surface asperities are mechanically and statistically independent. In the current project the effort has been devoted to: 1) quantification of the random and systematic errors incurred in processing stylus profile data to obtain the nine surface parameters as functions of the processing parameters, e.g., sampling frequency and sample length; 2) assessing the effect of the multidimensional gaussian assumption on predictions of the contact conditions; 3) assessing the effect of the assumption of mechanical and statistical independence of asperities; and 4) developing rules for setting a filter pass band for surface profile processing to yield values of the roughness parameters appropriate for specific applications.

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

51. ENERGY CHANGES IN TRANSFORMING SOLIDS — $ 90,000 — 01-04 82-4

George Herrmann, David M. Barnett
A. Golebiewska-Herrmann

This project, is concerned with enlarging our capabilities in analyzing energy changes accompanying diverse deformation and fracture processes in solids. A powerful method for characterizing energy changes of cracks and voids is based on (material) conservation laws. The basic quantity of interest in this connection is the so-called material momentum tensor, which plays a role analogous to the stress tensor. Several problems are currently under study. One involves energy changes associated with a circular void near a traction-free plane boundary; another explores the type and number of conservation integrals which might be established in shell theories. The calculation of the redistribution of solute impurity atoms near a stationary edge dislocation has been performed. Similar computations by previous investigators either erred mathematically or neglected to account properly for conservation of solute mass. The results of this calculation are significant for understanding a variety of physical phenomena ranging from impurity strengthing mechanisms in solids to gettering of impurities in semiconducting materials. The extension of this calculation to a moving edge dislocation is currently being undertaken in order to predict both solute redistribution and the solute drag force on the moving edge dislocation. An initial study of the proper prescription for defining chemical potentials of mobile diffusing species in inhomogeneously non-hydrostatically stressed solids is also being made.

STANFORD UNIVERSITY
Edward Ginzton Laboratory
Stanford, California 94305

52. HIGH FREQUENCY TRANSDUCERS $ 88,000 01-03
G. S. Kino 81-3

This research project has as its aim the development of high-frequency acoustic transducers suitable for nondestructive testing. During the year we have developed new kinds of acoustic transducer arrays suitable for use with acoustic imaging systems. These shear wave arrays use a metal buffer rod of the same material as that being examined and excite a shear wave at an angle of approximately 45 degrees to the surface. By this means we can make excellent contact to the material being examined and obtain very good acoustic wave images of cracks and other flaws in the materials. We have also been developing new techniques for the design of transducers in the 10-100 MHz range. In particular, we have arrived at new methods for constructing 50 MHz transducers, making use of our adaptive theory for the design of electrical and acoustic matching circuits. We have developed new techniques for constructing very thin piezoelectric layers for operating at 50 MHz. We are also constructing new types of focused transducers with the aim of making quantitative measurements of material properties with a 50 MHz acoustic microscope.

STANFORD UNIVERSITY
Mechanical Engineering Department
Stanford, California 94305

53. A NEW METHOD FOR PREDICTING MULTIAXIAL FATIGUE DAMAGE — $ 62,000 — 01-04, 81-3
D. V. Nelson

The objective of this project is to develop an improved, method for predicting the fatigue life of components which experience multiaxial cyclic straining. Existing methods are known to have deficiencies, such as an inability to account properly for the fatigue damage due non-proportional straining, often encountered in service. A test program is underway to provide a critical check of a promising new method which relates computed multiaxial cyclic plastic work to fatigue life, using only uniaxial fatigue and cyclic stress-strain properties as data input. Specimens of A533B pressure vessel steel are being tested in deflection-controlled, combined bending and torsion, applied both in-phase and 90 degree out-of-phase, at two different fixed ratios of bending-to-torsion strain, and at a number of different strain amplitudes to produce lives ranging between 10 to 10 cycles. The life to formation and subsequent growth rate of cracks from 0.1 mm size till fracture (10 mm size) are being recorded. Future tests will use specimens made from Type 304 stainless steel. In addition to providing a check of the plastic work approach, the data being generated in this project, as well as data being received from other researchers, will also be used to evaluate two other recently proposed life prediction methods, both of which assume multiaxial fatigue behavior is governed by critical combinations of maximum shear strain amplitude and the normal strains acting on planes of maximum shear.

STANFORD UNIVERSITY
Department of Chemistry
Stanford, California 94305

54.	EXPERIMENTAL AND THEORETICAL RESEARCH ON EFFICIENCY OF CHEMICAL, THERMAL AND COUPLED PROCESSES J. Ross	$45,000	01-06 82-4

Periodic perturbations of oscillatory reactions lead to resonance effects and the possibility of increased efficiency in energy transduction and power production. This research program is concerned with the coupling of chemical reactions with thermal and other engines; and resonances due to inertial effects, due to chemical reactions, and due to both causes. Conditions are sought for a given cyclic engine near resonances which maximize defined efficiencies and minimize dissipation. Research is planned on optimization of cycles for combined thermal and chemical engines and a search for upper limit theorems of the efficiency of chemical engines with non-zero throughput (reaction rates). The first year of the program consists of theoretical studies.

STANFORD UNIVERSITY
Department of Civil Engineering
Stanford, California 94305

55.	MOMENTUM AND HEAT TRANSFERS IN A COMPLEX, BUT WELL-DEFINED TURBULENT FLOW R. L. Street	$73,000	01-02 81-3

A basic study of a three-dimensional, variable density, recirculating flow 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 visualization has been carried out for flows in which the fluid is either 1) homogeneous or 2) stably stratified. 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-type (TGT) vortices, and the strength and the development of the thermocline in the stratified cases. Direct heat flux measurements and LDA measurements of velocities are being made. Comparison has been made with both two- and three-dimensional numerical codes. Some codes fail to represent accurately the flow because of defects in their formulations. However, several correctly formulated codes do reproduce the experimental results for laminar flows quite well, except for the TGT vortices which are not found in the numerical results. Turbulent flow cases and code modifications are to be examined.

STANFORD UNIVERSITY
Mechanical Engineering Department
Stanford, California 94305

56. OPTIMAL ENGINEERING DESIGN WITH UNCERTAIN PARAMETERS — $ 70,000 — 01-03 81-2
Douglass J. Wilde

Choosing the right sizes of system components, an important phase of any engineering design, becomes difficult when parameters -- requirements, properties, and costs -- cannot be predicted with certainty. This research aims to provide exact or approximate closed-form solutions of every deterministic problem generated by a change in design parameters, and to strengthen the foundations upon which a useful and rigorous probabilistic design optimization theory can be constructed. During the project's second year an article on hidden monotonicity was published as one result from the previous year's study of a magnetohydrodynamics plant optimization. Another paper extending the previous year's work on Gauss' algorithm in mechanism design exposed such pathologies as degeneracy and multiplicity, and showed how to handle them. Some promising new results applicable to optimization of the difficult signomial functions of engineering design are now under development.

SYSTEMS ENGINEERING FOR POWER, INC.
226 Maple Avenue West
Vienna, Virginia 22180

57. SPATIAL CORRELATION FACTORS IN WIND ENERGY SYSTEMS — $ 62,000 — 01-03 81-2

G. L. Blankenship,
L. H. Fink

Two aspects of the dynamics of wind energy systems are being considered in this study. Both are related to the impacts of spatial correlation in the variations of the wind energy distribution on the dynamical behavior of wind turbine systems. In the first case the paths of an array of wind turbines distributed over a large, contiguous area raises the possibility of energy exchanges among the machines through electromechanical interconnections in response to random variations in the space-time distribution of wind energy. The potential destabilizing effect of non-uniform energy distributions under both transient and steady state conditions is of special interest. It has been shown that certain coupling geometries promote energy exchanges, and hence instabilities, and that others have the reverse effect. In the second part of this study the effects of local turbulence in the wind flow on the dynamics of a single wind turbine are of interest. Given the blade dimensions (150-300 ft) and flexibilities associated with large turbines and other features of the turbine design, it is not unlikely that local, random variations in wind energy distribution across the swept area of the blades could induce oscillatory behavior in the electrical output of the turbine. Assuming that the local turbulence fluctuations are random and rapidly varying, exact stability boundaries have been computed for a linear model of the blade/wind dynamics. Current research is aimed at improving the model and understanding the coupling of these effects to the generator electromechanical system.

T. S. ASSOCIATES, INC.
Suite 200
11065 Little Patuxent Parkway
Columbia, Maryland 21044

58. IMPROVEMENTS IN THE HYDRAULIC DESIGN OF ROTARY DRILL BITS USED IN DEEP-HOLE DRILLING $ 0 01-01 81-1
T. R. Sundaram

The general objective is to develop a phenomenological model for the hydraulic removal of broken rock "chips" from the cutting faces of diamond drill bits used for drilling deep holes through hard rock formations. The overall effectiveness of the drilling, as well as the bit life itself, depend not only on the breaking of the rock by the diamond cutters, but also on the speedy removal, by a circulating mud slurry, of the rock fragments away from the cutting zone. Therefore an understanding of the chip-removal process, and of the proper procedures for the provision of flow channels on the bit face to control the flushing action, are important elements in improving drilling technology. In order to facilitate practical application of the results being developed, they are being expressed in terms of current industry practices. Work to date has concentrated on identifying the fluid dynamical phenomena that need to be included in a comprehensive model.

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

59. BIFURCATIONS AND FLUCTUATIONS IN FAR FROM EQUILIBRIUM SYSTEMS $100,000 01-06 81-3
Ilya Prigogine

In many instances, physico-chemical systems give rise to self-organization and complex behavior. Bifurcations and fluctuations constitute the basic mechanism of evolution far from thermodynamic equilibrium. The purpose of this research is to explore the implications of bifurcations and fluctuations in the modeling, design and stability of complex systems of interest in physics and engineering. Special emphasis is being placed on the following two aspects. First, the effects of temperature fluctuations on the performance of chemical reactors is being examined in connection with the onset of explosive behavior. Second, the coupling between a complex system and its environment is being considered. Previous work has shown the possibility of a new type of transition induced by environmental noise and external fields. The repercussion of these transitions is being studied for systems involving multiphotonic steps.

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

60. HEAT TRANSFER IN OSCILLATORY FLOW — $59,000 — 01-02 82-4

D. P. Telionis, T. E. Diller

The response of the velocity field and heat transfer of a single cylinder and bundles of cylinders to forced oscillations of the mean stream is investigated. Parallel experiments are conducted both in a wind tunnel and a water tunnel. In the first facility the emphasis will be given to heat transfer, whereas in the second the flow will be examined in detail via Laser-Doppler Velocimetry and Flow Visualization. Analytical efforts will be 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. Special attention will be directed at determining the range of parameters in which the overall heat transfer is improved with simultaneous decrease of the flow resistance. A scaled-down version of the proposed oscillating tunnel has been designed, constructed and calibrated. Design modifications have led to a well-defined sinusoidally oscillating flow. The necessary elements for modifications of the VPI water tunnel have been designed and fabricated. Preliminary tests of heat transfer and flow measuring equipment have been conducted.

UNIVERSITY OF WISCONSIN
Department of Chemical Engineering
Madison, Wisconsin 53706

61. THE DEVELOPMENT OF PROCESS DESIGN AND CONTROL STRATEGIES FOR ENHANCED ENERGY EFFICIENCY IN THE PROCESS INDUSTRIES — $130,000 — 01-03 80-3

M. Morari, 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 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 networks, 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 developments are under way.

BUDGET NUMBER INDEX

Number

01-01

Includes projects concerned with research related to friction and wear. See project numbers:

8, 18, 33, 34, 50, and 58

01-02

Includes projects concerned with research on the effects of turbulence, vibrations and noise, and heat transfer. See project numbers:

2, 5, 7, 9, 11, 12, 14, 17, 20, 27, 30, 35, 39, 41, 43, 55, and 60

01-03

Includes projects concerned with research on adaptive control systems, non-linear systems, modeling, sensors for hostile environments, and NDE instrumentation. See project numbers:

1, 6, 13, 15, 19, 21, 24, 25, 26, 28, 29, 32, 37, 40, 42, 47, 49, 52, 56, 57, and 61

01-04

Includes projects concerned with research on the macroscopic aspects of elastoplastic deformations and of crack propagation in structural materials. See project numbers:

3, 4, 16, 46, 51, and 53

01-05

Includes projects concerned with research on data bases, lean mixture ignitions, and modeling of real combustion systems. See project numbers:

22, 36, 44, and 48

01-06

Includes projects concerned with research on analysis of non-imaging optics, and noise and fluctuations in non-linear systems. See project numbers:

10, 23, 31, 38, 45, 54, and 59

PROJECT TITLES

PROJECT TITLES

PROJECT TITLES

PROJECT TITLES

PROJECT TITLES

INVESTIGATOR INDEX

United States
Department of Energy
Washington, DC 20545