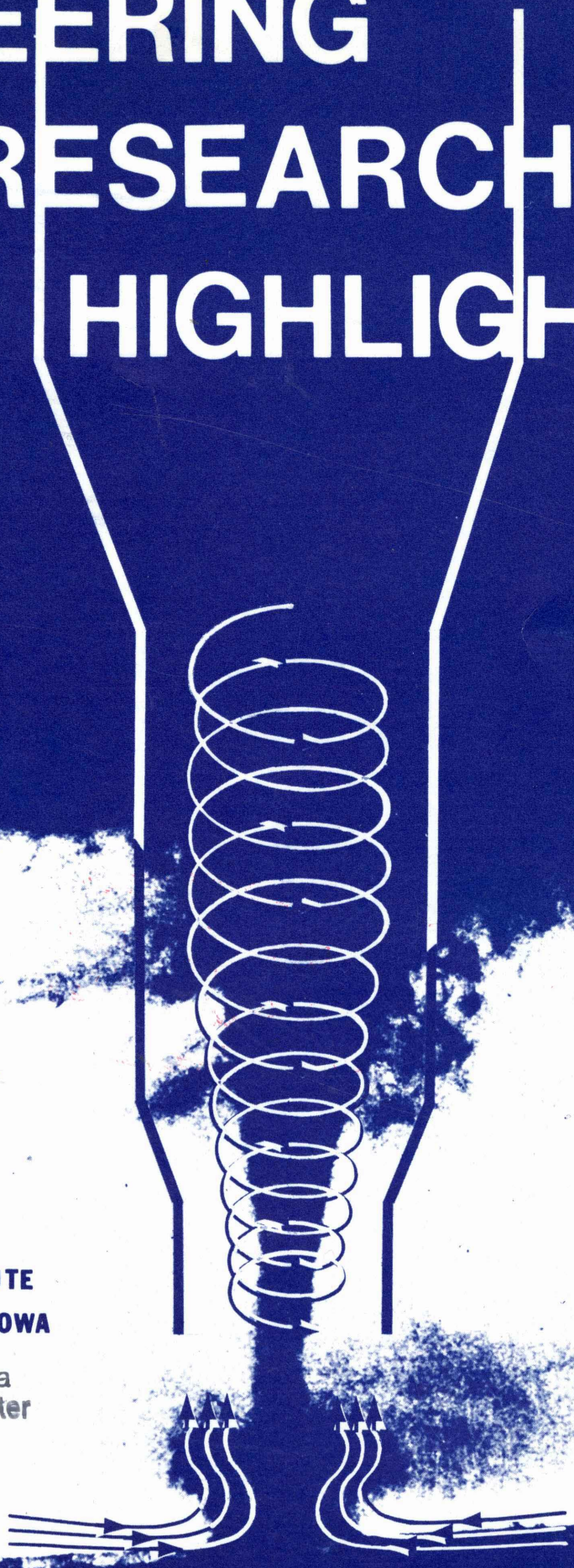
ENGINEERING RESEARCH HIGHLIGHTS



ENGINEERING RESEARCH INSTITUTE
IOWA STATE UNIVERSITY, AMES, IOWA
1975

Cover design by JoEllyn Buckmaster. Superimposed on the tornado shown is a sketch of the vortex generation device developed by Dr. C. T. Hsu, Department of Aerospace Engineering. For further information, see Tornado Simulation, page 2.

Preface

ENGINEERING RESEARCH HIGHLIGHTS provides a brief review of some of the research projects being supported by the Engineering Research Institute of Iowa State University. The Institute is the research administration and services arm of the College of Engineering and is engaged in encouraging, promoting, and supporting research in all the engineering disciplines. The involvement of the Engineering Research Institute in research is an involvement in the academic program of the College. Both research personnel and research projects are integrated with departmental goals. The academic staff participates in both teaching and research; however, as the occasion requires, staff may become involved in full-time research.

Research programs are conceived to be a vital part of a sound educational program and, in addition to providing new knowledge, provide the framework for: (1) the development and maintenance of a competent university staff; (2) an experimental base for a good graduate program; (3) communication of results, information, and principles resulting from research investigations; and (4) a commitment of the College to serve the community and government.

Funds for the research programs are obtained from state appropriations, industrial contracts, and government grants. Available funds for the fiscal year 1974-75 amounted to about $3,550,000 These funds were provided from the fol lowing sources:

Federal Funds	$1,485,000
Private and State Funds	$ 315,000
University Funds	$1,750,000

Approximately 125 staff members are actively engaged in research. About 120 graduate students are gainfully employed, as well as provided with a viable research atmosphere that supports a significant graduate program. About 100 master's degrees and 40 doctoral degrees were awarded during the past year.

Of the more than 170 research projects only a few are reported in any detail in this issue. Inquiries are invited about any of the ongoing research projects.

Paul W. Peterson
Director, Engineering Research Institute

ENGINEERING RESEARCH HIGHLIGHTS

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Features in this issue

ENGINEERING RESEARCH HIGHLIGHTS is a publication of the Engineering Research Institute, College of Engineering, Iowa State University, Ames, Iowa. The objectives of ENGINEERING RESEARCH HIGHLIGHTS are to acquaint readers with the engineering research activities and capabilities of the Research Institute and to promote engineering education and research at Iowa State University.

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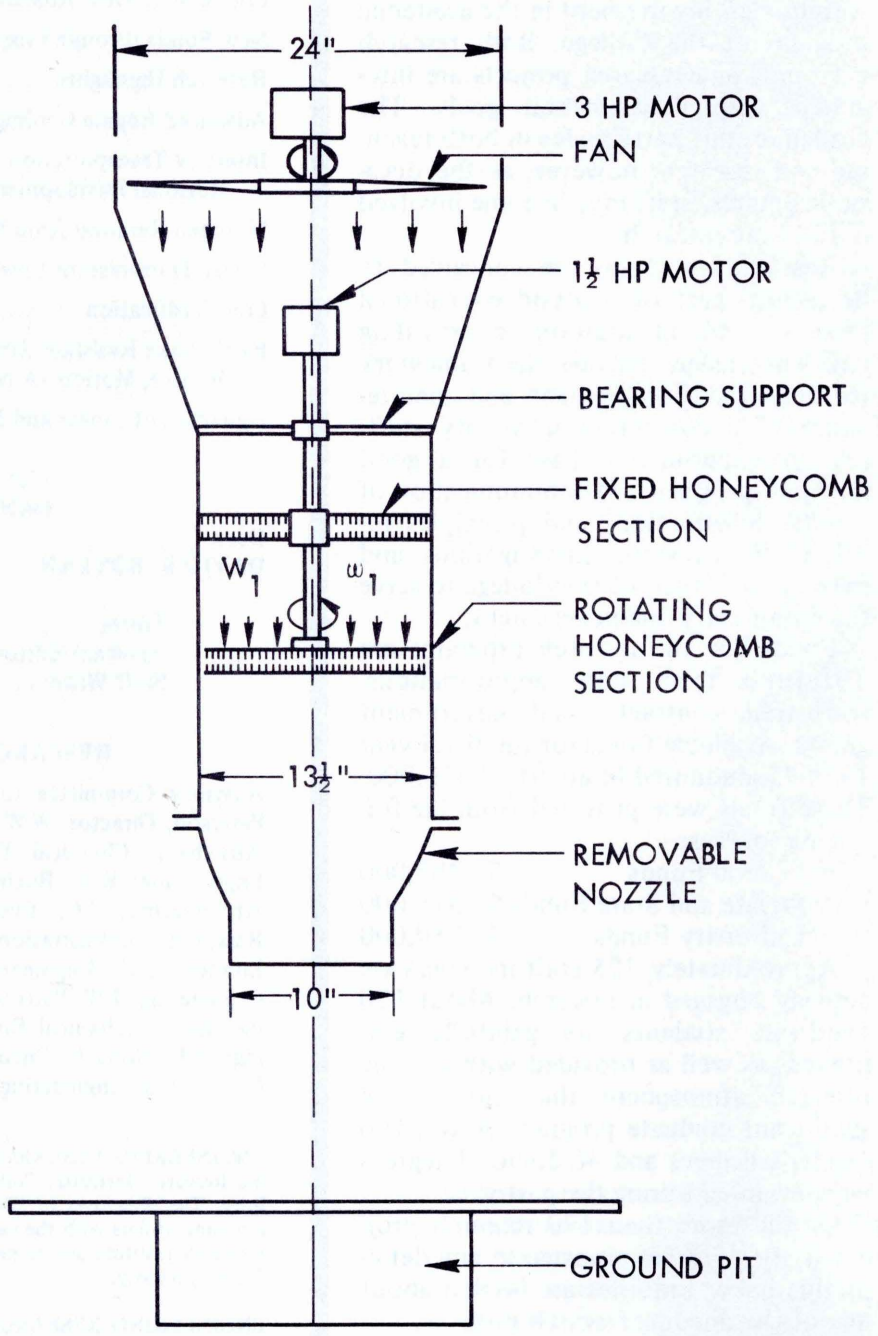
TORNADO SIMULATION

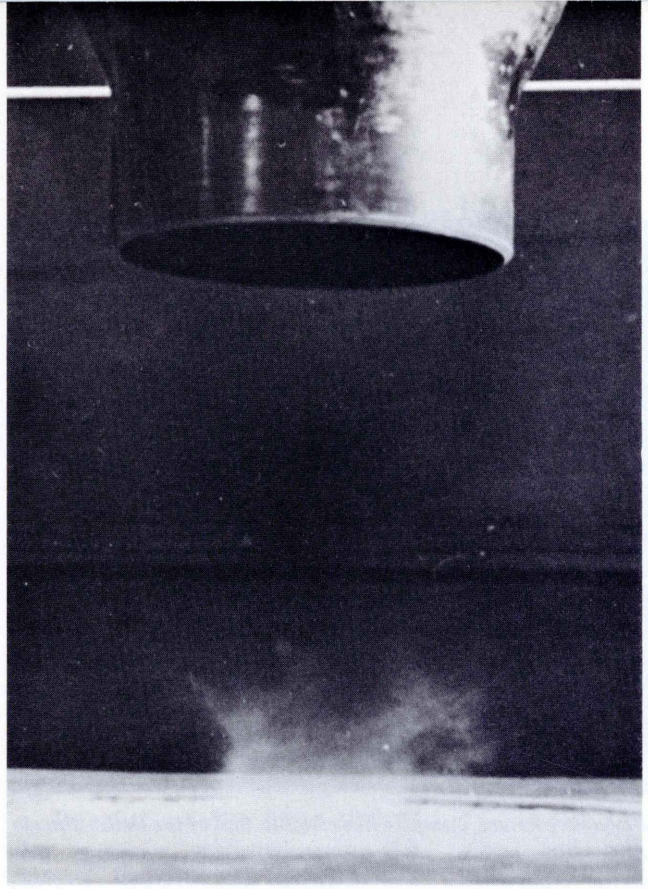
Tornadoes are responsible for over $75 million worth of damage to homes and businesses each year. As yet, however, the phenomenon is poorly understood, and means of controlling or preventing tornado damage have yet to be developed. At ISU, Drs. Cheng-Ting Hsu and Frederick W. Stuve of the Department of Aerospace Engineering are concerned with this problem. They are involved in research directed toward the increased understanding of tornado behavior. This research is supported by the National Science Foundation and the Engineering Research Institute and has been in progress since 1971.

One reason the tornado and its flow field are not well understood is simply that the phenomenon is too dangerous to observe. Laboratory simulation of the tornado flow field would allow observation without danger. According to Dr. Hsu, there have been many attempts at laboratory simulation; however, the existing laboratory set-ups can only demonstrate the principle of "vortex formation" in the clouds; they do not simulate the touchdown phenomenon on the ground.

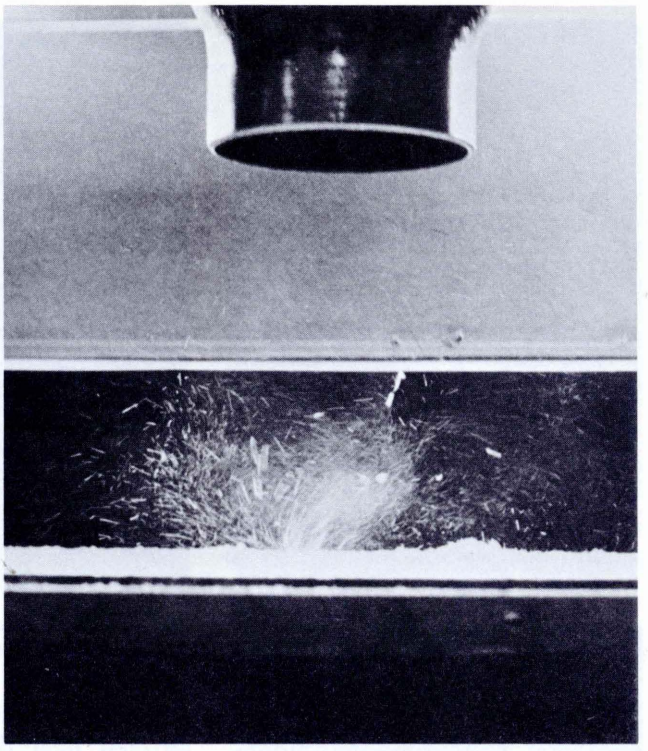
In 1971, Dr. Hsu became interested in why tornadoes are able to produce such large suction forces and mysterious motions on the ground. He then designed a new device for vortex generation (see figure at right). In this device, swirling flow is produced by passing air through a rotating honeycomb section and is then thrown out from the nozzle exit to simulate the rotating clouds of a tornado. Dr. Hsu explained that the interaction of this vortex flow with the earth's



Vortex generator designed by Dr. Hsu.



Flour dust cloud. Flour originally stored in the ground pit is sucked up in a circular cylindrical shape with a hollow inner core and is then thrown outward.

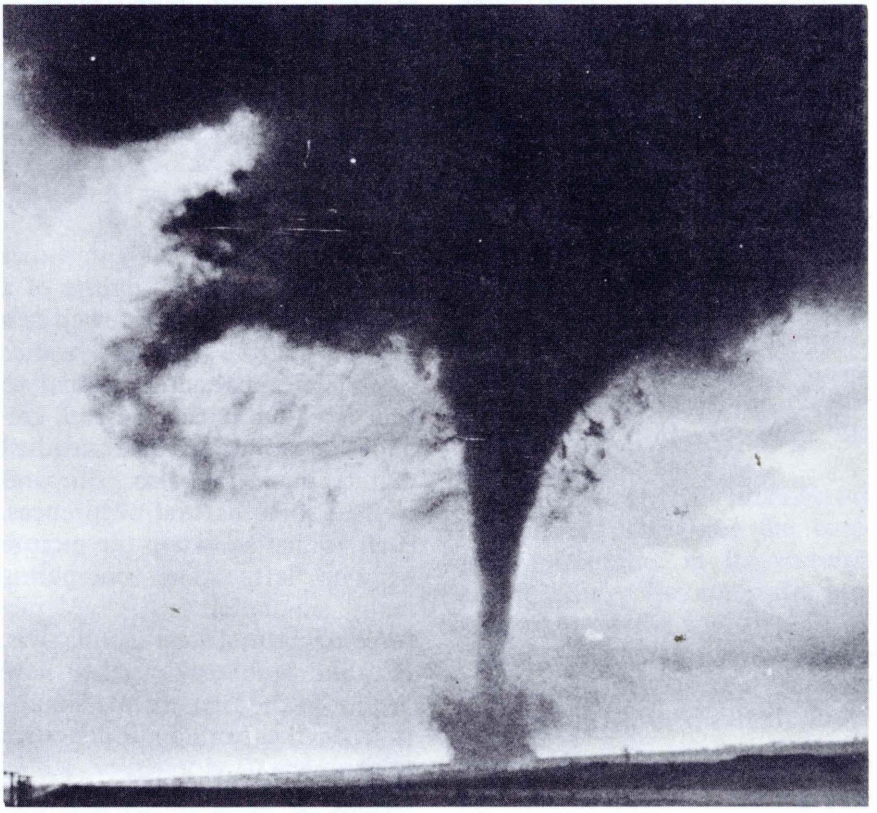


Sawdust cloud of conical shape.

boundary layer is responsible for the tornado-suction mechanism.

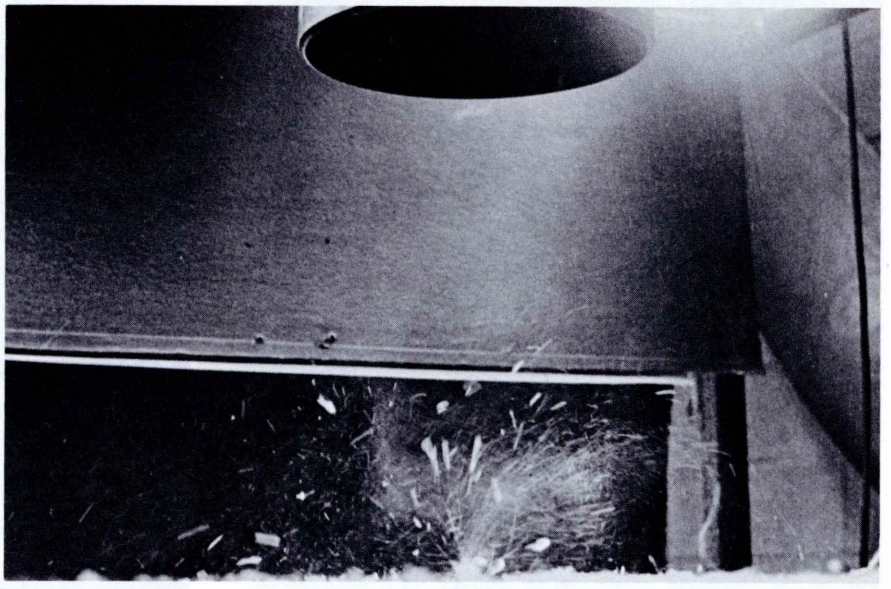
The pictures at the top of the page compare two simulations with a real tornado. The simulations compare well with the dust clouds of natural tornadoes such as the Dallas tornado (1957) shown at the right. The dust cloud of the Dallas tornado was about 500 ft. tall. Dr. Hsu noted that the tornado funnel is the water condensation boundary, which cannot yet be simulated in the present laboratory set-up, and therefore does not appear in the two left-hand simulation pictures.

Dr. Hsu explains the theory behind the characteristic motion of tornadoes. "Above the earth's boundary layer, the centrifugal (outward-directed) force of the swirling motion is balanced by the inward, radial pressure gradi-



Dallas tornado, 1957. Compare the tornado dust cloud with the flour and sawdust simulations produced by the vortex generator.

Exploding dust cloud of the Dallas tornado.



Sawdust cloud of violent explosive nature. Compare this cloud to that of the Dallas tornado pictured at the left .

ent. However, this balance is destroyed near the ground due to the frictional retardation of the tornado's tangential motion. The excessive inward radial pressure gradient will build up a centripetal (inward-directed) force which, in turn, produces the horizontal convergence of wind and a large updraft velocity near the outer edge of the dust cloud.

The picture at right shows the violent explosive nature of a sawdust cloud. When viewed in a motion picture, the appearance of this phenomenon is similar to that created when a hand grenade is exploded. The sawdust cloud simulation also compares well to some natural occurences, such as that shown in the picture at the left. After comparing many simulated dust cloud pictures of natural dust clouds, Drs. Hsu and Stuve believe they have produced the first correct simulation of the tornado touchdown phenomena.

At present, a large tornado simulation wind tunnel with a much more sophisticated design is under construction. The new project is jointly supported by ISURF, ERI, and the Department of Aerospace Engineering. The vortex generating device in the new tunnel is made primarily of plexi-glass, and the blowing fan is replaced by a commercial blower.

When the tunnel is complete, velocity and pressure measurements of the entire flow field will be carried out. Later, structure damages will be modeled for the purpose of developing structural designs which will better withstand tornado disasters. In particular, protection of nuclear reactor plants and waste fuel storage from incident tornado passages will be examined during this phase of research.

It is to be hoped that a thorough understanding of tornadoes developed through this and similar research projects may also lead to the development as means of modifying or even preventing torandoes.

Planning and Evaluation
ELECTRICAL POWER DISTRIBUTION

Service to Iowa utilities and engineering firms is provided by the Engineering Research Institute at Iowa State University through the implementation of the Power System Computer Service. "The computer service is a cooperative effort by industry and the university to try and understand the nature of large-scale power networks and the methods of solution," says Professor P. M. Anderson of Electrical Engineering.

Because of the large size of the power networks in the United States, the solution of complementary programs requires the use of the large-scale digital computers available at Iowa State. "The preparation of computer programs for such networks is itself a major effort which has involved several of the Electrical Engineering faculty for nearly a decade," Anderson says.

The computer service program provides two types of service to Iowa's industry. The first type is that of problem solving. The company submits data which describe the power network of the firm. The data are coded for computer use, the computer solution is obtained, and the results are mailed back to the firm.

The second type of service is that of program preparation. Special versions of university programs are made available to the users of the computer service at a nominal charge. "A number of users have been able to take advantage of this service option to do much of their computing in-house at great savings," Anderson says.

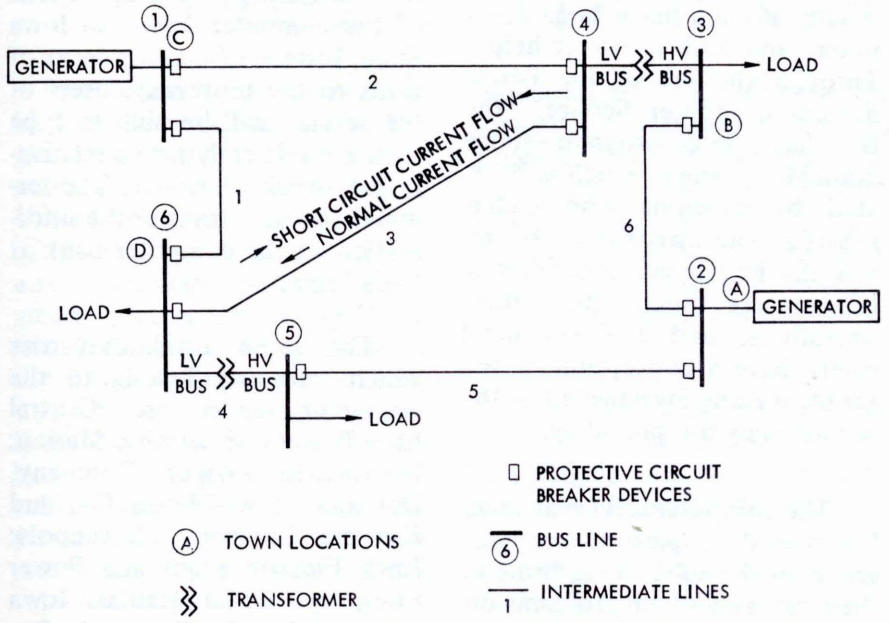
There are three basic types of programs that are handled by the computer service. The first is the load flow program which uses the forecasts of the loads on a normal network and determines whether or not the system will be able to satisfy those loads. The load flow program is particularly useful in the construction of new system transmission lines.

A second type of program deals with a network under short-circuit conditions. A program which solves the problems of networks under transient conditions is the third kind handled by the computer service. The programs dealing with networks under transient conditions are costly to operate because of the complexities involved in obtaining a solution. Such programs are utilized in reliability studies.

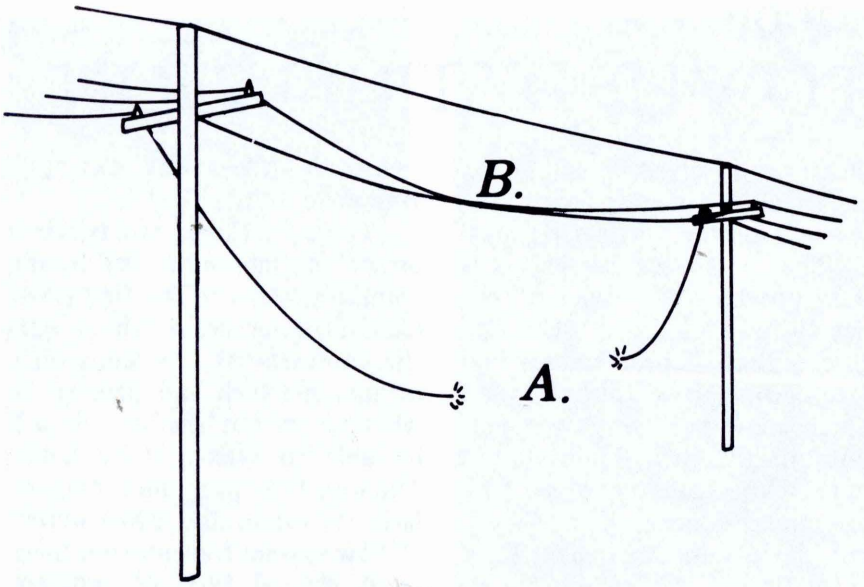
The computer service provides a mutual benefit for both the subscribing companies and Iowa State. The Electrical Engineering Department gains by having programs available for its own use. Since computer programs require continual maintenance and revision, the service makes it possible to keep the programs up to date.

The Electrical Engineering Department also uses the computer programs in its research and teaching. The computer programs solved for the Iowa utilities and engineering firms are often reduced to smaller versions for use by Iowa State students.

From such programs, students are able to practice solving problems in design optimization.



Typical 6-bus power system. For planning, programs can analyze the system for adequacy to handle predicted demand growth and indicate where new transmission lines are required to handle larger demands without overloading any one component in the system. Other programs can predict the amount of current flow through each line in the system under various conditions, indicating what capacity lines must have to handle the expected demands on the system.



A. Line downed by ice storm. B. Temporary short, lines touching. As indicated on the previous figure, flow character changes under short circuit or break conditions. Protective circuit breakers interrupt current flow when a preset current flow toward the short or break is reached. The circuit will automatically open in a short time. As long as abnormal conditions exist, the line will be caused to remain open until reclosed manually. Computer programs can predict what current flow will occur under short circuit conditions; this varies from line to line in the power system, and circuit breakers must be set differently for each line.

Practice in using programs that include practical operating data is invaluable to the electrical engineering students.

The Power System Computer Service originated in the late 1940's with the design and construction of an alternating current (AC) network analyzer. Fairly large systems could be represented with the network analyzer, which was operative until 1965. Eleven Iowa and Nebraska utilities subscribed to the analyzer service offered by Iowa State.

By 1965, it was feasible to solve large-scale programs on the digital computer. Working with a digital computer is more economical than a network analyzer and solutions for much larger systems can be obtained more quickly.

Currently, there are seven Iowa industries which subscribe to the computer service. "The companies in Iowa are not large," Anderson explains. "They usually do not have large computers and look to us for help." Through the use of the Power System Computer Service, "the firm has a large program service available to them which is operated by someone who understands the problem being solved." Private computer service bureaus are usually mechanical operations, and the personnel rarely have a conception of the problem being investigated or the service they are providing.

The computer service at Iowa State sends copies of the programs to the subscribing firms so they can run small problems on their own computers. "We'll probably work ourselves right out of work," Anderson says, "as these firms purchase larger computers of their own."

To be members of the computer service, the users are charged a fixed rate. An extra computer charge is added for each job solved at Iowa State. The additional charge covers the cost of the use of the programs.

All money accumulated by the computer service is directed back into the project. During 1973, computer service money made it possible for one graduate student at Iowa State to work with the timely topic of equivalent circuits. In the future, a new fault program may be designed. Although the design of a new fault program will not involve any research at first, it will generate research of its own; there is virtually no end to the improvements that can be made on computer programs.

The advent of small computer terminals which can be purchased by the subscribing firms will simplify the operations of the computer service at Iowa State. Instead of mailing decks of cards to the university, users of the service will be able to type their data directly into a relatively inexpensive terminal. The terminal can then transfer the information to the computer bank at Iowa State.

The seven Iowa industries which currently belong to the computer service are: Central Iowa Power Cooperative, Marion; Interstate Power Company, Dubuque; Iowa-Illinois Gas and Electric Company, Davenport; Iowa Electric Light and Power Company, Cedar Rapids; Iowa Power and Light Company, Des Moines; Iowa Public Service Company, Sioux City; and Iowa Southern Utilities Company, Centerville.

Robert W. Israel, Koehring District Manager, and Prof. James M. Hoover and Dr. Richard L. Handy, Civil Engineering, hold an on-site conference.

COOPERATIVE DUST ABATEMENT PROGRAM

According to Prof. James M. Hoover, Department of Civil Engineering, ISU, the two million miles of unpaved roads in the United States represent over 60% of the nation's total road, street, and highway mileage. "The greater part of this mileage is on the 'secondary road systems' of the 3,043 counties of the country." These roads produce millions of tons of dust annually (about one ton per mile per daily vehicle per year). "In turn, the pleasant and enjoyable use of adjacent homes and public and private property is destroyed, deterioration of automobiles is hastened by a factor of five to ten, and air is polluted with as much as 100 times more solid airborne particles than are found in urban industrial air." Furthermore, the incidence of fatal accidents is 2.3 times as great on unpaved as on paved roads, and road maintenance costs are unnecessarily high, requiring 20-30 blade gradings per year plus annual replacement of gravel or crushed stone.

ISU is doing something about this dust problem. The University's Engineering Research Institute (Soil Research Laboratory), Linn County, Iowa, and Koehring Road Division are conducting a cooperative testing program to determine the most economical and effective methods for controlling dust production and upgrading unimproved roads through the use of soil stabilizers and dust palliatives (suppressors). Acting as program supervisors and coordinators are Prof. Hoover and Dr. Richard L. Handy of the Dept. of Civil Engineering, ISU, William G. Harrington, Linn County Highway Engineer, and Robert W. Israel, Koehring District Manager. Also cooperating in the program are nineteen manufacturer/distributors of soil stabilization/dust palliation products.

The test sites for the project were contributed by Linn County, each consisting of a 1000-ft. stretch of road treated with one of the soil stabilizers contributed by the participating manufacturer/distributers. Each product was

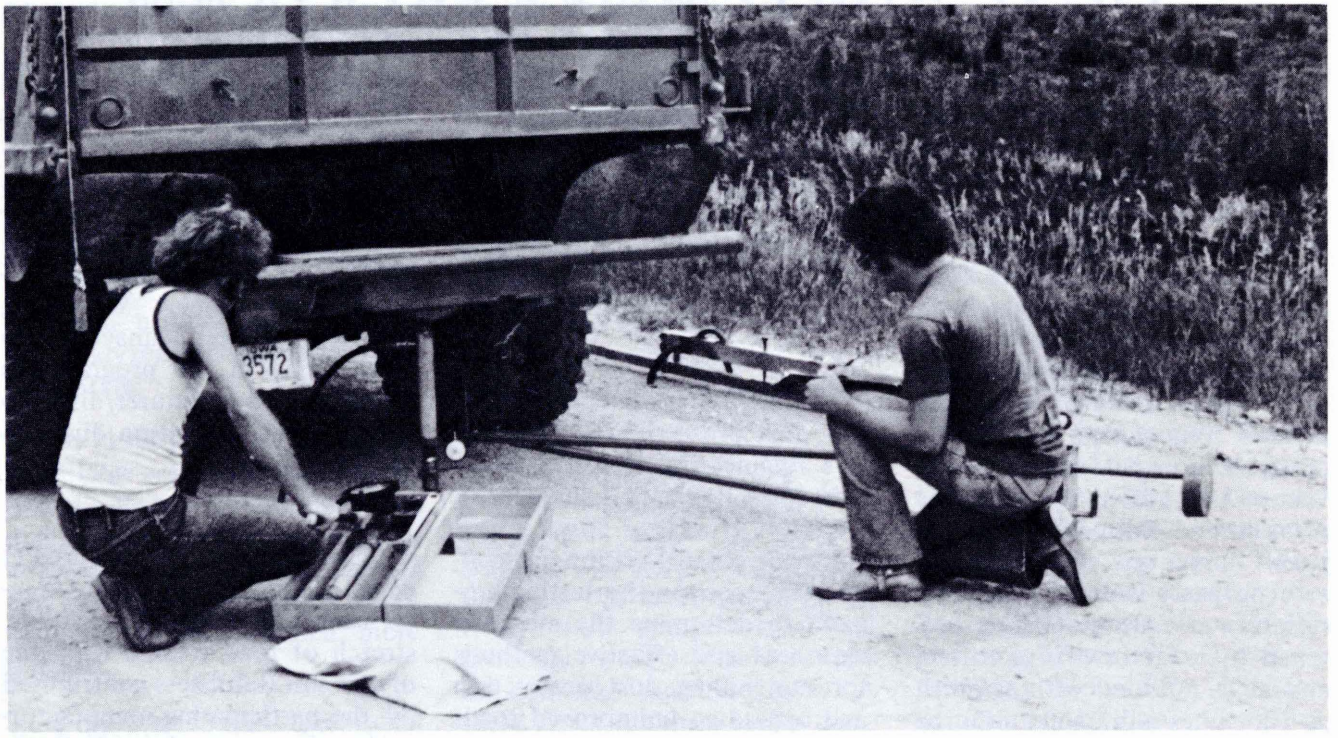
applied according to the manufacturer's recommendations and under the direct supervision of one of his agents. A comparable control section, untreated, was also selected adjacent to each test site. The construction equipment for the project was provided by Koehring and Allis-Chalmers Construction Machinery Division, while equipment operators were provided by Linn County.

The Linn County road tests are being performed by graduate student Lee Squier, through the Soil Research Laboratory. The testing program will continue over a 3- to 5-year period and includes collection of on-site surface data as well as laboratory testing and comparison of data from core specimens taken from the test sites both before and immediately after treatment and at regular intervals thereafter. The costs of this testing program are being defrayed by unrestricted grants from the participating manufacturer/distributors.

During the construction phase of the project, Koehring produced an educational film through the ISU Film Production Unit, with technical advice from Profs. Hoover and Handy. The film will be used by professional engineers, contractors, and students. It outlines a typical county's secondary road problems, sets forth construction techniques used for roadway soil stabilization, and shows generalized groupings of the various products used. The film also details the various ill effects which the dust produced by traffic on unimproved roadways can have on our lives.

Prof. Hoover points out that the dust problem has become so acute in many areas that controlling legislation is being considered or has already been passed. In Iowa, the legislature has passed a resolution banning all "fugitive dust." Many roads will require upgrading before they can be sufaced, and the balance will need both a dust palliative and a soil stabilizer mixed into the top road surface or into the entire base.

When the project is complete, the data collected will provide engineers, contractors, and manufacturers alike with a guide to construction techniques and types of soil stabilization and dust palliation materials to be used under various conditions. As Prof. Hoover points out, the project is "a unique contribution to both the educational and application aspects of soil stabilization for both the P.E. and the road user." It has, furthermore, been accomplished without the use of state funds.



Lee Squier, graduate student in Soil Engineering, and Steve Sage, senior in Civil Engineering, perform in-place testing.

NEW FOODS THROUGH ENZYME TECHNOLOGY

Enzymes are organic molecules which function in the life processes of all plants and animals. Without itself being used up, each enzyme catalyzes a specific chemical reaction, varying from the breakdown of proteins to amino acids for use in cell construction to the breakdown of starch to glucose for energy production to the buildup of polymeric molecules from simple starting materials. The specific reactions encouraged will not take place in the absence of the specific enzyme required. Because of their relationship to organic chemistry, enzymes are of primary interest to the pharmaceutical and food-related industries. Recently, the use of enzymes in industrial processes has become more feasible because of a number of discoveries that indicate their stability may be enhanced by attaching them to solid surfaces by either chemical or physical means. This has encouraged a great increase in the amount of research conducted in the general field of enzymic processes by both universities and commercial firms.

At Iowa State, research in the general field of immobilized enzymes was initiated several years ago by Dr. George T. Tsao and Dr. Yoon Y. Lee of the Dept. of Chemical Engineering and Nuclear Engineering. Their original work was with the enzyme glucoamylase, which catalyzes the breakdown of partially hydrolyzed starch (dextrin) to glucose. They also investigated the action of a second enzyme, glucose isomerase, which catalyzes the reaction of glucose to a mixture containing equal parts of glucose and fructose. These reactions are commercially attractive, since the glucose-fructose mixtures produced are sweeter than are equal concentrations of cane or beet sugar.

The research involves the discovery of such system parameters as optimal reaction temperatures, solution sterilization methods, and enzyme immobilization methods. Just recently, this laboratory scale research has evolved into a new project for developing a pilot-scale reactor. The work is sponsored by the National Science Foundation and the Engineering Research Institute, ISU. Corning Glass Works is also cooperating in the project and has provided samples of its porous ceramic beads as an immobilization base. Recently Dr. Peter J. Reilly has taken over direction of the research from Drs. Tsao and Lee. Other members of the Dept. of Chemical Engineering and Nuclear Engineering involved in the project are Profs. George Burnet and Edgar V. Collins.

The project now focuses on four specific enzymic processes: 1) the production of glucose from starch intermediates using immobilized glucoamylase; 2) the conversion of glucose to fructose using glucose isomerase; 3) the enzymic hydrolysis of lactose in milk to glucose and galactose; 4) the production of fructose and the polymer dextran from sucrose with the enzyme dextransucrase. A second project sponsored by the same institutions has also been initiated. It deals with the enzymic breakdown of the second most common constituent of cellulosic materials, xylan, to the sugars xylose and arabinose, and will employ corn cobs and corn hulls as a feedstock.

Because of the delicate nature and specificity of enzymes, the study of enzymic processes is rather complex. Most enzymes promote only one specific reaction, and each functions best at a specific temperature, which differs from enzyme to enzyme. Enzyme reactions must also be protected from bacterial growth and other contaminants, so that only the desired chemical reactions occur. In addition, enzymes are difficult to retain in reaction containers. If the enzyme is in free solution with the materials being processed, it is lost when these materials are withdrawn. Even when enzymes are immobilized by attaching them to or trapping them inside of solid materials, the enzyme activity decreases over a period of time, and the enzyme must eventually be replaced; furthermore, the activity of the enzymes varies from one immobilization material to another, and their decay can be acceler-

ated by inappropriate temperatures and other reaction variants. It is obvious that any serious investigation of enzyme processes must investigate the optimal immobilization methods, reactor configuration and reaction variants such as temperature and pH for each enzymic process studied. The project headed by Dr. Reilly is directed to investigation of all these areas.

Laboratory research has demonstrated that both glucoamylase and glucose isomerase are easily attached to porous glass or porous silica that has been modified by the addition of a reactive group containing an amine. The actual linkage occurs by binding the compound glutaraldehyde to both the amine and the enzyme. Other effective solid carriers that have been used by others are cellulose and nylon fibers and hollow tubes, ion exchange resins, gels of various compositions, and microcapsules. Prof. Reilly notes that with any carrier it is essential to bind a large amount of enzyme to the solid to obtain as high an activity as possible, and to this end it is helpful to use materials with high surface areas per weight. The carriers employed in this project are very small beads with an extensive pore structure. The enzymes are attached to the surfaces of the pores, and reactants and products diffuse in and out. It has been shown that the bead size affects the reaction rate, since when the beads are larger the pores are long, and diffusion of the reactants to the enzyme becomes difficult. The same thing occurs when the pores are very narrow.

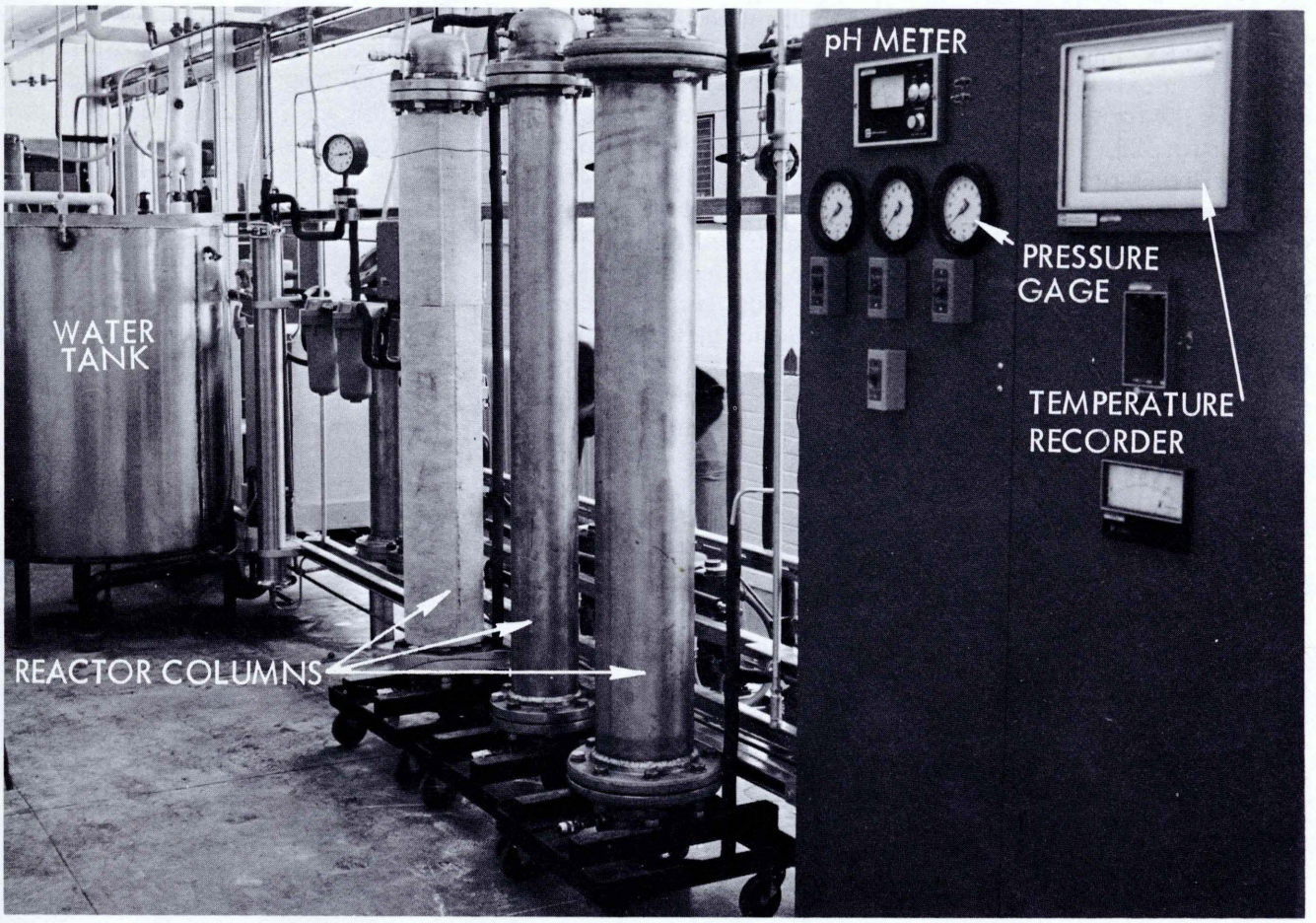
Both glucoamylase and glucose isomerase have been found to be very stable, even at temperatures above 55 °C, where most other enzymes lose activity very quickly. At body temperature, for instance, they last almost indefinitely. Each is most stable and active at a certain pH, glucoamylase at about 4.5 and glucose isomerase somewhat above 7. If it were desired to obtain a glucose-fructose mixture from starch, the most efficient method would be to use both enzymes in one reactor. This is not presently possible, Dr. Reilly points out, because their pH optima are so different. Research is underway to modify the enzymes or carriers by adding reactive groups to them so that the two enzymes can be used together.

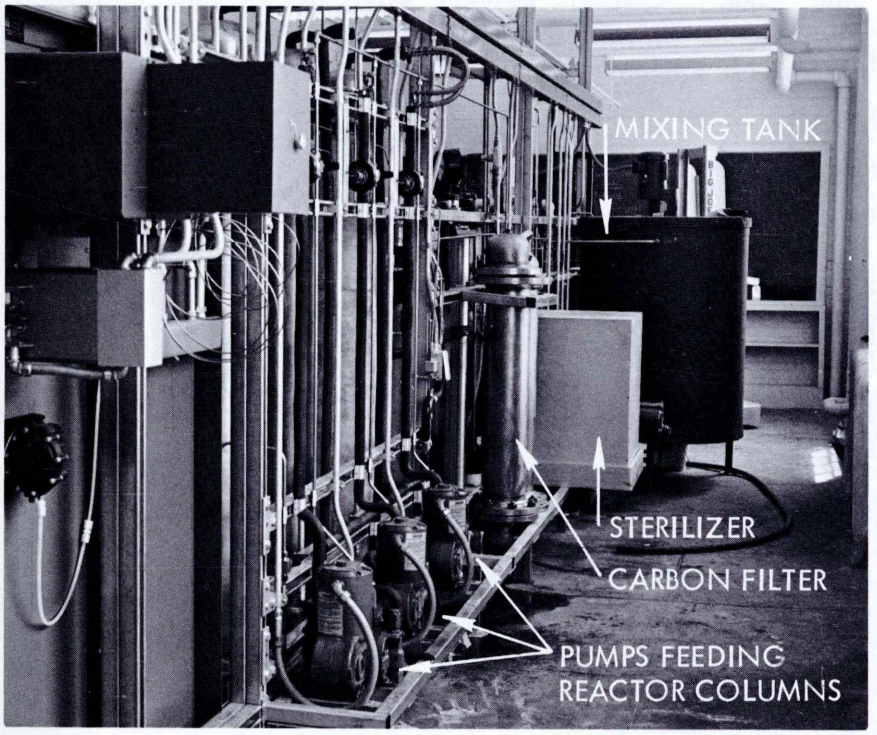
The glucoamylase reaction has been investigated in a pilot plant built for the purpose that has a capacity of 1000 lbs of glucose per day. The equipment for this phase of the project has been selected and designed in such a way that any item of equipment can be connected with any other item for testing other kinds of enzymic processes in the future. Photos of the pilot-scale glucoamylase reactor system are shown. The actual design allows continuous operation of the system through the inclusion of duplicate filters and three reactor columns. Filters are designed to be used alternately, and reaction columns can be run in series or in parallel, to gain optimal processing of the starch intermediates.

The equipment has been operated for unbroken periods as long as 80 days with no loss of glucoamylase activity and with conversions to glucose of over 90 percent. Microbial contamination was almost completely eliminated by heating the feed before it reached the enzyme reactor. A backup procedure, flushing the entire system with an aqueous chloroform solution, was successfully employed after the system was disrupted by a pump failure.

Both of the enzymes most thoroughly investigated at Iowa State, glucoamylase and glucose isomerase, are presently being used commercially, the first in the free form and the second after being immobilized. They currently help to produce materials of greater value than any other enzymic process operation in this country. The product of the glucoamylase reaction, glucose syrup, is used in the food industry to pack fruits and vegetables and as a general sweetener. The glucose-fructose mixture produced by glucose isomerase is sweeter than glucose, so there is an incentive to employ both enzymes rather than just glucoamylase, Prof. Reilly notes.

The other enzymes included in the Iowa State effort have been studied to a lesser extent than glucoamylase or glucose isomerase. The enzyme lactase, or more properly β-galactosidase, breaks down lactose found in milk to the simpler sugars glucose and galactose. This is important because a significant part of the world's population cannot digest lactose well and therefore does not use dairy products as much as would be possible. Lactase also is easily linked to porous glass and silica and seems to be quite stable, at least when fed pure lactose solutions. Use of milk as a feedstock may lead to quite different results, since it is so heterogeneous. It is with feeds of this type that the use of a pilot plant is most helpful, according to Prof. Reilly, since scaling up to a large process is more difficult with more poorly characterized process streams.





Two views of the pilot scale glucoamylase reactor system. The water tank flows into the mixing tank, where starch, water, and acid are mixed. This mixture is fed through a steam sterilizer, cooler, carbon adsorber, and filter before being pumped into the reactor columns, where the starch intermediates are converted to glucose.

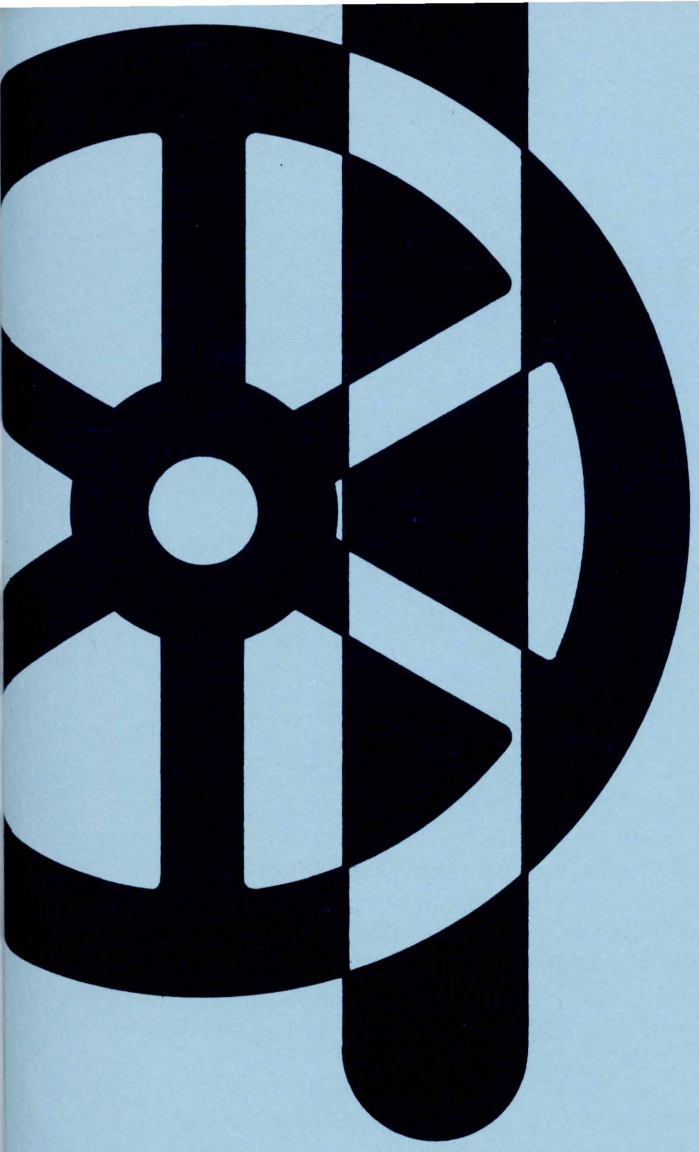
Another enzyme that is a good candidate for pilot-plant investigation is dextransucrase, which catalyzes the formation of dextran and fructose from sucrose. Though living organisms produce many polymeric materials such as dextran, few of the enzymes that are active in their formation have been stabilized by attaching them to solids. It is quite possible that the rate of reaction will be significantly decreased by the difficulty encounted by dextran in leaving the pores of the carrier. Usually carriers such as porous ceramics are contained in tightly packed tubular reactors, with the feed entering at one end and the product leaving at the other. With dextransucrase, the viscosity of the process stream will increase greatly as it travels through the reactor and dextran molecules of progressively greater length are formed. This leads to a number of most interesting engineering problems. Whether the type of carrier and reactor used up to now will be feasible for this reaction is open to question.

In a project newly started, agricultural wastes rather than foodstuffs are used as feed for the enzymic reaction. For many years researchers have been working on methods to break down cellulose, which is a polymer composed like starch of glucose units, but bound in a different fashion that makes it more difficult to degrade. The next most common constituent of cellulosic materials like wood is xylan, which is a polymer composed mainly of the sugar xylose. Xylose is much like glucose in structure but is not commonly used in food. It is fairly sweet, however, and one of its derivatives, xylitol, is even sweeter.

It takes at least three enzymes to break down xylan to its constituents, and to this point much less work has been accomplished on the breakdown of xylan than on that of cellulose. The most feasible feedstuffs for this process are derivatives of corn or other annual plants, in which xylan is present in concentrations above 30 percent. Two materials, corn cobs and corn hulls, come immediately to mind. According to Dr. Reilly, the first has become steadily more difficult to obtain as combines that chop up cobs have become more common. Corn hulls, on the other hand, are one of the major products of corn processing plants and are used in animal feed.

The xylan breakdown enzymes are currently being investigated by the Iowa State group, and since they are not produced commercially at this time, they will have to be isolated and purified before their properties can be studied. Whether this process will eventually be attempted in the pilot plant is at present undecided. Since the pilot plant has been designed to be quite versatile, the conversion to xylan breakdown should not be too difficult.

This research program in immobilized enzymes is one of the largest at any United States university and, hopefully, will offer a considerable contribution to the advancement of enzyme technology. The knowledge gained through this research should, in addition, make the enzymic processing of food and agricultural wastes more common in the future.



RESEARCH HIGHLIGHTS

AEROSPACE ENGINEERING

Robert F. Brodsky
Department Head
and Professor

Department Faculty Members	Areas of Research Interest
Distinguished Professor	
Ernest W. Anderson, Ph.D.	
Professors	
Dale A. Anderson, Ph.D.	Fluid mechanics
Cheng-Ting Hsu, Ph.D.	Fluid mechanics, high-temperature gas dynamics
James D. Iversen, Ph.D.	Aerodynamics of rotating bodies, vortex flows, environmental aerodynamics, hypersonics
Merlin L. Millett, Jr., Ph.D.	Hydrospace engineering, multimodel transportation systems
Lennox N. Wilson, Ph.D.	High speed experimental aerodynamics, turbulent combustion, combustion noise, acoustics, turbulent flow, aerochemistry
Associate Professors	
Paul J. Hermann, M.S.	Dynamic systems analysis, aerospace automatic control systems development and analysis, simulation of dynamic systems
Thomas J. McDaniel, Ph.D.	Structural dynamics
Bion L. Pierson, Ph.D.	Computational methods in parameter optimization and optimal control problems, flight mechanics, control theory
John C. Tannehill, Ph.D.	Computational fluid mechanics, astrodynamics
Assistant Professors	
William D. James, Ph.D.	Low speed aerodynamics, aeroelasticity
Leverne K. Seversike, Ph.D.	Flight mechanics, optimization techniques, control systems

OPTIMAL CONTROL OF DYNAMIC SYSTEMS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: L. K. Seversike

Current projects in optimal control of dynamic systems include:

Simulation of Vehicle Motion during Atmospheric Entry. The simulation (digital) of the entire motion of a shuttle-type vehicle during the atmospheric entry phase of the flight is desired. Both the trajectory (translation) and the stability (oscillatory) characteristics due to control system inputs are being investigated. Due to the time-varying nature of the coefficients in the differential equations of motion, conventional methods for determining the stability, longitudinal and lateral-directional, are no longer applicable. The problem of handling non-linear aerodynamics for the stability derivatives also arises. Hence, several different techniques are being investigated so that an adequate simulation of the motion can be developed.

Passive Attitude Control of Satellites. Four basic mathematical models (assemblage of rigid bodies, quasi-rigid bodies, rigid bodies with flexible appendages, and elastic bodies) have been employed in the analysis of the gravity-gradient passive control technique when such factors as structural flexibility, orbit eccentricity induced perturbations, gravitational anomalies, solar pressure, atmospheric drag, and on-board sloshing are considered. Comparative studies of these basic models are the primary interest at this time. Additional studies using these models with spin-stabilized satellites are planned.

Recent publications:

Born, G. H., E. J. Christensen and L. K. Seversike, "Special Perturbations Employing Osculating Reference States," ERI Preprint 72174, Iowa State University, Ames (1972). (Accepted for publication in Celestial Mechanics.)

Olson, R. L., "Numerical Investigation of Optimal Control of an Atmospheric Reentry Vehicle Using Dynamic Programming," ME Paper, Iowa State University, Ames (1972).

FINITE DIFFERENCE SOLUTION OF FLOW FIELDS

SPONSOR: NASA

PRINCIPAL INVESTIGATOR: D. A. Anderson

RESEARCH ASSISTANTS: V. Shankar, J. Daywitt

Current research sponsored by NASA under Project 1028 is broken into two separate phases. The first area of study is an analysis of axial corner flows. The major application of the results is to engine intake systems of supersonic aircraft and to wing-body junctures of vehicles moving at supersonic speeds. Finite difference solutions for compression-compression and compression-expansion flows have been obtained. These solutions compare well with experiment.

The second area of study involves construction of a blunt body code to support future work on shock wave propagation problems. The major interest is in generating a flow containing gradients (particularly vorticity) due to nose bluntness and then studying propagation of shock waves in the resulting field. The blunt body code has been completed and results compare favorably with other solutions available.

Recent publications:

Fattahi, Behrooz, "Application of Conservative Finite-Difference Methods to Advection Problems," ME Paper, Iowa State University, Ames (1971).

Pratt, Philip W., "Finite Difference Solutions to the Equations of Fluid Flow Around an Elliptic Cone," MS Thesis, Iowa State University, Ames (1972).

Vogel, Jerald M., "Numerical Calculation of Flow Fields about Rectangular Wings of Finite Thickness

in Supersonic Flow," PhD Dissertation, Iowa State University, Ames (1973).

Anderson, D. A., "A Comparison of Numerical Solutions to the Inviscid Equations of Fluid Motion," ERI Preprint 73225, accepted for publication in Journal of Computational Physics (October 1973).

Anderson, D. A. and B. Fattahi, "A Comparison of Numerical Solutions to the Advection Equation," ERI Preprint 72118, submitted for publication to the Journal of Atmospheric Sciences (March 1974).

Shankar, Vijaya, "Numerical Solution for Inviscid Supersonic Corner Flows," presented at AIAA Region V. Student Conference, Minneapolis, Minnesota (April 1974).

FINITE DIFFERENCE SOLUTION OF FLOW FIELDS

SPONSOR: NASA – Ames Research Center

PRINCIPAL INVESTIGATOR: D. A. Anderson

RESEARCH ASSISTANTS: J. E. Daywitt, V. Shankar

This research effort is structured in two separate parts. The first part will assess the effect of airfoil geometry changes on the flow field produced by a rectangular wing moving at supersonic speed. Specific sections are suggested which include changes in both thickness distribution and airfoil camber. The second part is a study of the numerical difficulties which occur in the calculation of flow fields in regions where the fluid variables change very rapidly near a solid boundary with large surface curvature. Specific ideas which may eliminate this flow instability will be outlined, and may include mesh refinement, coordinate transformations, and altered difference schemes. The test body being used for this research is a highly elliptical cone which is known to exhibit cross-flow instability.

Recent publications:

Fattahi, Behrooz, "Application of Conservative Finite-Difference Methods to Advection Problems," ME Paper, Iowa State University, Ames (1971).

Pratt, Philip Wayne, "Finite Difference Solutions to the Equations of Fluid Flow Around an Elliptic Cone," MS Thesis, Iowa State University, Ames (1972).

Vogel, J. M., "Numerical Calculation of Flow Fields about Supersonic Rectangular Wings," PhD Dissertation, Iowa State University, Ames (1972).

Anderson, Dale and B. Fattahi, "Numerical Solutions of the Advection Equation Using Conservative Form," Engineering Research Institute Preprint 72118, Iowa State University, Ames (October 1973).

Anderson, Dale, "A Comparison of Solutions of the Inviscid Equations of Fluid Motion," Engineering Research Institute Preprint 72247, Iowa State University, Ames (October 1973).

FLOW FIELD SOLUTION

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: D. A. Anderson

The flow field produced by a lifting elliptic cone has been computed using various techniques. The difficulty with these available solutions is that the vortical layer is incorrectly treated. As a result, the streamline pattern and the constant entropy surfaces do not agree. The present study includes the solution of the elliptic cone flow field using a finite-difference approach with particular attention being paid to the vortical layer and the vortical singularity. Results to date indicate that the mistreatment of the vortical layer may be relatively unimportant. In addition, the lift-off of the vortical singularity is difficult to observe due to the numerical viscosity of finite difference methods.

SHOCK IMPINGEMENT STUDIES

SPONSOR: NASA, Engineering Research Institute

PRINCIPAL INVESTIGATOR: D. A. Anderson

RESEARCH ASSISTANT: J. Daywitt

The research work in this project is structured in three phases. The first is a study of the shock-expansion pattern produced when shock

waves of opposite families intersect. The second deals with the geometry produced when shocks of the same families intersect. Both phases I and II are confined to problems where the flow behind the initial shock intersection is fully supersonic. The third phase of the investigation is a study of the flow field produced by the intersection of two shock waves of opposite families in which regions of supersonic flow exist after the initial intersection. The results of this program will be specifically applicable to the shock impingement problem related to the Space Shuttle vehicle.

Sharp shock or shock fitting routines are used in phases I and II. The bow shock and the incident shock are to be fit in phase III. Initially, the resulting shock pattern is to be studied using shock capturing. Ultimately, the goal of phase III is to fit the entire shock pattern for that type of intersection.

SIMULATION OF THE EOLIAN MODIFICATION OF MARTIAN CRATERS

SPONSOR: NASA – Ames Research Center

PRINCIPAL INVESTIGATOR: J. D. Iversen

RESEARCH ASSISTANT: B. R. White

This investigation is a continuation of a previous research project. It concerns the use of an open-circuit wind tunnel and numerical computation on a digital computer to simulate the flow patterns of sand and dust over the surface features on Mars. The effects of properties of the Martian atmosphere and the turbulent structure of the planetary boundary layer have begun to be ascertained by close attention to the effects of appropriate modeling parameter variations in the wind tunnel. A systematic study of model parameters in the wind tunnel is presently being pursued, and the results, along with digital simulation, are being used to determine the proper simulation of Martian environment for studies of eolian processes of specific Martian surface features. Results of these and previous simulations are aiding in the interpretation of Mariner 9 imagery, are providing input to the geologic mapping of Mars program, are aiding in the establishment of planet-wide meteorological patterns, and will provide input on Martian surface characteristics, particularly wind speeds and size of atmosphere-borne particles, for the Viking program.

Recent publication:

Iversen, J. D., B. R. White, R. Greeley and J. B. Pollack, "Simulation of Martian Eolian Phenomena in the Atmospheric Wind Tunnel," SPACE SIMULATION, Proc. AIAA/ASTM/IES/NASA Space Simulation Conf., NASA SP-336, 191-213 (1973).

DYNAMICS OF LINEAR AND NONLINEAR STRUCTURES COMPOSED OF NONPERIODIC UNITS

SPONSOR: National Science Foundation

PRINCIPAL INVESTIGATOR: T. J. McDaniel

RESEARCH ASSISTANTS: T. L. Dix, G. M. DeVault, R. E. Bartels

See feature article, page 108, for more information on this project.

COMPUTATIONAL METHODS IN OPTIMIZATION WITH APPLICATIONS TO AEROSPACE PROBLEMS

SPONSORS: Engineering Research Institute, NASA - Marshall Space Flight Center (December 1, 1971 - August 31, 1973)

PRINCIPAL INVESTIGATOR: B. L. Pierson

RESEARCH ASSISTANTS: A. M. Andronikou, I. Chen, N. A. Thorp, K. R. Williams

Mathematical optimization techniques have long been a strong component of modern aerospace design. The major emphasis of this project has been to develop new and more efficient computational methods for applying optimal control theory to trajectory optimization and optimal structural design. Methods currently under development include: the discrete variable approach, conjugate direction gradient methods, augmented penalty function methods, projection operator methods, and modified quasilinearization. These methods are being applied to optimal reentry trajectories, minimum time-to-climb V/STOL aircraft trajectories, branched optimal space trajectories, optimal dynamic soaring, and a class of panel flutter/optimization problems.

Recent publications:

O'Doherty, R. J. and B. L. Pierson, "A Numerical Study of Augmented Penalty Function Algorithms for Terminally Constrained Optimal Control Problems," Engineering Research Institute Preprint ERI-72081, Iowa State University, Ames (March 1972) (accepted for publication in the Journal of Optimization Theory and Applications).

Bucher, K. R. and B. L. Pierson, "A Perturbation Technique Applied to an Optimal Re-entry Control Problem," Astronautica Acta, 17: 3, 239-244 (June 1972).

Rajtora, S. G. and B. L. Pierson, "An Automated Gradient Projection Method for Optimal Control Problems," AIAA Journal, 10: 7, 949-951 (July 1972).

Pierson, B. L., "A Survey of Optimal Structural Design under Dynamic Constraints," Intern. J. for Numerical Methods in Engineering, 4: 4, 491-499 (July-August 1972).

Pierson, B. L., "Discrete Approximation to Minimum Weight Panels with Fixed Flutter Speed," AIAA Journal, 10: 9, 1147-1148 (September 1972).

Pierson, B. L., "A Modified Conjugate Gradient Method for Optimization Problems," Intern. J. of Control, 16: 6, 1193-1196 (December 1972).

Willoughby, J. K. and B. L. Pierson, "The Projection Operator Applied to Gradient Methods for Solving Optimal Control Problems with Terminal State Constraints," Intern. J. of Systems Science, 4: 1, 45-57 (January 1973).

Rajtora, S. G. and B. L. Pierson, "A Projection Operator Algorithm for Optimal Control Problems with Unspecified Initial State Values," Preprint Volume, Joint Automatic Control Conference, Ohio State University, Columbus, Ohio, June 1973, pp. 711-721.

Pierson, B. L. and S. S. Russell, "Further Discrete Variable Results for a Panel Flutter Optimization Problem," Intern. J. for Numerical Methods in Engineering, 7: 4, 537-543 (1973).

Pierson, B. L., "Application of a Gradient Projection Optimal Control Method to a Class of Panel Flutter Optimization Problems," Technical Report 73186, Engineering Research Institute, Iowa State University, Ames (August 1973).

O'Doherty, R. J. and B. L. Pierson, "A Numerical Study of Multiplier Methods for Constrained Parameter Optimization," Intern. J. of Systems Science, 5: 2, 187-200 (February 1974).

FINITE-DIFFERENCE SOLUTIONS OF AEROSPACE PROBLEMS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: J. C. Tannehill

RESEARCH ASSISTANT: G. R. Eisler

This project is concerned with the application of finite-difference techniques to the solution of aerospace problems for which analytical solutions are not possible. Current work is involved with the calculation of hypersonic rarefied flows using either the complete Navier-Stokes or Burnett equations.

Recent publications:

Tannehill, J. C. and E. W. Anderson, "Intermediate Altitude Rocket Exhaust Plumes," J. Spacecraft and Rockets, 8: 10, 1052-1057 (October 1971).

Tannehill, J. C. "A Simplified Numerical Scheme for Calculating the Flow of a Chemically Reacting Gas," Intern. J. for Numerical Methods in Engineering, 6: 595-598 (July 1973).

TURBULENT FLOW STUDIES

SPONSOR: National Science Foundation Institutional Grant

PRINCIPAL INVESTIGATOR: L. N. Wilson

RESEARCH ASSISTANT: R. A. Martin

Turbulent Mixing of Scalar Properties. Understanding of the mechanism of mixing of scalar properties and passive contaminants in turbulent flows is of fundamental importance to the design of most practical reacting systems. Experimental information is scarce, however, due to the lack of suitable instrumentation which can

be used to measure scalar turbulent properties. Recently, a cross-correlation technique has been devised which allows such measurements to be made, not only in cold flows, but also in high-temperature combustion regions. Since the techniques are new, some "proving" of the instrument is still necessary by making comparisons with more conventional instruments. This study has two primary goals.

1) Measurements are being made in grid generated isotropic turbulence under conditions where hot wire measurements of both temperature and velocity fluctuations can be made. Temperature fluctuations are generated by heating the grid. The results will be compared directly with cross-correlation measurements of temperature fluctuations.

2) Concurrently, a study is also being made of the statistical behavior of temperature fluctuations in isotropic turbulence to aid in the understanding of the mechanisms involved.

At the conclusion of this study, confidence will have been obtained in the use of cross-correlation techniques, and more complex flows can then be studied.

Turbulence in Flows of Varying Density. A variety of turbulence-diffusion models has been suggested in the past to explain the observed mixing behavior of jet, wake, and boundary layer flows with large mean-density gradients. The results obtained have been inconsistent, and attempts to obtain proper correlation parameters have been unsuccessful. The present study has resulted to date, in similarity solutions for the limiting cases of very low axis densities for pure wake and pure jet flows using the classical assumptions of an eddy diffusivity and a constant turbulence Reynolds number. The solutions predict axis-velocity and density decay laws for both flow types in agreement with experimentally-observed decay rates. The proper scaling parameters for density variations in turbulent flow have thereby been obtained by extending the classical constant density approach: no new turbulent diffusion model was required.

Recent publication:

Wilson, L. N., "Turbulence in Flows of Varying Density," Project SQUID Annual Meeting, March 1974. Also to be presented at the AIAA Fluid Dynamics Meeting, June 1974.

TORNADO FLUID DYNAMICS

SPONSOR: National Science Foundation

PRINCIPAL INVESTIGATOR: C. T. Hsu

MAJOR STAFF: F. W. Stuve

See feature article on "Laboratory Simulation of Tornado Behavior," for more information on this project.

VIBRATIONAL ANALYSIS OF SKIN-STRINGER STRUCTURE USING FINITE ELEMENT AND TRANSFER MATRIX METHODS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: T. J. McDaniel

RESEARCH ASSISTANTS: G. M. DeVault, T. Dix

The finite element method and the transfer matrix method have been combined for the study of the dynamics of aerospace structures. The advantages of both methods have been combined in the present study of skin-stringer structures, consisting of a thin metal skin supported by frames and stiffened by light stringers. The finite element method is used in the study as it allows more general structural configurations and boundary conditions to be considered. The stiffness matrix for each strip of finite elements in one coordinate direction is formulated and converted to transmission form. One can use these transfer matrices to transmit in the other coordinate direction. Nodal variables which occur in the finite element analysis of such structures are conveniently eliminated by transmission techniques. This method uses smaller matrices and less computer time than the finite element analysis without reducing the number of degrees of freedom. This analysis is used to generate the frequency response of complex aerospace, which is required in the dynamic analysis of structures under deterministic or random loading. Frequency and modal information can also be obtained from the analysis.

Recent publications:

Henderson, J. P. and T. J. McDaniel, "The Analysis of Curved Multispan Structures," J. Sound and Vib., 8: 2, 203-219 (1971).

McDaniel, T. J., "Dynamics of Circular Periodic Structures," J. Aircraft, 8: 3, 143-149 (March 1971).

McDaniel, T. J. and J. D. Logan, "Dynamics of Cylindrical Shells with Variable Curvature," J. Sound and Vib. (June 8, 1971).

McDaniel, T. J., "Dynamics of Noncircular Stiffened Cylindrical Shells," J. Sound and Vib. (May 9, 1972).

McDaniel, T. J., "Dynamics of Stiffened Cylindrical Shells with Spatially Varying Curvature," Air Force Materials Lab., AFML-TR-134 (July 1972).

NUMERICAL COMPUTATION OF THREE-DIMENSIONAL VISCOUS BLUNT BODY FLOWS WITH AN IMPINGING SHOCK

SPONSOR: NASA

PRINCIPAL INVESTIGATOR: J. C. Tannehill

RESEARCH ASSOCIATE: T. L. Holst

The primary goal of this research is to be able to numerically predict the high pressures and heating rates generated by an extraneous shock impinging on a blunt body in a hypersonic flow. An example of this type of flow field occurs on the Space Shuttle vehicle at the point where the bow shock from the nose intersects the blunt leading edge of the wing, resulting in a severe aerodynamic heating problem. The approach that is being used to compute this type of flow field is a "time-dependent," finite-difference method which solves the complete set of compressible Navier-Stokes equations. Some of the calculations are being performed on the new ILLIAC IV computer at NASA Ames Research Center.

Recent publications:

Tannehill, J. C. and R. A. Mohling, "Development of Equilibrium Air Computer Programs Suitable for Numerical Computation Using Time-Dependent or Shock-Capturing Methods," NASA Contractor Report CR-2134 (September 1972).

Mohling, R. A., "Numerical Computation of the Hypersonic Rarefied Flow Past the Sharp Leading Edge of a Flat Plate," PhD Thesis, Iowa State University, Ames (1972).

Tannehill, J. C., R. A. Mohling and J. V. Rakich, "Numerical Computation of the Hypersonic Rarefied Flow Near the Sharp Leading Edge of a Flat Plate," AIAA Paper No. 73-200, presented at the AIAA Aerospace Sciences Meeting in Washington, D.C. (January 1973).

Tannehill, J. C., "A Simplified Numerical Scheme for Calculating the Flow of a Chemically-Reacting Gas," *Intern. J. for Numerical Methods in Engineering,* 6: 595-598 (1973).

Tannehill, J. C., R. A. Mohling and J. V. Rakich, "Numerical Computation of Hypersonic Viscous Flow Over a Sharp Leading Edge," AIAA Journal (February 1974).

VIBRATIONAL RELAXATION OF ANHARMONIC OSCILLATORS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: C. T. Hsu

Nonequilibrium vibrational relaxation processes usually occur in high temperature flows, behind strong shocks, during a reentry period and in sudden supersonic expanding conditions of gas dynamic lasers. The chemical rate constant for these excitation and de-excitation processes is a very important but difficult quantity to obtain. Results of recent observations on the de-excitation rate have been very confusing since a difference of several orders of magnitude has been reported. The present analytical study of this de-excitation rate, using a model of anharmonic oscillators, aims to clarify this phenomenon. It is found indeed that the de-excitation rate has an extremely high value at the initial stage, decreasing rapidly, and finally approaching the excitation rate in the later secular adjustment period. Laboratory observation on this de-excitation rate will depend on the particular instant when it is observed.

Recent publications:

Hsu, C. T. and F. H. Maillie, "Vibrational Relaxation of Anharmonic Oscillators with Vibration-Vibration and Vibration-Translation Energy Exchanges," J. of Chemical Physics, 52: 1767 (1970).

Hsu, C. T. and L. D. McMillen, "On the First Moment Relaxation Equation of Anharmonic Oscillators," J. of Chemical Physics, 53: 4107 (1970).

Hsu, C. T. and L. D. McMillen, "Time-Dependent Solutions for De-excitation Rates of Anharmonic Oscillators," J. of Chemical Physics, 56: 5327 (1972).

AGRICULTURAL ENGINEERING

Clarence W. Bockhop
Department Head
and Professor

Agricultural engineering is jointly administered by the colleges of engineering and agriculture. Experimental work is conducted at a number of outlying farms and in the fields of many farmer cooperators. Programs include both basic and applied research in all areas of agriculture. Among the areas in which research is carried out are soil and water resources, field power and machines, materials handling, crop conditioning and processing, agricultural structures and environment, and animal waste management. Research is primarily supported through the Agriculture and Home Economics Experiment Station.

ANIMAL WASTE MANAGEMENT WITH POLLUTION CONTROL

SPONSORS: Iowa State University Agriculture and Home Economics Experiment Station, USDA Regional Research

PRINCIPAL INVESTIGATORS: R. J. Smith, T. E. Hazen (Co-leaders)

RESEARCH ASSISTANTS: B. Parker, R. Fehr

The title of this project is very descriptive because it indicates the objective sought, rather than the means by which the objective will be achieved. Until 1973, the majority of the work was related to swine. The basic unit is a 700-head finishing unit on the ISU Swine Nutrition Station, which now has an automated, hydraulic manure-handling system using treated recycled wastewater. This was developed by this project and by its predecessor. The previous project developed the in-building wastehandling and treatment components, and the present project has investigated techniques for recycling overflows from the system through cropland. Several years of data are now available relating the effect on anaerobic lagoon effluent on the soil and crops. A temporary storage technique for the screened fecal solids using manure-lime-soil pellets was also developed but this has not been taken beyond the laboratory stage.

In 1974, a 100-gallon mixed and heated anaerobic digester was built. This digester will be used to evaluate the potential of generating methane from a mixture of beef manure and chopped corn stover. By April 1974, the digester had been acclimated successfully to beef manure alone. The trial with the manure-stover mixture will progress for the remainder of the year. At this stage, the investigation is very preliminary, with just sufficient data collected to indicate if it warrants further research

REGIONAL DEVELOPMENT AND MANAGEMENT OF LAND AND WATER RESOURCES WITHIN IOWA

SPONSOR: Iowa State University Agriculture and Home Economics Experiment Station

PRINCIPAL INVESTIGATOR: H. P. Johnson

MAJOR STAFF: C. E. Beer, J. L. Baker, W. Lovely

RESEARCH ASSISTANTS: S. Barisas, J. Gregory

The project objectives are (1) to project needs for land and water resources in a regional context for agriculture, industry, municipalities and recreation, (2) to develop analytical models (physical) relating water yield, quality and land use, and to develop complementary regional analysis models. The project is cooperative with Agronomy and Economics.

Studies conducted within the project are (1) agricultural interaction with Ames Reservoir, (2) hydrology of small watersheds (western Iowa), and (3) movement of pesticides with runoff and into soil profile.

QUALITY OF TILE EFFLUENT

SPONSOR: Iowa State University Agriculture and Home Economics Experiment Station

PRINCIPAL INVESTIGATOR: H. P. Johnson

MAJOR STAFF: J. L. Baker

RESEARCH ASSISTANT: M. Bina

The objective of the project is to determine the plant nutrient content (N,P) of effluent from subsurface drainage systems under cultivated land. Field studies are emphasized.

STUDY OF SEDIMENT POLLUTION AND MOVEMENT BY ACTIVATION ANALYSIS PRINCIPLES

SPONSOR: Iowa State University Agriculture and Home Economics Experiment Station

PRINCIPAL INVESTIGATOR: C. E. Beer

MAJOR STAFF: H. P. Johnson

RESEARCH ASSISTANTS: B. Nudd, W. P. David

A mathematical erosion model has been developed for a 19 mi^2 watershed. The model requires overland flow and stream flow as inputs. To accomplish the input, the erosion model is superimposed on a watershed model that generates the overland flow. Both the watershed model and erosion model were calibrated from gaged data and then tested on data not used in the development. The difference between the actual and simulated data was approximately 15 percent.

Concurrent with the sediment and flow measurements on the 19 mi^2 watershed, nutrient (nitrogen) outflow from the watershed was determined. A nitrogen balance based both on measured and assumed data was constructed.

CONDITIONING, DRYING AND STORING CORN ON FARMS

SPONSOR: Iowa State University Agriculture and Home Economics Experiment Station

PRINCIPAL INVESTIGATOR: G. L. Kline

MAJOR STAFF: R. A. Norton, R. A. Saul

RESEARCH ASSISTANT: V. G. Haynes

Develop and test improved methods and equipment for drying, conditioning and storing corn on farms to provide capacities associated with changing harvest methods, to maintain grain quality, and to reduce equipment and operating costs.

Newly harvested shelled corn was simultaneously dried and heat treated (roasted) for beef cattle feeding trials. Using a counterflow dryer, the corn was dried from 23 to 13.5 percent using air at 430F. The corn kernels were darkened and puffed but appeared quite palatable when fed. In the feeding trials, both heat treating (roasting) and high-moisture ensiled corn showed approximately a 7 percent advantage in daily gain and feed efficiency by comparison with corn dried with heated air in the conventional manner.

EQUIPMENT AND TECHNIQUES FOR WEED CONTROL

SPONSOR: Iowa State University Agriculture and Home Economics Experiment Station

PRINCIPAL INVESTIGATOR: W. G. Lovely

MAJOR STAFF: W. F. Buchele, H. P. Johnson

Early preplant applications of herbicides gave effective weed control up to planting time in corn and soybeans planted on corn or soybean ground without tillage. Applying a burndown herbicide at planting time was also effective for short-term control with these no-till systems. Both the preplant and burndown treatments required chemical and/or mechanical cultivations for full-season control. Commonly used preemergence and postemergence herbicides gave effective weed control in corn and soybeans where the tillage system used had weeds under control at planting time. Herbicide losses from controlled watersheds showed that

90 percent of the losses occurred when a runoff-causing rainfall occurred within 10 days of application. Losses were substantially larger with conventional tillage than with conservation tillage. The area of weed control from a single granule increased with soil moisture and weed seed depth. The effective area decreased as the depth of granule placement increased. Precise equidistant granular spacings on the soil surface were as effective at half-rates as full rates were with conventional equipment. Conventional fan-jet spray nozzles were as effective as foam nozzles for applying glyphosate to control weeds in June and in late July. Applying glyphosate just prior to soybean leaf drop looks promising as a method for killing mature weeds to speed up harvest.

ARCHITECTURE

Martin D. Gehner
Department Head
and Professor

Department Faculty Members	Areas of Research Interest
Professors	
Wesley I. Shank, M. Arch.	Historic preservation; statewide windshield survey of historic architecture
Vernon F. Stone, B. Arch.	New town analysis for Iowa
Visiting Professor	
Raymond D. Crites, B. Arch.	Energy conservation, solar-electric habitation
Assistant Professors	
David A. Block, M. Arch.	Energy conservation, solar-electric habitation
Paul Shao, M.F.A.	Asiatic influences in pre-Columbian American art and architecture
Richard G. Wilson, Ph.D	The Prairie School in Iowa; enhancement of socio-economic integration in Des Moines housing

A SOLAR ELECTRIC HABITATION
PHASE II

SPONSOR: Iowa Electric Light and Power

PRINCIPAL INVESTIGATOR: R. D. Crites

MAJOR STAFF: D. Block, P. Sidles

This project is the second part of a four part project. The first part was completed in June 1974 with the publication of a booklet describing the preliminary design concepts of an energy conserving single family residence utilizing a solar assisted heat pump for space conditioning. The second part consists of the preparation of contract documents for construction. The third part, if funded, will be the construction of the residence, and the fourth part will be instrumentation and documentation of energy consumption and space conditions in the habitation.

ASIATIC INFLUENCES IN PRE-COLUMBIAN AMERICAN ART AND ARCHITECTURE

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: P. Shao

This project involves a comparative investigation of the occurrences of congruent motifs in art and architecture of East Asia and Mesoamerica.

STATE HISTORIC PRESERVATION PROGRAM

SPONSOR: Iowa Conservation Commission

PRINCIPAL INVESTIGATOR: W. I. Shank

This project is the western portion of a statewide general survey of the historic architecture of Iowa and is in its second year. The result will be a

file card with a photograph mounted on it and containing basic information on the building for each historic structure.

THE SUBURBAN ARCHITECTURE OF McKIM, MEAD AND WHITE

SPONSOR: National Science Foundation Institutional Grant

PRINCIPAL INVESTIGATOR: R. G. Wilson

This project is an investigation of the sources for the American suburban style of architecture in the later 19th Century and its development. The iconography and development of Charles F. McKim's county houses have been the major research thrust.

PORTABLE HIGH-CAPACITY LOST-WAX AND FOAM-DISPLACEMENT FOR THREE-DIMENSIONAL DESIGN CURRICULUM

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: P. Shao

The objective of this project is to develop a low-cost, portable lost-wax and foam displacements foundary outfit for high school and college art classes.

STUDIES OF HISTORIC IOWA ARCHITECTURE, PHASE II

SPONSORS: Iowa Arts Council, Engineering Research Institute

PRINCIPAL INVESTIGATOR: W. I. Shank

RESEARCH ASSISTANT: J. Langholz

This project is the second part of a four-part project. The first part was completed in 1972 with publication of ten monographs on ten historic buildings in the state. The second part emphasizes institutional buildings and a study of the roles of architect, builder, and client in the design and construction process and will include some contemporary buildings of note. Possible publication of further monographs is anticipated.

BIOMEDICAL ENGINEERING

Richard C. Seagrave
Head of Program
Professor-in-charge

Department Faculty Members	Areas of Research Interest
Distinguished Professor	
Donald F. Young, Ph.D.	Biomedical fluid mechanics
Professors	
Richard C. Seagrave, Ph.D.	Transport phenomena, chemical reaction analysis, air pollution, physiological modeling
Allan G. Potter, Ph.D.	Application of engineering principles in development of emyoelectric control systems for upper extremity braces
Associate Professors	
William H. Brockman, Ph.D.	Real and modeled information processing within living systems, electrophysiological events and artificial intelligence, sensory protheses
David L. Carlson, Ph.D.	Biomedical electronic instrumentation, laboratory computer development
Raymond T. Greer, Ph.D.	Characterization of biomaterials, scanning electron microscopy
Curran S. Swift, Ph.D.	Physiological monitoring devices, electrical safety, minicomputer applications, artificial organs (heart), clinical engineering

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TRANSPORT PHENOMENA

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: R. C. Seagrave

MAJOR STAFF: J. L. Barbee

RESEARCH ASSISTANTS: L. Filosa, L. S. Powell, H. Valenta, Jr., P. Yip

EEG Activity and Control Dynamics during Anesthesia. The interaction of cerebral blood flow, uptake of anesthetic agent by the brain, and electroencephalographic (EEG) activity is being studied. Previous work has indicated that certain spectra of the overall EEG signal may provide information about brain levels of anesthetic agent. Model studies and animal experiments are being planned to further develop and confirm these ideas.

Temperature Changes during Porcine Stress Syndrome. This project is concerned with the thermodynamics and energy transport mechanisms that govern the behavior of swine during the events characterized as stress syndrome. Very large core temperature changes apparently occur over short times, and the role of temperature has yet to be

fully characterized. Initial efforts will be devoted to collection of appropriate data and physical parameters, as well as dimensional analysis.

Analysis of Respiratory and Circulatory Mass Transfer. Some preliminary work has raised the possibility of measuring cardiac output non-invasively with a frequency response method. In a separate project, some techniques for assessing and describing the effects of ventilation/perfusion inequality on the performance of the lung have been developed. This project will combine these two ideas and attempt to determine the effects of the latter phenomena on the former method.

Models of Renal Transport. Work by Raymond Carr (MS 1973) has demonstrated the feasibility of applying chemical engineering concepts to the quantitative description of mass transfer in the human kidney. A multi-compartment model has been developed that tracks the concentration of several chemical species through seven compartments representative of nephron segments for steady-state behavior.

Recent publications:

Seagrave, R. C., "Modification of Engineering Simulation Techniques for Biological Problems," Analog/Hybrid Computer Ed. Soc. Trans., 3: 247-257 (1971).

Seagrave, R. C. and M. V. Coffey, "A Model of Neonatal Thermoregulation," Proc. 1972 San Diego Biomedical Symposium, 11: 219-226 (1972).

Seagrave, R. C., K. W. Preasse, M. L. Kaeberle and F. K. Ramsey, "A Model of Granulopoiesis in Cats," Laboratory Investigation, 28: 292-299 (1973).

Seagrave, R. C. and A. Zwart, "Oscillations in Cerebral Blood Concentrations during Flow Measurement and Halothane Anesthesia," Digest of the Tenth Intern. Conf. on Medical and Biological Engrg., 2: 40 (1973).

Seagrave, R. C., A. Zwart, J. E. W. Beneken and J. F. Crul, "Optimization of Combined Infusion-Inhalation Ether Anesthesia," Digest of the Tenth Intern. Conf. on Medical and Biological Engrg., 1: 337 (1973).

Seagrave, R. C. and N. C. Miller, "A Model of Human Thermoregulation during Water Immersion," Computers in Biology and Medicine, 4: 1-18 (1973).

Seagrave, R. C. and A. Zwart, "Non-Invasive Determination of Pulmonary Blood Flow by a Frequency Response Technique," Proc. of the 26th Annual Conf. on Engrg. in Medicine and Biology, 15: 292 (1973).

Seagrave, R. C. and F. L. Kinne, "Effects of Mixing Patterns in Respiratory Gas Exchange," J. Appl. Physiol., 36: 698-705 (1974).

SPECTRAL ANALYSIS OF BIOLOGICAL SIGNALS USING COHERENT OPTICAL TECHNIQUES

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATORS: W. H. Brockman and A. A. Read

RESEARCH ASSISTANT: R. F. Cannata

Part I of this research dealt with the evaluation of several data input formats suitable for optical analysis of real one-dimensional biological signals. The primary methods investigated were area and density modulation of the amplitude transmittance of photographic film transparencies. The optical computing system consisted of a He-Ne laser, a spatiac filter used to produce a diverging beam, a thin converging lens, and the input transparency. The light distribution at the diffraction pattern plane of this system is proportional to the fourier transform of the data on the transparency.

Part II of the project was the development of a non-hozographic means of optically computing the correlation between or convolution of two input signals such as EEG, ECG, etc. This is accomplished through the use of a simple-to-implement filter placed in the frequency plane and subsequent retransformation using a second thin lens.

DEVELOPMENT OF A COMPUTER PROGRAM TO EVALUATE ELECTRIC POTENTIALS FOR MULTIPLE ELECTRODE GEOMETRIES IN NONHOMOGENEOUS VOLUME CONDUCTORS

SPONSOR: Medtronic, Inc.

PRINCIPAL INVESTIGATOR: W. H. Brockman

RESEARCH ASSISTANT: R. H. Hillman

A Fortran Language Program suited for IBM-360 or similar systems was developed to compute static electric potential fields in a nonhomogeneous volume conductor. The direct application of the program is in the optimal electric stimulation of selected volumes of neural tissue in humans. Electrode-tissue geometries are user-specified in analytic or point-by-point form, and serial-section two-dimensional potential computer typed maps are the output format. The basic computational technique is a numerical overrelaxation iterative evaluation of difference equation approximations to Laplace's equation for potential.

A MODIFIED CABLE MODEL FOR NEURON PROCESSES WITH NON-CONSTANT DIAMETERS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: W. H. Brockman

RESEARCH ASSISTANT: G. M. Strain

The neuron axon cable model was expanded and developed to describe the linear subthreshold transmembrane potential of any circular cross section, thin membrane neuron fiber whose radius can be expressed as an analytic function of position, r(x). The transmembrane time constant was shown under the condition of space clamp to be independent of changes in geometry. Three typical neuron geometries were modeled (dendrite-soma, soma-axon, and dendrite-soma-axon) and the solutions to the resulting differential equations were numerically evaluated. The geometry-induced effects are attributed to changes in current density and physiological correlates of the effects were proposed.

A SYSTEM TO STUDY AMPLITUDE- AND TIME-QUANTIZED HUMAN SPEECH

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: W. H. Brockman

RESEARCH ASSISTANT: E. M. O'Brien

This research was directed toward electronically reducing human speech waveforms to minimal forms which retain intelligibility, ultimately for application to sensory aid systems for the profoundly deaf. A system was devised to reduce the signal to a three level, time quantified form particularly well suited for digital processing and analysis techniques. A novel squelch system was developed to eliminate noise between words. Initial tests using phonetically balanced spoken word lists as inputs show a surprisingly high intelligibility without the need for appreciable listener training even when the quantizing rate is as low as 10 KHZ.

FLUID MECHANICS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: D. F. Young

This project is concerned primarily with the application of basic fluid mechanics concepts and principles to problems in biology and medicine. The role of blood flow in the pathogenesis of cardiovascular disease is being studied extensively. Other work in progress is concerned with basic problem and solution techniques in the area of steady and unsteady viscous flow which have applications in the field of biomedical fluid mechanics.

Recent publications:

Krueger, J. W., D. F. Young and N. R. Cholvin, "An In-Vitro Study of Flow Response by Cells," J. Biomechanics, 4: 1, 31-36 (1971).

Avula, X. J. R. and D. F. Young, "Start-up Flow in the Entrance Region of a Circular Tube," ZAMM, 51: 517-526 (1971).

Morgan, B. E. and D. F. Young, "An Integral Method for the Analysis of Flow in Arterial Stenoses," (to be published in Bulletin of Mathematical Biology).

DEVELOPMENT OF COMPUTER PROGRAM TO EVALUATE ELECTRIC POTENTIALS

SPONSOR: Medtronic, Inc., Minneapolis, Minnesota

PRINCIPAL INVESTIGATOR: W. H. Brockman

MAJOR STAFF: D. L. Carlson

RESEARCH ASSISTANT: R. H. Hillman

This project involves the development of a Fortran Language Program suited for IBM 360 system use to compute static electric potential fields in a non-homogeneous volume conductor. The direct application of the program is in the optimal electric stimulation of neural tissue. Electrode-tissue geometries will be user-specified in analytic form, and serial-section two dimensional potential computer typed maps will be the output format. The basic computational technique involved is the numerical iterative computation of difference equation approximations to Laplace's Equation for Potential.

EFFECTS OF STENOTIC OBSTRUCTIONS ON FLOW IN ARTERIES

SPONSOR: National Institute of Health

PRINCIPAL INVESTIGATOR: D. F. Young

MAJOR STAFF: N. R. Chovin

RESEARCH ASSISTANTS: A. C. Roth, R. L. Kirkeeide

This project focuses on determining pertinent hydrodynamic characteristics related to flow in arterial stenoses, and on ascertaining the role of these characteristics in the development of arterial disease associated with the presence of stenotic obstructions. By means of both *in vitro* and *in vivo* experiments, the following characteristics and their interrelationships are being investigated: (1) stenosis geometry, (2) flow resistance, (3) localized regions of separated flow and turublence for both steady and unsteady flow conditions, and (4) histopathology of arterial sections which have been exposed to the abnormal flow induced by stenoses.

The *in vivo* experiments use large mongrel dogs and involve artificial inducement of arterial stenoses. The stenosis inducement technique and data gathering techniques are now being standardized. Future research will place emphasis on obtaining reliable, quantitative evaluation of observed biological effects of stenoses.

Recent publications:

Krueger, J. W., D. F. Young and N. R. Cholvin, "An *In Vitro* Study of Flow Response by Cells," J. Biomechanics, 4: 1, 31-36 (1971).

Tsai, F. Y. and D. F. Young, "Some Turbulence Measurements in an Arterial Stenosis," Proc. of the Tenth Annual Rocky Mountain Bioengineering Symposium, 59-62 (1973).

Young, D. F. and N. R. Cholvin, "Resistance Characteristics of Arterial Stenoses," Digest of the Tenth International Conf. on Med. and Biol. Engr., 2: 45 (1973).

Young, D. F. and F. Y. Tsai, "Flow Characteristics in Models of Arterial Stenoses – Part I, Steady Flow," J. Biomechanics, 6: 4, 395-410 (1973).

Young, D. F. and F. Y. Tsai, "Flow Characteristics in Models of Arterial Stenoses – Part II, Unsteady Flow," J. Biomechanics, 6: 5, 547-559 (1973).

CLINICAL ENGINEERING

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: C. S. Swift

RESEARCH ASSISTANT: D. Bauer

This project differs from most in Biomedical Engineering in that it is specifically directed toward applications in the clinical environment. As a clinical engineering project it does not involve a single intensive project; rather it involves a series of smaller projects carried out in conjunction with Dr. Gary Fanning at Mary Greeley Hospital. The projects include the development of a compact peripheral nerve stimulator for use in anesthesia, an electrical safety study of various areas of the hospital, and the development of a switching system for the Intensive Care Unit's remote monitoring system.

CERAMIC ENGINEERING*

David R. Wilder
Department Head
and Professor

Department Faculty Members	Areas of Research Interest
Professors	
David R. Wilder, Ph.D.	Ceramic engineering
Thomas D. McGee, Ph.D.	Glass properties and processes; refractories for industrial applications; bone and tooth prostheses; dielectric and piezoelectric materials; electron, scanning electron and optical microscopy; infrared, X-ray diffraction and X-ray small angle scattering
Elmer A. Rosauer, Ph.D.	Electron beam analysis of inorganic materials, materials science
David M. Martin, Ph.D.	Composition and properties of silicate glasses, surface properties, mechanical properties of materials

ANALYSIS OF MATERIALS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: E. A. Rosauer

Clay Skins in Soils

The term "clay skin" refers to a thin (20-300 micron) coating of clay mineral particles adhering to the wall of a void in a natural soil. The clay minerals comprising this coating are believed to be water transported down from the surface soil layer where weathering processes have altered feldspars to form the clay minerals. Light microscopic investigations show layering within the clay skin parallel to the supporting surface; however, instrumental resolution limits observation of individual particle orientation. Investigations in progress with the scanning electron microscope should reveal the micromorphology of such clay skins and provide information regarding their genesis.

Conversion Coatings on Metals

Steel is frequently treated with a phosphate solution to produce a conversion coating which resists corrosion and improves adhesion of subsequent polymer coatings. The effectiveness of the conversion coating is at least partly due to the epitaxial nature of the initial phosphate-metal layer. This is evidenced by certain extraordinarily intense (hkl) maxima obtained by x-ray diffractometry. Treatment of an α-iron panel with a manganese phosphate bath produces a conversion coating consisting of the mineral species, hureaulite, an iron-manganese phosphate; treatment with zinc phosphate both produces mainly hopeite, a hydrated zinc orthophosphate, with some phosphophyllite, a iron-zinc phosphate. Scanning electron microscopy reveals gross morphological differences not only between the two conversion coatings but also on the surface of the host metal. Future work will include a systematic study of surfaces from the cleaning treatment up to polymer application.

ELECTRONIC CERAMIC MATERIALS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: T. D. McGee

This research has been conducted to determine the effect of stoichiometry on the electronic properties of barium titanate. A vacuum microbalance is being used to determine the weight loss of high purity $BaTiO_3$ when mixed $CO:CO_2$ gases are introduced to control the oxygen pressure at temperatures of 1000 to 1400 ^{o}C. High temperature X-ray diffraction is being used to determine the phase composition under the same conditions.

KINETICS OF BASIC OXYGEN FURNACE (BOF) SLAG REACTIONS

SPONSORS: American Iron and Steel Institute, Engineering Research Institute

PRINCIPAL INVESTIGATOR: T. D. McGee

RESEARCH ASSISTANT: S. Bose

The objective is to study the solution rate of high-purity, tar-bonded and -impregnated BOF refractories as a function of slag composition. The research is directed toward specific slag attack problems involved in BOF practice. The first year of research involved the following:

1. Establishment of a reproducible corrosion test with a standard set of burned and impregnated refractories and a standard slag. This included testing various slag furnace configurations and methods for controlling furnace atmosphere.
2. Characterization of tar-impregnated, tar-bonded, and tar-bonded and tempered refractories by making complete physical property measurements on representative bricks from each shipment. Each specimen was weighed and measured and its bulk density determined. The scanning electron microscope was used to determine the structure of the specimens as received, coked, and completely oxidized.
3. Development of test slags of varying composition in order to control the corrosion rate.
4. Exploration of various methods of analyzing the slag test results, including measuring, photographing, optical microscope, and scanning microscope techniques.

Present research involves the following:

1. Comparison of slags of different composition to determine the effect of composition on slagging rate.
2. Extensive measurements of the mechanisms of corrosion, including oxidization rates, penetration-structure relationships, solution rates, contact angle measurements, etc.
3. Analysis of the results – using statistical methods where appropriate.

Recent publication:

McGee, T. D. and C. D. Wirkus, "Mullitization of Alumino-Silicate Gels," Bull. Am. Cer. Soc., 51: 7 (July 1972).

DEFORMATION MECHANISMS OF CERAMIC MATERIALS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: T. D. McGee

MAJOR STAFF: C. D. Wirkus, Electron Microprobe Laboratory

RESEARCH ASSISTANT: I. J. Yoon

This research is a fundamental study of the mechanisms which contribute to the deformation of ceramic materials at high temperatures. This has included an analysis of point defect concentrations and mobility in sodium chloride – a model ceramic material.

Also under the project is the operation of the electron microprobe laboratory by C. D. Wirkus. He is currently studying the effect of high energy radiation on carbon filament composites.

Research soon to begin is an electron microprobe analysis of the structure of Si_3H_4 for high temperature gas turbines.

A fundamental study of the oxidation reduction mechanisms in silicate glasses is also included.

Recent publication:

McGee, T. C. and C. D. Wirkus, "Mullitization of Alumino-Silicate Gels," Bull. Am. Cer. Soc. 51: 7 (1972).

OSTEOCERAMICS

SPONSOR: Iowa State University Research Foundation

PRINCIPAL INVESTIGATOR: T. D. McGee

Ceramic artificial teeth are being implanted in dogs by Dr. DeYoung to test ceramic compositions for use as a bone or tooth prosthesis. The ceramic compositions are combinations of $Ca_3(PO_4)_2$ and $MgAl_2O_4$ which are hard and strong and which have solubility products similar to hydroxyapatite, the mineral constituent of bone.

Recent publication:

U.S. Patent No. 3,787,900. "Artificial Bone or Tooth Material" (January 24, 1974).

ELECTRON MICROSCOPY OF COLLOIDAL METAL PARTICLES IN ALKALI HALIDES

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATORS: Y. A. Ekmanis, E. A. Rosauer

Replicas of previously-prepared alkali halides were found to be extraction replicas with metal-containing colloidal particles. These particles were examined in the scanning and the transmission electron microscopes. It is shown that qualitative and quantitative elemental analysis of such colloidal particles may be performed in both instruments. Comparisons are made and limitations are discussed.

SEM SUPPORT

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: D. M. Martin

This project is intended to cover a variety of activities associated with the scanning electron microscope. These activities fall into three categories, as follows:

1. Support of external service, not directly charged. An example of this service is the current carbon fiber work for Aerospace Corp. Operating funds are necessary for shop work, supplies and technician time.
2. Development of external funding for service/research. These activities generally involve the demonstration of typical results for a prospective customer, including microscope time, photographic, and technical illustration work.
3. Development of devices and modifications to the equipment. Current projects include a scanning transmission device utilizing photo diode detectors including an electron diffraction capability. The ability to do electron diffraction in the SEM is important for a wide variety of materials research work.

SURFACE STUDIES ON NaCl

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: E. A. Rosauer

Etch pits on sodium chloride surfaces are thought to be emergence sites of dislocations. Chemical treatment of NaCl single crystal surfaces with an ammonium chloride-methanol solution yields oriented overgrowths as well as etch pits. Since thermodynamical equilibrium was not established during the brief etching process, overgrowths possess several habits and orientations. Evidence suggests that the overgrowths are NaCl and that these are nucleated at microsteps of the etch pit. Microsteps appear to continue to grow as a result of NaCl still in solution. Measurements have been made to determine the precise orientation of the NaCl overgrowths to the NaCl substrate.

SILICATE MELTS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: D. M. Martin

The objectives of this project are as follows:

1. To establish exact composition limits and melting conditions for Iowa shale glass.
2. To establish exact temperature history for controlled crystallization of Iowa shale glass and establish properties of product.
3. To design and begin construction of a small, continuous pilot manufacturing facility for shale glasses.
4. To support glass experimentation in other areas, including melting and durability analysis.

VAPOR/SILICATE GLASS REACTION PHENOMENA

SPONSOR: National Science Foundation

PRINCIPAL INVESTIGATORS: D. M. Martin, T. D. McGee

The importance of glass surface reactions with the ambient atmosphere has long been recognized. The beautiful irridescence of ancient Roman glass due to centuries of contact with the atmosphere led L. C. Tiffany to develop surface treatments to mimic those fantastic film optical effects. The purposeful reaction of a variety of chemicals with glass surfaces has been a practice for centuries for both decorative and practical applications and is generally poorly understood.

This research is designed to look at treatments applied to glass surfaces during forming, their influence on forming, and their influence on room temperature properties. Glass fibers will be drawn in various gases and the influence of those gases on the fiber drawing characteristics will be determined. The fiber drawing process is a dynamic process in which any surface reactions which occur must occur rapidly, making available the opportunity for exploration of the area of surface kinetics at high temperatures. Equilibrium surface tensions for the gases and glasses in question will also be determined by a modification of the equilibrium bubble technique.

The second major aspect of this work is finding out what effect the high temperature surface treatments have on the room temperature properties of the glass. As a starting point, the free energy of wetting for the treated surfaces will be evaluated by adsorbtion isotherm, a technique which involves the determination of the quantity of gas adsorbed on a known surface area as a function of gas pressure. The determination of the free energy and kinetics of wetting for water is important to this work as it yields a result which indicates whether or not changes have been made on the glass surface which will alter its long term stability.

Although it is expected that useful information along those lines will be developed, the overall goal of this work is more a basic investigation of surface reactions. Glass fibers are mostly surface, so that this approach allows us to separate the surface effects from bulk effects. Much previous ground has been covered in this area of research, and close contact with industry and other laboratories will be maintained to avoid needless duplication. It is hoped that a logically consistent, relatively complete picture of the role that atmosphere plays in both the forming and the end use of glass articles will be developed as a result of this work.

Recent publication:

Poole, J. P., Proc. Workshop on Glass Research for the Glass Container Industry, Bedford Springs, Pennsylvania, October 15, 1971, edited by G. J. McCarthy, Pennsylvania State University, published by the Engineering Division, National Science Foundation.

DIBORIDES

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: D. M. Martin

The goal of this research is to manufacture and characterize titanium diboride/aluminum oxide compacts at high densities through the reaction,

$$T_i O_2 + Al + B_2 O_3$$

$$T_i B_2 + Al_2 O_3$$

In order to achieve high densities, hot pressing will be utilized. This reaction has been demonstrated to go at reasonable temperatures and the high density compacts manufactured will be tested to determine their physical properties.

HIGH TEMPERATURE CREEP AND CREEP RECOVERY IN OXIDE SINGLE-CRYSTAL SOLID SOLUTIONS

SPONSOR: National Science Foundation

PRINCIPAL INVESTIGATOR: T. D. McGee

RESEARCH ASSISTANTS: S. Rahman, V. Nehring

Research is being conducted to determine the basic high-temperature deformation mechanisms in transition element oxide single crystals. Single crystals of Ni_x0 and Co_x0 are being grown in a direct current arc by the arc transfer method. These crystals are grown from rods of Ni or Co (or alloys of Ni or Co) or from sintered oxide mixtures. There is no crucible in the crystal growing

process to introduce contaminants.

Creep measurements are being made in the compressive mode in air and under controlled oxygen partial pressure in furnaces constructed at Iowa State University. Creep recovery processes are also being studied to determine their nature in solid solutions of NiO and CoO and in similar solid solutions where a small amount of second phase, such as spinel, is present.

The creep data and the creep recovery data are being evaluated in terms of diffusion data obtained from similar specimens at Iowa State University.

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*Effective July 1, 1975, the Departments of Ceramic and Metallurgical Engineering will be combined to form the Department of Materials Science and Engineering. Dr. David R. Wilder will serve as Head of this new department.

CHEMICAL ENGINEERING AND NUCLEAR ENGINEERING

George Burnet, Jr.
Department Head
and Professor

Department Faculty Members	Areas of Research Interest
Professors	
George Burnet, Ph.D.	Adsorption dynamics, process chemistry, fertilizer technology, reaction mechanism and kinetic studies, applications of gas chromatography
Richard A. Danofsky, Ph.D.	Reactor kinetics
William H. Abraham, Ph.D.	Chemical process dynamics and control
Maurice A. Larson, Ph.D.	Fertilizer processing technology, crystallization processes
Donald M. Roberts, Ph.D.	Reactor physics, reactor instrumentation, neutron activation analysis, heat transfer, materials
Richard C. Seagrave, Ph.D.	Transport phenomena, chemical reaction analysis, air pollution, physiological modeling
John D. Stevens, Ph.D.	Liquid-vapor equilibria, crystallization, emulsion polymerization
Thomas D. Wheelock, Ph.D.	Development of electrofluid reactor system for coal gasification, chemical desulfurization methods for coal, decomposition of calcium sulfate, properties and characteristics of fluidized beds of fine powders such as flour and starch
Associate Professors	
James C. Hill, Ph.D.	Fluid mechanics, fluid turbulence and turbulent transport, mechanics of aerosols and particle-fluid systems, air pollution control, heat convection, anemometry
Kenneth R. Jolls, Ph.D.	Fluid dynamics, thermodynamics, application of modern electronic instrumentation to problems in chemical engineering research and practice
Benjamin M. Ma, Ph.D.	Aerospace and nuclear science and engineering, liquid-metal fast breeder reactors, controlled thermonuclear fusion, radioisotopes, space, energy
Allen H. Pulsifer, Ph.D.	Transport processes in fixed and fluidized beds

Peter J. Reilly, Ph.D.	Biochemical engineering, fermentation kinetics, immobilized enzyme technology
Zeinab A. Sabri, Ph.D.	Controlled thermonuclear reactors, nuclear power reactor design and safety, separation processes
Agust Valfells, Ph.D.	Classical charged particles, isotope separation

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USE OF IMMOBILIZED ENZYMES TO PRODUCE SUGARS FROM AGRICULTURAL PRODUCTS

SPONSORS: National Science Foundation, Engineering Research Institute, Corning Glass Works

PROJECT COORDINATOR: P. J. Reilly

MAJOR STAFF: E. V. Collins, G. Burnet

RESEARCH ASSISTANTS: D. Lee, G. Lee, E. Chen, H. Kaboli

Enzymes can be employed to many biochemical reactions. Often they can be made more stable and more easy to remove from the reaction mixture by attaching them to solid materials such as porous glass or cellulose. In this project four different enzymes immobilized to glass are being studied:

1. Glucoamylase helps to break down partially hydrolyzed corn starch to glucose. This process has been investigated both in the laboratory and in a 1000 lb/day pilot plant.
2. Glucose isomerase catalyzes the formation of a glucose-fructose mixture from the glucose feedstock produced by the previous process. This mixture is as sweet as an equal concentration of sucrose and is now being produced commercially.
3. Lactase catalyzes the hydrolysis of lactose in milk or whey to the simpler sugars glucose and galactose. Removal of lactose would allow dairy products to be consumed by the many who cannot digest it.
4. Dextransucrase helps to convert sucrose to fructose and dextran, a polymer composed of glucose. Fructose is very sweet while dextran is used as a blood plasma extender and a drilling mud additive.

See feature article, page 9, for more information on this project.

Recent publications:

Fratzke, A. R., Y. Y. Lee, and G. T. Tsao, "Kinetics and Thermal Deactivation of Glucose Isomerase Immobilized on Porous Glass," presented at AIChE-VTG Joint Meeting, Munich, West Germany, September, 1974.

Lee, Y. Y., K. Wun, and G. T. Tsao, "Kinetics and Mass Transfer Characteristics of Glucose Isomerase Immobilized on Porous Glass," presented at AIChE 77th National Meeting, Pittsburgh, Pa., June, 1974.

Lee, Y. Y. and G. T. Tsao, "Mass Transfer Characteristics of Immobilized Enzymes," J. Food Sci. 39: 667-672 (1974).

Lee, D. D., Y. Y. Lee and G. T. Tsao, "Continuous Production of Glucose from Dextrin by Glucoamylase Immobilized on Porous Silica," presented at 10th Midwest ACS Meeting, Iowa City, Iowa, November, 1974.

Marsh, D. R., "Kinetics of Immobilized Glucoamylase," PhD Thesis, Iowa State University, Ames (1973).

Marsh, D. R., Y. Y. Lee and G. Tsao, "Immobilized Glucoamylase on Porous Glass," Biotech. Bioeng., 15: 483-492 (1973).

Wun, K., "Kinetics and Mass Transfer Studies of Glucose Isomerase Immobilized on Porous Glass," unpublished MS Thesis, Iowa State University, Ames (1973).

PRODUCTION OF XYLOSE FROM AGRICULTURAL WASTES BY ENZYMES

SPONSORS: National Science Foundation, Engineering Research Institute, Corning Glass Works

PRINCIPAL INVESTIGATOR: P. J. Reilly

MAJOR STAFF: G. Burnet

RESEARCH ASSISTANTS: A. Fratzke, U. Gunduz, N. Kundel, G. Oguntimein

Wood is composed of a number of substances, among which are cellulose, a polymer of glucose; hemicellulose, a group of polymers of xylose and several other sugars; and lignin, a polymer of a number of substituted phenols. An intense effort has been underway elsewhere to break down cellulose in urban and agricultural wastes to produce glucose. To this point there has been no equivalent effort to treat hemicellulose and lignin.

The work at Iowa State is concerned with the hydrolysis of xylan, a major constituent of hemicellulose, to its component sugars. The feed-stock will be corn cobs and corn hulls, which are comparatively rich in xylan. After purification, the kinetics and stability of the three enzymes, both in free form and when attached to a solid carrier such as porous silica, will be determined under a number of different conditions.

FOIL ACTIVATION PERTURBATION

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: D. M. Roberts

The experimental determination of neutron slowing down parameters or Fermi age is accomplished by exposing cadmium-covered indium foils at known distances from the source of fast neutrons and measuring the relative activation profile produced by an irradiation of appropriate duration. The age is then found from the mean square distance traveled by the neutrons in slowing down to the energy of the principal indium resonance, i.e., age = $(1/6)(\overline{r^2})$. The foil detectors are usually supported and positioned by a stringer, which is generally left in the medium being explored during the irradiation period. There is some indication that when the support structure is made of material having different moderating properties than the matrix medium, the local flux is perturbed, which leads to an incorrect determination of the age.

Experiments have been carried out using the I.S.U. – UTR-10 graphite thermal column as the matrix medium and both air and hydrogen-rich plastic as the perturbing material. The measured slowing down density "q" was fitted to the equation $q \simeq r^{-2} A \exp(-r/h)$ for the case of air and $q \simeq r^{-2} A[\exp(-r/h_1) + B \exp(-r/h_2)]$ for the plastic case with the results given below.

Thickness of perturbing material	h (air)	h_1 (plastic)	h_2 (plastic)	B (plastic)
0 cm	13.2cm	13.2 cm	cm	–
1.83	14.1	8.1	38.9	1.57×10^{-3}
4.60	17.1	6.5	38.9	2.03×10^{-4}
10.17	22.1	3.8	38.9	1.11×10^{-7}

Continuing work will seek to understand these results from a theoretical point of view.

COMPARISON OF VARIOUS PLASMA-STABILIZATION METHODS FOR CONTROLLED THERMONUCLEAR FUSION: MAGNETIC SHEAR AND MAGNETIC FIELD FEEDBACK FOR PLASMA STABILIZATION

SPONSOR: Air Force Office of Scientific Research

PRINCIPAL INVESTIGATOR: B. M. Ma

To improve the stability and containment time of plasma contained in a magnetic field, the plasma stabilization for controlled thermonuclear fusion must be developed. The methods of dynamic and feedback stabilization are of primary importance and have been given top consideration in this project. The project has already reviewed various stabilization methods and has compared the effectiveness of these methods. Work is now being done on development of a new, original method for improving the effectiveness of plasma stabilization. From previous work, the principles (or methods) of magnetic shear and magnetic-field feedback for plasma stabilization have, in general, been introduced and developed. These principles, applied to a toroidal theta pinch, are being analyzed. Present work focuses on the stability analysis for neutral equilibrium and feedback stabilization of toroidal high-β theta pinch with a magnetic shear and magnetic-field feedback system on a consideration of the principle of magnetic well (i.e. minimum average magnetic field, B) for suppressing purely hydromagnetic (or MHD) modes of interchange instabil-

ity, if the modes occur in a toroidal high-β theta pinch.

The computed analytical results will be compared with experimental data based on the use of a toroidal high-β theta pinch for experiments on magnetic field feedback stabilization with various combinations of helical magnetic fields.

Recent publications:

Ma, B. M., "Mechanisms of Fuel Element Failure Propagation for a Large Liquid-Metal Fast Breeder Reactor," Engineering Research Institute Preprint 73001, Iowa State University, Ames (January 1973).

Ma, B. M., "Magnetic-Field Feedback Stabilization of Toroidal Theta Pinch," International Congress on Waves and Instabilities in Plasmas, Innsbruck, Austria (April 2-7, 1973).

Ma, B. M., "Complementary Heating Methods for Tokamak Devices," International Congress on Waves and Instabilities in Plasmas, Innsbruck, Austria (April 2-7, 1973).

Ma, B. M., "Swelling, Creep, and Thermal Fatigue Analysis for Cylindrical Fusion Reactor Vacuum Wall," Invited Lecture of the research paper presented at the Second International Conference on Structural Mechanics in Reactor Technology, Berlin, West Germany (September 10-14, 1973).

Ma, B. M., "Comparison Between New-Ordering Theoretical Results and Experimental Data of the Scyllar Sector (Toroidal Theta Pinch)," paper presented at the Annual American Physical Society Plasma Physics Meeting, Philadelphia, Penn. (October 30-November 3, 1973).

Ma, B. M., "Design of Fuel Elements," International Atomic Energy Agency (United Nations) Report No. 898, to the Government of Argentina, National Atomic Energy Commission, Argentina, November 27, 1973.

Ma, B. M., "Irradiation Swelling, Creep, Thermal-Shock and Thermal-Fatigue Analysis of Cylindrical CTR First Wall," Intern. Journal of Nuclear Engineering and Design, 28, 1974.

Ma, B. M., "Magnetic Shear and Helical-Field and Conducting-Wall Feedback Stabilization for Toroidal Plasma Confinement (Theta Pinch, Tokamak)," Annual Report, ISU-ERI-74130, 1974.

Ma, B. M., "Irradiation Bowing and Stress Analysis of LMFBR Fuel Elements," ANS Conference on Fast Reactor Safety, Paper No. F-8, Beverly Hills, Calif., April 2-4, 1974.

Ma, B. M., "Helical Field and Conducting-Shell Feedback Stabilization of Toroidal Theta Pinch," Proc. 1st Topical Meeting on the Technology of Controlled Nuclear Fusion, 276-285, San Diego, Calif., April 16-18, 1974.

Valfells, A., Z. Sabri, B. M. Ma, and Y. C. Chiu, "A Tetrahedrally Symmetric Well for Target Plasma Reactors," Proc. 1st Topical Meeting on the Technology of Controlled Nuclear Fusion," 412-422, San Diego, Calif., April 16-18, 1974.

Ma, B. M., "Irradiation Swelling, Creep, and Thermal Fatigue Analysis for LMFBR Pressure Vessels," 1974 ASME Pressure Vessel and Piping Conf., Miami Beach, Fla., June 24-28, 1974.

Ma, B. M., "Some Energy Resources and Evaluation of Energy Conversion Systems," Proc. 1974 Modern Engineering and Technology Symposium, Chinese Institute of Engineers (Federation of Chinese Societies of Engineers), Paper No. A-3, Taipei, Taiwan, July 15-20, 1974.

INVESTIGATION OF SHEAR STRESS AND MASS TRANSFER AT THE WALL IN FLOWING LIQUID SYSTEMS

SPONSORS: Engineering Research Institute, Chemical Engineering Department

PRINCIPAL INVESTIGATOR: K. R. Jolls

RESEARCH ASSISTANT: R. C. Sanderson

The analog computer is being used to simulate pulsatile Newtonian flow through a circular tube in which a diffusion-controlled chemical reaction is occurring at the wall. This type of flow field is found in certain pieces of chemical process equipment and is often used to model blood flow in the larger vessels in the body. Several recent investigations of shear stress and mass transfer in flowing liquid systems of other geometries have

also utilized diffusion-controlled reactions as a means of measurement.

This project will apply advanced analog/hybrid programming techniques to simulate the coupled transport processes involved in this flow system. An attempt will be made to use the Monte Carlo technique with random signal generators to solve for the time-varying reaction rate which results from the pulsations in the flow. Expressions will be sought to characterize this variation and to account for any phase difference with the fluctuating shear stress.

The results, in addition to increasing our understanding of pulsatile flow, will also provide information of value to those who use diffusion-controlled reaction techniques in fluid mechanics research.

Recent publications:

McFeeley, J. J., "The Response of a Diffusion-Controlled Electrode to Pulsed Laminar Flow," PhD Thesis, Poly. Inst. of Bkln. (1972).

McFeeley, J. J., R. D. Patel and K. R. Jolls, "Approximate Low-Frequency Solution for Pulsatile Laminar Flow in a Tube," Chem. Engr. Sci. 28: 11.2105 (1973).

CONTROL OF POLYMERIZATION PROCESS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: W. H. Abraham

RESEARCH ASSISTANT: D. Loebach

Experimental studies are being made of the continuous emulsion polymerization of polystyrene, as an example of difficult control problems encountered in complex chemical process systems. Work was completed this year to determine by direct experiment the rate of nucleation of latex particles, a key factor in such a reaction system. Work now in progress has the objective of relating product molecular weight to reaction conditions, especially the effect of latex particle size. The work mentioned is preliminary to later studies of control.

Recent publication:

Peppard, Bruce Devlan, "Particle Nucleation Phenomena in Emulsion Polymerization of Polystyrene," PhD Thesis, Iowa State University, Ames (1974).

KINETICS OF CRYSTALLIZATION IN A DILUTE SYSTEM

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: J. D. Stevens

RESEARCH ASSISTANT: P. M. Schierholz

This research involves the analysis and modeling of dilute particulate systems. The work completed to date involved determination of the crystallization kinetics in dilute solutions of calcium carbonate. By measuring the crystal size distribution under varying supersaturations, the kinetics were determined. The kinetic data were then fit to power law models. A Model TA Coulter Counter was used for the size distribution measurements.

Results to date demonstrate the applicability of the population balance theory to light crystal suspensions. Many of the results have important implication in water softening plant operation.

CRYSTALLIZATION KINETICS

SPONSORS: National Science Foundation, Engineering Research Institute

PRINCIPAL INVESTIGATOR: M. A. Larson

MAJOR STAFF: Dr. E. T. White (Visiting Professor 1974)

RESEARCH ASSISTANTS: L. L. Bending, J. Helt

The critical phenomenon in industrial crystallization from solution is secondary nucleation. As a result of the extensive work in crystallization from solution in the past 10 years, the analysis and experimental techniques are now available to make important advances in understanding this phenomenon. This project continues the study of this phenomenon with a mixed suspension, mixed product removal type crystallizer with a point source of nuclei. The objective of the research is to more clearly define the hydrodynamic, energetic and chemical effects on the nuclei production and the effectiveness of the nuclei produced in surviving in the system sufficiently long to contribute to the population of the product size range.

Experiments are being conducted to measure very small crystal populations (1-50μm) which exist in an MSMPR crystallizer operated under various conditions of temperature, supersaturation and additive concentrations. Interpretations of these distributions will provide the increased understanding of secondary nucleation which is desired.

The modelling of crystal size distribution and the description of the kinetics which is anticipated, as a result of this research will permit better design of crystallization processes, so that more control of crystal size distribution can be achieved.

The current effort is concerned with measurement secondary nucleation rate and the characterization of the mechanism of secondary nucleation. Contact nucleation rates and size dependent growth rates are measured with a continuous contacting continuous nucleator. The data is analyzed *in situ* with a Coulter Particle Counter. In other experiments the extremely small supersaturation exhibited by some crystallizing systems is measured *in situ* with a newly developed technique using a differential refractometer. The results of these experiments will give kinetic models relating growth and nucleation to supersaturation, contact energy and contact frequency.

Recent publications:

Larson, M. A. and A. D. Randolph, "Theory of Particulate Processes: Application in Continuous Crystallization," Academic Press, New York (1971).

Larson, M. A. and P. R. Wolff, "Distributions from Multistage Crystallizers," CEP Symposium Series 110, 67: 97-107 (1971).

Larson, M. A., Editor, "Crystallization from Solution: Factors Influencing Size Distribution," CEP Symposium, Series 110, 67 (1971).

Larson, M. A. and S. M. Shor, "Effects of Additives on Crystallization Kinetics," CEP Symposium, Series 110, 67: 32-42 (1971).

Larson, M. A. and W. J. Genck, "Temperature Effects on Growth and Nucleation Rates in Mixed Suspension Crystallization," CEP Symposium, Series 121, 68, 57-66 (1972).

Larson, M. A., "The Other Conservation Law," J. of the Ramsey Society, University College London (1972).

Larson, M. A. and J. Mullin, "Crystallization Kinetics of Ammonium Sulfate," J. of Crystal Growth, 20: 183-191 (1973).

Larson, M. A. and J. Garside, "Crystallizer Design Techniques Using the Population Balance," The Chemical Engineer, 274: 318-327 (June 1973).

Larson, M. A., L. E. Bauer, and V. Dallons, "Contact Nucleation of $MgSO_2.7H_20$ in a Continuous MSMPR Crystallizer," 29: 1253-1261 (1974).

PROCESSES FOR DESULFURIZATION OF IOWA COAL

SPONSOR: Energy and Mineral Resources Research Institute

PRINCIPAL INVESTIGATORS: T. D. Wheelock, A. H. Pulsifer

RESEARCH ASSISTANTS: R. L. Bunn, T. K. Huang

Various chemical treatment methods for the industrial removal of sulfur from Iowa coals are being investigated and evaluated. These methods include several variants of both hydrodesulfurization and selective oxidation processes. A number of laboratory experiments have been carried out and the results of these experiments show that considerable amounts of sulfur can be removed from some Iowa coals under selected treatment conditions.

CHEMICAL INSTRUMENTATION

SPONSORS: Engineering Research Institute, Chemical Engineering Department

PRINCIPAL INVESTIGATOR: K. R. Jolls

RESEARCH ASSISTANT: R. L. Riedinger

An instrument has been designed for the precise measurement of isothermal heats of reaction in solution. Based on a design published by N.B.S., platinum resistance thermometers sense

temperature differences as small as 50 x 10^{-6} °C between reacting and reference solutions. A high gain, phase-sensitive detector converts this off-balance signal into a variable dc level which is monitored through an A/D converter by a PDP 8/L minicomputer. Rectangular current pulses are supplied to temperature-stable resistance heaters in the two solutions to maintain thermal balance under computer control. The desired reaction heats are then computed by summing the rates and quantities of heat added.

The results of this project should yield a reliable technique for the measurement of thermochemical data under nearly isothermal conditions and utilizing relatively small sample sizes. The sensitivity of the temperature sensing circuits has been demonstrated by the Bureau of Standards and is an important feature of this work. The use of direct computer control with the calorimeter will not only contribute to increased accuracy and reproducibility in the work but will also provide for experimental innovations such as temperature-programmed calorimetry. This project will be the first to be automated using the new data acquisition system in the Chemical Engineering Department's Direct Digital Control Laboratory.

Recent publications:

Riedinger, Randal, "An Automatic Differential Calorimeter Utilizing Linear Computation of Heat Release," presented at the 72nd National AIChE Meeting, St. Louis (1972).

Jolls, K. R. and Randal L. Riedinger, "Applied Electronics for Chemical Engineers," a 13-article CE Refresher series in Chemical Engineering magazine, beginning May 15, 1972.

STATIC AND DYNAMIC INFERRED REACTIVITY

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: R. A. Danofsky

The purpose of this research is to develop mathematical models of nuclear reactor systems. Two general areas of research are being developed. One area is related to the modeling of nuclear power plants for incorporation into large dynamic models. The second area is related to the development of models of fast reactor cores to provide a more detailed understanding of the determination of basic reactor parameters.

BUBBLE SIZE DISTRIBUTION IN AERATION PROCESSES

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: M. A. Larson

RESEARCH ASSISTANT: G. Martin

In the aeration of polluted waters the rate of transfer of oxygen to the water depends in part on the surface area of the bubbles of oxygen or air used. In order to predict mass transfer rates as a function of the depth at which the aerating gas is introduced, it is necessary to know how the surface area of swarms of bubbles changes as the bubbles rise. This project is concerned with the development of a mathematical model relating the bubble size distribution to the pressure and mass transfer rate.

TRANSPORT PHENOMENON AND REACTOR ANALYSIS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: R. C. Seagrave

MAJOR STAFF: J. L. Barbee

RESEARCH ASSISTANTS: D. D. Roth, J. L. Kearns, L. Filosa, L. S. Powell

Analysis of Selectivity in Variable-Volume Reactors. Work begun by Lund and continued by Ridlehoover is being extended to elucidate generalized relationships for selectivity increases obtainable in variable-volume stirred tank reactors. Using an analog computer with an associated digital logic expansion system, the generalized reactor equations are being examined for wide classes of competing and consecutive reactions. Optimization techniques will be employed in an attempt to maximize the yield increases of desired intermediates in the generalized kinetic scheme, using the model reactor.

Analysis of the Droplet Size Distribution During Monopropellant Spray Combustion. A mathematical model for an ideal thrust chamber is

being proposed to elucidate the effect of droplet size distribution on combustion intensity. The model consists of an impingement atomizer which produces a Nukiyama-Tanasawa droplet size distribution. This distribution is then utilized as the input to a combustion chamber, the output of which flows into an exhaust nozzle. The steady-state system incorporates population balances and the quasi-steady-state burning rate of monopropellants combusting in an atmosphere of their decomposition products. Ultimately, the model should afford a rational approach for minimizing the amount of unburnt material emitted from spray combustion processes which provides for increased efficiency and a decrease in combustion generated pollutants.

Recent publications:

Seagrave, R. C. and Monty M. Lund, "Optimal Operation of a Variable Volume Stirred Tank Reactor," AIChE Journal, 17: 30-37 (1971).

Seagrave, R. C. and M. S. Selim, "Solution of Moving-Boundary Transport Problems in Finite Media by Integral Transforms. II. Problems with a Cylindrical or Spherical Moving Boundary," Ind. Eng. Chem. Fundamentals Quarterly, 12: 9-13 (1973).

Seagrave, R. C. and M. S. Selim, "Solution of Moving-Boundary Problems in Finite Media by Integral Transforms. III. The Elution Kinetics of the Copper Amine Complex from a Cation-Exchange Resin," Ind. Eng. Chem. Fundamentals Quarterly, 12: 14-17 (1973).

Seagrave, R. C. and G. A. Ridlehoover, "Optimization of Van de Vusse Reaction Kinetics using Semibatch Reactor Operation," Ind. Eng. Chem. Fundamentals Quarterly, 12: 444-447 (1973).

KINETICS OF CRYSTALLIZATION IN A DILUTE SYSTEM

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: J. D. Stevens

RESEARCH ASSISTANT: P. M. Schierholz

This research is part of a long-range study which involves the analysis and modeling of dilute particulate systems. This phase concerned measurement of the crystallization kinetics in dilute solutions of calcium carbonate. By measuring the crystal size distribution under varying supersaturations, the kinetics were determined. The kinetic data was then fit to power law models. A Model TA Coulter Counter was used for the size distribution measurements.

The results demonstrate the applicability of the population balance theory to light crystal suspensions and show the kinetics of calcium carbonate precipitation to be nonlinear. The results have important implication in water softening plant operation.

PHYSICAL PROPERTIES OF MATTER

SPONSORS: Engineering Research Institute, Alumni Achievement Fund

PRINCIPAL INVESTIGATOR: K. R. Jolls

RESEARCH ASSISTANTS: L. D. Jensen, C. M. Smeigh, D. J. Lafayette

Pictorial views of three-dimensional thermodynamic phase diagrams are being generated through computer graphics. These diagrams portray the functional relationship among sets of thermodynamic variables such as pressure-volume-temperature, enthalpy-pressure-temperature, entropy-pressure-temperature and several others. The final results are obtained as ink drawings on a paper chart using a CALCOMP plotter or 35 mm negatives using a microfilm plotter. Data for the drawings are obtained from both equations of state and large tabulations of thermodynamic data in storage in the University computer.

The goal of this project is to produce a collection of computer generated phase diagrams that can be used in the teaching of thermodynamics. Such diagrams are extremely useful for illustrating the complex way in which physical properties depend upon one another in systems at equilibrium. Although a few selected diagrams have been available in certain textbooks, the complexity of the drawings themselves, combined with their three dimensional character, has discouraged past attempts at producing a collection of accurately drawn pictorial views.

Computer graphics provides the capability both to construct the diagrams and to perform the

being proposed to elucidate the effect of droplet size distribution on combustion intensity. The model consists of an impingement atomizer which produces a Nukiyama-Tanasawa droplet size distribution. This distribution is then utilized as the input to a combustion chamber, the output of which flows into an exhaust nozzle. The steady-state system incorporates population balances and the quasi-steady-state burning rate of monopropellants combusting in an atmosphere of their decomposition products. Ultimately, the model should afford a rational approach for minimizing the amount of unburnt material emitted from spray combustion processes which provides for increased efficiency and a decrease in combustion generated pollutants.

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Seagrave, R. C. and Monty M. Lund, "Optimal Operation of a Variable Volume Stirred Tank Reactor," AIChE Journal, 17: 30-37 (1971).

Seagrave, R. C. and M. S. Selim, "Solution of Moving-Boundary Transport Problems in Finite Media by Integral Transforms. II. Problems with a Cylindrical or Spherical Moving Boundary," Ind. Eng. Chem. Fundamentals Quarterly, 12: 9-13 (1973).

Seagrave, R. C. and M. S. Selim, "Solution of Moving-Boundary Problems in Finite Media by Integral Transforms. III. The Elution Kinetics of the Copper Amine Complex from a Cation-Exchange Resin," Ind. Eng. Chem. Fundamentals Quarterly, 12: 14-17 (1973).

Seagrave, R. C. and G. A. Ridlehoover, "Optimization of Van de Vusse Reaction Kinetics using Semibatch Reactor Operation," Ind. Eng. Chem. Fundamentals Quarterly, 12: 444-447 (1973).

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PRINCIPAL INVESTIGATOR: K. R. Jolls

RESEARCH ASSISTANTS: L. D. Jensen, C. M. Smeigh, D. J. Lafayette

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Computer graphics provides the capability both to construct the diagrams and to perform the

determination of droplet size distribution, measurement of spray formation and acceleration patterns, and determination of the optimum droplet diameter for the collection of particulates in a certain size range. This scrubber will be large for a laboratory model, having a capacity of 2500 cfm at a throat velocity of 300 fps, requiring a 25 hp blower. Atomization processes will be recorded with an ultra high speed movie camera (44,000 pps), and droplet size distribution will be determined by microscopic analysis of molten wax droplets which have been frozen in flight.

Theory of Particulate Collection. Computer studies have just been completed on the simultaneous effects of particle inertia, electrical forces, viscous forces, and geometric interception on the target efficiencies for particle collection by spherical collectors, e. g. droplets of scrubbing liquid. These studies were made by numerical solution of particle trajectories for various electrical forces: coulombic force between charged particle and charged collector, induced charge forces, dipole interaction forces, and uniform external electric fields. In many cases particulate collection can be considerably enhanced with the use of electrical forces. These results should be useful in the design of spray-electrostatic precipitators and for wet scrubbers which make use of electrical atomization.

Laser Doppler Anemometer for Two Phase Flow. The laser Doppler anemometer is a device which measures velocity of a fluid by monitoring the Doppler shift of laser light scattered from particles that are being convected by the fluid. A laser anemometer is currently being constructed to measure local slip velocities in a highly dispersed two phase flow. After some preliminary light scattering experiments, it is hoped that the instrument can be used to determine drag coefficients for accelerating droplets.

Recent publications:

Nielson, K. A. and J. C. Hill, "Capture of Aerosol Particles by Spherical Collectors," Environ. Sci. Technol., 8: 767 (August 1974).

Nielsen, K. A., "Effect of Electric Fields on Target Efficiencies for Spheres," Engineering Research Institute Technical Report, ISU-ERI-Ames-74127, Iowa State University (June 1974), $10.

TURBULENT TRANSPORT

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: J. C. Hill

Calculations made by the principal investigator at Goddard Space Flight Center on the theory of heat transfer in isotropic turbulence have been further analyzed and extended. Green's functions for the temperature field had been computed with the direct interaction approximation and other turbulence theories; this information was used to calculate eddy diffusivities, temperature spectra, correlation functions, and other statistical properties. The direct interaction results compare well with previous heat transfer experiments in a wind tunnel. The most recent calculations include the effect of Prandtl number on the eddy diffusivity and an estimate of the relation between Eulerian and Lagrangian scales.

Another topic of current interest is the study of the effect of turbulence on rates of chemical reactions. This effect is important in such areas as combustion and photochemical smog formation. Studies on this topic will soon be possible as the result of the gift (from the Philco-Ford Co.) of a large, recirculating, gas flow loop designed for experiments on the effect of chemical kinetics on turbulent heat transfer rates. Currently, an invited critical review is being prepared for publication on the subject of mixing and chemical reaction in homogeneous turbulence.

Recent publication:

Hill, J. C., "Estimation of Eddy Diffusivities in Isotropic Turbulence," Sixty-Fourth Annual AIChE Meeting, San Francisco, California (November 1971).

CIVIL ENGINEERING

Carl E. Ekberg, Jr.
Department Head
and Professor

Department Faculty Members	Areas of Research Interest
Distinguished Professor	
Edward R. Baumann, Ph.D.	General water supply and pollution control, water filtration (sand and diatomite), oxygen transfer in activated sludge, process applications
Professors	
Carl E. Ekberg, Jr., Ph.D.	Analysis and design of structural concrete systems, including precast conventionally reinforced and precast prestressed concrete
Kenneth A. Brewer, Ph.D.	General transportation planning, street traffic network analysis, highway maintenance operations, traffic flow theory, urban transportation systems
Robert L. Carstens, Ph.D.	Traffic engineering: highway traffic safety; planning of transportation systems, including highways, airports, mass transit facilities
John L. Cleasby, Ph.D.	Water and wastewater treatment, filtration
Turgut Demirel, Ph.D.	Soil stabilization (bonding mechanisms and adhesion), highway engineering
Merwin D. Dougal, Ph.D.	Surface water problems, water quality
Richard L. Handy, Ph.D.	Soils and materials: mechanical, chemical and crystallographic properties and engineering behavior of soils and related materials (rock, stabilized soils, ice, concrete)
James M. Hoover, M.S.	Soil engineering, soil stabilization, foundation engineering, highway engineering, pavement systems
Ti-Ta Lee, Ph.D.	Structural engineering
Robert Lohnes, Ph.D.	In-situ engineering properties of soils, engineering classification of tropical soils (laterites), applied geomorphology, soil creep, soil-leachate interaction

Jack L. Mickle, Ph.D.	Soil mechanics and the soil-water system; most recently, soil excavation stability
Charles S. Oulman, Ph.D.	Water supply and pollution control, physical-chemical applications
Wallace W. Sanders, Ph.D.	Behavior or structures and structural components
Lyle V. A. Sendlein, Ph.D.	Groundwater contamination, sanitary landfills, water supply systems
Associate Professors	
Tom A. Austin, Ph.D.	Application of systems analysis to water resource planning and management, including both water quality and quantity
Hotten A. Elleby, Ph.D.	Computer applications to structural engineering, structural analysis, applied research, instrumentation
Fred W. Klaiber, Ph.D.	Analysis of structural systems, reinforced concrete
Dah-Yinn Lee, Ph.D.	Bituminous materials, granular materials for pavements, soils, waste as paving materials, polymers as civil engineering materials
Stanley L. Ring, Ph.D.	Street and highway planning and design, highway agency organization and administration, transportation planning, airport planning and design, traffic engineering
James C. Young, Ph.D.	Biological waste treatment process design and application
Assistant Professors	
Lowell F. Greimann, Ph.D.	Static and dynamic analysis of structures with experimental verification
James P. Reilly, Ph.D.	Geodesy and photogrametry, coal research, mining engineering

Sanitary Engineering & Water Resources

WATER POLLUTION CONTROL STUDIES

SPONSOR: Lakeside Equipment Corporation

PRINCIPAL INVESTIGATORS: J. L. Cleasby, E. R. Baumann

Continuing support has been provided for general interest water pollution control research since 1958, and various topics of mutual interest to the sponsor and investigators have been studied. Some of the more important past topics have been:

Evaluation of optimum design of peripheral feed settling tanks by model analysis;

Comparison of performance of peripheral feed settling tanks and center feed settling tanks by model analysis;

Evaluation of the 0_2 transfer efficiency of a bladed rotor when operated in a section of an aeration tank and when operated in a full-scale oxidation ditch, and field testing of a bladed rotor in actual installations.

WATER QUALITY STUDY: SAYLORVILLE RESERVOIR

SPONSOR: U.S. Army Corps of Engineers, Rock Island District

PRINCIPAL INVESTIGATOR: E. R. Baumann

MAJOR STAFF: C. S. Oulman, D. B. McDonald (University of Iowa), W. Merkley (Drake University)

RESEARCH ASSISTANTS: L. Naylor, J. Burnett

During the past few years there has been increased emphasis in the United States on the problems related to water use. Many state and federal agencies have found it desirable to study in detail the effects of man's activities on the quantity and quality of water. One major area of interest in Iowa, for example, is the effect of impounding reservoirs on the quality of the water released from the reservoir with respect to the preimpoundment quality. Water quality changes which result could have significant effects on fish and wildlife, channel vegetation, use of water for municipal and industrial water supply, and recreation. Some of these effects can be beneficial, others detrimental.

Present project work now includes extensive analyses of accumulated data. Such data analyses as are necessary for control of the sampling and analysis program are being carried out routinely as part of the project work. It is anticipated that future projects will continue the sampling and analysis program and pursue such studies of accumulated data as may, at some later date, seem desirable.

The major objective of this project is an evaluation of the water quality upstream and downstream of the Saylorville impoundment. It is therefore necessary to investigate all factors which may influence this water quality, including not only chemical and physical parameters but also biological factors such as algae and plankton pulses and macroinvertebrate populations. Specifically, the study focuses on three major areas:

1. Determination of the physical and chemical characteristics of the waters of the Des Moines River above and below the Saylorville Reservoir impoundment area.
2. Determination of the composition and fluctuations of planktonic population in the reservoir area and adjacent stretches of the river.
3. Correlation of the above factors as they affect one another, and determination of the overall relationship between these factors and the quality of the water within the study area. The program sampling and analyses are designed to yield data pertinent to these areas.

Recent publications:

Baumann, E. R. and S. Kelman, "Sources and Contributions of Nitrogen and Phosphorus to an Iowa Stream," Proc. of the 26th Industrial Conference, Purdue University, Lafayette, Indiana, Engineering Extension Series No. 140, Part I, 54-64 (1971).

Baumann, E. Robert and J. DeBoer, "Preimpoundment Water Quality Study, Saylorville Reservoir, Des Moines River, Iowa, Annual Report," Engineering Research Institute, Iowa State University, Ames, 72262 (October 1972).

Baumann, E. Robert, C. S. Oulman and L. Naylor, "Preimpoundment Water Quality Study, Red Rock and Saylorville Reservoirs, Des Moines, River, Iowa, Annual Report," Engineering Research Institute, Iowa State University, Ames (December 1973).

Baumann, E. R., J. G. DeBoer and C. S. Oulman, "Five-Year Study of Des Moines River Water Quality," Proc. Amer. Soc. of Civil Engineer (in press).

EVALUATION OF NITRIFICATION-DENITRIFICATION PROCESSES FOR REMOVAL OF NITROGEN FROM WASTEWATER

SPONSORS: U.S. Office of Water Resources Research, Iowa State Water Resources Research Institute

RESEARCH ASSISTANTS: C. D. Biskner, W. S. Cameron, F. D. Porta

See feature article, page 100, for more information on this project.

BACKWASH OF GRANULAR FILTERS USED IN WASTEWATER FILTRATION

SPONSOR: U. S. Environmental Protection Agency

PRINCIPAL INVESTIGATOR: J. L. Cleasby

RESEARCH ASSISTANTS: W. F. Barry, G. A. Rice

Granular filters are already widely used in water treatment and are beginning to play an increasingly important role in wastewater treatment, especially tertiary treatment. Many questions related to the optimum backwashing of granular filters, particularly those composed of dual or multiple media, are unanswered. The questions include the following:

1. What degree of expansion provides optimum cleaning of the media during backwashing?
2. What degree of intermixing at the interface of two media provides best filtration and easiest backwashing?
3. How can the degree of expansion and intermixing be calculated from measurable or known properties of the media and the water?
4. Are air scour or surface wash valuable adjuncts to water backwashing?

The objective of this project is to answer these questions; partial answers have been obtained in previous research, but the present project continues the research effort in the following areas.

Various filter media (sand, garnet, anthracite coal) have been separated into uniform sizes, and flow rate versus expansion data have been collected. Mean size and specific gravity of each media have been measured. Available expansion versus flow rate models have been found to be inadequate for nonspherical particles such as crushed anthracite coal and garnet sand. Therefore, new correlations have been developed for these materials. The new models are not yet adequate for crushed coal and additional work on this question continues. Granular beds of two media have been expanded to determine the validity of existing models for prediction of the degree of interfacial intermixing; the wastewater filtering efficiency of filters with different sizes and types of filter media and the ease of backwash of these filters are being observed both with and without air scour or surface wash auxiliary, and with and without fluidization and expansion during the water backwash; and the cleanliness of the filter media, after various backwash methods have been used, is being measured.

Recent publications:

Malik, A. M., "Air and Water Backwashing of Granular Filters," unpublished MS Thesis, Iowa State University, Ames (1972).

Amirtharajah, A. and J. L. Cleasby, "Predicting Expansion of Filters During Backwash," Jour. Amer. Water Works Assoc., 64: 1:52-59 (January 1972).

Amirtharajah, A. and J. L. Cleasby, "Filtration," Chapter 4, Physiochemical Processes for Water Quality Control, edited by Walter J. Weber, Jr., John Wiley & Sons, Inc., 139-198 (1972).

Cleasby, J. L., "Behavior of Deep Granular Filters," Industrial Water Engineering, 32-36 (January 1972).

Cleasby, J. L., "Backwash of Granular Filters Used in Wastewater Filtration," First Annual Progress Report, Engineering Research Institute, Iowa State University, Ames, 72198 (August 1972).

Boss, R. R., "Hydraulics and Intermixing of Sand and Coal Filters," unpublished MS Thesis, Iowa State University, Ames (1973).

Cleasby, J. L., "Deep Granular Filters, Modeling and Simulation," Mathematical Modeling in Environmental Engineering, (Proc. Eighth Annual Workshop of the Assoc. of Environmental Engineering Professors), edited by T. Keinath, Clemson University (1973).

Stangl, E. W., "Air and Water Backwash of Wastewater Filters," unpublished MS Thesis, Iowa State University, Ames (1973).

Woods, C. F., "Expansion and Intermixing of Garnet and Silica Sand During Backwashing of Granular Filters," unpublished MS Thesis, Iowa State University, Ames (1973).

Ragunathan, P., J. L. Cleasby and J. A. Cerwick, "Coagulation, Cake Filtration and Filtrability," Journ. American Water Works Assoc., 65: 202-213 (March 1973).

Cleasby, J. L., "Filter Control, Try These New Ideas," Water and Wastes Engineering, 10: 51-53 (June 1973).

Cleasby, J. L., "Backwash of Granular Filters Used in Wastewater Filtration," Second Annual Progress Report, Engineering Research Institute, Iowa State University, Ames, 73215 (September 1973).

Baumann, E. R. and J. L. Cleasby, "Design of Filters for Advanced Wastewater Treatment," prepared for Environmental Protection Agency, Technology Transfer Program (October 1973).

RURAL WATER SUPPLY SYSTEMS: IMPROVED PLANNING STRATEGIES THROUGH SYSTEMS ANALYSIS

SPONSORS: U.S. Office of Water Resources Research, Iowa State Water Resources Research Institute

PRINCIPAL INVESTIGATOR: T. A. Austin

RESEARCH ASSISTANTS: R. B. Robinson, R. S. Schulz

Generations of Americans living on farms and in small communities have been forced to depend on cisterns, hard or polluted water in poorly constructed wells, or expensive hauling for their domestic water supply. Accompanying these types of water supplies is the possibility of contamination and resulting illness, since many of the shallow wells and surface water supplies are becoming polluted to the point of endangering public health.

It would be a gross inaccuracy to imply that the lack of good quality water and adequate wastewater disposal was the cause of the migration from rural to urban environments. Other more complicated social and economic factors have resulted in this migration. However, inadequate water supplies and outdoor privies could be two components that have contributed to rural changes.

Although a tremendous amount of research has been conducted into planning, design and management of urban water supplies and wastewater disposal systems, little effort has been directed toward defining and solving the special problems confronted in planning and designing rural water systems.

Specifically, the objectives of this research are to:

Evaluate the state-of-the-art of planning strategies presently used by institutions (local, state and federal) and private consultants in planning rural water supply systems. This includes the review of present design, operation, and management criteria used in rural water system operations.

Investigate the use of systems analysis techniques (optimization and simulation) for improving the planning, design, operation, and management of rural water systems.

Information concerning the present state-of-the-art of the strategies used in the planning of rural water systems is being collected by questionnaire and personal interviews with local, state, and federal personnel and private consultants involved with rural water systems. The conceptual framework for improved planning of rural water systems is being developed through the use of concepts from systems analysis. The strategy consists of a logical outline of the procedures required in planning rural water systems supplemented by computer programs and optimization methods where applicable. The outline will delineate the unique considerations involved in planning rural water systems and will emphasize optimum (minimum cost) system design subject to physical, economic, and legal constraints.

EFFECTS OF AQUIFER PARTICLE MOVEMENT ON WATER WELL PRODUCTIVITY

SPONSOR: Iowa State University Research Foundation

PRINCIPAL INVESTIGATOR: T. A. Austin

A better understanding of the impact of aquifer particle movement on the decline of well capacity is needed to improve water well design criteria. Clay, silt, and sand particles frequently move into gravel pack formations surrounding the well screen and into the openings of the well screen. Progressive loss of well capacity, that is, a decrease in the well discharge per foot of drawdown, is common with wells drilled into sand and gravel formations, including those drilled in Iowa and in the Iowa State University and municipal well fields in Ames. Operational problems, reduced pumping capacity, and reduced well life all result in increased cost of water supply. This study was designed to develop the laboratory test equipment and test procedures required to evaluate the migration and deposition of clay, silt, and sand particles in a simulated well operation. The test apparatus consists of a quarter-circle horizontal section of an aquifer, gravel pack and well screen which simulates the actual radial, horizontal flow towards a well. Piezometers and pressure transducers are being used to measure the piezometric head at various points in the apparatus. Clogging of the formation near the edge of the gravel pack and the well screen is being evaluated from changes in the piezometric heads. Those changes are directly related to increased drawdown and loss of well productivity. Preliminary tests are being conducted to validate the utility of the apparatus and its applicability to other problems.

In addition, the framework for a coordinated interdisciplinary research program into water well design procedures and other groundwater problems is being formulated. This framework will provide guidance in and support for future research funding from several alternative sources.

WATER SUPPLY AND POLLUTION CONTROL PROJECT DEVELOPMENT

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATORS: E. R. Baumann, C. S. Oulman

RESEARCH ASSISTANTS: D. Watson, J. Lorence

Many times preliminary studies are required to evaluate the state-of-the-art and the technical feasibility of making advances in certain areas of water supply and pollution control. The direct reuse of treated wastewater for potable uses depends on the ability to control dissolved organics, viruses and chlorides that might carry over. Reverse osmosis processes offer economic potential for control of chlorides if their capacity can be maintained. Virus levels in waters may be correlated to water turbidity due to the adsorption of viruses on clay colloids. This possibility has resulted in reduction in the allowable drinking water turbidity from 10 J.T.U. prior to 1962, to 5 J.T.U. currently. The new EPA drinking water standard (1974?) is scheduled to reduce this to 1 J.T.U. The American Water Works Association has a "goal" of 0.1 J.T.U. The reverse osmosis membrane clogging potential also is related to water turbidity.

Currently, potable water treatment practice can consistently produce water turbidities of 0.1-0.5 JTU. Direct filtration of wastewaters can produce effluent turbidities of 3-5 JTU. With chemical pretreatment for phosphorus removals, effluent turbidities of 0.6-1.0 JTU are possible.

This project is concerned with evaluation of methods which will permit consistent achievement of turbidity levels of 0.1 JTU. Previous research has demonstrated that coating of filter media with catonic polyelectrolytes can improve significantly the removal of colloidal suspended solids. This study will:

1. Evaluate the effect of many different polymers on the surface potential of filter media and the hydraulic resistance of the media, as a function of water ionic strength and pH.

2. Evaluate the principles controlling the effective use of promising polymers for reducing the turbidity of wastewaters during direct filtration through diatomite and/or dual-media granular filters.

A second basic study is being directed at the problem of dewatering the new types and larger volumes of wastewater sludges that will be gener-

ated in tertiary treatment processes. Currently, laboratory and field methods which may be used to predict "yield" of sludge dewatering filters are being evaluated. Plant scale studies have been conducted at Boone and Des Moines and are in planning stages at other communities, which may include Ames, Cedar Rapids, and Waterloo. Once "yield prediction" is improved, studies will be conducted to determine methods for improving filter yield at reduced cost.

Recent publications:

Burns, D. E., E. R. Baumann and C. S. Oulman, "Particulate Removal on Coated Filter Media," Journal Amer. Water Works Assoc., 62:2, 121-126 (February 1970).

Baumann, E. R. and C. S. Oulman, "Polyelectrolyte Coatings for Filter Media," Filtration and Separation, 7: 6, 682-690 (November/December 1970). (Gold Medal Award Paper by the Filtration Society, England.)

McCauley, J. P., "Field Evaluation of Vacuum Filter Yield Prediction," unpublished MS Thesis, Iowa State University, Ames (August 1972).

Ogedengbe, Martins O., "Polyelectrolytes in the Treatment of Wastewaters," unpublished PhD Thesis, Iowa State University, Ames (November 1972).

Shelley, Thomas R., "Evaluation of Sludge Dewatering Properties," unpublished MS Thesis, Iowa State University, Ames (November 1971).

WATER QUALITY STUDY: RED ROCK RESERVOIR

SPONSOR: U.S. Army Corps of Engineers

PRINCIPAL INVESTIGATOR: E. R. Baumann

MAJOR STAFF: C. S. Oulman, D. B. McDonald, (University of Iowa), W. Merkley (Drake University)

RESEARCH ASSISTANTS: L. Naylor, J. Burnett

Both collection and analysis of data are involved in the present research effort. The analyses aim toward evaluation of the state of water quality in Lake Red Rock and upstream and downstream thereof. Since the study of said water quality is the major objective of this project, it is necessary to investigate all of the factors which have influence on the water quality. These include not only chemical and physical parameters, but also biological factors such as algae and plankton pulses and macroinvertebrate populations. Specifically, the four major aspects of the study are:

1. Determination of physical and chemical characteristics of the waters of the reservoir and the Des Moines and Raccoon Rivers above and below the impoundment area.
2. Determination of the composition and fluctuations of the bacterial and planktonic populations in the reservoir area and adjacent river reaches.
3. Determination of the effects of operational activities, such as changes in reservoir levels, on factors cited above.
4. Correlation of above factors as they affect one another, and determination of the overall relationship between these factors and the quality of water within the lake and adjacent reaches of the river. The program of sampling and analysis is designed to yield data pertinent to these areas.

A STUDY OF ALTERNATIVE GROUNDWATER SOURCES AND WELL LOCATIONS FOR THE CITY OF AMES, IOWA – PHASE II

SPONSORS: City of Ames, Iowa, Engineering Research Institute

PRINCIPAL INVESTIGATORS: M. D. Dougal, L. V. A. Sendlein

RESEARCH ASSISTANTS: M. Nicklin

This research program is a continuation of groundwater geology and hydrology studies in the Ames area which were initiated in 1963. This program has been supported by the City of Ames and Iowa State University. Projected increases in the demand for water indicate that the Ames community and the university will require full development of the existing source of water and alternative sources must be explored. The current effort is directed to those alternative sources of supply. This program is being conducted jointly by the Departments of Civil Engineering and Earth Science. Additional but complementary water

quality studies of the groundwater are being carried out by the Department of Chemistry at Iowa State University.

Two specific studies are now being pursued. The first is additional groundwater and aquifer identification in the Squaw Creek area of the combined Skunk River-Squaw Creek-Ames surficial aquifer system. Additional geophysical studies are being conducted to confirm the nature of the sand and gravel "out-wash fan," a localized phenomena in which the university well field is located. Hydrologic studies include field observations of groundwater levels, pumping tests of the university well field; analytical studies will lead to evaluation of the availability of water, the yield of wells and permissible drawdowns in this aquifer formation. Training of students in geophysical methods and in groundwater hydrologic techniques has been a corollary accomplishment.

The second study involves a detailed geologic and hydrologic analysis of the surficial aquifer in the vicinity of the "old gas plant" in east Ames. Exploration of this area has indicated that coal-tar residues (containing aromatic hydrocarbon compounds) still exist in the flood plain deposits, despite previous removal of the basic waste pit contents. The extent of these deposits and of their movement is being determined. Complimentary water quality studies, to identify the constituents in the water have been conducted by the Department of Chemistry at Iowa State University, with additional analyses being proposed as a continuing monitoring function.

The project will provide Ames and Iowa State University with a comprehensive inventory and full identification of its groundwater source of water supply. The availability of water from the several parts of the surficial aquifer system is being determined, which will aid municipal and university planning in meeting future demands. The underlying bedrock aquifers will be studied in the final phases of the study, and additional digital and analog computer modeling conducted for all of the systems.

Recent publications:

Dougal, M. D., L. V. A. Sendlein, R. L. Johnson and M. S. Akhavi, "Groundwater and Surface Water Relationships for the Skunk River at Ames," Special Report, Engineering Research Institute, Iowa State University, Ames (1971).

Dougal, M. D., L. V. A. Sendlein and J. F. Wiegand, "Evaluation of the Groundwater Resource in the Upper Skunk River Basin," Chapter 2, Appendix 5, Physical Relationship with the Urban Section, Ames Reservoir Environmental Study, ISWRRI-60-A5, Iowa State Water Resources Research Institute, Iowa State University, Ames (1973).

Rossmiller, R. L., J. F. Wiegand, M. D. Dougal and J. L. Cleasby, "Future Water Supply Requirements and Alternative Sources of Supply at Ames," Chapter 3, Appendix 5, Physical Relationship with the Urban Section, Ames Reservoir Environmental Study, ISWRRI-60-A5, Iowa State Water Resources Research Institute, Iowa State University, Ames (1973).

Svec, H. J., J. S. Fritz, and G. V. Calder, "Trace Soluble Organic Compounds in Potable Water Supplies," ISWRRI-54, Iowa State Water Resources Research Institute, Iowa State University, Ames (1974).

DESIGN PARAMETERS FOR WATER POLLUTION CONTROL AT AMES, IOWA

SPONSORS: City of Ames, Iowa, Engineering Research Institute

PRINCIPAL INVESTIGATORS: E. R. Baumann, H. F. Seidel, J. C. Young

MAJOR STAFF: E. R. Baumann, J. L. Cleasby, C. S. Oulman, J. C. Young

RESEARCH ASSISTANTS: C. D. Biskner, W. S. Cameron, F. D. Porta, R. von Langen, G. Rice

New water quality standards in Iowa and the nation now require that nearly all water pollution control plants be expanded to provide improved treatment. Most Iowa plants use a trickling-filter process which cannot produce an effluent which will meet the new standards without addition of tertiary or advanced wastewater treatment facilities. Ames is typical of Iowa cities with regard to plant improvement needs. Therefore, detailed studies, including pilot-plant and full-plant

operation studies, are being conducted at Ames to provide information that will be of value to all other cities in Iowa faced with similar problems.

The studies conducted to date have developed and demonstrated techniques which can be used effectively by cities in meeting both the "Best Practical Treatment" required now and the "Best Available Treatment" requirements of the 1980's. Work completed to date includes evaluation of effects of flow and load variations on plant design, expanding existing trickling filter plant secondary capacity with activated sludge units, tertiary treatment by plain filtration, phosphate precipitation in tertiary units followed by filtration, and ammonia reduction in packed-bed reactors followed by filtration. Work in progress includes further evaluation of granular media filter design, use of packed-bed reactors for both nitrification and denitrification, and sludge dewatering on filters. These studies are being conducted at Ames using 20-40 gpm pilot plants and in nearby cities (Des Moines, Boone, Waterloo, and Cedar Rapids) which already have sludge dewatering filters.

Recent publications:

McCauley, Joseph P., "Field Evaluation of Vacuum Filter Yield Prediction," unpublished MS Thesis, Iowa State University, Ames (1972).

Ogedengbe, Martins O., "Polyelectrolytes in the Treatment of Wastewaters," unpublished PhD Thesis, Iowa State University, Ames (1972).

Stewart, Michael C., "Advanced Waste Treatment with Pulsed Adsorption Beds," unpublished ME report, Iowa State University, Ames (1972).

Veenstra, Henry R., "Nitrification in Biological Contact Reactors Supplemented with Pure Oxygen," unpublished MS Thesis, Iowa State University, Ames (1972).

Young, J. C. and E. R. Baumann, "Chemical Methods for Nitrification Control," Special Report, Engineering Research Institute, Iowa State University, Ames, 72154 (August 1972).

Baumann, E. R. and J. Y. C. Huang, "Granular Filters for Tertiary Wastewater Treatment," First Pacific Chemical Engineering Congress, Part I, 88-98 (October 1972).

Baumann, E. R. and G. L. TeKippe, "Tertiary Treatment for Ammonia Reduction," The 29th Research Conference Proceedings: Filtration and Separation, Tokai-Branch, Society of Chemical Engineers, Japan, 115-128 (October 1972).

Clausen, Sam L., "Activated Carbon for Tertiary Treatment of Final Effluent," unpublished MS Thesis, Iowa State University, Ames (1973).

Roskopf, Robert F., "Trickling Filter-activated Sludge Combinations for Domestic Wastewater Treatment," unpublished PhD Thesis, Iowa State University, Ames (1973).

TeKippe, George L., "Removal of Ammonia from Iowa's Wastewaters," unpublished MS Thesis, Iowa State University, Ames (1973).

Young, J. C., "Chemical Methods for Nitrification Control," J. Water Pollution Control Federation, 45: 4, 637 (April 1973).

Roskopf, R. F., J. C. Young and E. R. Baumann, "Trickling Filter-Activated Sludge Combinations for Domestic Wastewater Treatment," Engineering Research Institute, Iowa State University, Ames, 73107 (May 1973).

Baumann, E. R. and J. L. Cleasby, "Design of Filters for Advanced Wastewater Treatment," Special Report, Technology Transfer Program, Environmental Protection Agency (in press).

Baumann, E. R. and J. Y. C. Huang, "Granular Filters for Tertiary Wastewater Treatment," J. Water Pollution Control Federation (in press).

Young, J. C., E. R. Baumann and D. J. Wall, "Packed-bed Reactors for BOD and Ammonia Removal from Secondary Effluents," J. Water Pollution Control Federation (in press).

Soil Engineering

USES OF WASTES IN HIGHWAY CONSTRUCTION

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: D. Y. Lee

RESEARCH ASSISTANT: B. Paulsen

The objective of this project is to make preliminary laboratory investigations of the potential laboratory investigations of the potential uses of scrap tire rubber, waste plastics, waste crank oils, and coal-burning power plant bottom ashes, and SO_2 scrubbing spentlime in the areas of soil stabilization and asphalt paving mixtures.

To date, two waste oils (2 percent to 12 percent) have been experimented on with three soils (a clay, a loess and a sand) with varying amounts (0-10 percent) of secondary additives (emulsions, phosphoric acid, calcium chloride, etc.), with respect to optimum moisture content, density, dry strength, immersion strength, and erosibility. Next efforts will be the determination of oil leaching. Tests were also conducted on various asphalt concrete mixtures with two ground tire scraps from Goodyear, one spentlime from TVA, one bottom ash from ISU Power Plant, and one bottom ash from the City of Ames Power Plant. Experiments will be continued on the evaluation of the physical-chemical properties of the bottom ash and the types of aggregates that are most suited for asphalt concrete mixes and the properties of rubber-asphalt concretes at high rubber contents (5-10 percent).

MODIFICATIONS OF ASPHALT AND ASPHALT PAVING MIXTURES BY SULFUR ADDITIVES

SPONSOR: The Sulphur Institute

PRINCIPAL INVESTIGATOR: D. Y. Lee

RESEARCH ASSISTANT: B. Paulson

The focus of this research has been on the effects of sulfur and sulfur polymers as additives on paving asphalt and asphalt concrete. Research indicates that it is potentially possible that the treatment of aggregates with small amounts of sulfur may not only improve adhesion, water resistance, stability and tensile strength of asphalt mixtures, but may also reduce the asphalt content required and make unsuitable absorptive aggregates satisfactory for highway uses.

More recent research has focused on a greater variety of sulfur-sulfur-polymer types, wider ranges of sulfur concentration and more asphalt types and grades, and has involved a more detailed study of adhesion and stripping properties and fatigue characteristics of sulfurized asphalt and asphalt paving, a detailed evaluation of weathered materials and a study of the mechanisms of sulfurization of asphalt and H_2S evolution and remedies.

CLAY STRENGTH AND RATE PROCESS THEORY

SPONSOR: National Science Foundation

PRINCIPAL INVESTIGATORS: T. Demirel, R. A. Lohnes

RESEARCH ASSISTANTS: J. Hartwell, O. Erol

One objective of this study is to investigate a correlation between yield strength and basic sod parameters, such as activation energy and flow unit volume, which are defined by rate process theory. A second objective of the work is to test rate process theory as it applies to clays and to modify the theory as experimental evidence dictates.

Previous activities were involved with fabrication of testing equipment and limited testing. Present research involves further testing and analysis of data in order to evaluate parameter correlations and the rate process theory as applied to soils. The test data are being analyzed according to modifications in the rate process theory in order to test the significance of the inflection point on the tertiary time-deformation curves as being the point in the stress history of the sample where a critical structure or fabric occurs.

Recent publication:

Choudry, T. I., "Rate Process Theory as Applied to Clay Slurries," unpublished MS Thesis, Iowa State University, Ames (1973).

SOIL TRENCH CAVE-IN ACCIDENT STUDY

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: J. L. Mickle

This continuing research includes soil studies, accident case histories, existing laws and rules, and construction procedures. The gathering and dissemination of information is vital for this project. Many presentations ranging from a formal paper to brief talks have been made. Close cooperation with the Iowa Employment Safety Commission and the Occupational Safety and Health Administration has been sought and achieved.

Suggested recommended practices governing trenching in Iowa soils are the ultimate goal of the investigation.

Recent publications:

Mickle, J. L., "Safety and Factors of Safety in Trench Construction," presented at annual meeting of Highway Research Board, Washington, DC (January 1969). (Available as HRB Record No. 269).

Mickle, J. L. and R. J. Schaffer, "Safety in Trench Construction," Proc. Ltd. of the 20th Annual Conference of Soil Mechanics and Foundation Engineering, University of Minnesota (March 1972).

Mickle, Jack L. "Soil Compositions (Trench Safety)," An invited presentation at the Second Annual Governor's Safety Conference, November 26-30, 1973, Des Moines, Iowa.

CHEMICAL COMPACTION AIDS FOR FINE-GRAINED SOILS

SPONSOR: U.S. Department of Transportation - Federal Highway Administration

PRINCIPAL INVESTIGATORS: J. M. Hoover, R. L. Handy

MAJOR STAFF: T. Demirel

CONTRIBUTING FULLBRIGHT FELLOW: K. J. Fernando

Most methods for strengthening or stabilizing soils involve artifical compaction of the soil by rollers, vibrators, tampers, etc. Because of the large expenditures made for soil compaction in this country, a number of chemical "compaction aids" have been marketed in recent years, ostensibly to improve the ease of compaction (compactibility) of fine-grained soils. Hopefully, by the use of such aids, either less effort would be required to compact a soil to a given density and strength, the moisture content for compaction might be less critical, or the soil might be compacted in thicker layers than would otherwise be possible under a given set of circumstances. Any of these effects, if not offset by parallel disadvantages, could have considerable economic impact on costs of earthwork for highways, football stadiums, earth dams, etc. To date, a competent and reliable evaluation of compaction aids has not been forthcoming, primarily because of proprietary interests of the manufacturers and the lack of controlled experimentation in the field. The few independent investigations that have been made yielded inconclusive or conflicting results, particularly in regard to strength of the end product.

The present research is the first systematic extensive investigation of chemical compaction aids by an independent group. Phase 1 involves development of a mechanistic theory of compaction based on a literature review of the subject and on preliminary evaluations with a limited number of soils. Phase 2 will involve an extensive laboratory study with a wide variety of soils representative of the U.S., and Phase 3 will involve field tests, each succeeding phase to depend on results and evaluations from the preceding phase.

STRENGTH AND STRUCTURE OF LATERITES AND LATERITIC SOILS

SPONSOR: Army Research Office – Durham

PRINCIPAL INVESTIGATORS: R. A. Lohnes, T. Demirel

MAJOR STAFF: D. Y. Lee, J. L. Mickle

One objective of the present research is to contribute to the development of a classification system which will better predict the engineering behavior of deeply weathered tropical (lateritic) soils. A previous project, "Shear Strength of Tropical Soils in Relation to Composition and Environment," demonstrated that there are systematic trends in the engineering properties of tropical soils which relate to degree of weathering and soil structure. Further, the most sensitive measures of the

strength of the lateritic soils studied were measurements of creep and soil cohesion. Results of the research provided a model for a quantitative classification of engineering behavior based upon tests made on undisturbed soil samples. The specific gravity of the particles showed promise as a simple empirical key to classification.

The present work continues research on inceptisols, lateritic soils, and laterites to verify, modify, and finalize the model. The scope of the research includes soil sampling and field testing in Hawaii in order to study a group of basalt-derived soils and a group of ash-derived soils in various degrees of weathering ranging from slightly weathered inceptisols through lateritic soils to indurated laterites.

The laboratory work includes studies of engineering properties such as strength, compressibility, stress-strain-time characteristics, and specific gravity. Since soil structure is essential in interpreting engineering behavior, the engineering properties are being correlated with scanning electron microscope studies, pore size distribution as measured by mercury injection, and mineralogic studies. The use of thermal analyses for studies of mineralogy and structure is also being attempted.

DISTRIBUTION OF WHEEL LOADS IN HIGHWAY AND RAILWAY BRIDGES

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: W. W. Sanders, Jr.

MAJOR STAFF: H. A. Elleby

The staff members are involved in the implementation of past research conducted by the investigators into the current AASHTO and AREA specifications.

Recent publications:

Sanders, W. W., Jr. and H. A. Elleby, "Distribution of Wheel Loads on Highway Bridges," National Cooperative Highway Research Program Report No. 83, Highway Research Board, Washington (1970).

Sanders, W. W. Jr., "Wheel Load Distribution in Highway and Railway Bridges," Developments in Bridge Design and Construction, Crosby Lockwood and Son, London, 540-556 (1971).

EVALUATION OF CHEMICALLY STABILIZED SECONDARY ROADS, LINN COUNTY, IOWA

SPONSORS: Engineering Research Institute, Linn County, Iowa, Koehring Road Division, 17 manufacturer/distributors of soil stabilization/dust palliation products

PRINCIPAL INVESTIGATORS: J. M. Hoover, R. L. Handy

RESEARCH ASSISTANTS: L. Squier, S. Saye

See the feature article "Cooperative Dust Abatement Program" for further information on this project.

Geodesy & Photogrammetry

GEODESY AND PHOTOGRAMMETRY

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: R. L. Hardy

MAJOR STAFF: J. P. Reilly, W. Gopfert, Research Associate

The major objective of this project is to provide photographic, computational, and digitizing support for new ideas and concepts concerning automated cartography, photogrammetry, and remote sensing data processing. Exploratory work in geodetic data processing and computation is an important adjunct of the major objective. It is expected, as a result of this activity, to develop meaningful proposals for research work in greater depth and to seek outside sources of grant or contract support. A recent example of success with this approach was the award of a two-year $60,000 grant from the National Science Foundation for a project entitled "Geodetic Applications of Multiquadric Equations," During the preproposal state of

development the above mentioned multiquadric project was supported by the Engineering Research Institute.

The activities currently underway or contemplated are:

(1) Development of advanced techniques for storing photographic, remote sensing, or map information in analytical equation form. This will allow computer digitizing and analytical processing of map information by mathematical subroutines. Computer processing can then be applied to both map making and to map or imagery utilization.

(2) A study of coherent optics in mapping (holography and Fourier optics) for applications in engineering and earth science.

(3) Experimentation with the concept of dynamic parallax and special effects generators to produce stereoscopic applications in photogrammetry, movies, and television.

(4) Investigation of VLBI (very long baseline interferometry) for applications in geodesy.

(5) A study of techniques for evaluating radar or laser altimetry data from satellites to determine geoidal undulations and gravity anomalies on a global basis.

Recent publications:

Hardy, R. L., "Analytical Topographic Surfaces by Spatial Intersection," Photogrammetric Engineering, 37: 5, 452-458 (1972).

O'Hayre, H. J., "Transformation of Digitized Imagery into Picture Functions Using Sparse Arrays of Picture Elements," unpublished MS Thesis, Iowa State University, Ames (1973).

GEODETIC APPLICATIONS OF MULTIQUADRIC EQUATIONS

SPONSOR: National Science Foundation

PRINCIPAL INVESTIGATOR: R. L. Hardy

STAFF: W. Gopfert

RESEARCH ASSISTANT: E. Herbrechtsmeier

This project is concerned with the determination of a rigorous and more complete theory of multiquadric equations, including a new multiquadric form of spherical harmonic analysis. It also involves the development of multiquadric formulas and procedures for future use in the applied aspects of geodesy. The multiquadric series, and the related method of analysis, was an original discovery by the principal investigator. It was first reported in the literature in 1971.

In this new study of multiquadric equations, formal definitions of the multiquadric function, proof of existence of solutions, and proof of convergence of various forms of the multiquadric series are being developed. Orthogonal relationships and other methods of developing coefficient formulas are also being investigated, the theory of the osculating mode for multiquadric profiles is being expanded to surfaces, and the multiquadric harmonic functions are being developed more completely.

The recently discovered harmonic form of the multiquadric series for the gravitational potential shows particular promise as a useful mathematical technique in classical and satellite geodesy. The problems being considered under this area of the investigation are (1) terrain and isostatic reductions, (2) astro-geodetic determination of geoidal surfaces (as opposed to local profiles), (3) gravimetric determination of the geoid (Stokes' problem), and (4) gravity and potential at great heights, derived from ground and ocean surface observations of gravity.

All formulas suggested for use in geodesy are being checked by computation and plotting routines. Either fictitious or easily accessible existing data are used for this purpose. Data collection, as such, is not a part of this project.

Recent publications:

Hardy, Rolland L., "Multiquadric Equations of Topography and Other Irregular Surfaces," J. of Geophysical Research, 76: 8, 1905-1915 (1971).

Cain, Joel M., "A Study of Multiquadric Equations," unpublished MS Thesis, Iowa State University, Ames (1971).

Woodbury, Paul W., "An Investigation of Methods for Estimating Gravity Anomalies and Their Application to Height Difference Determinations," unpublished MS Thesis, Iowa State University, Ames (1971).

Hardy, Rolland L., "Geodetic Applications of Multiquadric Analysis," Allgemeine Vermessungs–Nachrichten, 79: 10, 398-406 (1972).

Hardy, Rolland L., "Analytical Topographic Surfaces by Spatial Intersection," Photogrammetric Engineering, 37: 5, 452-458 (1972).

Transportation Engineering

INTEGRATED ANALYSIS OF SMALL CITIES INTERCITY TRANSPORTATION

SPONSOR: U.S. Department of Transportation

PRINCIPAL INVESTIGATOR: R. L. Carstens

MAJOR STAFF: Kenneth H. Brewer, Stanley L. Ring, M. L. Millett, Jr., R. O. Richards, Jr., W. H. Thompson,

RESEARCH ASSISTANT: D. Young

See feature article, page 98, for more information on this project.

TRAFFIC ATTRACTION TO COMPETING SHOPPING CENTERS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATORS: S. Ring, R. L. Carstens

MAJOR STAFF: Seven part-time students

The purpose of this study was to obtain data relative to travel to competing major shopping centers in Waterloo, Iowa, and to formulate and test mathematical models describing this interactance. A record of the license plate numbers of all vehicles parked at the shopping centers was made over a period of one week for selected hourly periods. Approximately 41,000 vehicle numbers were recorded representing all but three of the 50 states. The summary classification of these raw data into origins (county and state), the stratification into time periods, and the cross classification provided an insight into shopping patterns at the two centers.

Approximately 30,000 local county vehicle plate numbers were punched on data processing cards along with classification information. Employee's cards were removed and the remaining 21,000 vehicles were considered shoppers. Identification of a shopper's origin was obtained from vehicle registration addresses and punched on the data processing card. The address was correlated with an urban area census tract, and the final cards represented 15,000 shopper trip interchanges from 34 census tracts to two shopping centers. These data were dependent variable T_{ij}. This study has demonstrated the suitability of a license plate survey as a data gathering technique. In conjunction with the home address/census tract method of identifying trip origin a simple method has been tested for processing large amounts of data.

Basic characteristics of the population, travel time from residence to each center, and the attractiveness factors of the centers were evaluated as independent variables. The final model form that evolved after statistical evaluation was:

$$T_{ij} = (\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots \beta_n X_{ni})(Z_j / d_{ij}^{X})$$

where

T_{ij} = shopper trips from census tract i to center j

β = a regression constant

X_{ni} = social economic characteristics of the population

Z_j = Shopping center attractiveness factor

d_{ij} = travel time from tract i to center j

x = an empirically developed exponent

Through an iterative process various forms of the shopping center attractiveness factor (Z) were tested for the highest coefficient of determination. The same technique was used for refining the travel time exponent (x).

FREEWAY OPERATIONS ANALYSIS OF I-80 TO I-29 INTERCHANGE

SPONSOR: Iowa State Highway Commission

PRINCIPAL INVESTIGATOR: K. A. Brewer

MAJOR STAFF: S. L. Ring

RESEARCH ASSISTANTS: B. Thorson, G. T. Smith (undergraduates)

Traffic forecasting processes estimate the future demand on highway facilities in order to design the geometric highway configuration. While the existing procedures may be adequate for estimating the capacity needed for a facility, little insight is provided into the effect a particular geometric pattern may have on driver-roadway interaction. Consequently, roadways may be designed adequately in capacity but have hazardous (or undesirable) traffic operations characteristics at traffic volumes well below capacity.

This research analyzes an interchange which encountered erratic driver behavior in the early years of its design life. Volume variations, traffic composition, and lane distribution are being examined as contributing factors to the erratic maneuvers. Driver expectancies and human factor concepts are integrated into the analysis.

Structural Engineering

FATIGUE BEHAVIOR OF WELDMENTS IN THICK ALUMINUM ALLOYS

SPONSOR: Welding Research Council

PRINCIPAL INVESTIGATOR: W. W. Sanders, Jr.

The objective of this research is a better understanding of the fatigue behavior of weldments in thick aluminum products. Present work focuses on the fatigue strength of weldments in thicknesses, configurations, and environments which are frequently found in practice but for which there exist little or no data. The study directly relates to the following critical areas: joint configuration, effect of loading history, and effect of marine environment.

Recent publications:

Sanders, W. W., Jr., "Fatigue Behavior of Aluminum Alloy Weldments," Welding Research Council Bulletin No. 171, New York (April 1972).

Sanders, W. W., Jr. and S. M. Gannon, "Fatigue Behavior of Aluminum Alloy 5083 Butt Welds," Welding Research Council Bulletin No. 199, New York (October 1974).

ULTIMATE LOAD BEHAVIOR OF FULL-SCALE HIGHWAY TRUSS BRIDGES

SPONSOR: Iowa State Highway Commission and Federal Highway Administration

PRINCIPAL INVESTIGATOR: W. W. Sanders, Jr.

CO-INVESTIGATOR: H. A. Elleby

MAJOR STAFF: F. W. Klaiber

The objectives of this research are to relate specification criteria to the actual bridge behavior as determined from tests on available truss bridges, to determine an estimate of the life expectancy of components of these bridge types, to determine the behavior of timber bridge decks used in these bridges, and to improve load rating estimation techniques.

The tests are being conducted on several spans from old pin connected high-truss bridges built about 1900. These bridges are being removed as the result of the construction of a large reservoir.

Recent Publications:

Sanders, W. W., Jr. and H. A. Elleby, "Distribution of Wheel Loads on Highway Bridges," National Cooperative Highway Research Program Report No. 83, Highway Research Board, Washington (1970).

Sanders, W. W. , Jr. and H. A. Elleby, "Feasibility Study of Dynamic Overload and Ultimate Load Tests of Full-Scale Highway Bridges," Final Report to the Iowa State Highway Commission,

Engineering Research Institute, Iowa State University (January 1973).

INVESTIGATION OF COLD-FORMED STEEL DECKING AS REINFORCEMENT FOR CONCRETE SLABS

SPONSOR: American Iron and Steel Institute

PRINCIPAL INVESTIGATOR: M. L. Porter

CO-PRINCIPAL INVESTIGATOR: C. E. Ekberg, Jr.

The purpose of this research is to provide information on the composite behavior and analysis of concrete floor slabs reinforced with cold-formed steel decking. The information is to be used for the formulation of a uniform set of design criteria and specifications for the engineering design of such floor slabs.

To date, the research has centered around the experimental testing to ultimate failure of 353 full-scale specimens. The experimental specimens have been reinforced with various steel deck corrugated profiles as obtained from several different manufacturers. The various types of experimental tests that have been performed are as follows: one-way slab elements, pushout specimens, slab elements subjected to repeated loading, slab elements continuous over two or three spans, elements containing supplementary reinforcing, specimens reinforced with decking having various surface coatings, full-size floor panels (16' x 12') subject to two-way bending action, slab elements subjected to uniform loading (as compared with concentrated loading for the other specimen tests).

Current work involves the determination of various regression analysis approaches for predicting the failure load or ultimate load of steel deck reinforced slabs. Emphasis of the current work is being placed upon finalizing specifications for the design of floor slabs reinforced with cold-formed steel decking.

Recent publications:

Ekberg, C. E., Jr. and R. M. Schuster, "Floor Systems with Composite Form-Reinforced Concrete Slabs," Eighth Congress of the International Association for Bridge and Structural Engineering, Final Report, Zurich, 385-394 (1968).

Porter, M. L. and C. E. Ekberg, Jr., "Investigation of Cold-Formed Steel-Deck-Reinforced Concrete Floor Slabs," Proceedings of First Specialty Conference on Cold-Formed Steel Structures, Dept. of Civil Engineering, University of Missouri-Rolla (August 19-20, 1971).

Porter, M. L. and C. E. Ekberg, Jr., "Summary of Full-Scale Laboratory Tests of Concrete Slabs Reinforced with Cold-Formed Steel Decking," Ninth Congress of the International Association for Bridge and Structural Engineering, Preliminary Report, Zurich, 173-183 (1972).

Porter, M. L. and C. E. Ekberg, Jr., "Behavior of Concrete Slabs Reinforced with Three-Inch Deep Cold-Formed Steel Decking," Oral Presentation given at Second Specialty Conference on Cold-Formed Steel Structures, St. Louis, Missouri (October 1973).

NATIONAL SUPERVISORY TRAINING PROGRAM;
PHASE I, PRELIMINARY DEVELOPMENT

SPONSOR: Associated General Contractors of America - Education and Research Foundation

PRINCIPAL INVESTIGATOR: J. G. Russo

Although construction is the largest industry in the United States ($80 billion annual expenditures), it has had a perpetual problem of developing and maintaining well-trained field supervisors. These foremen and superintendents deal with the complexities of the construction field operations with little knowledge of current methods of supervising men, materials, and equipment in the most efficient manner.

This research identifies the dire need for a nationally coordinated supervisory training program for construction foremen and superintendents. It investigates all aspects of the situation and develops recommendations and guidelines for the formulation and implementation of a 160 hour, 8 course training program.

Course and class durations and grading, locations for the methods of presentation, recognition of completion, evaluation and control, as well as program funding and marketing, are included in the guidelines developed.

ELECTRICAL ENGINEERING

Julius O. Kopplin
Chairman and
Professor

Department Faculty Members	Areas of Research Interest
Distinguished Professors	
Warren B. Boast, Ph.D.	Electrical instrumentation and measurement
Arthur V. Pohm, Ph.D.	Computer devices, systems and applications
Professors	
Paul M. Anderson, Ph.D.	Power systems, energy systems
Harrington C. Brearley, Jr., Ph.D.	Computer hardware, switching theory, fault detection in sequential circuits
Robert G. Brown, Ph.D.	Estimation theory, navigation applications
Abdel-Aziz A. Fouad, Ph.D.	Power system dynamics, direct energy conversion, technology assessment
Hsung-Cheng Hsieh, Ph.D.	Electromagnetic theory and its application, plasma physics (electromagnetic wave interaction with plasma), microwave solid state devices, solid state plasma phenomena
George G. Koerber, Ph.D.	Piezoelectric surface waves
Anthony N. Michel, Ph.D., D.Sc.	Automatic control systems, nonlinear control theory (stability theory), optimal control theory (numerical optimization)
Essam Nasser, Ph.D.	Ionization of gases, corona phenomena, power-system insulator contamination, field computations
Robert E. Post, Ph.D.	Microwave engineering, radiowave propagation
Allan G. Potter, Ph.D.	Solar energy systems, orthotic brace design
Alvin Read, Ph.D.	Fields and waves, including coherent optics, lasers, and holography
David D. Robb, Ph.D.	Power systems

Terry A. Smay, Ph.D.	Computer systems, emphasis on memory design
Roy Zingg, Ph.D.	Computer system architecture
John P. Basart, Ph.D.	Radio astronomy, interferometry
Associate Professors	
Dale W. Bowen, Ph.D.	Energy systems
David L. Carlson, Ph.D.	Biomedical electronic instrumentation
Chester Comstock, Jr., Ph.D.	Material properties of thin magnetic films; vacuum deposition techniques
Glenn E. Fanslow, Ph.D.	Applications of microwave power in the processing of materials
Charles J. Herget, Ph.D.	Control systems theory, random processes in automatic control systems, estimation theory and applications, system identification
Donald C. Scouten, Ph.D.	Identification of severe storms by use of sferics
David T. Stephenson, Ph.D.	Antenna applications, radio astronomy, remote sensing of atmospheric phenomena
Curran S. Swift, Ph.D.	Biomedical engineering: physiological monitoring devices, electrical safety, minicomputer applications
Assistant Professors	
James D. McMechan, M.S.	Radio propagation and frequency measurements
John R. Pavlat, M.S.	Computer solutions of large power systems
William H. Brockman, Ph.D.	Real and modeled information processing within living systems, electrophysiological events and artificial intelligence, sensory prostheses

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POWER SYSTEM COMPUTER SERVICE

SPONSORS: Iowa Southern Utilities Co.
Iowa Power and Light Co.
Iowa Public Service Co.
Iowa-Illinois Gas & Electric Co.
Iowa Electric Light and Power Co.
Interstate Power Co.
Central Iowa Power Cooperative

PRINCIPAL INVESTIGATOR: P. M. Anderson

MAJOR STAFF: J. R. Pavlat

RESEARCH ASSISTANT: D. Witt

See feature article, page 5, for further information on this project.

AFFILIATE PROGRAM IN ELECTRIC POWER

SPONSORS: Interstate Power Company, Iowa-Illinois Gas and Electric Company, Iowa Electric Light and Power Company, Iowa Power and Light Company, Iowa Public Service Company, Iowa Southern Utilities Company, Omaha Public Power District, Stanley Consultants, Inc., Wisconsin Power and Light Co.

PROGRAM MANAGER: P. M. Anderson

PRINCIPAL INVESTIGATORS: P. M. Anderson, D. W. Bowen, A. A. Fouad, H. W. Hale, C. J. Herget, E. C. Jones, K. C. Kruempel, J. D. Musil, E. Nasser, A. G. Potter, D. D. Robb

RESEARCH ASSISTANTS: I. Atiyyah, W. G. Bloethe, T. Gonen, S. M. Jargo, D. K. Pantalone, H. Parekh, D. Witt

The Affiliate Research Program in Electric Power supports graduate students interested in pursuing research in electric power, encourages interest and participation in this area by students and faculty, and provides an exchange of ideas with supporting industries. It is confined to the broad area of electric power systems, power utilization, and energy conversion.

Research is normally conducted on six to eight projects annually with Affiliate support. Recent projects have involved the application of digital computers in power system protection, the computation of fields in the vicinity of bundled conductors on EHV lines, energy resource forecasting, power plant dynamic model identification, and studies in power system stability.

In all projects an attempt is made to have direct involvement of the supporting companies. This permits the student-faculty team to draw upon the experience and know-how of the industry and helps keep the projects in areas of direct concern to the industry.

Recent publications:

Nasser, E. and M. Heiszler, "Streamer Onset in Air in Nonuniform Fields," IEEE Power Engineering Society Meeting, Paper C73158-3, New York, January 28-February 2, 1973.

Nasser, E. and M. S. Abou Seada, "Digital Computer Calculation of Streamer Threshold of Bundle Conductors," IEEE Power Engineering Society Meeting, Paper C73159-1, New York, January 28-February 2, 1973.

Fetzer, E. E. and P. M. Anderson, "Observability in the State Estimation of Power Systems," IEEE Paper T73 480-1, presented at the IEEE Summer Power Meeting, Vancouver, British Columbia, July 1973.

Schroder, D. C. and P. M. Anderson, "Compensation of Synchronous Machines for Stability," IEEE Paper C73 313-4, presented at the IEEE Summer Power Meeting, Vancouver, British Columbia, July 1973.

Stuart, T. A. and C. J. Herget, "A Sensitivity Analysis of Weighted Least Squares State Estimation for Power Systems," IEEE Trans. on Power Apparatus and Systems, PAS-92: 1696-1701 (September-October 1973).

Fouad, A. A., "Trends in Stability Analysis of Power Systems," Proc. of Eleventh Annual Allerton Conference on Circuit and System Theory, 54-63 (October 1973).

Nasser, E., "Photomultiplier Measurement of Impulse Streamer Onset," Paper MA-6, Twenty-Sixth Gaseous Electronics Conference, Madison, Wisconsin, October 16-19, 1973.

Nasser, E., "Computation of Coefficient of Ionization by Electron Collision," Paper FD12, Meeting of American Physical Society, Yale University, New Haven, Connecticut, December 10-12, 1973.

Ault, Harold James, "Generalized Digital Computation of Transmission Line Impedances," MS Thesis, Iowa State University, Ames (1973).

Finnegan, Orville Eugene, "Economic Dispatch with Pollution Constraints," MS Thesis, Iowa State University, Ames (1973).

Kunihara, T., "Computerized Protection of a Three-Phase Transmission Line," PhD Thesis, Iowa State University, Ames (1973).

Finnegan, O. E. and Fouad, A. A., "Economic Dispatch with Pollution Constraints," IEEE Winter Power Meeting, Paper No. C74-155-8, New York (January 1974).

Nasser, E. and H. Parekh, "Computation of the Potential and Field of a Stranded Twin-Bundle Conductor Above Ground," IEEE Power Engineering Society Winter Meeting, Paper C74084-0, New York, January 27-February 1, 1974.

Witt, Daniel Dean, "Power System Network Reduction for Load Flow Studies," MS Thesis, Iowa State University, Ames (1974).

COHERENT OPTICS AND HOLOGRAPHY

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATORS: A. A. Read, W. A. Ellingson

MAJOR STAFF: W. H. Brockman, R. L. Hardy

RESEARCH ASSISTANTS: G. W. Griffith, R. F. Cannata, W. M. Gopfert

One of the purposes of this project is to build a capability to do quality work in the developing area of coherent optics and holography. Capability exists for optical hologram exposure, development, and reconstruction and for optical (analog type) computing.

One research area involves the sequential holographic storage of a set of individual radiographic images each taken from a different perspective. Subsequent simultaneous reconstruction of all these stored images generates a three-dimensional aerial image of the radiographed object. This aerial image can be tomographically scanned to study the internal structure of the object. Extension of this effort has been spun off into a project entitled "Three-dimensional Imaging: Holography and Other Coherent Optical Imaging Techniques."

A second research area involves optical computing. Optical transparencies, lenses, and uniform wavefront coherent light from a laser can be combined to perform optical computing functions in the analog sense. For example, a parallel wavefront coherent beam passing through an optical transparency one focal length in front of a thin convex lens produces at the back focal plane of the lens a two-dimensional light amplitude and phase distribution that is the Fourier transform of the two-dimensional light amplitude and phase distribution on the back side of the transparency, i.e., a light distribution that contains the frequency and phase information of the spatial transmission characteristic of the transparency. A second lens can produce a second transformation that will generate an image of the object transparency. In a manner similar to what is done with electrical networks in the case of temporal electrical signals, one can use stops, slits, phase shifters, and other optical transmission control means including holographic filters in the frequency plane to modify the spatial frequency content of a signal transparency. Upon retransforming, this will produce an output image that is a modified version of the input. This procedure can be used to enhance, attenuate, correlate, or otherwise substantially modify selected features of the input image. Sometimes the extraction of frequency information from a data record is all that is desired.

Recent publications:

Read, A. A., "Holography, Composite Holograms, and Tomography," Engineering Research Institute, Iowa State University, Ames (1972).

Ellingson, W. A., H. Berger, and N. Lapinski, "A Comparison of Several Three-Dimensional Radiographic Imaging Techniques," Seventh Intern. Conf. on Nondestructive Testing, Warsaw, Poland (June 1973).

Read, A. A. and R. F. Cannata, "Spectral Analysis of One-Dimensional Data Records by Coherent Optical Techniques," Engineering Research Institute, Iowa State University, Ames (1973).

Ellingson, W. A., "Tomographic Imaging of Three-Dimensional Reconstructions through the Use of Optical Holographic Techniques," PhD Thesis, Iowa State University, Ames (1974).

Cannata, R. F., "Optical Spectral Analysis of Biological Signals Using Coherent Optical Techniques," PhD Thesis, Iowa State University, Ames (1974).

Griffith, G. W., "Optical Data Processing of Complex Valued Two-Dimensional Data Using Holographic Storage Techniques," unpublished MS Thesis, Iowa State University, Ames (1974).

COHERENT OPTICAL SPECTRUM ANALYZER

SPONSOR: National Science Foundation Institutional Grant

PRINCIPAL INVESTIGATORS: W. H. Brockman, A. A. Read

This project is a spin off of the "Coherent Optics and Holography" project described above. The purpose of this research is to investigate the use of optical techniques in the analysis of one-dimensional signals recorded as optical transparencies. Primary interest is in biological signals. An automatic spectrograph is being built to permit automatic plotting of the frequency distribution of a signal as a function of time. This can then be used to investigate the variation with time of signals of interest such as electrocardiograms, electroencephalograms, and human and animal sounds, among others.

Investigations into the use of the correlation of two one-dimensional signals to extract useful identification or diagnostic information are also being made.

One optical computing area under study is the use of coherent optical techniques in the analysis of one-dimensional temporal data records stored as optical transparencies. Records have been stored in both density and area modulated formats. Procedures have been devised for determining the frequency spectrum of such stored records and for determining the correlation between two density modulated records. The effort in this direction concerned primarily with biological signals is listed separately under the title of "Coherent optical spectrum analyzer."

A second optical computing area under study concerns optical computing as a tool in helping the earth scientist in his efforts. This includes selective enhancement or attenuation of certain features of earth science images and signals to improve the recognizability of features of interest, in the correlation of different images of mapping and pattern recognition purposes, and to transform one type of display into another. Many of the signals and images of interest arise from remote sensing situations such as photographic and scanning images from satellites and high altitude aircraft.

A third optical computing study involves Fourier transforming a complex-numbered sampled field to obtain a picture of the object. Such transformations are common in x-ray and neutron diffraction and in radio astronomy scanning studies. These transformations are two-dimensional and are usually performed using a digital computer. The study here is to investigate the viability of doing this optically. The sampled field is stored as four overlayed exposures on a hologram with the phase of reference beam being recorded, viz., positive real, positive imaginary, negative real, and negative imaginary. Upon reconstruction the hologram adds the four exposures together to produce at the proper position the transform of the sampled field which is the image desired.

TIME-SHARED COMPUTER SYSTEMS RESEARCH

SPONSOR: National Science Foundation, Iowa State University

PRINCIPAL INVESTIGATORS: R. M. Stewart, R. J. Zingg

MAJOR STAFF: T. H. Smay, C. T. Wright, J. W. Anderberg

RESEARCH ASSISTANTS: H. Richards, Jr., W. A. Kwinn, P. C. Hutchison, O. P. Agrawal, K. A. Glasnapp, M. E. Theys, C. L. Smith, W. E. Jones, L. M. Alarilla, Jr.

The present research program in time-shared interactive computing systems is based upon the SYMBOL IIR computing system. The SYMBOL IIR computing system embodies novel and advanced architectural concepts. It was developed by Fairchild Camera and Instrument Company as a vehicle for systems research related to the product line of the parent company. ISU was to evaluate the first model design concepts and assist in subsequent extensions. Fairchild, however, decided not to develop and market SYMBOL as a commercial product. Sole responsibility for the SYMBOL system has become an important benefit to ISU in that it has been necessary to acquire locally the level of understanding of the system that had existed at Fairchild.

The SYMBOL system is a logically complete entity with a minimum of logical artifacts to burden the user. There were, however, a number of basic assumptions made in the system design and implementation. The total significance and validity of these assumptions were largely untestable or

unprovable before the fact. They are now testable in a meaningful environment, and will provide the basis for major extrapolation. The richness of the implementation combined with its logical coherence provides a vehicle for a major and significant research program.

The objectives of the present research are to provide an evaluation of the present system formulation and its underlying assumptions and to extend and/or reformulate the system on the strength of the initial evaluation.

Recent publications:

Zingg, R. J. and H. Richards, Jr., "SYMBOL: A System Tailored to the Structure of Data," Proc. Natl. Electronics Conf., 27: 306-311 (1972).

Zingg, R. J. and H. Richards, Jr., "Operational Experience with SYMBOL," Sixth Annual IEEE Computer Society Conference, San Francisco, California (1972).

Richards, H. Jr. and R. J. Zingg, "The Logical Structure of the Memory Resource in the SYMBOL-2R Computer," ACM-IEEE Symposium on High-Level-Language Computer Architecture, University of Maryland, College Park, Maryland (1973). [Also published as ACM SIGPLAN Notices, 8:11 (1973).]

Richards, H. Jr. and C. Wright, Jr., "Introduction to the SYMBOL 2R Programming Language," ACM-IEEE Symposium on High-Level-Language Computer Architecture, University of Maryland, College Park, Maryland (1973). [Also published as ACM SIGPLAN Notices, 8:11 (1973).]

Hutchison, P. C. and K. Ethington, "Program Execution in the SYMBOL 2R Computer," ACM-IEEE Symposium on High-Level-Language Computer Architecture, University of Maryland, College Park, Maryland (November 1973). [Also published as ACM SIGPLAN Notices, 8: 11 (1973).]

Anderberg, J. W. and C. L. Smith, "High-Level Language Translation in SYMBOL 2R," ACM-IEEE Symposium on High-Level-Language Computer Architecture, University of Maryland, College Park, Maryland (November 1973). [Also published as ACM SIGPLAN Notices, 8: 11 (1973).]

COMPUTER PERIPHERAL CONTROL

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: D. L. Carlson

RESEARCH ASSISTANT: D. E. Gayou

The purpose of this research is the development of a computer peripheral controller. This controller interfaces an Innovex flexible disk memory unit to a DEC PDP-8/E minicomputer and enables information transfer at a data rate of 14,000 12-bit words/second. The disk memory, under the direction of the controller, store 96K words on disk cartridges, which are removable.

Important design features of the controller include seven basic instructions and five additional instructions, programmed data transfer, automatic multisector read and write operations, fully automatic formatting, and safeguards to prevent loss of data resulting from inappropriate user instruction sequences.

It is expected that this memory system will enhance the program library and bulk data storage capabilities of the PDP-8/E computer.

STUDY OF SOLID STATE PLASMA PHENOMENA

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATORS: H. C. Hsieh, R. M. Stewart, C. A. Scammon

The overall objectives of this project are (1) to gain good physical understanding of phenomena which relate to the electromagnetic wave interaction with solid-state plasma in a material, such as semiconductor and semimetal, and (2) to consider various possible applications, in particular, to the construction of practical devices. The project is presently divided into two phases:

Microwave Propagation and Instability in Semiconductors. The question of how microwave noise emission is excited within the material and how the wave propagates in and out of the material is considered. The theory of excitation and propagation is developed and the propagation characteristics of the wave are examined in detail. The possibility of application of the theory to the

explanation of certain class of microwave emission is also investigated.

Negative Differential Conductance Effect Associated with Bulk Effect Semiconductor Devices. This study is stimulated by observed wave instability in microwave bulk semiconductor devices such as avalanche diode and Gunn effect diode. An avalanche diode (Gunn effect diode) is considered to be a diode in which wave instability associated with the continuity equation (momentum equation) is utilized to generate radio frequency (rf) power since the instability is caused by changes in carrier density (changes in carrier momentum). Thus we may investigate the existence of wave instabilities, caused by changes in carrier temperature, in the presence of static electric and magnetic fields; these are of interest as a new class of instabilities capable of being utilized for the generation of rf power.

Recent publications:

Hsieh, H. C., "Effects of Static Electric Field on Propagation of Electromagnetic Wave in a Magneto-Plasma," Proc. 1971 Intern. Symposium on Antenna and Propagation, Sendai, Japan, September 1-3, 1971, 155-156.

Hsieh, H. C., "Effect of Static Electric Field on the Propagation of Electromagnetic Waves in Indium Antimonide," Phys. Rev. B., 6: 4160-4168 (1972).

Hsieh, H. C., "Amplification of Helicon-Wave in a Semiconductor Plasma," Fourteenth Annual Meeting of Plasma Physics Div. of the Am. Phys. Soc., Monterey, California, November 13-17, 1972, Bull. Am. Phys. Soc., Series II, 17: 11, 1014 (1972).

Hsieh, H. C., "Amplification of Helicon-Wave in Indium Antimonide," J. Appl. Phys., 44: 2412-2414 (1973).

Hsieh, H. C., "Transverse Phonon-Helicon Interaction in a Semiconductor," J. Appl. Phys., 45: 1, 489-491 (1974).

Hsieh, H. C., "Microwave Propagation in an Extrinsic Semiconductor Subject to Crossed Static Electric and Magnetic Fields," Proc. Fifth Colloquium on Microwave Communication, Budapest, Hungary, June 24-30, 1974.

BOILER MODELING FOR DYNAMIC PERFORMANCE

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: P. M. Anderson

MAJOR STAFF: P. R. Johansen

Research in utility boiler modeling is divided into three categories: low-order models for studies of electric network interaction, medium-order models for studies of boiler control systems, and high-order models for detailed studies of the boiler pressure and temperature transient behavior. This project is in the high-order modeling area and is aimed initially at the compiling of a high-order digital computer model of a large utility boiler. Studies will be made of digital techniques and modeling methods which can be used to optimize digital solutions.

Recent publications:

Anderson, P. M., "Mathematical Modeling of Boiler for Dynamic Stability Simulation," Proc. Power Plant Dynamics, Control, and Testing Symposium, Knoxville, Tenn. (October 1973).

Anderson, P. M. and S. Nanahorn, "An Analysis and Comparison of Certain Low-Order Boiler Models," ISA Power Instrumentation Symposium, Boston, May 1974.

Anderson, P. M., "Modeling Thermal Power Plants for Dynamic Stability Studies," Cyclone Copy Center, Ames (1974).

APPLICATIONS OF MICROWAVE POWER

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: G. E. Fanslow

This research is on noncommunications oriented applications of microwaves such as the processing of materials with microwave power and the effects of microwaves on biological substances. Materials processing studies are concerned with method, quality of product, economics and the question, "Can microwave processing help us use our energy resources more efficiently?" The biological studies are directed toward the possibility of using microwaves as a nonpolluting

replacement for chemical insecticides and herbicides. Studies have ranged from drying field corn with microwaves to determining the ovicidal level of microwaves on the eggs of the "southern" corn rootworm.

Recent publications:

Fanslow, G. E., L. L. Gittins, W. F. Wedin and N. P. Martin, "Power Absorption and Drying Patterns of Forage Crops Dried with Microwave Power," 1972 Microwave Power Symposium, Government Conference Center, Ottawa, Canada, and J. of Microwave Power 8: 1, 83-88 (1973).

Fanslow, G. E., "Field Patterns in Slotted Waveguides," 1974 IMPI Microwave Power Symposium, Marquette Univ., Milwaukee, Wisc. (May 1974).

Fanslow, G. E., J. F. Tollefson and J. C. Owens, "Ovicidal Effects of Electromagnetic Energy at 2.45 GHz on Eggs *Diabrotica undecimpunctata howardi Barber,*" 1974 IMPI Microwave Power Symposium, Marquette Univ., Milwaukee, Wisc. (May 1974).

Fanslow, G. E., "Liquid Crystal Mapping of Slotted Waveguide Fields," J. of Microwave Power, 9: 3 (1974).

Fanslow, G. E., "Infrared Monitoring of Microwave Heating Effects," Second Biennial Infrared Information Exchange, St. Louis, Mo., 1974.

RADIO ASTRONOMY EXPERIMENTS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: J. P. Basart

RESEARCH ASSISTANT: D. J. Smith

Current research is primarily concerned with determining the angular structure of radio sources in the decametric wavelength region of the spectrum. Two principal methods are used: interferometry and lunar occultations.

Very long baseline interferometer experiments have been conducted between radio telescopes at Boulder and Haswell, Colorado and Ames, Iowa. The angular resolution between Boulder and Ames is approximately one second of arc at a radio frequency of 26 MHz. Fourteen radio sources have been detected thus far on the Boulder-Ames baseline.

Preliminary work is underway to observe lunar occultations of radio sources at 26 MHz. These observations are particularly difficult because of the short (10 minute) duration of the events and the large ionospheric disturbance of the radio signals. As the signal-to-noise ratio decreases, the effective resolution of the radio source decreases. Signal analysis techniques are being investigated which will enhance the recovery of occultation diffraction pattern from the noise.

Recent publications:

Shawhan, S. D., T. A. Clark, W. M. Cronyn and J. P. Basart, "Decametric-Wavelength Very Long Baseline Interferometry," Intern. Union of Radio Science Conf., Washington, DC, April 13-15, 1972.

Basart, John P., Stanley Shawhan, Willard Cronyn and Thomas Clark, "Very Long Baseline Interferometry at 26 MHz," Mid-America State Universities Association Fourth Annual Astrophysics Conf., University of Missouri at Columbia, April 21-22, 1972.

Sinclair, A. C. E., J. P. Basart, D. Buhl and W. A. Gale, "Precision Interferometric Observations of Venus at 11.1-Centimeter Wavelength," Astrophysical Journal, 175: 555-572 (July 15, 1972).

Shawhan, S. D., T. A. Clark, J. P. Basart and W. M. Cronyn, "An Upper Limit to the 11.2 m-λ Flux of Saturn Using VLBI," 139th Meeting of the American Astronomical Society, Las Cruces, New Mexico, January 9-13, 1973 (Abstract) Bull. Am. Astron. Soc., 5: 1, 36 (1973).

Wesseling, K. H., J. P. Basart, "Simultaneous Interferometer-Phase and Water-Vapor Measurements," Radio Science, 9: 349-353 (March 1974).

RADIO ASTRONOMICAL OBSERVATORY

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: J. P. Basart

MAJOR STAFF: D. E. Hufferd

The radio astronomical observatory provides facilities for research and student instruction in astronomical observations and radio frequency systems. Uses of the 26 MHz telescope include very long baseline interferometry, lunar occultations, and scintillation studies of the interplanetary medium. Computer programs have been developed for scheduling observations, data collection, and data analysis. In addition to maintaining and updating this telescope system, development work is in progress on a 405 MHz telescope and on a signal processor for very long baseline interferometry.

Recent publications:

Russell, S. F., "Noise and Sensitivity-Measurement Theory for Receiving Systems and Circuits," unpublished MS Thesis, Iowa State University, Ames (1973).

Lamfers, D. D., "An Analog Processor for Very Long Baseline Interferometer Data," unpublished MS Thesis, Iowa State University, Ames (1973).

Shawhan, S. D., T. A. Clark, W. M. Cronyn and J. P. Basart, "An Upper Limit to the 11.4 m Flux of Saturn Using VLBI," Nature, Physical Science, 243: 65 (May 28, 1973).

Cronyn, W. M., S. D. Shawhan and J. P. Basart, "26 MHz VLBI Observations with One and Three Seconds of Arc Resolution," VLBI Symposium, Pasadena, California (February 1974).

ANTENNAS AND RADIATING DEVICES

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: D. T. Stephenson

MAJOR STAFF: D. C. Scouten, G. VonBokern

This project supports faculty and graduate student research in antenna engineering and radio noise measurements. Recent graduate student projects have dealt with antenna requirements for radio astronomy. An analog computer simulation has been developed which provides a real-time, interactive display of the radiation patterns of antenna arrays. A major emphasis currently is to develop a technique for position-fixing of the sources of sferics, or bursts of radio noise from severe thunderstorms.

Recent publications:

Scouten, D. C., D. T. Stephenson, and W. G. Biggs, "A Sferic Rate Azimuth-Profile of the 1955 Blackwell, Oklahoma, Tornado," J. Atmos. Science, 29: 5, 929-936 (July 1972).

Stephenson, D. T. and S. K. Finley, "Use of Log-Periodic Feeds in Corner Reflectors," IEEE Trans., AP-20: 6,770-772 (November 1972).

Scouten, D. C., and D. T. Stephenson, "An Intervalometer for Sferics Direction Finding at 73.6 MHz," 8th Annual Congress Canadian Meteorological Society, London, Ontario, May 1974.

CHARACTER RECOGNITION PROCESSOR RESEARCH

SPONSORS: Engineering Research Institute, Solid State Affiliates

PRINCIPAL INVESTIGATORS: A. V. Pohm, R. J. Zingg, T. A. Smay

RESEARCH ASSISTANTS: C. Grell, J. Griffin

This project involves the study and development of new pattern recognition equipment which will be applicable to mini-computers. A research recognition processor has been built for recognition of hard printed characters and test results have been very encouraging. An advanced version of the machine is being designed and tested which will work in conjunction with a standard mini-computer. Such an arrangement will drastically reduce costs and make pattern processing an option which can be attached to a mini-computer when appropriate.

The study will involve the development of an extended processor, the development of a set of appropriate macro instructions, and an assembly routine for convenient use on the mini-computer. At the present time, the new processing array has been completed and is undergoing tests.

Recent publications:

Brown, Roger, "A Specialized Computer Display System," unpublished MS Thesis, Iowa State University, Ames (1972).

Kurihara, Toshio, "Computerized Protection of a Three Phase Transmission Line," PhD Thesis, Iowa State University, Ames (1973).

NAVIGATION SYSTEMS ANALYSIS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: R. G. Brown

RESEARCH ASSISTANTS: V. L. Schwenk, L. Ascher

Various applications of optimal (Kalman) filtering to integrated navigation systems have been investigated over the past decade. A recent study just completed involved an application of optimal filtering to geodesy. In this application, Transit Navigation Satellite and precision clock data were used as the measurement inputs to the Kalman filter. The feasibility of using optimal detection techniques to detect the group delay in the OMEGA navigation system is currently being investigated.

Recent publications:

Winger, D. J. and R. G. Brown, "Error Analysis of an Integrated Inertial/Doppler-Satellite System with Continuous and Multiple Satellite Coverage," Engineering Research Institute, Iowa State University, Ames (January 1971).

Winger, D. J. and R. G. Brown, "Performance Analysis of a Two-in-View Doppler Satellite/Inertial Navigation System," Proc. 1971 NAECON Meeting, Dayton, Ohio (May 1971).

Ott, L. E. and R. G. Brown, "Kalman Filter with Complementary Constraint and Integrated Navigation Systems Applications," Engineering Research Institute, Iowa State University, Ames, 72022 (February 1972).

Van Allen, R. L. and R. G. Brown, "An Incremental Velocity Measurement Algorithm for Use in Inertial Navigation Alignment," Engineering Research Institute, Iowa State University, Ames, 72023 (February 1972).

Brown, R. G., "Integrated Navigation Systems and Kalman Filtering: A Perspective," J. of the Institute of Navigation, 19: 4, 355-362, (Winter 1972-73).

WAVE PROPAGATION STUDIES

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: R. E. Post

RESEARCH ASSISTANTS: T. L. McRoberts, J. Davies, J. D. Knighten

During the past year funds allocated for wave propagation studies were used to help support work on the following topics:

The propagation characteristics of microstrip transmission line. This subject served as a PhD dissertation topic for Thomas L. McRoberts. The work resulted in a new and mathematically more tractable method of determining the eigenvalues of the characteristic equation governing the propagation characteristics of microstrip transmission line. The format of Dr. McRoberts' solution is amenable to mode matching techniques and should serve as a prelude to the full wave characterization of step discontinuities in microstrip transmission line.

The electrical characterization of chalcogenide glasses at microwave frequencies. This subject is a PhD dissertation topic being studied by Mr. John Davies. Mr. Davies is making measurements of the complex permittity of chalcogenide glasses in the X Band (8.2 to 12.4 GHz) frequency range. After the measurements have been completed, a study of the potential application of this material to practical microwave devices will be undertaken. At this time the dielectric constant measurement techniques are being evaluated.

An analysis of the "wigglyline" directional coupler. The "wigglyline" directional coupler is a popular planar directional coupler configuration which is compatible with microstrip technology and exhibits good directivity characteristics. There is no adequate and rigorous theoretical basis for this structure at this time. Mr. J. D. Knighten has been working on an analysis as a PhD dissertation topic. When completed, this analysis will be used to develop design criteria and to optimize the physical parameters of the structure in terms of

directivity, coupling, and driving point impedance. To date, the analytical technique has been formulated and several computer simulations run.

A STUDY ON PARAMETER IDENTIFIABILITY AND ACCURACY OF PARAMETER ESTIMATES

SPONSOR: NASA – Ames Research Center

PRINCIPAL INVESTIGATOR: C. J. Herget

COLLABORATING SCIENTIST: G. T. Chapman

RESEARCH ASSISTANT: C. H. Lee

The topic of system identification has been studied quite intensively in the past few years because of the numerous areas of application. One application of current importance is the identification of the stability and control derivatives (physical parameters) from actual flight test data. These data have classically been obtained from wind tunnel tests of scale model aircraft; however, there is now an urgent need to obtain an accurate force and moment description of present aircraft under actual flight conditions, particularly with respect to high angle of attack conditions. This need has stimulated the development of computer algorithms for identifying the forces and moments experienced by an aircraft in flight. The problem posed (physical parameter identification) is challenging and involves the use of a multi-dimensional set of nonlinear differential equations with multiple inputs and outputs to describe dynamic aircraft behavior.

A number of algorithms have been proposed for the identification of the stability and control derivatives associated with these differential equations. Through the use of computer simulation as the primary means of performance assessment, with few applications to actual flight test data, limited confidence in a few of the proposed algorithms has been obtained. Considerably more experience is needed in applying the algorithms, however, and many questions remain to be answered, particularly with respect to high angle attack. The present research addresses itself to two fundamental questions:

1. Can the unknown parameters of the system be identified from input-output data?
2. If the parameters are identifiable, how much confidence can be placed on the parameter estimates?

A system identification problem closely related to physical parameter identification from input-output data is canonical parameter identification, which has been thoroughly studied and for which the two questions raised above have been fairly well resolved. Canonical parameters are such that when given parameters in canonical form are applied to observed input data they will produce observed output data with a fair degree of accuracy. These canonical parameters may have, however, little or no recognizable relationship to physical parameters. The primary purpose of canonical representations is to obtain a model which gives a good match to input-output data. However, preliminary investigations indicate that the identifiability of physical parameters can be resolved by knowing the identifiable canonical parameters, in certain simple cases, and that there is a strong possibility of generalizing these results.

This research work is using previous results of canonical parameter identification investigations to obtain physical parameter identification information. The work is being closely correlated with that of others in this field and is being pursued within the following guidelines:

1. The results should be meaningful and useful and stress the physical significance of the results.
2. The results should have general and broad applications in system identification but should stress the application to the identification of aircraft stability and control derivatives.

Recent publications:

Herget, C. J. and D. P. Passeri, "Parameter Identification of a Class of Multiple Input/Output Linear Discrete Time Systems," Proc. of the 1972 Joint Automatic Control Conf., Stanford University, Stanford, California (1972).

Herget, C. J. and T. A. Stuart, "A Sensitivity Analysis of Weighted Least Squares State Estimation for Power Systems," IEEE Trans. on Power Apparatus and Systems, PAS-92: 5, 1696-1701 (1973).

STABILITY OF INTERCONNECTED SYSTEMS AND RELATED TOPICS IN CONTROL

SPONSOR: National Science Foundation

PRINCIPAL INVESTIGATOR: A. N. Michel

The current research project is an outgrowth of work previously supported by the Department of Defense (and the State of Iowa) under Project Themis. The primary objectives of the project are to make original contributions in the control systems area and to provide meaningful research experience for graduate students, particularly at the doctorate level. Currently, work is being done in the following areas:

1. Stability analysis of large-scale interconnected systems.
2. Numerical optimization of distributed parameter systems, and
3. Design techniques for nonlinear control systems.

Approximately 70 percent of the research effort is being focused in area 1, 20 percent in area 2, and 10 percent in area 3.

Recent publications:

Michel, A. N. and D. W. Porter, "Stability Analysis of Composite Systems," IEEE Trans. on Automatic Control, 17: 2, 222-226 (1972).

Porter, D. W. and A. N. Michel, "Stability of Multiple-Loop Nonlinear Time-Varying Systems," Technical Report, Engineering Research Institute, Iowa State University, Ames, 73167 (1973).

Cornick, D. E. and A. N. Michel, "Numerical Optimization of Linear Distributed Parameter Systems," Journal of Optimization Theory and Applications, 14: 1, 73-98 (July 1974).

Porter, D. W. and A. N. Michel, "Input-Output Stability of Time-Varying Nonlinear Multiloop Feedback Systems," Proceedings of the 1974 Joint Automatic Control Conference, 75-82, Austin, Texas, June 1974.

Michel, A. N., "Stability Analysis of Stochastic Large-Scale Systems," Accepted for publication in Zeitschrift fur Angewandte Mathematik und Mechanic.

Porter, D. W. and A. N. Michel, "Input-Output Stability of Time-Varying Nonlinear Multiloop Feedback Systems," IEEE Transactions on Automatic Control, 19: 4, 422-427 (August 1974).

Michel, A. N., "Stability Analysis of Stochastic Composite Systems," Accepted for publication in IEEE Transactions on Automatic Control.

Michel, A. N., "Stability Analysis and Trajectory Behavior of Composite Systems," Proceedings of the 1974 IEEE International Symposium on Circuits and Systems," 240-244, San Francisco, Calif., April 1974.

Michel, A. N., "Stability Analysis of Stochastic Large-Scale Systems," Proc. of Eighth Annual Princeton Conference on Information Sciences and Systems, 151-154, Princeton University, Princeton, New Jersey, March 1974.

Michel, A. N. and R. D. Rasmussen, "Stability Analysis of Stochastic Interconnected Systems," to be presented and included in the Proceedings of the Twelfth Annual Allerton Conference on Circuit and System Theory, University of Illinois, October 1974.

Michel, A. N. and R. D. Rasmussen, "Stability Analysis of Stochastic Interconnected Systems," submitted for publication in IEEE Transactions on Automatic Control.

Michel, A. N. and R. D. Rasmussen, "Stability of Stochastic Interconnected Systems," Advances in Control and Dynamic Systems: Theory and Applications, Vol. 12, Chapter X, C. T. Leondes, Editor, Academic Press, 1975.

BUFFERED MEMORY RESEARCH STUDY

SPONSOR: Fabri-Tek, Inc.

PRINCIPAL INVESTIGATOR: A. V. Pohm

RESEARCH ASSISTANTS: O. Agrawal, C. Cheng

This program involves an analysis of the use of buffering in conjunction with large core memories to achieve enhanced cycle times and access times. Factors such as flexibility, modularity, minimum cost, minimum sensitivity to hit ratio, read-write ratios, error detection and recovery, power supply compatibility, package compatibility, multi-part capability and ease of maintenance are being examined.

The research has three major objectives:

1. Preliminary design, construction, test, and debugging of a buffered memory system (construction and evaluation of buffer and associated electronics).
2. Construction of test equipment and collection of data from ISU Computation Center 360/65 on hit ratios for various problem classes.
3. Software analysis (construction of program and performance of test evaluation of various tapes to determine hit ratios).

Recent publications:

Pohm, A. V., O. Agrawal, C. Cheng, Fabri-Tek Buffered Memory Study, Interim Report (August 1972).

Pohm, A. V., "An Efficient Flexible Buffered Memory System," IEEE Trans. on Mag., 9: 173 (1973).

Pohm, A. V., G. Bridges, O. Agrawal, C. Cheng, G. Fisher, Fabri-Tek Study, Initial Study Final Report, Ames ERI No. 74124 (August 1974).

AFFILIATES PROGRAM IN SOLID-STATE ELECTRONICS

SPONSORS: Fabri-Tek, Inc., International Business Machines, Inc., Honeywell, Inc., Energy Conversion Devices, Inc., Control Data Corp.

PROGRAM MANAGER: A. V. Pohm

MAJOR STAFF: Materials – T. A. Smay

Devices, Circuits and Components – A. V. Pohm

RESEARCH ASSISTANTS: S. Doctor, C. Grell, J. Griffin, G. Fisher

The Affiliates Program, at the present time, includes three major research areas:

Electronic Systems and Applications – In the past decade giant strides have been made in the cost and performance of electronic devices. These changes have made feasible many systems which previously were economically prohibitive. Under the Affiliates Program, work is conducted on special new systems and applications such as research character recognition processors, buffered memory systems, automatic memory management schemes and terminal oriented communication networks.

Materials and Devices – With support from the Affiliates Program, work is conducted on the properties of various solid-state materials and devices. Work includes research on memory cells, recording media, and properties relating to semiconductors, ferromagnetics, ferroelectrics and other materials. As examples of such activity, work is conducted on bubble memories, semiconductor memories, and the properties of amorphous semiconductors.

Sensors and Instrumentation – Application of special devices and instruments in natural and biological science is becoming very wide spread. With support from the Affiliate Program, work is conducted on the feasibility of electronically activated limbs, measuring and telemetry circuits for monitoring biological systems, automatic data accumulation for experiments and numerous other types of activities. With the increasing availability of low-cost digital computing equipment, automated experiment control and its associated instrumentation are becoming increasingly important.

Recent publications:

Borgstahl, R., "Digital System Design and Simulation," PhD Dissertation, Iowa State University, Ames (1972).

Kao, V., "Filament Formation in Bulk Samples of Amorphous Chalcogenide $As_{55}Te_{35}Ge_{10}$," PhD Dissertation, Iowa State University, Ames (1972).

Pohm, A. V. and R. J. Zingg, "Analysis of a 10^{12} Bit Flexible Disk Pack Memory," IEEE Trans. on Mag., 8: 574 (September 1972).

Pohm, A. V., "Competitive High Speed Memory Technologies," AIP Conf. Proc., 5 (March 1972).

Pohm, A. V., Annual Report, Affiliates Program in Solid State Electronics, Engineering Research Institute, Iowa State University, Ames ERI No. 73096 (May 1973).

Doctor, S., "Secondary Emission of Chalcogenide Glasses," PhD Dissertation, Iowa State University, Ames (1973).

Pohm, A. V., "Potential Impact of Bubbles on Virtual Memory Systems," Presented at Intermag. Conf., Toronto, May 1974.

Pohm, A. V., S. Doctor, S. Koenck, and O. P. Agrawal, Annual Report, Affiliates Program in Solid State Electronics, Ames ERI No. 79142 (June 1974).

ENGINEERING SCIENCE AND MECHANICS

Harry J. Weiss
Department Head
and Professor

Department Faculty Members	Areas of Research Interest
Distinguished Professor	
Donald F. Young, Ph.D.	Biomedical fluid mechanics
Professors	
Harry J. Weiss, D. Sc.	Applied mathematics, applied mechanics
Kenneth G. McConnell, Ph.D.	Acoustics, vibrations, dynamic testing, random fatigue, modeling
Gundo A. Nariboli, Ph.D.	Applied mathematics, mechanics of solids and fluids, rheology, wave-propagation, differential equations, transformation theory
William F. Riley, M.S.	Experimental stress analysis
Associate Professors	
Christian P. Burger, Ph.D.	Experimental stress analysis, application of photoelasticity and photoplasticity to earthquake and seismic problems, transient thermal stresses in structures, rolling and extrusion of metals
Raymond T. Greer, Ph.D.	Materials characterization, microstructure-microchemistry-property correlations, scanning electron microscopy
Jasson Gryzagoridis, Ph.D.	Heat transfer, thermal stress analysis
Thomas R. Rogge, Ph.D.	Wave propagation in elastic media; vortex motion; numerical techniques applied to continuum mechanics
Lester W. Schmerr, Jr., Ph.D.	Stress waves in solids, theoretical seismology, ocean acoustics
Chang-Tsan Sun, Ph.D.	Linear and finite elasticity and viscoelasticity, theory of plasticity, wave propagation, continuous media under initial stress, and rheology

Yu-Min Tsai, Ph.D.	Fracture mechanics, stress waves in elastic and viscoelastic materials
Assistant Professors	
David K. Holger, Ph.D.	Fluid mechanics, acoustics
Bruce R. Munson, Ph.D.	Fluid mechanics, rotating flows, non-Newtonian fluids

BRITTLE FRACTURE AND STRESS WAVES

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: Y. M. Tsai

The project covers three main subjects of research: contact stresses, stress waves, and fracture mechanics. The propagation of cracks in brittle material at constant and accelerating speeds is being investigated. Closed-form solutions for crack shapes and dynamic stress distributions are obtained for a penny-shaped crack and a finite line crack running in infinite elastic solids.

Stress pulses produced by impact on surfaces of polymer plates of various thicknesses were recorded experimentally, and a theoretical analysis was also conducted to predict the plate pulses observed. A close agreement between theory and experiment was obtained, and both the theory and the experiment showed that the plate pulses are of different character than the half-space surface pulses.

Dynamic local stress distribution around the contact area between a projectile and a finitely thick plate was studied by solving three-dimensional equations of motion. This was conducted, by invitation, for presentation of a paper to the symposium on the mechanics of contact between deformable bodies, sponsored by the International Union of Theoretical and Applied Mechanics (IUTAM) and held in the Netherlands, August, 1974.

Recent publications:

Tsai, Y. M., "Dynamic Contact Stresses Produced by the Impact of an Axisymmetrical Projectile on an Elastic Half-Space," Int. J. Solids Structures, 7: 543 (1971).

Tsai, Y. M. and K. Dilmanian, "Impact of Spheres on Elastic Plates of Finite Thickness," Devel. Mech., 6, Proc. Twelfth Midwest Mech. Conf., L. H. N. Lee et al. eds., 1009 (1971).

Tsai, Y. M. and G. A. Nariboli, "Torsional Waves in an Infinite Elastic Rod of Elliptical Cross Section," Acta Mechanica, 13: 117 (1972).

Tsai, Y. M., "Stress Distribution, Crack Shape, and Energy for a Penny-Shaped Crack in a Plate of Finite Thickness," Engr. Fracture Mechanics 4: 155 (1972).

Tsai, Y. M., "Exact Stress Distribution, Crack Shape, and Energy for a Running Penny-Shaped Crack in an Infinite Elastic Solid," Int. J. Fracture, 9: 157-169 (1973).

Tsai, Y. M., "Propagation of a Brittle Crack at Constant and Accelerating Speeds," Int. J. Solids Structures, 9: 625-642 (1973).

Maier, L. R., Jr. and Y. M. Tsai, "Wave Propagation in Linear Visco-elastic Plates of Various Thicknesses," Engineering Research Institute Preprint 72266, Iowa State University, Ames (1972) (to appear in J. Mech. Phys. Solids).

Tsai, Y. M., "Dynamic Stress Distribution Around the Tip of a Running Crack," Engineering Research Institute Preprint 73216, Iowa State University, Ames (1973) (to appear in Engr. Fracture Mechanics).

PHOTOELASTIC STUDIES OF SHOCK WAVES

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: C. P. Burger

MAJOR STAFF: W. F. Riley

See feature article, page 106, for more information on this project.

PROJECT TITLE: MICROSTRUCTURE – PROPERTY CORRELATIONS OF ENGINEERING MATERIALS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: R. T. Greer

RESEARCH ASSISTANTS: A. Rosovsky, T. Sullivan, J. Gasper, T. Besmann

Scanning electron microscopy and scanning transmission electron microscopy are being used to establish microstructural-microchemical relationships for several classes of materials. These observations (including the identification of the presence of micropores or cavities) are being related to mechanical and optical properties.

Recent publications:

Besmann, T. and R. T. Greer, "Changes in Morphology of Polymers as a Result of Gamma Irradiation: Low Density Bulk Polyethylene," Proc. Seventh National Conf. of the Electron Probe Analysis Society of America, San Francisco, California, July 17-21, 22A-22C (1972).

Sullivan, T. J. and R. T. Greer, "Discussion of a Paper by Irshad R. Mufti – Geothermal Aspects of Radioactive Waste Disposal Into the Subsurface," J. of Geophysical Research, 77: 17, 3174-3176 (1972).

Greer, R. T., "Significance of Microstructure Associated with Growth of Microcrystalline Chalcedony (α-Quartz)," Proc. Sixth Intern. Conf. on X-ray Optics and Microanalysis, Sept. 5-12, 1971, Osaka, Japan (G. Shinoda, K. Kohra, and T. Ichinokawa, eds.), University of Tokyo Press, 771-778 (1972).

Greer, Raymond T., "Image Contrast Effects from Superimposed Submicron Structural Networks," Proc. Fifth European Congress on Electron Microscopy, September 5-12, Manchester, England, Institute of Physics (London and Bristol), 486-487 (1972).

Greer, Raymond T., "Test Specimens for High Resolution Scanning Electron Microscopy," Proc. of the Electron Microscope Society of America, New Orleans, Louisiana (C. J. Arceneaux, ed.), Claitor's Publishing Division, Baton Rouge, 238-239 (1973).

Greer, Raymond T., "Comparative Morphology of Serpentines by Scanning Electron Microscopy," Proc. Eighth Intern. Congress on Electron Microscopy, Canberra, Australia, (August, 1974, in press).

Greer, R. T., "Test Specimens for High Resolution Scanning Electron Microscopy," Electron Microscopy: Physical Aspects (B. M. Siegel, ed.), John Wiley & Sons, Inc., New York (1974, in press).

FINITE ELEMENT ANALYSIS APPLIED TO PROBLEMS IN MECHANICS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: T. R. Rogge

The Finite Element Analysis is a numerical method which has been successfully used to solve plane stress and plane strain problems for linear isotropic homogeneous elastic materials. The method is capable of handling complicated geometries and, thus, has supplemented the traditional experimental methods used to handle such problems. Two programs are now debugged and running to handle the above type of problems.

Additional work with the Finite Element method will be directed towards the area of fluids, plasticity, heat transfer, and nonlinear materials.

PHOTOMECHANICS METHODS FOR INELASTIC STRESS ANALYSIS

SPONSOR: Army Research Office - Durham Contract No. DAHC 0474G0105

PRINCIPAL INVESTIGATOR: W. F. Riley

RESEARCH ASSISTANT: L. W. Zachary

This research program is concerned with the development of materials and procedures for extending the method of photoelasticity from the elastic into the inelastic region of material response. The work to date has shown that different blends of polyester resins, when subjected

to different thermal cures, can yield a wide variety of material response characteristics. Some of the curves obtained are similar to those of conventional engineering structural materials such as mild steel and aluminum and can be denoted by the same dimensionless mathematical expressions. The materials have the ability to withstand large deformations (50-100% elongation) while maintaining satisfactory levels of optical response and well defined optical patterns. Work in progress is concerned with completing the material characterization and establishing the law of yielding.

Recent publication:

Morris, D. H. and W. F. Riley, "A Photomechanics Material for Elastoplastic Stress Analysis," Experimental Mechanics, 12: 10, 448-453 (1972).

ON SOME ASPECTS OF WAVE-PROPAGATION

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: G. A. Nariboli

Current research consists of two objectives. The first of these is the study of wave propagation and diffusion problems in a continuum, based on the theory of singular surfaces.

The model of the continuum is described by a system of partial differential equations in a set of field variables. A singular surface in the continuum is one across which at least some of the field variables or their derivatives suffer discontinuities. These discontinuities impose constraints (compatibility conditions) on the field variables. These compatibility relations, together with the field equations, make possible a study of the growth of various discontinuities across the moving singular surface.

Solutions for such wave propagation problems have been found for some media and are being investigated for other types of media and geometrical configurations by the use of Group-invariance and Backlund transformations applied to the system of equations.

Considerable work has been done on far-field solutions of wave-propagation problems. To match these solutions with suitable ones near a boundary, a boundary layer theory has often been used. Most such theories have been ad hoc. The second objective of current research is to formulate a reasonable theory of an elastic boundary-layer suitable to both linear and nonlinear wave propagation problems.

Recent publications:

Nariboli, G. A. "Photo-Elastic Waves," Int. J. Engineering Science, 10: 765-774 (1972).

Nariboli, G. A. and W. W. Predebon, "Shock Waves in a Hyperelastic Medium," J. Appl. Math. and Mech. (ZAMM), 52: 133-136 (1972).

Nariboli, G. A. and W. C. Lin, "Dispersive Shear Waves in Two-layer Elastic Medium," Appl. Scientific Research, 27: 451-462 (1973).

Nariboli, G. A. and W. C. Lin, "A New Type of Burger's Equation," J. Appl. Math. and Mech. (ZAMM), 53: 505-510 (1973).

PHOTOMECHANICS METHODS FOR EXPERIMENTAL STRESS ANALYSIS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: W. F. Riley

RESEARCH ASSISTANT: L. W. Zachary

This research program is concerned with the development of optical methods for solving new or unusual experimental stress analysis problems. Currently, dynamic photoelasticity methods are being used to study the interaction between various types of structures such as dams, building foundations, tunnels, etc., and propagating stress waves such as those induced by earthquake loadings. Holography and interferometry methods are being developed for vibrational analysis and non-destructive testing.

Recent publications:

Ligon, J. B. and W. F. Riley, "Close-Field Optical Analysis of an Explosive Loading Function," Experimental Mechanics, 14: 5, 184-189 (1974).

Burger, C. P. and W. F. Riley, "Effects of Impedance Mismatch on the Strength of Reflected and Refracted Waves in Layered Solids," Experimental Mechanics, 14: 4, 129-137 (1974).

VIBRATION TEST TECHNIQUES

SPONSORS: A. O. Smith Corporation, Engineering Research Institute

PRINCIPAL INVESTIGATOR: K. G. McConnell

RESEARCH ASSISTANTS: J. M. Lee

Current research is in the area of high cycle random fatigue. The objective of the research is to study the effects of variable RMS amplitudes on the statistical aspects of random fatigue.

Previous work under this project has included the following:

1. Sinusoidal Simulation of Fatigue under Random Loading – The narrowband random fatigue of automotive frame steel was duplicated using a variable amplitude sinusoidal loading which exhibited the same peak probability distribution.
2. Damping of Metals – The internal damping of aluminum, steel, and brass in longitudinal vibration was measured using five techniques and theories in order to verify the easier technique.
3. Properties of Hysol 8705 – The nonlinear properties of Hysol 8705 were investigated under impact and sinusoidal loadings.

Recent publication:

Thakkar, R. B. and K. G. McConnell, "Sinusoidal Simulation of Fatigue under Random Loading," presented at Winter 1974 SAE Automotive Engineering Congress, Detroit, Michigan, Paper No. 740217.

UTILIZATION OF ELECTRON INTERACTIONS IN MATERIALS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: R. T. Greer

RESEARCH ASSISTANT: J. Gasper

For critical evaluation and interpretation of very high magnification, high resolution scanning electron microscope photomicrographs, it is necessary to understand the details of electron interactions in the sample and subsequent signal generation for the recorded micrograph. This requires use of theoretical Monte Carlo single scattering and multiple scattering models and computer calculations for the interaction of electrons with materials. Experiments utilize data developed by computer simulations for a variety of test configurations and are helping to set bounds for resolution, establish types and thicknesses of coatings for samples, and aid in developing correct interpretations of micrograph features such as the presence of subsurface voids and cavities.

Recent publication:

Gasper, J. K. and R. T. Greer, "Void Characterization by Monte Carlo Techniques Applied to Scanning Electron Microscopy," Scanning Electron Microscopy – 1974, (Om Johari, editor), ITT Research Institute, Chicago, Illinois, 243-250 (1974).

DEVELOPMENT OF MODELING TECHNOLOGY FOR BUNDLED TRANSMISSION LINES WITH EMPHASIS ON STATIC AND DYNAMIC STABILITY OF TWISTED BUNDLES

SPONSOR: Edison Electric Institute

PRINCIPAL INVESTIGATOR: K. G. McConnell

RESEARCH ASSISTANTS: W. P. Zemke, M. Eide

See feature article, page 102, for more information on this project.

ELASTIC WAVES AT A PLANE BOUNDARY

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: L. W. Schmerr, Jr.

Problems involving the interaction of transient elastic waves with vertical and horizontal plane boundaries are being investigated in this research program. Exact expressions for the various reflected, refracted, and interface waves generated at a boundary are being obtained analytically through the use of Fourier transforms and the Cagniard-Pekeris inversion technique. The primary objectives of this study are (1) to predict the possibility of spalling or delamination of materials at regions of rapid impedance change in a structure and (2) to model the dynamic interaction of seismic waves in the earth with buried walls or building foundations.

Recent publications:

Scherr, L. W., "Shear Waves in a Rigid-Free Wedge Due to a Moving Load," Proc. Thirteenth Midwestern Mechanics Conference, 7: 609-620 (1973).

Schmerr, L. W., "Pulse Distortion of an SV-Wave at a Free Surface," J. Appl. Mech., Trans. ASME, 41: 298-299 (1974).

Schmerr, L. W., "A Class of Shear Wave Problems in an Elastic Wedge," Engineering Research Institute Preprint 73027, Iowa State University, Ames (1973).

LUNAR SAMPLE CHARACTERIZATION

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: R. T. Greer

The interrelations of microstructure and chemistry are being examined for terrestrial and lunar feldspar samples. Lamellar spacing and compositional variations and their relations to optical properties of the material are being developed by high resolution scanning electron microscope and X-ray microchemical analyses.

INVESTIGATION OF LAMINATED COMPOSITE MATERIALS UNDER DYNAMIC IMPACT LOADINGS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: C. T. Sun

RESEARCH ASSISTANT: P. W. Sun

The investigation of dynamic response of laminated composite cylindrical shells has been achieved by using the classical method of separation of variables, combined with Mindlin and Goodman procedure for treating time-dependent boundary condition and/or external dynamic loadings. This method was first applied by Mindlin and Goodman to investigate vibrations of beams under time-dependent boundary conditions and was subsequently extended to sandwich plates by Yu. Numerical examples show that, contrary with the classical prediction by Timoshenko, the ratio between the dynamic resonse to the corresponding static response may be greater than two for the composite materials and stacking sequence selected in the example problem.

Recent publications:

Sun, C. T., "Double Fourier Series Solution to General Anisotropic Plates," J. of Mathematical and Physical Sciences, 6: 2, 205-223 (June 1972).

Sun, C. T., R. L. Sierakowski, and N. Cristescu, "On the Theory of Thermal Locking Media," Analele of the University of Bucharest Metematica - Mecanica, 21: 71-89 (November 1972).

Sun, C. T. and R. L. Sierakowski, "Studies on the Dynamic Impact of Jet Engine Blades," 43rd Shock and Vibration Bulletin, Part 4, 11-19 (December 1972). (Presented at the 43rd Shock and Vibration Symposium, December 1972, Pacific Grove, California.)

Sierakowski, R. L., C. T. Sun and P. W. Sun, "An Approximate Solution for Bending of Anisotropic Laminated Plates," Developments in Mechanics, 7: 899-910 (August 1973) and Proc. Thirteenth Midwestern Mechanics Conference, Pittsburgh, Pennsylvania (August 1973).

Sun, C. T. and R. L. Sierakowski, "Studies on the Impact Structural Damage of Composite Blades," to be published in Proc. Symposium on Foreign Object Impact Behavior of Composites. (Presented at the Symposium on September 20, 1973.)

Sierakowski, R. L. and C. T. Sun, "Experimental Investigation of the Dynamic Response of Cantilever Anisotropic Plates," to be published in 44th Shock and Vibration Bulletin. (Presented at the Symposium, December 6, 1973.)

Sun, C. T. and P. W. Sun, "Laminated Composite Shells Under Axially Symmetric Dynamic Loadings," to be published in J. of Sound and Vibrations, 35: 3 (August, 1974).

Whitney, J. M. and C. T. Sun, "A Refined Theory for Laminated Anisotropic Cylindrical Shells," J. of Applied Mechanics, Paper No. 74-APM-B.

Sun, C. T. and J. M. Whitney, "Vibrations of Laminated Composite Thick Cylindrical Shells," to be published in J. of Acous. Soc. of America.

Sun, C. T. and J. M. Whitney, "Forced Vibrations of Laminated Composite Plates in Cylindrical Bending," to be published in J. of Acous. Soc. of America.

INDUSTRIAL ENGINEERING

Keith L. McRoberts
Chairman and
Professor

Department Faculty Members	Areas of Research Interest
Professors	
Harold A. Cowles, Ph.D.	Engineering valuation and depreciation, governmental regulatory systems, public utility rate making, corporate modeling
Herbert T. David, Ph.D.	General statistical theory, engineering statistics, operations research
Keith L. McRoberts, Ph.D.	Search techniques in combinationally explosive optimization, production scheduling and plant layout, use of simulation in system analysis
Gerald W. Smith, Ph.D.	Capital budgeting, capital expenditure analyses, engineering economy, project justification
Associate Professors	
Roger W. Berger, Ph.D.	Theoretical-analysis of alternative estimators for the Weibull distribution, applied-improvement of training methods using computer assistance, computer simulation of capital investments, life cycle cost analysis and information
John C. Even, Jr., Ph.D.	Operations research applications, queueing theory and applications, decision systems analysis, safety engineering

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TELEPHONE RATE COMPUTER PROGRAM DEVELOPMENT

CO-PRINCIPAL INVESTIGATORS:
H. A. Cowles, G. E. Lamp, Jr.

IOWA COMMERCE COMMISSION INVESTIGATOR: R. Osborn

RESEARCH ASSISTANT: J. Trzeciak

An ongoing problem of the regulation of telephone public utilities is the development of specific rates to produce the proper revenues as determined by the regulatory agency. A telephone company rate filing is designed to produce the revenue sought by the company. The revenue as determined by a regulatory commission to be fair and reasonable may not be the same as the revenue sought by the company. A computer program was written to adjust the proposed rates to obtain rates which will yield the allowed revenues. Funding was received and the project has been completed.

Recent publication:

Lamp, G. E., Jr., "Package Treatment Plant Prices," accepted for publication by the J. of Water Pollution Control Federation.

AMES BUS STUDY

SPONSOR: City of Ames

PRINCIPAL INVESTIGATOR: K. L. McRoberts

RESEARCH ASSISTANT: J. M. Trzeciak

On April 1, 1974, a study began with the objective of designing a comprehensive public transportation system for the City of Ames, Iowa. The system was to be developed, refined, and implemented by September 1, 1974. In the initial phases of the study, alternative methods of transportation were considered in an effort to provide the most efficient operational system. An operating budget for the new system was set at $150,000. This project required interfacing with such groups as the Ames City Council, Office of the Ames City Manager, Midwest Transportation Inc., and the Citizens Advisory Committee on Transportation.

The end result of the project was that the proposed system was implemented as designed.

ENGINEERING VALUATION – PROJECT DEVELOPMENT

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: H. A. Cowles

Current investigations under way involve the use of valuation techniques in the field of Human Resource Accounting and the development of simplified valuation techniques for the appraisal of industrial properties for tax purposes. Both projects are only in preliminary stages, but the first has received partial outside funding. Funding is being sought for the second.

Recent publication:

Cowles, H. A., H. T. David and G. E. Lamp, "Sequential Aspects of a Less Parametric Life Analysis," accepted for publication in the J. of Institute of Statistical Mathematics.

OPERATIONS RESEARCH AND APPLIED STATISTICS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: R. W. Berger

This was a study of various methods of estimating parameters of the Weibull distribution. Particular emphasis was placed on the variance of shape and life estimators. Large-scale Monte Carlo simulation was used to compare linear regression, nonlinear regression, and percentile methods of estimation. It was found that the percentile method, which is by far the simplest to apply, also gave the best results in most cases.

Recent publication:

Berger, R. W. and K. Lawrence, "Estimating Parameters by Linear and Nonlinear Regression," Technometrics (November 1974).

OPERATIONS RESEARCH

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: K. L. McRoberts

RESEARCH ASSISTANT: J. Trzeciak

Research under this project is being pursued in two separate areas:

1. Time-Share Applications. This research continues the development of time sharing programs for support of research and development uses.

2. Keyword Index Preparation of Principal Research Sources. This work is to develop simplified indexing for quick research reference of seven journals. The keyword index will be updated annually with the current index containing five years' information. Updating is done by deleting the oldest year and adding the current year.

Recent publications:

McRoberts, K. L., "Warehouse Location by Density Minimization (WODEN)," IE paper (March 1972).

Orum, S. A. and K. L. McRoberts, "Time-Share Execution of the Urban Mass Transit Game, Programming Guide and Procedure Manual," Engineering Research Institute, Iowa State University, Ames,72059 (March 1972).

McRoberts, K. L. and S. A. Orum, "A User's Manual for Plant Layout Analysis, by Computer (Plan) with Time-Shared Option (Plant)," Engineering Research Institute, Iowa State University, Ames,72089 (June 1972).

Krishnamachari, V., H. Bell and J. T. Jones, "Recovery of Creep Resistant Substructure in Rutile Under Reduced Stress Conditions," Engineering Research Institute, Preprint 72319, Iowa State University, Ames (December 1972).

MECHANICAL ENGINEERING

Arthur E. Bergles
Chairman and
Professor

Department Faculty Members	Areas of Research Interest
Professors	
Arthur E. Bergles, Ph.D.	Laminar flow heat transfer in horizontal tubes, two-phase flow, boiling heat transfer, condensation heat transfer, two-phase instabilities, augmentation of convective heat transfer
William J. Cook, Ph.D.	Theoretical and experimental investigations of fluid mechanics and heat transfer in steady and unsteady compressible flows
Robert C. Fellinger, M.S.	Fossil fuel resources conversion and utilization
Alexander Henkin, Ph.D.	Influences of manufacturing processes on materials properties and vice versa
Bruce L. Johnson, Ph.D.	Prediction of control system element performance and computer aided analysis of system performance and stability
Charles R. Mischke, Ph.D.	Engineering design, computer-aided design, optimization, reliability
George K. Serovy, Ph.D.	Internal flow, turbomachinery, heat transfer
Associate Professors	
Shyam Bahadur, Ph.D.	Mechanical and frictional properties of polymers and their relationship with morphological and chemical structure
Jerry L. Hall, Ph.D.	Experimental dynamics and heat transfer; measurements (including statistics), designs of experiments
George H. Junkhan, Ph.D.	Fluid mechanics, fluids and heat transfer instrumentation, heat transfer to gas flows, augmentation of convective heat transfer
Patrick Kavanagh, Ph.D.	Fluid mechanics of turbomachinery performance analysis and design

Theodore H. Okiishi, Ph.D.	Turbomachine fluid mechanics
Leo C. Peters, Ph.D.	Product safety, product liability, wear analysis, theory of failure for complex dynamic loading, fastener integrity and function
Richard H. Pletcher, Ph.D.	Fluid mechanics and heat transfer
Assistant Professors	
Thomas A. Auten, Ph.D.	Effects of high pressure on mechanical behavior of materials, densification of aggregates, workhardening and fracture toughness of alloys
James E. Woods, Ph.D.	Environmental control methods for health and comfort of occupants and for reduction of energy consumption

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ANALYSIS OF TURBULENT BOUNDARY LAYERS

SPONSOR: National Science Foundation

PRINCIPAL INVESTIGATOR: R. H. Pletcher

RESEARCH ASSISTANTS: C. Dancey, I. K. Madni

The objective of this research program is the development of analytical methods for predicting characteristics of turbulent flows of current technological interest both in traditional engineering applications and in some environmental problem areas where no satisfactory prediction methods currently exist or where comparisons of predictions with experimental data can lead to a better understanding of turbulent flows by revealing the strengths and limitations of the various models for turbulent transport mechanisms.

Recent work includes the development of finite-difference calculation methods and transport models for a broad class of turbulent boundary layer flows, including flows with pressure gradient and heat transfer. The turbulent transport model has been extended to include flows with wall blowing and suction. A similar approach has been applied to confined turbulent flows with heat transfer with good results. Work in progress now includes the development of calculation methods for separating and reattaching boundary layer flows, the prediction of buoyant thermal plumes, and the continued analysis of confined turbulent flows.

Recent publications:

Pletcher, R. H., "Calculation Method for Compressible Turbulent Boundary Flows with Heat Transfer," AIAA Journal, 10: 3, 245-246 (1973).

Pletcher, R. H., "The Prediction of Transpired Turbulent Boundary Layers," J. of Heat Transfer, 96: 1, 89-94 (1974).

Pletcher, R. H. and R. M. Nelson, "Heat Transfer to Laminar and Turbulent Flow in Tubes with Variable Fluid Properties," Fifth Intern. Heat Transfer Conf., Tokyo, Japan, September 1974.

Nelson, R. M. and R. H. Pletcher, "An Explicit Method for the Calculation of Confined Turbulent Flows with Heat Transfer," Proceedings of the 1974 Heat Transfer and Fluid Mechanics Institute, 154-170 (1974).

Dancy, C. L. and R. H. Pletcher, "Boundary Layer Finite Difference Method for Calculating Through the Separation Point and Into the Region of Recirculation for Incompressible Laminar Flow," Engineering Research Institute Technical Report ISU-ERI-Ames 74103, Heat Transfer Laboratory Report HTL-2 (1974).

HEAT TRANSFER AUGMENTATION METHODS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: G. H. Junkhan

RESEARCH ASSISTANT: J. K. Hagge

Both passive and active systems are being explored for augmentation of convective heat transfer in this recently-begun project. Current interest in experimental efforts is centered on surface scrapers for forced convection. One experimental test apparatus is now in operation. Test results from this apparatus indicate a significant increase in convective heat transfer coefficients for laminar boundary layers with a modest power input to the scraper. Some improvement in turbulent boundary layer convective coefficients has been obtained with a greater expenditure of scraper power.

Recent publication:

Hagge, J. K., "Mechanical Augmentation of Air Convective Heat Transfer," MS Thesis, Iowa State University (November 1974).

FRACTURE RESISTANCE AND ORDINARY TENSILE PROPERTIES OF METALS

PRINCIPAL INVESTIGATOR: T. A. Auten

UNDERGRADUATE RESEARCH ASSISTANT: C. Spooner

Objectives. The lower limit of the resistance of a metal to rapid fracture can be analyzed by measuring its resistance to the propagation of existing cracks. This is accomplished by fracture toughness testing, a process requiring more expensive equipment and skilled personnel than the more common tensile testing. This research program is directed at establishing relationships between tensile properties and fracture toughness to permit designing from the fracture resistance point-of-view without performing the costlier type of test.

Results. Age-hardenable Al alloys have been selected for study due to the wide range of properties attainable by simple heat treatments. In the first three months of work the tensile properties for a stock of 2011 Al have been established and toughness measurements will proceed in the coming year.

THE RELATIONSHIP BETWEEN HARDNESS AND TENSILE PROPERTIES OF METALS AND ALLOYS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: A. Henkin

RESEARCH ASSISTANT: R. Burds

The replacement of a destructive tensile test by a non-destructive hardness test and the cost savings associated with it give ample reason to take a new look at an old unsolved problem.

Objectives. 1. Study the hardness and uniaxial tensile properties of a wide spectrum of metals and alloys. 2. Establish a variety of possible models relating a single hardness value of a set of hardness values to yield strength, flow stress, and tensile strength.
3. Examine the applicability of a single universal model to all materials. Failing in the above, attempt will be made to find a set of models, each of which shall describe properly the desired relationship for one class of materials. A class of materials will be based on physical characteristics and not on chemical composition.

State of Project. The extensive early research in this field has been critically evaluated. The first objective has been fully carried out. Experimental data has been determined to complement previously conducted research. A few preliminary models have been established, though not general enough to serve as a universal relationship.

Future Work. Future work will concentrate on the last two objectives.

DEVELOPMENT OF METHODS FOR ENHANCEMENT OF IN-TUBE CONDENSATION

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: A. E. Bergles

RESEARCH ASSISTANT: J. H. Royal

This research program involves experimental and analytical effort directed toward enhancement or augmentation of forced flow condensation in horizontal (or slightly inclined) tubes. A number of thermal systems utilize this type of condenser. Since the condensing side frequently represents a

significant part of the overall thermal resistance, substantial reductions in condenser size can result from increased condensing coefficients.

The experimental facility, located in the new Heat Transfer Laboratory, has been designed to operate single tubes of various geometries in a nominally horizontal in-tube condensation mode over a wide range of temperatures and pressures. Variable mass flow rates of both the condensing fluid and the coolant allow the establishment of various flow regimes in the condenser and the determination of part-load performance. Due to the interest in testing various fluids, the design provides for open or closed loop testing with water, refrigerants, or industrial organic chemicals of interest. The loop is also equipped with fixtures to allow the angle the condenser makes with the horizontal to be varied up to inclinations of 10^{o}.

During the first phase of this project the apparatus has been operated with once-through flow of building service steam. Data have been obtained for smooth-tube test sections. Smooth tubes with twisted-tape inserts and internally-finned tubes are currently being tested.

COMPUTER-AIDED DESIGN

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: C. R. Mischke

RESEARCH ASSISTANTS: T. K. Ho, P. C. Ho

This project is a continuing effort in the development of a computer-aided design seed package useful to the project and design engineer and involves (1) extension of the optimization capability of the package by investigation of algorithms for unconstrained and constrained optimization developed here and elsewhere, (2) extension of design subroutine coverage, (3) creation of bases for designing to a reliability specification, (4) maintenance of the current capability, and (5) provision for graduate theses and projects, together with the opportunity for graduate students to participate in research in computer-aided design.

Recent publications:

Mischke, C. R., "Experiencing System and Community Level Design – Step I: Organizing the Computer," American Society of Engineering Education, Annual Meeting, Ames, Iowa (June 1973).

Short Course: Four-day Workshop in Computer-Aided Design American Society for Engineering Education Annual Meeting, Ames, Iowa (June 1973).

Mischke, C. R., "Assessment of Ultimate Fidelity of an Eccentric Circular Disk Cam with Translating Flatfaced Follower as a Function Generator," Journal of Engineering for Industry, 96: 2, 256-260 (1974).

Mischke, C. R., "Designing to a Reliability Specification," Winter Meeting, Mississippi Valley Section of Society of Automotive Engineers, Paper 740643, Waterloo, Iowa (January 1974).

INVESTIGATION OF LAMINAR FLOW HEAT TRANSFER IN HORIZONTAL TUBES UNDER NORMAL AND AUGMENTED CONDITIONS

SPONSOR: National Science Foundation (with the collaboration of Heat Transfer Research, Inc.)

PRINCIPAL INVESTIGATOR: A. E. Bergles

RESEARCH ASSISTANTS: S. W. Hong, S. M. Morcos

Laminar flow heat transfer in tubes is encountered in a wide variety of engineering situations; if it occurs, it will usually represent the dominant thermal resistance in a heat exchanger. The prediction of laminar heat-transfer coefficients is generally accomplished by referring to current textbooks. These textbook laminar flow analyses are generally restricted to constant fluid properties. In actual practice, however, experimental data usually exhibit considerable deviations from the analytical predictions, in large part due to the inadequacy of the constant property assumption. Accordingly, recent analytical and experimental work has focused on determining the effects of variable properties. At present, however, the variable property work has been applied to only a fraction of the geometries and boundary conditions for which constant property solutions are available.

The present research program is designed to obtain more accurate predictions for laminar flow heat transfer in horizontal circular tubes under normal conditions, and to develop more effective

methods of augmenting the relatively low heat transfer coefficients associated with laminar flow. Analytical solutions have been carried out for uniform heat flux models which are reasonable approximations of the actual physical situations. However, it appears to be beyond the limits of present computational capability to account for developing flows, variation of transport properties (particularly density and viscosity), and conduction effects in the tube wall. Hence, the primary solution to the problem is being based on experimental results.

An experimental facility has been constructed in the new Heat Transfer Laboratory, and tests have been made with electrically heated glass and steel tubes, using water and ethylene glycol as the working fluids. A correlation has been developed for the fully-developed case, taking into account the effects of temperature-dependent fluid properties and different tube wall materials. The correlation is in satisfactory agreement with the limited data available from other studies.

Tests have been run with metal tubes having full-length twisted-tape inserts to enhance heat transfer coefficients. Heat transfer coefficients for water are improved up to several hundred percent. Additional enhancement devices are scheduled for testing.

These studies are being coordinated with and complemented by tests on a large industrial-scale apparatus at Heat Transfer Research, Inc.

Recent publications:

Bergles, A. E., "Recent Developments in Convective Heat Transfer Augmentation," Applied Mechanics Review, 26: 675-682 (1973).

Morcos, S. M. and A. E. Bergles, "Combined Forced and Free Laminar Convection in Horizontal Tubes," Engineering Research Institute Technical Report ISU-ERI-Ames-74008, Heat Transfer Laboratory Report HTL-1, Iowa State University, Ames (1974).

Hong, S. W., "Laminar Flow Heat Transfer in Ordinary and Augmented Tubes," PhD Thesis, Iowa State University, Ames (November 1974).

Hong, S. W., S. M. Morcos and A. E. Bergles, "Analytical and Experimental Results for Combined Forced and Free Laminar Connection in Horizontal Tubes," Proc. of the Fifth Intern. Heat Transfer Conf., Tokyo, Japan (1974).

Bergles, A. E., A. R. Blumenkrantz, and J. Taborek, "Performance Evaluation Criteria for Enhanced Heat Transfer Surfaces," Fifth Intern. Heat Transfer Conf., Tokyo, Japan, September, 1974.

AXIAL-FLOW COMPRESSOR AND PUMP FLUID MECHANICS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: T. H. Okiishi

RESEARCH ASSISTANTS: C. R. Pullen

The research program is broadly intended to help develop calculation methods for predicting the overall as well as detailed (blade-element) performance, under design and off-design operating conditions, of turbomachinery. More specifically, a recently acquired axial-flow compressor is being used in combination with an axial-flow pump performance prediction computer program developed for NASA by the ISU Turbomachinery Research Group in developing better methods for calculating blade-element losses and deviation angles in a multi-stage environment. An immediate objective was determination of the actual range of research capability of the compressor. Subsequent objectives for compressor research during the year included an investigation of the "loss-of-solution" encountered in the execution of most turbomachinery performance prediction computer programs and the development of improved loss and deviation angle correlating parameters and/or calculation methods.

Recent publication:

Pullen, C. R. and T. H. Okiishi, "Radial Equilibrium Solution Loss Associated with Axial Flow Pump Off-Design Performance Prediction," Engineering Research Institute Technical Report ISU-ERI-Ames 74098, Turbomachinery Components Research Laboratory Report TCRL-1 (1974).

EFFECT OF COLD FORMING ON THE STRUCTURE AND PROPERTIES OF POLYMERS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: S. Bahadur

Conventional methods for the processing of polymers involve shaping the viscous molten polymer in a mold cavity. The production rate in these processes is limited by the cooling time needed to solidify the part. Furthermore, very high molecular weight materials cannot be satisfactorily produced by these processes due to very high viscosity of the material in the molten state. It has been recently recognized that coldforming takes care of both of these problems. In addition, the mechanical properties of the material are considerably improved as a result of coldforming.

The major thrust of research in this area involves the following:

(a) feasibility of coldforming operation
(b) effect of coldforming on the structural changes in the material at the microscopic level
(c) effect of the coldforming on the properties of the material
(d) relationship between the changes in structure and mechanical properties.

Recent studies involve tne effect of cold and warm extrusion on the structure and properties of polypropylene, hot and cold rolling of polyoxymethylene, and the effect of annealing on the anisotropic properties of rolled polyoxymethylene.

Recent publications:

Bahadur, S. and A. Henkin, "Investigation of the Ductility of Rolled Polymers," Polymer Engineering and Science, 13: 6, 422 (November 1973).

Bahadur, S., "Strain Hardening Equation and the Prediction of Tensile Strength of Rolled Polymers," Polymer Engineering and Science, 13: 4, 266 (July 1973).

SHOCK TUBE LABORATORY

SPONSORS: NASA, Engineering Research Institute

PRINCIPAL INVESTIGATORS: W. J. Cook, J. L. Hall

Experiments in the Shock Tube Laboratory are short-duration (0.5 to 2 milliseconds) studies of high-speed, high-stagnation temperature gas flow. The shock tube, 50 ft. long with a 3 in. by 6 in. cross-section is designed for single diaphragm operation with driver gas pressure to 1,000 psi. The pneumatic diaphragm breaker can be used with either mylar or metallic diaphragms.

The tube is equipped with a Schlieren system for flow visualization and a one-microsecond time base counter for wave velocity determination. Other facilities include a monochrometer and test section with quartz windows for emission, absorption, and radiation measurements typically encountered in chemical kinetic and radiation gas-dynamic studies. Other instrumentation includes a variety of temperature, heat flux, and piezoelectric pressure transducers.

Major work continues in the areas of high-speed heat transfer, boundary layers, subsonic and supersonic flows, wave interactions, and chemical kinetics.

Current projects include a study to correlate heat transfer rates for the turbulent boundary layer on a flat plate at low supersonic Mach numbers with high wall cooling, a study of the stability of the shock-induced unsteady laminar boundary layer on a flat plate, an investigation of the feasibility of using the shock tube as a facility for investigating the performance of transonic airfoils at extremely high Reynolds numbers, and the smog forming potential of simple hydrocarbons, the latter being studied via shock tube chemical kinetics, coupled with a fast response sampling system and gas chromatograph species analysis. Also, a project is underway to add a high vacuum driven (test) section to the existing shock tube facility.

Recent publications:

Kunze, Dennis R., "An Investigation of Transition to Turbulence in the Shock-Induced Unsteady Boundary Layer on a Flat Plate," MS Thesis, Iowa State University, Ames (1972).

Renaud, Merle A., "A Study of the Response Characteristics of Coated Thin-Film Heat Flux

Gages," MS Thesis, Iowa State University, Ames (1972).

Cook, William J., "Prediction and Measurement of Heat Transfer Rates for the Shock-Induced Unsteady Laminar Boundary Layer on a Flat Plate," NASA Contractors Report CR 114582, NASA Ames Research Center, Moffett Field, California (October 1972).

Renaud, Merle A., and William J. Cook, "Response of Coated Thin-Film Heat Flux Gages: Analysis and Interpretation," Engineering Research Institute Technical Report ERI 73046, Iowa State University, Ames (1973).

Geringer, Kerry G., "Experimental Investigation of Turbulent Boundary Layer Heat Transfer Rates on a Flat Plate in Low Mach Number Supersonic Flows with High Wall Cooling," MS Thesis, Iowa State University, Ames (1973).

Cook, William J., "Experimental Study of the Shock-Induced Unsteady Laminar Boundary Layer on a Flat Plate," to be published in the Physics of Fluids (May 1974).

Richards, Donald E., "Correlation of Results of Shock Tube Heat Transfer Experiments for the Turbulent Boundary Layer on a Flat Plate," unpublished MS Thesis, Iowa State University, Ames (May 1974).

Luu, Minh, "A Theoretical and Experimental Study of the Stability of the Unsteady Shock Induced Boundary Layer on a Flat Plate," unpublished MS Thesis, Iowa State University, Ames (May 1974).

Herrin, John R., "Shock Tube Pyrolysis of Simple Hydrocarbons to Determine Their Smog Forming Potential," unpublished MS Thesis, Iowa State University, Ames (May 1974).

Cook, William J. and Merle A. Renaud, "Analysis and Interpretation of the Response of Coated Thin-Film Heat Flux Gages," Fifth Inter. Heat Transfer Conf., September 2-7, 1974, Tokyo, Japan.

Hall, J. L., "Boundary Layer Development and Transition in Shock Tube Flows with Shock Induced Exothermic Reactions," Fifth Intern. Heat Transfer Conf., September 1974, Tokyo, Japan.

TURBOMACHINERY COMPONENTS RESEARCH PROGRAM

SPONSORS: NASA, Department of the Navy-Naval Air Systems Command, National Academy of Science - National Research Council, Detroit Diesel Allison Division of General Motors Corporation, National Science Foundation, Iowa State University Research Grants Committee, Engineering Research Institute

PRINCIPAL INVESTIGATORS: G. K. Serovy, T. H. Okiishi, P. Kavanagh, G. H. Junkhan

RESEARCH ASSISTANT: E. C. Hansen

This program is directed toward development of improved design and analysis systems for axial-flow compressors, fans, pumps and turbines, as well as for fluid system components such as inlets, diffusers and transfer systems which interact with these turbomachines. Both analytical and experimental projects are included.

Current project titles are:

NASA Grant NSG 3033 - Blade-Surface Boundary Layer and Wake Computational Models for Estimation of Axial-Flow Compressor and Fan Blade-Row Deviation Angles and Losses.

Naval Air Systems Command Contract N00019-74-C-0401 - Duct Flow Analysis Methods for V/STOL Propulsion Systems Applications.

Detroit Diesel Allison - Transonic Flow Analysis in Axial-Flow Turbomachinery Cascades by the Time Dependent Method of Characteristics.

NAS-NRC - Evaluation of Background and Current Status of Aerodynamic Design and Development of Multistage Transonic Axial-Flow Compressor Configurations for Aircraft Propulsion Systems.

National Science Foundation Grant GK-38460 - Low Mach Number, Multi-Stage, Axial-Flow Research Compressor.

Recent publications:

Delaney, R. A. and P. Kavanagh, "Entrance Region Flows in Supersonic Axial-Flow Compressor Cascades with Subsonic Inlet Axial Velocity Component. General Method of Characteristics for Unsteady Flow," Engineering Research Institute, Iowa State University, ERI-73076, 1973.

Delaney, R. A. and P. Kavanagh, "Transonic Flow Analysis in Axial-Flow Turbomachinery Cascades by a Time-Dependent Method of Characteristics. Numerical Method of Characteristics for Two-Dimensional Plane Unsteady Flow," Engineering Research Institute, Iowa State University, ERI-73276, 1973.

Miller, M. J., T. H. Okiishi, G. K. Serovy, D. M. Sandercock, and W. R. Britsch, "Summary of Design and Blade-Element Performance Data for 12 Axial-Flow Pump Rotor Configurations," NASA TN D-7074, 1973.

Serovy, G. K., P. Kavanagh, T. H. Okiishi, and M. J. Miller, "Prediction of Overall and Blade-Element Performance for Axial-Flow Pump Configurations," NASA CR-2301, 1973.

Sato, S. and T. H. Okiishi, "Preliminary Development of a Computer Program for Estimating the Off-Design Performance of an Axial-Flow Compressor by Stage-Stacking," Iowa State University Engineering Research Institute Special Report ERI-ISU-AMES-73270, January 1974.

Miller, M. J. and G. K. Serovy, "Deviation Angle Estimation for Axial-Flow Compressors Using Inviscid Flow Solutions," ASME Paper 74-GT-74, 1974.

Junkhan, G. H., "Analysis of Simulated Axial-Flow Turbomachine Wakes for Estimation of Frequency-Response Requirements for Fast-Response Pressure Probes," ASME Paper 74-GT-102, 1974.

Delaney, R. A. and P. Kavanagh, "Transonic Flow Analysis in Axial-Flow Turbomachinery Cascades by a Time-Dependent Method of Characteristics," Final Report, Engineering Research Institute, Iowa State University, ERI-74034, 1974.

MECHANISMS OF FRICTION AND WEAR OF POLYMERS

SPONSOR: National Science Foundation

PRINCIPAL INVESTIGATOR: S. Bahadur

RESEARCH ASSISTANTS: M. A. Saleem, M. K. Kar, A. J. Stiglich, F. D. Hsiao

The sliding motion between journal and bearing, tire and road, brake shoe and drum, die and workpiece, and several similar polymer-metal pairs is common in engineering applications. Wherever sliding takes place, friction and wear are inevitable. Apart from friction and wear, the bonding at the interface and the subsequent fracture determine the surface finish of the polymer part produced by any forming method. Whereas minimum wear may, except in an abrasion process, always be a desirable feature, the friction needed may be large or small. The solution to complex problems like this is not possible unless a better understanding of friction and wear is achieved. This project is concerned with (1) dependence of friction and wear on the operating variables (2) prediction of wear for specific conditions (3) study of the fracture at the polymer-metal sliding interface.

The dependence of sliding friction and normal load and contact pressure has been studied. The investigation has further been extended to the practical situation of the extrusion of polymers through a die. The dependence of the coefficient of friction between the polymer billet and die on the contact pressure has been determined. The dependence of wear on the operation variables (sliding velocity, contact pressure, and sliding time) has also been investigated. At present, the work is in progress on the dependence of wear on the surface finish. An equation has been developed, using dimensional analysis, for prediction wear. The equation has been applied with success to the case of polyoxymethylene and PTFE-filled polyoxymethylene.

Future work will be directed to the understanding of the mechanism of fracture at the sliding interface on a microscopic level. These studies will involve the use of scanning and

transmission electron microscopy, infrared spectroscopy, and mass spectrometry.

In terms of equipment, the Tribology Laboratory has one friction apparatus and two wear testing facilities. The friction apparatus is capable of providing sliding friction data over a large velocity range in the temperature range 60° to -110 °C and under controlled environmental conditions.

Recent publications:

Kar, M. K. and S. Bahadur, "An Adhesive Wear Model for Unfilled and Filled Polyoxymethylene," accepted for publication in Wear.

Bahadur, S., "Dependence of Polymer Sliding Friction on Normal Load and Contact Pressure," accepted for publication in Wear.

Saleem, M. A. and S. Bahadur, "Polymer Friction Under Conditions of Deformation Processing," proceedings of the International Symposium on Polymer Friction and Wear, American Chemical Society, 1974.

Bahadur, S., "Mechanisms of Dry Friction in Deformation Processing of Polymers," NSF Grant GK – 27845, Final Report ISU-ERI-Ames-73105 (May 1973).

FLUID POWER LABORATORY

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: B. L. Johnson

RESEARCH ASSISTANTS: R. K. Peterson, G. R. Schade

Recent work has been directed toward improving the dynamic and steady-state characteristics of a mobile hydraulic control system. A mathematical model of the control system was developed and found to be in good agreement with data taken on the test in the Fluid Power Laboratory. The analysis suggested spool value modification for optimum performance. A new value was tabulated which performed essentially according to prediction. This study has demonstrated the advantages of a combination of analysis and experiment to improve hydraulic control systems.

Two-place flow phenomena in an axial spool value were investigated. Cavitation of the hydraulic fluid was found to cause significant variations in the discharge coefficient, as measured in the laboratory. An empirical expression was developed to describe the data in the pressure ratio range where compressibility was important. The study has relevance for practical hydraulic systems.

Recent publications:

Schade, G. R., "Flow Characteristics of a Two-Phase Mixture in an Axial Spool Valve," PhD Thesis, Iowa State University, Ames (May 1974).

Peterson, R. K., "Steady State Optimization of a Hydraulic Flow Control Valve," MS Thesis, Iowa State University, Ames (August 1974).

INSTRUMENTATION DEVELOPMENT FOR FLUID MECHANICS

SPONSOR: Engineering Research Institute

PRINCIPAL INVESTIGATOR: J. L. Hall

RESEARCH ASSISTANT: J. Herrin

Current research includes work in the following areas:

1. Development of a chemical sampling system for short duration reactions, coupled with gas chromatograph analysis of sampled species. This system is currently being used in kinetic studies involving pyrolysis of simple hydrocarbons relative to their smog forming potential.

2. Comparison of techniques for determining boundary layer transition. Optical methods have been compared to both surface temperature and heat flux methods as part of this work.

3. Development of a quantitative Schlieren system for determination of fluid density and various relaxation times.

Recent publications:

Hall, J. L., "An Intermediate Laboratory Course in a Measurement Sequence," Event 3227, ASEE Annual Conference, Iowa State University, Ames (June 1973).

Hall, J. L., "Comparison of Techniques for Determination of Boundary Layer Transition in Shock Wave Induced Flows," AIAA – ASME Thermophysics and Heat Transfer Conference (1974).

NATURAL GAS USAGE IN IOWA

SPONSOR: Power Affiliate Research Program

PRINCIPAL INVESTIGATOR: R. C. Fellinger

RESEARCH ASSISTANT: S. M. Jargo

This project is directed toward developing a comprehensive picture of costs, supply, and distribution of natural gas within the State of Iowa. Data for various customer classifications have been analyzed to determine current use patterns as well as past trends. This investigation should provide a background for policies which will maintain minimum use and optimum distribution of this important resource.

SYSTEMS ON AGRICULTURAL AND INDUSTRIAL MACHINES

SPONSOR: Deere and Company

PRINCIPAL INVESTIGATOR: A. E. Bergles

MAJOR STAFF: G. H. Junkhan

RESEARCH ASSISTANT: R. L. Bunn

Air-cooled heat exchangers are used almost exclusively in agricultural and industrial machines for rejecting heat to the environment. Typically, a heat rejection about equal to the horsepower output of the engine must be accommodated. A number of heat exchangers are usually required: liquid-to-air exchangers for engine coolant, transmission oil, and hydraulic fluid; a refrigerant-to-air exchanger for the cab air conditioner condenser; and an air-to-air intercooler.

In the past ten years engine horsepower requirements have increased, and, since the system size must be kept as small as possible in order to conform to the overall machine package profile, severe demands are now made on cooling systems. A more recent additional problem is the requirement that noise from the fan, which consumes about five percent of the engine horsepower, must be reduced.

Heat exchanger designs by major manufacturers are readily available, and have been used with rule-of-thumb methods for various applications for many years. Recently, new exchanger designs from other corporations have appeared, making great claims as to the savings gained. There are, unfortunately, no generally accepted performance criteria to evaluate heat exchangers. Further work is therefore required to develop performance criteria for cooling systems used in agricultural and industrial machines. The objectives of this project are as follows:

1. To determine the probable limits of improvement of liquid-to-air heat exchangers which have been used or suggested for use on agricultural and industrial machines.
2. To develop criteria for the evaluation of cooling system performance, which will permit comparison of different systems. These criteria will provide standards for evaluating system performance, both from the design viewpoint and the field performance viewpoint. They will also permit evaluation of manufacturers' specifications for heat exchanger cores.
3. To develop a cooling system selection procedure based on realistic system design constraints.

METALLURGICAL ENGINEERING*

Monroe S. Wechsler
Department Head
and Professor

Metallurgy and metallurgical engineering research at Iowa State is done primarily in the Ames Laboratory under contract with the United States Atomic Energy Commission. This program is administered through the University's Energy and Minerals Resource Research Institute. A small effort is administered by the Engineering Research Institute.

Most metallurgical engineering projects include research and development studies on materials of interest to energy research and development. Emphasis has been in basic theoretical and experimental research in solid state metals, particularly at very high temperatures. Pioneering development work has contributed fundamental knowledge basic to the utilization of nuclear energy and in providing the materials required for its application. Particular interest also has been in preparing quantities of very pure materials. Twelve research groups maintain programs in metallurgy and metallurgical engineering in the Ames Laboratory.

Activities in the Engineering Research Institute have been primarily in application of materials in energy storage, energy conversion, and high temperature, hostile environments.

ALLOY THEORY OF METALLIC SYSTEMS/PHYSICAL METALLURGY OF THE RARE EARTHS

PRINCIPAL INVESTIGATOR: K. A. Gschneidner, Jr.

Current work includes preparation of high purity rare earth metals, superconductivity in La_3In-base alloys, the low temperature physical and electronic behaviors of cerium allotropes, preparation of single crystals of the light lanthanide metals and rare earth intermetallic compounds and low temperature heat capacity (1-20K) studies of rare earthbase solid solution alloys.

DIFFUSION AND ELECTRICAL CONDUCTION IN NON-METALLIC SOLIDS

PRINCIPAL INVESTIGATOR: J. W. Patterson, Jr.

The focus of this research is diffusion and electrical conduction in non-metallic solids such as solid electrolytes and crystalline ceramics. Work involves the determination of the ionic and electronic components of electrical conductivity and the implications thereof for the application of these materials in energy storage, energy conversion and high temperature, hostile environments. Specific examples include materials for solid electrolytes in batteries or fuel cells, as electrodes and insulators in magnetohydrodynamic power generators, and refractory ceramic material in general.

PREPARATION, PURIFICATION, AND PROPERTIES OF REACTIVE METALS

PRINCIPAL INVESTIGATOR: O. N. Carlson

The research activities of this group include (1) the preparation and purification of reactive metals of interest as structural material in nuclear reactors, (2) the chemical diffusion and the thermotransport properties of solute atoms in these metals, (3) the development of electrotransport as a means of preparing ultra-high purity metals, and (4) the study of combined effects of solute concentrations and neutron-radiation produced defects on the strength and ductility of vanadium metal.

STRUCTURE CONTROL

PRINCIPAL INVESTIGATOR: J. D. Verhoeven

The central theme of the research program is manipulation of alloy structure by controlled phase transformations. The bulk of our work has been directed toward controlled solidification studies of alloys involving dendritic and eutectic microstructures. More recently we have examined controlled eutectoid and discontinuous precipitation reactions as a means of achieving structure control. The general aim of the research is to produce aligned composite alloys which have desirable mechanical or electrical properties.

METAL-HYDROGEN SYSTEMS/THORIUM METALS AND ALLOYS

PRINCIPAL INVESTIGATOR: D. T. Peterson

Equilibrium and kinetic behavior of metal-hydrogen systems forms the basis for a substantial part of this research program. The diffusion, electrotransport and thermodiffusion of hydrogen, deuterium and tritium in several metals of interest in fusion power reactors are being measured. Solid metal compounds which might be used to store hydrogen for power uses are also being investigated.

The mechanical properties of thorium metal and thorium alloys over a wide temperature range are also being studied. Thorium metal has promise as a component of fuel elements for nuclear power reactors.

RADIATION EFFECTS ON MATERIALS

PRINCIPAL INVESTIGATOR: M. S. Wechsler

The effect of radiation on the physical and mechanical properties of metals and alloys is being studied using chiefly the Ames Laboratory Research Reactor as a radiation source. The density, size distribution, and shape of defect clusters and voids upon neutron irradiation are investigated as a function of material and radiation variables. Special emphasis is on the influence of trace impurities on the radiation-produced defect clusters and voids and on the resultant radiation hardening and embrittlement, particularly in refractory metals.

MECHANICAL METALLURGY/ STRUCTURE PROPERTY RELATIONS

PRINCIPAL INVESTIGATOR: T. E. Scott

Specific current research activities include:

A study of the fundamental mechanisms contributing to precipitation hardening utilizing single crystals, magnetic measurements, interferometry, scanning electron microscopy and transmission electron microscopy.

A study of the three-dimensional strain distribution in rolled billets utilizing a photoplastic simulating model material.

A study of thermomechanical treatment by high-energy-rate extrusion in order to strengthen steels.

A study of the creep behavior of refractory metals in high vacuum and gaseous hydrogen environments.

A study of the basic mechanisms of hydrogen embrittlement of refractory metals.

A study of precipitation and dispersion hardening in the body-centered cubic refractory metals for 1000 ^{o}C applications. Determination of the mechanical properties of the rare earth metals.

A study of the effects of accelerator injected protons and deuterons on the structure and properties of refractory metals.

THERMODYNAMICS AND PHASE RELATIONS OF SALT AND METAL SYSTEMS

PRINCIPAL INVESTIGATOR: P. Chiotti

The research activities of this group have been in the areas of (1) high temperature phase relations, physical and thermodynamic properties of materials, (2) the application of such data to reaction kinetics and equilibria in fused salt-liquid metal systems, and (3) design of non-aqueous reprocessing methods for nuclear reactor fuels.

SURFACES AND INTERFACES

PRINCIPAL INVESTIGATOR: R. K. Trivedi

The research program is aimed at (a) understanding structure of solid surfaces by the use of LEED technique, (b) study of mobility of atoms on solid surfaces, and (c) explaining different microstructures exhibited by alloys.

RADIATION DAMAGE/CRYSTAL IMPERFECTIONS

PRINCIPAL INVESTIGATOR: C. W. Chen

Research activities in these two closely-related fields deal primarily with the effect of interstitial impurity atoms of carbon or oxygen on (1) the formation of voids in neutron-irradiated nickel, (2) radiation hardening in thorium, and (3) the morphology of dislocations and stacking faults in niobium and niobium-chromium alloys.

ALLOY PHASES

PRINCIPAL INVESTIGATOR: J. F. Smith

Research activity is concerned with problems bearing on phase stability, crystal structure, elasticity, and related physical properties of metals and alloys. These areas of activity are interrelated. The general goal of the research is to develop sufficient understanding of alloy phases such that prediction of the occurrence, nature, and properties of alloy phases would be possible for those alloy systems which have not yet been fully explored. When it is recognized that the possible number of elemental combinations to form binary systems is alone the order of 4000, and when this is expanded to ternary, quarternary, and higher order systems, it is readily seen that such a goal has merit. In the present state of development, the situation is such that there is some understanding of the factors which lead to phase formation and stability; with this understanding it is possible to anticipate with some reliability the general class of phases which might occur within a given alloy system, but any prediction of specific stoichiometries or crystal structures must be largely based on empirical analogy. In contrast, the prediction of the elastic behavior of phases for which the elastic parameters have not been determined can be made with reasonable reliability.

FERROUS ALLOYS

PRINCIPAL INVESTIGATOR: F. X. Kayser

The primary interest of this research is in the nature and properties of ferrous alloys. This includes single and polycrystalline austenites, quenched and tempered steels, and Fe-Al-Si magnetic and transformer sheet alloys.

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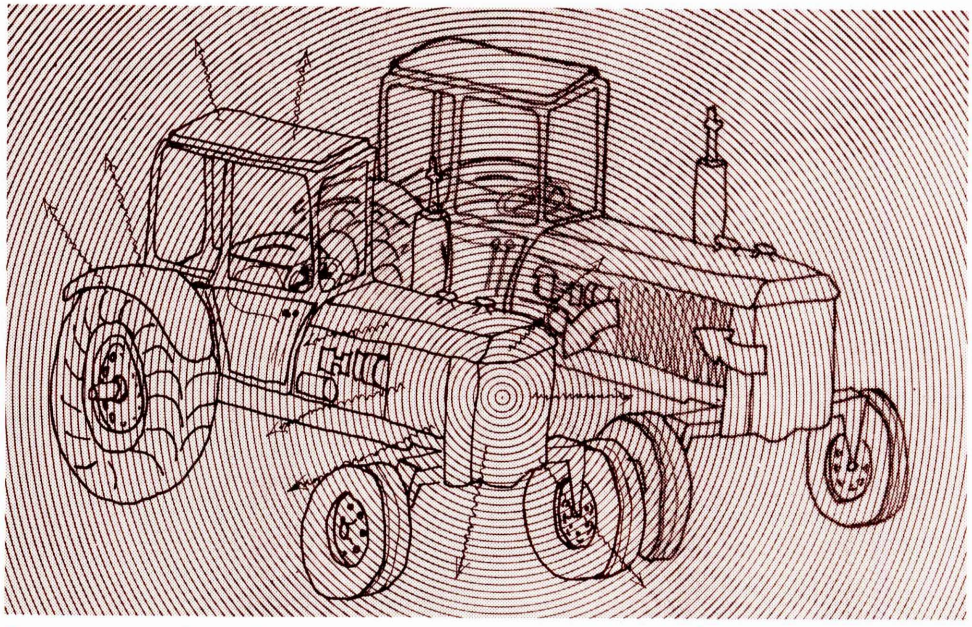
*Effective July 1, 1975, the Departments of Ceramic and Metallurgical Engineering will be combined to form the Department of Materials Science and Engineering. Dr. David R. Wilder will serve as Head of this new department.

ADVANCED ENGINE COOLING SYSTEMS

In recent years, dramatic improvements have been made in the power output (per unit displacement or per unit weight) of diesel engines. This development has progressed to the point where the cooling system is the limiting design consideration on many agricultural and industrial vehicles. Air-cooling limits are being reached due to large power consumption and noise generation. These problems have led to the desire to substantially reduce the airflow, or reduce the forced draft entirely. Radically different cooling systems may be required to achieve this objective.



Present engine cooling techniques use a fan-induced air flow to remove heat. (A) Research on advanced cooling systems is directed toward a possible redesigning of the cooling envelope, to exclude the fan. Elimination of the fan from the cooling design will reduce noise, reduce engine size and weight, and increase the engine's energy efficiency. One such system (B) might dissipate heat through radiative/convective heat transfer surfaces.

Under the sponsorship of Deere and Company, Arthur E. Bergles, Jerry L. Hall, George H. Junkhan, and Ted H. Okiishi of the Mechanical Engineering Department are conducting a one-year exploratory study of alternatives to the present engine cooling systems for diesel engines. The project is being conducted under the assumption that it is possible to redesign the whole cooling envelope. Drs. Bergles and Junkhan are conducting a concurrent project designed to establish the limits of conventional technology. That project will provide a basis of comparison for the advanced cooling systems developed under this project.

The major effort of this research is concerned with a number of radical alternatives to present cooling technology. Direct air cooling of the engine is being explored. A number of unconventional schemes for augmenting heat transfer in radiator-type heat exchangers are also being considered: spray cooling, gas-solids suspensions, surface scrapers, fluid vibration, and electrostatic fields. Ionic air flow is being considered as a method for moving air without a fan. The fan could also be eliminated by dissipating enough heat through radiative/convective heat transfer surfaces. Heat pipes and thermoelectric cooling are being considered, for investigation with existing cooling systems, and the possibility of utilizing auxiliary thermodynamic cycles is also being explored.

It is hoped that this open-ended investigation of cooling system alternatives will contribute toward a viable alternative to the noisy and power consuming systems presently available. In view of the present concern with environmental noise and fuel consumption, this is a most timely investigation.

INTERCITY TRANSPORTATION AND REGIONAL DEVELOPMENT

Research conducted by an interdisciplinary directed by Dr. Robert L. Carstens, Civil Engineering, and funded by the U.S. Department of Transportation indicates that most small communities are poorly served by for-hire carriers of persons or goods. Many have no passenger rail service, no bus service, and no air service. Others, having such services, find poorly coordinated schedules that severely reduce the mobility of travelers not using private automobiles. Similarly, poor rail service and inefficient motor truck transportation handicap shippers of commodities. Such a situation can only discourage community and regional growth by imposing on the residents of the area a life quality which is less attractive than that offered by areas with better transportaion facilities and the resulting availability of goods and services, as well as opportunities for cultural and social activities, either in or near the local community.

The purpose of the project under Dr. Carstens' direction is to define those long-range transportation planning policies, transportation programs, and transportation regulations which can enhance the urban life quality and stimulate the urban processes within the small (less than 50,000 persons) cities which are central place entities.

According to Dr. Carstens, "the function of a central place community in an essentially rural region (such as Iowa) should be to provide for the region those functions and services which will tend to enhance the life quality of all residents of the region, functions and services that are expected as a matter of course to be afforded by a metropolitan city for its associated regions." The primary effort of the first phase of this project has been to identify, formulate, and document those policies, plans, programs, and regulations which reinforce the role of a central place city as a complete urban entity.

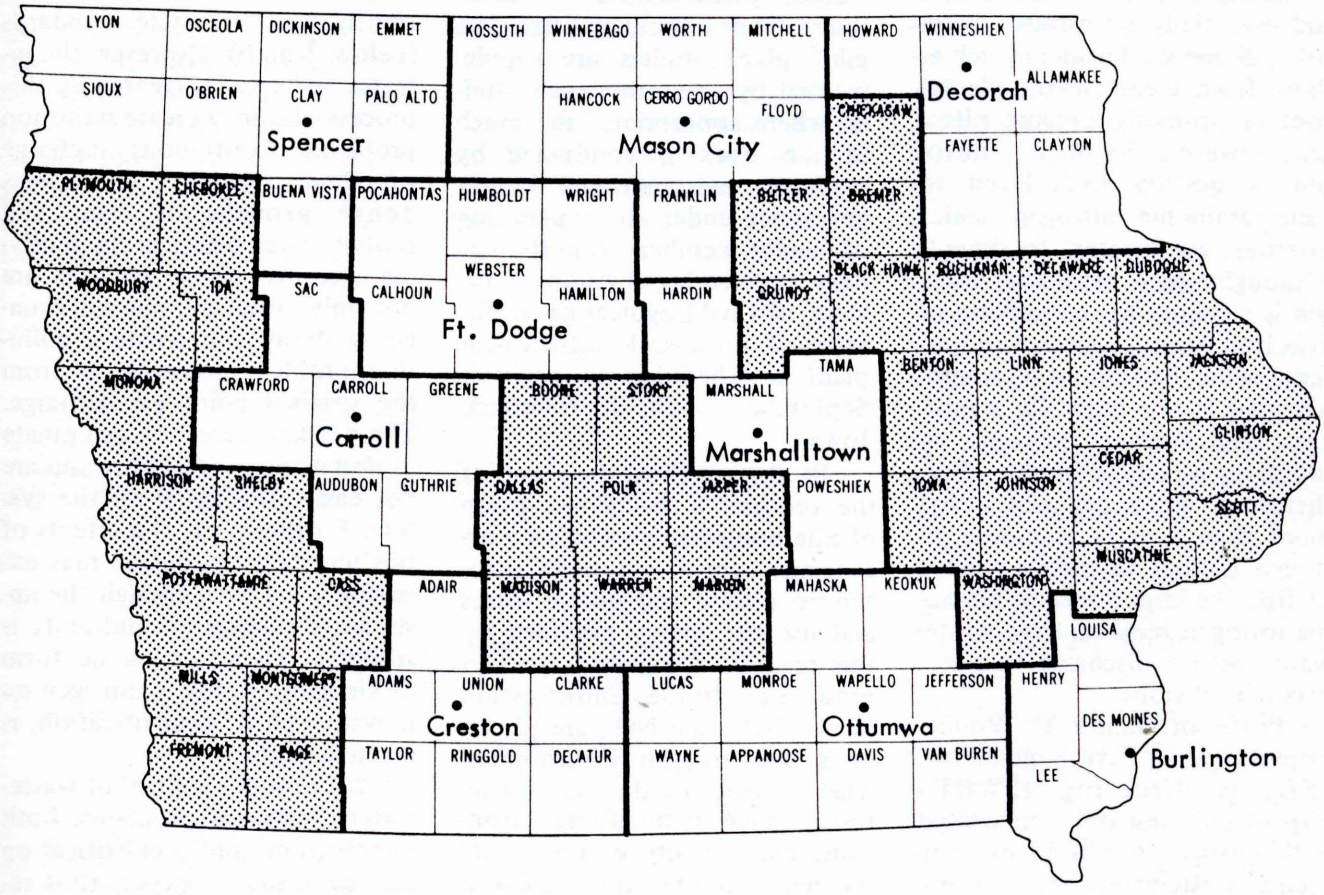
In Iowa, 16 cities have been designated centers of state planning regions. Nine of these that have populations smaller than 50,000 (See figure) have been analyzed to determine the degree to which they function as regional central places and how transportation may enhance that role. Existing data sources of state agencies were extensively utilized for the analysis and supplementary data was collected through questionnaire contact with businesses and industries in three of the regions being investigated (Mason City, Ottumwa, and Spencer).

Research indicates that appropriate development of transportation services within a region can encourage either centralization or decentralization of economic, social, and cultural activities. Research data also suggests that provision of a transportation planning function with responsibility for a multimodal system wherein highways, railroads, waterways, and air service are considered together as serving various components of the demand for transportation services is necessary to effectuate transportation policies and programs for regional development.

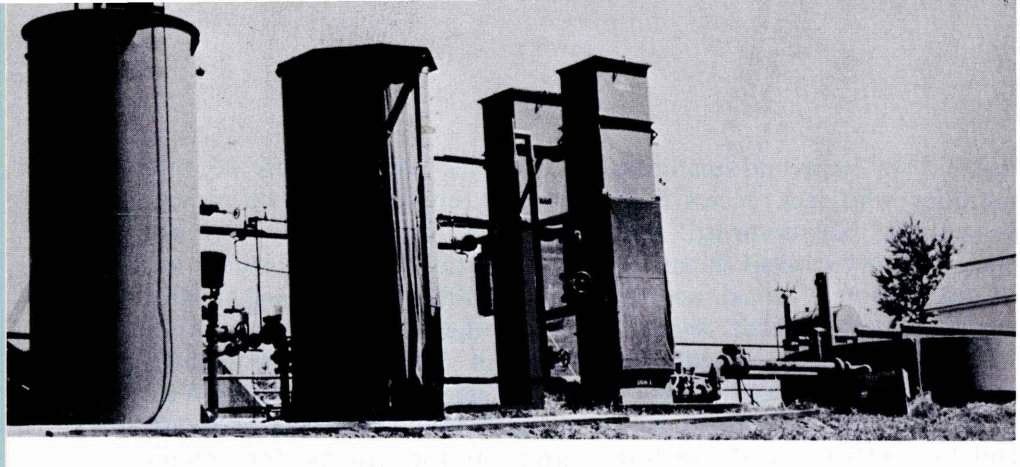
Such a regional growth program would, of course, require the most efficient use possible of available transportation facilities. Quite possibly, according to Dr. Carstens, some railroad trackage should be abandoned and motor truck service substituted for rail service on inefficient, low-volume branch lines. (Railroad rights-of-way which may be useful in view of possible future developments should, however, be preserved intact rather than abandoned.) "Regulatory practices should be modified to permit the supply of motor truck service to be more responsive to the market place. Bus and airline schedules should be better coordinated. Rural public transportation should be provided so that residents of farms and small communities who lack access to an automobile are afforded sufficient mobility to avail themselves of the economic, social, and cultural opportunities available within their regions. Greater use should be made of air taxi service in view of the energy efficiency and time efficiency of this form of transportation."

Dr. Carstens indicates that if these developments were to come about, they would tend to enhance the quality of life of residents of regions that are predominantly rural in nature. "Hopefully, this would encourage a healthy growth in such regions, growth in terms of numbers of inhabitants."

In the second phase of the project, emphasis will be placed on defining attitudes toward transportation in the study regions, with a view toward quantifying the latent or unsatisfied demand for transportation services. Time will also be devoted to quantifying usage of railroads and motor trucks for goods movement in the study regions, describing the role of barge transportation, and obtaining current data on patronage of intercity buses, passenger trains, and commercial air services. A suggested program for a demand-responsive air taxi service will also be developed, and further study will be devoted to the several rural-area bus services that are operating in the state.



The nine state planning regions included in this study. The cities shown have been designated as regional planning centers for their respective regions. Regional planning centers with populations greater than 50,000 were not included in the study.



Cherokee, Iowa, water pollution control plant. The first full-scale evaluations of nitrification were begun this year. Pilot-scale studies were performed in Ames, Iowa.

NITROGEN REMOVAL FROM WASTEWATERS

Nitrogen in wastewater may take any of four forms: organic nitrogen (protein), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3^--N), or nitrite nitrogen (NO_2^--N). Typical untreated municipal wastewater contains 10-50 mg/l of ammonia nitrogen and essentially no nitrates or nitrites. Some wastewaters (such as those from meat-packing plants) contain primarily organic nitrogen; however, the organic nitrogen is quickly hydrolyzed to yield ammonia nitrogen under normal wastewater treatment. Although some ammonia nitrogen is required for conversion of dissolved organic material to bacterial cells, the amount of ammonia used is not normally significant, and further ammonia removal is usually desirable. Furthermore, when one notes that more than 2 mg/l ammonia nitrogen is toxic to certain species of fish, the importance of ammonia nitrogen removal from wastewater before discharge to rivers becomes obvious.

Professor James C. Young, Department of Civil Engineering, ISU, is directing ISWRRI supported research concerned with nitrogen removal from municipal wastewaters through biological nitrification and denitrification. (The project has also received support from General Filter Co., Ames, Iowa, and the City of Ames.) The research is being conducted via pilot plant studies at the Ames, Iowa water pollution control plant, where an activated sludge or packed-bed reactor system is used to treat effluent from a trickling filter. The pilot plant studies are supplemented by laboratory-scale studies where appropriate, and much of the work is conducted by graduate assistants and hourly personnel under the supervision of faculty members from the sanitary engineering division of the Dept. of Civil Engineering. Evaluation of a full-scale nitrification plant is scheduled to begin in September 1974 at Cherokee, Iowa.

In the nitrification phase of the process, a specialized group of microorganisms (nitrifying organisms) convert ammonia nitrogen to nitrate and nitrite forms and use the energy provided by this reaction for growth and reproduction. In the denitrification phase, NO_2^- and NO_3^- are placed in a low oxygen environment where a specialized group of bacteria, called denitrifying organisms, use the nitrite and nitrate molecules in a reaction similar to the use of molecular oxygen by other aerobic microorganisms. In this reaction, the nitrite and nitrate nitrogen are converted to nitrogen gas, which is released harmlessly to the atmosphere.

Professor Young explained that nitrification alone can reduce ammonia nitrogen sufficiently to meet state standards (below 2 mg/l). However, the nitrates and nitrites created by this process also may create pollution problems. Continuous discharge of these nutrients encourages dense growths of algae and rooted water plants in the receiving streams. These growths are not only unsightly, but will eventually decay and create a pollution problem downstream from the original point of discharge. These plants tend to accumulate in downstream reservoirs and are not easily flushed from the system. Furthermore, the effects of this secondary pollution may exist for years even though the upstream discharge of nutrients is stopped. Therefore, some form of virtually complete nitrogen removal, such as denitrification, is often desirable.

With proper control of wastewater treatment processes, both nitrification and denitrification can be made to occur, thus removing not only ammonia nitrogen but nitrite and nitrate nitro-

gen as well. However, nitrification requires a high pH, low organic loading, and high dissolved oxygen levels, while denitrification requires a low pH, high organic loading, and low dissolved oxygen levels. These opposing optimum environmental factors prevent the promotion of simultaneous nitrification-denitrification to any significant extent, and make necessary complex flow schemes for the process.

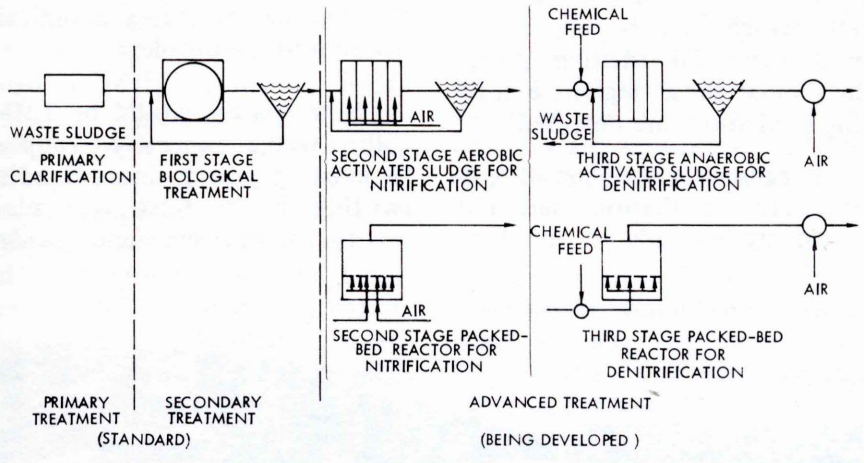
Biological nitrification-denitrification was chosen for investigation because it offers relatively low-cost nitrogen removal, as compared to physical and chemical methods, and has been used successfully in areas where water temperatures remain above 60 °C year around. However, when low wastewater temperatures reoccur, as is common in the midwestern states, the growth rate of the nitrifying organisms is severely limited at the very time when nitrification is needed most. Streams are often at their lowest flow during the winter months and are frequently covered by ice and snow, which limits the growth of algae and other plants, decreasing the amount of ammonia nitrogen used, and increasing the necessity for ammonia nitrogen removal. Therefore, the ability to regulate conditions so that nitrification will continue even in cold weather is especially important.

In the nitrification phase of the research, efforts are directed toward a determination of the highest organic loading and the lowest temperatures at which nitrification can be sustained in both the aerobic activated sludge and aerobic packed-bed reactor systems. As seasonal wastewater temperature decreases occur, adjustments in the plant operation are made in order to sustain nitrification at as high a degree as possible. Samples are collected and analyzed as needed to determine the ability of each unit in the system to remove organic carbon and to convert ammonia nitrogen to nitrites and nitrates.

The denitrification phase of the work is directed toward a comparative evaluation of the anaerobic activated sludge and anaerobic packed-bed reactor processes to determine their relative effectiveness, economics, and operability with respect to the denitrification process. Both processes have been used successfully for denitrification of nitrified wastewaters. Most experience, however, has been with the anaerobic activated sludge process. It is desirable to obtain more data on the anaerobic packed-bed reactor as used for denitrification because it offers some very attractive operational advantages over the activated sludge system. Furthermore, too little data are available on cold weather operation of either of these denitrification processes.

According to Prof. Young, recently imposed state and federal stream standards will probably require some form of nitrogen removal of almost every wastewater treatment plant discharging effluent to streams used for fishing, recreation, or water supply. In Iowa and other midwestern states, this may apply to more than 50% of the incorporated cities and towns. Presently, most state standards apply to ammonia-nitrogen only; however, removal of other nitrogen forms may also be required in the future, especially where reservoirs or diversion for domestic use exist downstream. It is already required of wastewater plants releasing effluent into such waters as those of Lake Tahoe and Lake Michigan.

The objective of this project is to develop an optimal plant design and guidelines for operating parameters which will allow year round use of biological nitrification-denitrification even in the midwest, where our cold winters have heretofore made this impossible.



Process diagram for wastewater treatment. The primary and secondary treatment phases encompass the standard treatment presently employed. The advanced treatment phase is the nitrification-denitrification treatment being developed by Dr. Young. Used together, nitrification and denitrification can accomplish almost complete removal of nitrogen pollutants, which may endanger fish and encourage algal and rooted water plant growth in the streams which receive plant effluent.

POWER TRANSMISSION LINE MODELLING TECHNOLOGY

Dr. Kenneth G. McConnell, Department of Engineering Science and Mechanics, has recently initiated a new project which will develop a useful tool for the study of new or unusual problems in the design of power transmission lines. The project is being conducted under a two-year grant from the Electrical Power Research Institute. The work includes construction of models of actual power transmission lines, and use of these models as experimental tools to solve specific design and maintenance problems. When complete, the research will yield two important tools for power companies and power line designers: 1) a model design guide and 2) a book of basic design data for use by transmission line designers confronted by damaging power line oscillation.

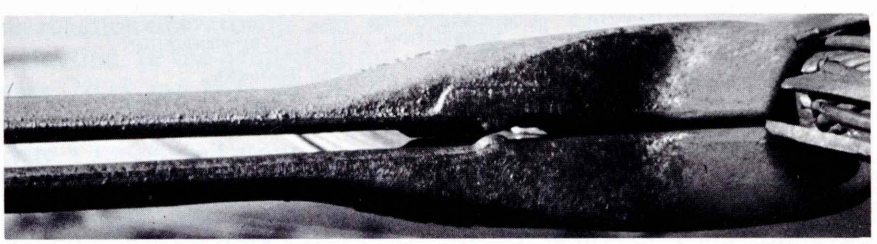
In growing numbers, the huge, six-armed steel towers which support power transmission lines are carrying bundled, rather than single conductor, lines. Each arm supports one bundle, which is commonly composed of two, three, or four conductor cables, but may also contain six or more cables in the near future. The entire bundle is the conductor; each cable is a subconductor and is separated from other subconductors in the bundle by a spacer. A typical two-conductor-bundle spacer is shown below. Also shown is the "fretting" damage found under the spacer clamp after it had been in place for some time. The damage is due to wind-induced subconductor oscillation. The elliptical orbit of the wind-induced subconductor oscillation eventually loosens the cable in its spacer; the movement of the subconductor cable within the spacer clamp produces fretting. If allowed to continue, fretting will first wear through the aluminum sheath of the cable, reducing conduction efficiency; it will then, more slowly, wear away the steel cable core. If the fretting were allowed to continue indefinitely, the line would break. There is, therefore, a great need for an engineering solution which will either control subconductor oscillation or guarantee a non-damaging spacer.

According to Dr. McConnell, the damaging oscillation occurs more frequently in open terrain (where air turbulence is low) than in hilly or wooded terrain (where air turbulence is high). However, "it is not possible to predict where subconductor oscillation will occur with any certainty. It is therefore desirable to develop an engineering solution which can be applied to both new and existing power lines once those regions exhibiting oscillations are detected."

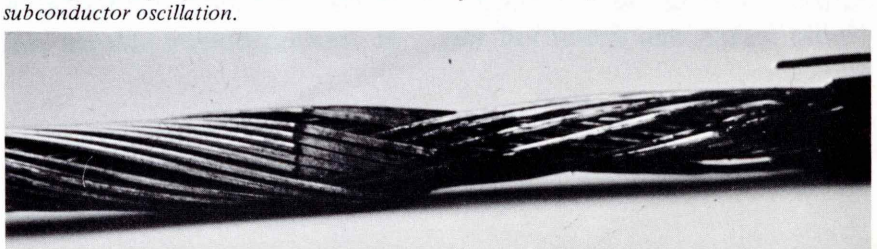
Because the problem of subconductor oscillation had not previously been placed on a firm analytical basis, Mark Whittlesey (in 1972, under the direction of Dr. McConnell) conducted a wind tunnel study of the problem for the Iowa-Illinois Gas and Electric Co. Mr. Whittlesey designed an experimental method to simulate the dynamics of a twin-bundled line (two-conductor bundle) in order to discover which parameters are essential to the occurrence of subconductor vibrations. A concurrent investigation, conducted by the National Research Council of Canada, has shown that subconductor oscillation in a particular line span (length of line between two towers) can be controlled by hanging the subconductors in such a manner that they are not parallel to one another (twisting them), as shown in the sketch below for a two-conductor bundle. Whittlesey's work indicates that this may be the only economical solution to the problem.

New spacers would be difficult as well as expensive to apply to existing power lines. Bundle twisting, by contrast, is a relatively inexpensive and easily

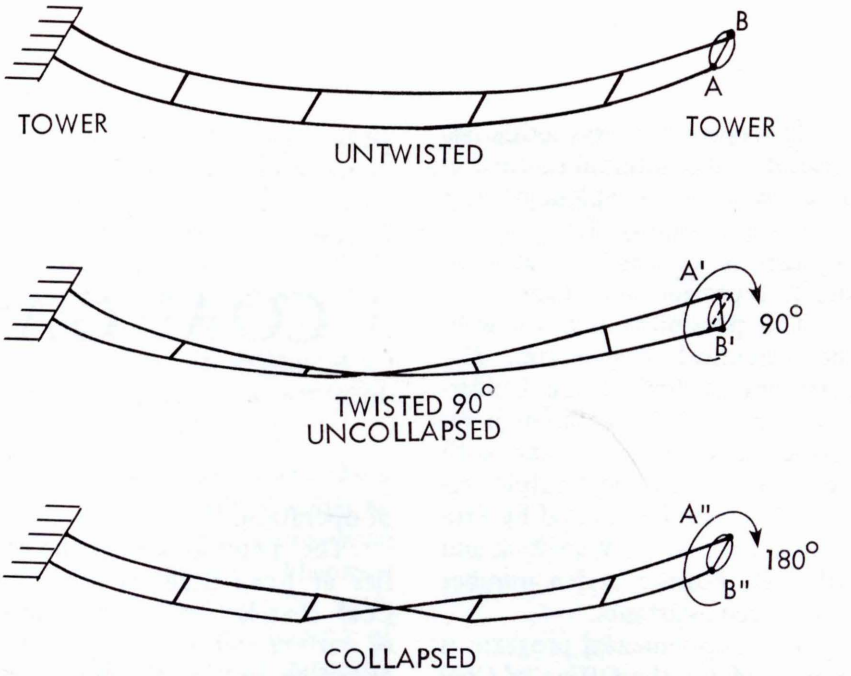
Portion of a typical two-conductor spacer.



Fretting damage found under the above spacer. Damage is due to wind-induced subconductor oscillation.



applied solution, according to Dr. McConnell, and it can be applied to both new and existing power lines with little difficulty. There are, however, some major barriers to the widespread application of this engineering solution. First, the twisted bundles exhibit "snap-over" stability at certain twist angles (angle of twisted lines with reference to the horizontal): the subconductors touch and will not return to their original positions unless corrected manually (conductor bundle collapses), as shown in the figure below. Secondly, the data necessary for predicting the occurrence of "snap-over" and the knowledge of how the twist per subspan (length of line between two spacers) is distributed over the transmission line span are presently unavailable. Dr. McConnell's research will help solve these problems. Once the power line model has been developed, it will be used to develop design data curves which will aid transmission line designers in applying bundle twisting where it is needed to control subconductor oscillation.



Two-conductor visualization of untwisted, twisted, and collapsed conductor bundles. Twisting the bundle can reduce fretting damage, but the angle of twist needs to be carefully adjusted to reduce the damage without producing a bundle collapse, in which the wires touch, producing a short condition.

In the model design phase of the project, over 100 inexpensive and readily available model materials (fishing lines, for example) are being tested for their axial, creep, flexural, and torsional properties. Then the conductor material properties are also measured, and are being paired with those model materials which best simulate their behavior under various testing situations.

After model material properties and conductor properties have been fully correlated, a two-conductor bundle model will be constructed. The model will be used to develop the measurement techniques required for model testing. When these techniques have been perfected and standardized, testing will be conducted to determine which system parameters (conductor spacing, subspan length, sag-span ratios, differential conductor tensions, differential tower heights, and amplitudes of vibration) have the greatest and least effect of "snap-over" stability and span-wise twist distribution. Three-, four-, and six conductor bundle models will then be constructed, and the influence of those parameters which were significant for the two-conductor bundle model will be determined for each.

A procedure for applying twisting to conductor bundles which exhibit subconductor vibration will be developed using the experimental data. This procedure will be supplemented with parameter design curves. These will enable transmission line designers to determine quickly and easily how many spacers, etc. are required to achieve the desired amount of twist per subspan for a given span, and how much the line can be twisted before "snap-over" instability will occur.

The model design guide will include a correlation of model material properties and actual conductor properties and will indicate which model material best simulates specific conductor behaviors for various testing purposes. The design guide will also lay down modelling laws and explain the various experimental techniques developed during the course of the project. This guide will be useful to the power industry not only for the study of non-linear "snap-over" stability and span-wise twist distribution, but also for the study of such problems as the optimal conductor configuration for spans which must accommodate highly unusual terrain elevations. The model of similitude being developed by Dr. McConnell will provide an important experimental tool which will facilitate the investigation of future design problems.

COAL GASIFICATION

The current energy crisis has promoted the national interest in other ways to supplement our natural gas supply. One way to do this is to gasify coal with steam to produce a fuel gas.

This possibility is not new to the Chemical Engineering Department at Iowa State University. Since 1965, research in reacting coal or coal char with steam using an electrofluid reactor has been conducted by Professors Thomas D. Wheelock and Allen H. Pulsifer and a number of research assistants.

The experimental program is sponsored by the Office of Coal Research of the U.S. Department of the Interior. The purpose of the research is to develop processes whereby various chemicals or fuel gases can be made from coal using the electrofluid reactor. The Institute of Gas Technology has undertaken a project to integrate such a process with coal hydrogasification to produce a methane-rich pipeline gas.

The gas produced from coal in the reactor contains methane, hydrogen, carbon monoxide, and carbon dioxide. The amounts of the individual gases are dependent upon the temperature and pressure of the reactor. "This gas mixture may be burned as a fuel, or processed further to produce a methane-rich pipeline gas," Wheelock says.

The experimental program in the Chemical Engineering Department is designed to demonstrate the general technical feasibility of the gasification process. It will determine equipment suitability, reveal the potential problem areas, and test the materials used in the construction of reactors and electrodes. It will also measure the overall gasification rate, conversions, and yields under different conditions of operation.

The material used in the gasifier at Iowa State is coal char. Coal char is basically composed of carbon and ash, and it is produced by heating the raw coal to a high temperature. When the coal char reacts with steam at high temperatures, the principal reactions which take place are the following:

$$C + H_2O = CO + H_2$$

$$CO + H_2O = CO_2 + H_2$$

$$C + 2H_2 = CH_4$$

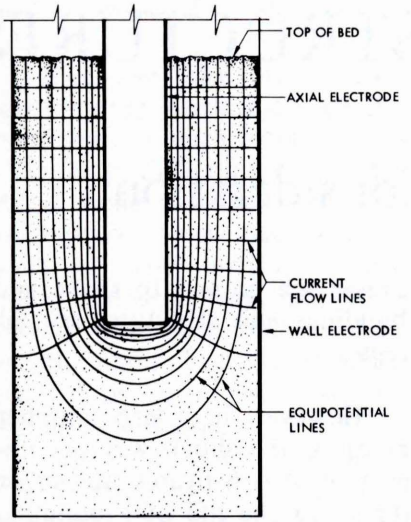
With the data obtained from the reactions, the composition of the product gas for different pressures, temperatures, and steam conversions can be estimated. A wide range of gas compositions can be obtained by varying the operating conditions. At high temperatures and low pressures, the product gas is essentially hydrogen and carbon monoxide. Conversely, at high pressures and low temperatures the gasifier product is composed of methane, hydrogen, carbon monoxide, and carbon dioxide.

From the results of the experimentation at Iowa State, it is possible to select the gasification conditions that should yield a specific product. The conditions can be varied to produce a gas that is rich in hydrogen, mostly hydrogen and carbon monoxide, or contains an appreciable concentration of methane.

All of the experimental fuel gases are produced in an electrofluid reactor. The reactor uses a fluidized bed of conducting particles and is heated by passing an electric current through it. The bed itself serves as a resistor between the electrodes that have been placed in contact with the bed. Since heat is generated directly within the bed, the electrofluid reactor is useful for conducting the gasification reactions which require large inputs of energy and which are favored by high temperatures. Since the reactor can be built with a refractory lining (an insulating lining inside a steel shell), it provides resistance to corrosion at high temperatures and contains the pressure.

Wheelock explains that one of the main objectives of the research is to develop a basic understanding of the electrical and physical behavior of the electrode-fluidized bed combinations. With this understanding, it will be possible to develop the optimum design and application of an electrofluid reactor for industrial uses. The known or predictable characteristics of the reactor systems are essential to the design and selection of matching power supplies and controls.

The electrical resistance in an electrofluid reactor is one of the most important variables. The resistivity of a fluidized bed is affected by the gas velocity, temperature, particle size, and the conductivity of the individual particles. The resistance is being thoroughly studied to determine the nature of electrical conduction and resistance. Coke, graphite, and coal chars are being used in the experimentation.



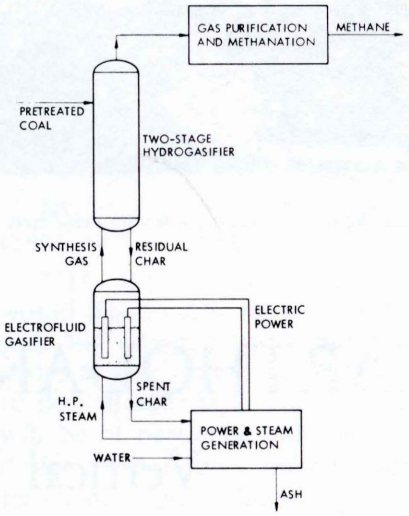
Predicted equipotential and current flow lines in a cylindrical bed in contact with concentric electrodes.

The basic laws of electromagnetic fields are used to analyze and predict the electrical characteristics of the reactors. The first figure illustrates the laws which predict the equipotential and current flow lines. The lines are drawn so that the voltage drop between adjacent equipotential lines is the same. Similarly, the current flow lines divide the reactor bed into increments of equal current flow. By considering the spacing of the equipotential and current flow lines, the origin of the generated heat can be determined. This is because the same amount of heat is generated within each of the small regions formed by the intersecting lines. There is some tendency for the center electrode to overheat in a concentric electrode system since a disproportionate amount of heat is generated in the region near the center electrode. This is where the equithermal increments are concentrated around the electrode.

The preliminary tests show that it is technically feasible to gasify coal char with steam in an electrofluid reactor. Wheelock explains that by using the reactor, "The rate of production of the synthesis gas was generally high and relatively constant until 85 to 90 percent of the original carbon had reacted."

Since the method is capable of producing a wide range of hydrogen-carbon monoxide mixtures and mixtures that contain methane, there are a number of potential industrial applications for the gasification of coal char using an electrofluid reactor. If the method were combined with the gas purification and shift conversion steps, it would be possible to produce essentially pure hydrogen that can be converted into ammonia or used in various hydrogenation reactions. It would also be possible to produce hydrogen-carbon monoxide mixtures that can be converted into methanol, higher alcohols, and aldehydes.

The use of an electrofluid gasifier to supply the hydrogen and carbon monoxide for the Hygas process has been seriously considered by the Institute of Gas Technology. In this application, the residual char from the hydrogasifier is converted by an electrofluid gasifier into a synthesis gas. The synthesis gas is then returned to the hydrogasifier, where it reacts with the coal to produce a methane-rich gas stream. It is then processed further to give methane. (See process diagram.)

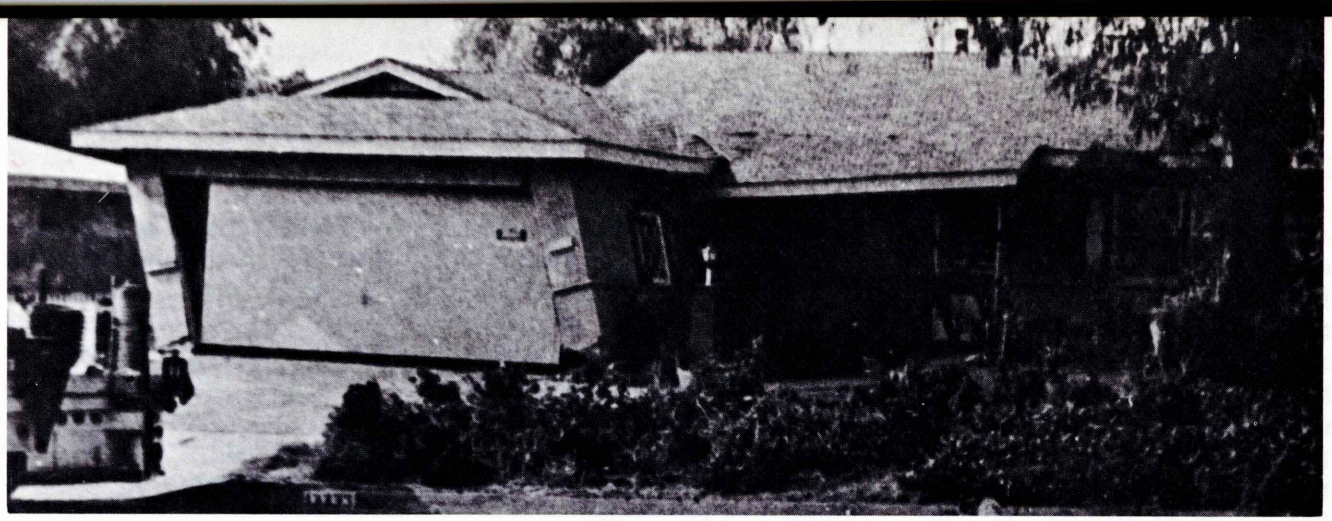


Hygas process diagram.

There is a considerable amount of development of the reactor system and conversion processes remaining. Work on the system and its several applications is continuing in the Chemical Engineering Department. Emphasis is being placed on developing a sufficient understanding of the system so that large-scale reactors may be designed.

Although the production of synthesis gas is receiving emphasis at Iowa State, some work is also being done with such processes as one to produce carbon disulfide. A part of the research includes investigation of possible catalysts for the reaction of carbon with steam. It is imperative that the catalysts be compatible with the electrofluid reactor system.

In the future, the Chemical Engineering Department at Iowa State hopes to broaden its experimental program to include research on processes that would be suitable for use with Iowa coal.



Earthquake damage to family residence. Damage is primarily a result of transverse or horizontal waves.

EARTHQUAKE-RESISTANT STRUCTURES

Vertical Motion- A New Design Consideration

When the Russians recently built a dam in northern India, the dam was designed to resist the normal horizontal vibration of an earthquake. But shortly after the dam was completed, an earthquake occurred and the dam was destroyed.

During the 1971 earthquake in San Fernando, California, large vertical motions were recorded along with the expected horizontal motions. The buildings had been constructed to resist the effects of the large horizontal vibratory motions, but not the vertical ones.

Instances such as these have prompted Professor William Riley and Associate Professors Christian P. Burger and Lester W. Schmerr of the Department of Engineering Science and Mechanics at Iowa State to explore the effects of an earthquake's vertical waves on structures.

The hazards of earthquakes to buildings and structures may arise from such sources as surface faulting, soil consolidation and settling, or landslides. Engineering has customarily viewed the earthquake hazard as bascially a problem of the vibration of the structure when the earthquake occurs. Such a viewpoint is usually expressed in the present building codes and earthquake protection studies.

Traditionally, it has been assumed that the damage to structures and buildings by earthquakes is due to the transverse or horizontal waves generated. But there is also the possibility that the earthquake's shock waves may cause damage to the structure. It is exactly this possibility that Burger is exploring.

A series of waves are generated by an earthquake. "When an earthquake occurs, large amounts of energy are released in the form of propagating stress waves that radiate from the earthquake's source," Burger explains. The first wave is a pressure wave, also known as a shock or impact wave. The shear wave follows the shock wave, and the last wave of the series is the transverse wave. It is the transverse wave that causes the ground to shake and buildings and structures to collapse.

However, in a large number of cases, the shock wave or impact wave constitutes the major threat to the life of a building. The wave is refracted and damages the structure before the vibratory motion of the transverse (horizontal) wave occurs. The impact wave weakens the structural joints of the building; thus, any precautions provided in the structure to resist the transverse waves are overcome by the impact of the shock wave.

When an earthquake contains a significant amount of high amplitude vertical motions, a series of vertical shocks at the base of the structure occurs. These shocks initially propagate into the interior of the structure. When the focusing, guiding, and reflection of the initial impact waves' pulses meet places of stiffness, local damage could be caused at the critical points in the structure. Such areas of con-

cern include the tapers, columns, joints, and connections of the building. The local damage at the critical points reduces the ability of the structure to survive the horizontal ground motions which follow. The action of the impact waves on the structure is of particular concern in concrete structures when there is a good possibility that the disintegration of the concrete or the breaking of bonds to the reinforcing materials could be produced by the initial waves and the stresses they produce.

Because the horizontal motion of an earthquake can also contribute to such an effect, it is extremely difficult to use the data collected from previous earthquakes to evaluate the dangers of the vertical impulse waves. Consequently, laboratory models have been built to evaluate the nature and extent of the dangers of the impact waves on buildings and structures.

"Particular emphsis is placed on determining the dangerous structural shapes and on locating critical areas in a structure where the damage mechanisms are important," Burger and Schmerr state. The effects of the impact waves on the local areas of reinforcement are also being studied. From the study, the areas where careless placement of reinforcement may actually reduce a structure's ability to withstand eqrthquakes will hopefully be identified.

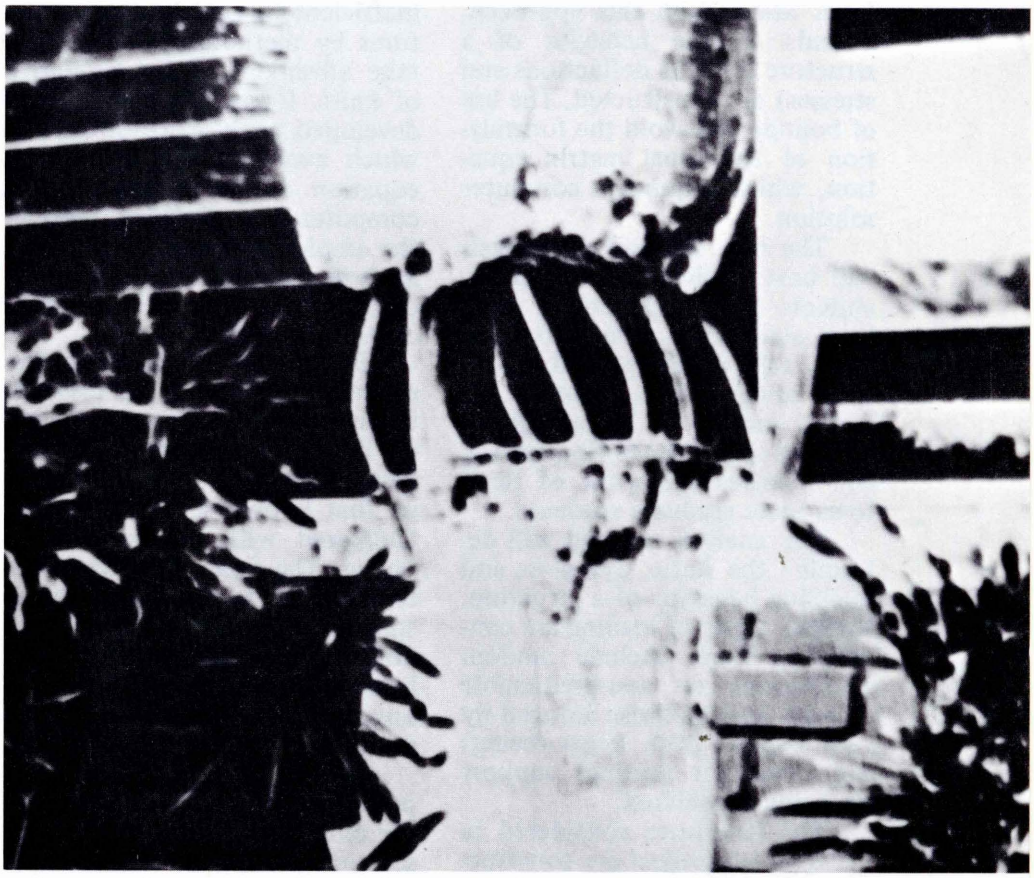
In the engineering mechanics laboratory at Iowa State, miniature models of the structures have been constructed. Small explosives are used to generate impact waves. When the explosive is ignited, it burns quickly and produces steep pulses against the laboratory model. A camera, synchronization gear, and timer are used to record and plot the paths of the impact waves.

The type of materials used will affect the nature of the wave produced. A concrete to steel bond may weaken under the impact of the impact wave, so the properties of the laboratory materials are matched to those of the actual structures.

There is a possibility that the earthquake's waves can travel along a large pipeline and damage a pumping station several miles away from the site of the earthquake. Riley, Schmerr, and Burger are also investigating the possibility that such a danger exists and, if so, how far the waves can travel as well as how strong they will be.

The three-year study is specifically aimed at identifying those areas where careless placement of reinforcements may reduce the ability of a structure to survive an earthquake. The design of joints where two systems of reinforcement meet, such as those between columns and beams, are being studied. From the results of the study, changes in the structural details at such points can be suggested.

"If we achieve what we would like to achieve, our results will be plugged into building codes as precautions on what not to do," Burger says. The findings will be of particular value in the design of buildings, nuclear containment vessels, highway overpass supports, and dams in regions near fault lines.



Structural damage to La Immaculata School, 1972 Managua Earthquake. Bonds between cement and steel reinforcing rods have been broken. Vertical shock waves may contribute to such damage, weakening structural resistance to subsequent transverse waves.

DYNAMICS OF LINEAR AND NONLINEAR STRUCTURES

A mathematical tool for efficiently analyzing large structures is being developed by Professor Thomas J. McDaniel of the Aerospace Engineering Department at Iowa State. With this approach, bounds to the behavior of a structure (i.e., its deflections and stresses) are constructed. The use of bounds will avoid the formulation of the usual matrix equation, which requires a computer solution.

The new method of analysis will have application for the architects and designers of such large structures as aircraft fuselages, tall buildings, and multispan bridges. The two-year research project is sponsored by the National Science Foundation and involves the work of three Iowa State graduate students.

The analysis method will determine the static, dynamic, and buckling behavior of a structure. Various types of loading are considered. These include random excitations or non-predictable changes such as those induced by a jet engine. Both linear (beam) and nonlinear (spring) support are being considered.

The structures considered in the research project are constructed of similarly shaped (nonperiodic) and sometimes identically shaped (periodic) units. An example of a nonperiodic structure is a tall building in which all of the floors have a similar shape, but the mass of each floor and the stiffness of each level varies in a predetermined fashion. This structure can behave either linearly or nonlinearly, depending on the level of excitation it receives from an earthquake or gusts of wind.

Most traditional methods of analyzing the forced motion of a large structure do not take advantage of the "similarity of the units" construction. Consequently, the traditional analysis requires the preparation of a large matrix equation. Since the equation is large and complicated, it must be solved by lengthy and expensive computer runs.

McDaniel first approached the study by analyzing periodic structures. He contends that it is inefficient to analyze large structures by methods which do not take advantage of the similarity of units. Using this idea, he has developed analyses of structures which avoid solving the matrix equation on the computer. The computer is still being used in the implementation of the new analysis method, but the amount of computer time will be significantly reduced.

Bounds are developed in the preliminary stages of the research to determine the upper and lower limits of the structural behavior. Simple problems are used so that known solutions can be compared with the bounds obtained. The final objective of the research is to find bounds to structural problems which cannot be exactly solved. These bounds are constructed from approximate solutions to the structural problem in question.

The usefulness of such approximate solutions depends on the closeness of the approximate solution to the unknown exact solution. Thus, one of the central purposes of the study is to provide a way of determining the "error bounds," which are a measure of the deviation of the approximate solution from the exact solution. When the error is sufficiently small, the approximate solution can be used to accurately predict the structural response.

The simplified method of analysis developed in the project is now being applied to other areas. Included are linear and nonlinear structures composed of nonperiodic units. Since exact solutions to the governing equations cannot be determined, approximate solutions must be developed for the various classes of structures. Error bounds are needed to determine the closeness of the exact solution and the approximate solution.

When the design of a structure is in the preliminary stages, the engineer can use the new analysis method to determine the approximate upper and lower bounds of structural response. In its final stage of design, the estimates can be refined to compute a more accurate response. As a result, a wide variety of linear and nonlinear structures which are subjected to various types of excitation can be analyzed with a minimal amount of computer time and effort.

The results of the analyses will be used by engineers in the design of structures so they may be protected from such failures as collapse or wearing out of the structure (fatigue). The research has particular application to aircraft, where sound and energy from the jet exhausts puts stress on the structure.

The determination of bounds to problems other than those in the structures area will have future significance to designers in all areas. "It will work in any particular area, not just with structures," McDaniel explains. Time and effort involved in solving the equations will be reduced and lengthy computer runs will be avoided.