VPI

Engineering

Mechanics

and Industry

I N T E R F A C E

VPI

Engineering

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and Industry

Appendices

INTERFACE: VPI ENGINEERING MECHANICS AND INDUSTRY*

In Brief

Industry and engineering education appear at times to move along diverging paths. Industry is understandably concerned with the problems of today and the immediately foreseeable future while engineering education has taken upon itself the task of preparing a man to enter a lifetime career. The fact is that the ultimate development of an engineer is the result of a partnership of education and industry with significant investment by both partners. The development of lines of communications between industry and engineering colleges, particularly at the departmental level, cannot help but make the partnership more effective.

A Department of Engineering Mechanics is at a disadvantage in many ways in opening and maintaining such lines of communications. The lack of large numbers of alumni, and the lack of a single professional society (as ASME, ASCE, etc.) prevent such a department from gaining identity in industrial circles. Probably the most difficult barrier to communications is the general lack of understanding of the capabilities of engineering mechanics graduates, and the abilities and interests of the staff of a present-day Department of Engineering Mechanics.

A knowledge of the applied mechanics of solids and fluids in the broadest sense, is one of the strongest common marks of an engineer, whatever label he may ultimately adopt. This knowledge is initially gained in courses in Engineering (or Applied) Mechanics, which are taught variously in different conventional departments or in a separate department of Engineering Science and Engineering Mechanics. Where a separate department exists, degrees at several levels may be available in Engineering Mechanics (or Engineering Science, Engineering Physics).

Several legitimate questions arise in connection with this situation. What does an Engineering Mechanics Department do that could not be done by an "old-line" department? What does an E.M. degree do for the student? What can he do better for a company than a man with a conventional engineering degree?

Rather than argue the above in detail, the following pages attempt to define the function of Engineering Mechanics by setting forth the past, present, and future of the Engineering Mechanics Department at VPI. By presenting the qualifications and interests of the staff, the work of the present student body and samples of the jobs being

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performed by the alumni, it is felt that an answer will be provided to the irreverent question

"What kind of a mechanics is an Engineering Mechanic?"

As given in more detail in a later section, Engineering Mechanics (originally Applied Mechanics) at VPI existed first as a service department for all engineering curricula. As a degree granting entity, it started with a Master's degree, progressing to the Ph.D. as increasing graduate enrollment permitted the building of a qualified staff.

In later years, it was recognized that there was a significantly large group of capable undergraduate students on campus that was interested in an engineering science program rather than in a specific technology. As it developed, there were enough students to justify offering a B.S. program. The program is differentiated from regular engineering curricula by its emphasis on a broad spectrum of engineering sciences, including more than average preparation in mathematics. Exposure to elements of design in several areas, plant visits, and the development of independent senior projects provide an introduction to open-ended problems characteristic of industry.

The graduates of the several degree levels in Engineering Mechanics are engaged in diverse activities in universities, research laboratories of all types and in design and development for industry. The training does not directly produce individuals narrowly concerned with highly specialized areas, as evidenced by a number of people who have moved into positions of responsibility for the work of other engineers. The point is that graduates at all levels have been most flexible in their choice of careers and in the types of jobs they have confronted.

Alumni in Industry

The following listing of some types of work or job titles of the department alumni in industry or research laboratories represents only a sampling of alumni job functions.

1. Numerical stress analysis of structures – ocean going vessels
2. Experimental stress analysis of structures – ocean going vessels
3. Underwater explosives research
4. Chief of hydrodynamics laboratory – shipyard
5. Branch head – structures research laboratory
6. Development engineer – fluid logic division – computers
7. Design of miniature control elements
8. Operations research – war games analysis
9. Research engineer – elastomeric vibration absorbers
10. Service failure analyst – aircraft
11. Research on layered composite materials
12. Structural designer – chemical processing industry

13. Design and development of plastics processing machines, using non-Newtonian fluid theory
14. Wave propagation and blast loading on shells
15. Direction, pioneering research division – major fiber industry
16. Manager, technical services – steel company
17. Director, experimental stress analysis laboratory
18. Project manager, recovery system – Discoverer satellite
19. Consulting structural engineer – responsible for "computerizing" the firm
20. Partner in firm offering computational services to industry

The list is intended to provide only a sampling of some of the positions and specific jobs of alumni of the department. In all cases listed, the individuals highest level of academic training was in Engineering Mechanics (some B.S., M.S., and Ph.D.) at VPI.

Although the department has not been in existence as a degree granting entity as long as "old-line" groups, the alumni list includes partners in consulting firms and research businesses, some vice presidents, managers, directors, and project engineers or managers. Some VPI Engineering Mechanics degree holders are internationally known for pioneering work in fluid mechanics, shell buckling, and composite material behavior. A canvass of the staff and its knowledge of alumni activity reveals very few men who have lost motivation toward engineering mechanics and are now doing something quite apart from engineering.

About twenty percent of the departmental alumni are engaged in teaching and research at a large number of universities. Individuals are operating now at all ranks: they include department heads, associate deans, a dean of engineering, and one dean of a graduate school. Since the focus of this brochure is on industrial relationships, the accomplishments of this segment of the alumni will not be reviewed beyond this brief mention.

The Department Past

In a sense, all active engineering graduates of VPI are alumni of the Engineering Mechanics Department. Since 1914 there has been a department with the words Applied Mechanics or Engineering Mechanics in the title. All engineers progressed through departmental courses with more or less ease. In 1932 the department was organized as the Department of Applied Mechanics and the name was changed to the present title in 1960.

Originally the department was charged with the teaching of undergraduate courses in solid and fluid mechanics. A few graduate courses were available as service courses for students in the programs approved at the time. In 1946 a Master of Science program was authorized and a planned growth in staff and course work led to the approval of a Doctor of Philosophy degree in 1951. Since 1947 a total of 199 M.S. degrees and 1

Master of Engineering degree have been earned; the number of doctorates awarded beginning in 1954 now totals 78.

An undergraduate program was initiated in Engineering Mechanics in 1956 with accreditation by ECPD in 1958, the third such curriculum to be approved. The program followed the suggestions of the ASEE report on evaluation of engineering education, especially with regard to emphasis on mathematics and the basic and engineering sciences.

Enrollment in the graduate program during the academic year reached a peak in 1966 at 93. In more recent years, the draft situation, large demands for engineering graduates at all levels and the development of local and somewhat competitive programs has reduced the number somewhat. Undergraduate enrollment figures are misleading in that freshmen are not counted in any event and that many of the students come to E.M. as a result of transfers from other curricula. The peak year for B.S. degrees was 1969 when 23 graduated. The total since the program started is 134 (including one woman – now in graduate school) with two thirds of this number pursuing or finished graduate work.

Course offerings have expanded in an evolutionary way from an essentially solid mechanics program to include a variety of areas within the interests of people with mechanics training. A listing of present courses at undergraduate and graduate levels is included in an appendix. The appropriate catalogs, available on request, will provide a brief description of each course.

Since its earlier stirrings, the department has had strong research orientation, even in the days of heavy teaching loads and minimal inside and outside support for research projects. Some modest outside support has been provided in past years by the Research Corporation, the U.S. Navy, the Army Research Office, NASA, consulting engineering firms, and by private industry usually interested in fairly specific problems. Much was done without specific support using some departmental operating funds for supplies and only occasionally some modest help from the now defunct Engineering Experiment Station.

The department and VPI in general, have come a long way since the days when teaching a graduate course was permitted if it were taken on as an extra load for the department.

THE DEPARTMENT TODAY

Faculty Interests/Capabilities

During the tenure of Professor Dan H. Pletta as department head, the faculty has increased from four to twenty-five full time equivalent members. The FTE designation refers to the authorized strength of teaching staff. Actually, a number of additional people are working on various percentages of supported research, increasing the staff manpower significantly.

In total, the faculty presents a broad spectrum of educational, research and industrial experience as well as a rather diverse background of state and country of birth. All members have at least one advanced degree from major U.S. universities with a wide distribution of institutions represented. With a low average faculty age, the experiences in other institutions are fairly fresh with the result that it might be said that the department is at least in step with the practices of similar organizations at other major engineering schools.

The faculty of the rank of Assistant Professor or above is listed below with a brief and not totally informative statement as to the major interests of each man. A capsule professional biography for each man is also included, as Appendix A. Even these cannot completely define the interests and capabilities of the individuals. Although the activities of the department are usually subdivided informally into four divisions: fluids, materials and experimental mechanics, solids, and motion, the fact is that there are no walls around any of the areas and individual faculty members will have teaching and research interests encompassing several areas.

Faculty	**Areas of Interest**
Dr. H.F. Brinson	experimental solid mechanics, viscoelasticity, fracture mechanics
Dr. R. Chicurel	dynamics, shells
Dr. Jerry Counts	dynamics, wave propagation, structural dynamics
Dr. R.T. Davis	fluid mechanics, numerical methods in fluids and solids
Dr. D. Frederick	solid and continuum mechanics, composites, plates and shells
Dr. H. Gonzalez	solid mechanics, viscoelasticity, fracture, anistropy
Dr. R.A. Heller	fatigue, creep, reliability of structures
Dr. C.T. Herakovich	plasticity, continuum and structural mechanics
Dr. M. Hoshiya	structural mechanics, probabilistic applications
Dr. J.E. Kaiser	fluid mechanics, viscous flow, boundary layer
Dr. V. Maderspach	structural mechanics, plate and shell stability
Prof. F.J. Maher	structural mechanics, aerodynamics of structures
Dr. R.P. McNitt	continuum mechanics, fracture mechanics, dynamics
Dr. D.T. Mook	fluid mechanics, stability, non-Newtonian fluid
Prof. A.A. Pap	dynamics, structures, solids mechanics, plates and shells
Prof. D.H. Pletta	structural mechanics, stress analysis, materials
Dr. K.L. Reifsnider	materials science, continuum theory of material defects
Prof. C.W. Smith	solid mechanics, experimental stress analysis, fracture mechanics
Dr. D.G. Smith	fracture mechanics, stress waves in solids
Dr. G.W. Swift	solid mechanics, numerical analysis
Prof. J.H. Sword	solid mechanics, computational methods
Dr. H.W. Tieleman	fluid mechanics, experimental analysis of turbulence
Dr. M.J. Werle	fluid mechanics, viscous fluids, numerical analysis

Teaching Program

Not easily reflected by the capsule biographies is a strong staff dedication to teaching. This is evidenced by the teaching awards presented to staff members. These include four local awards and two regional (Western Electric Fund) awards. It is interesting to note that the alumni who are teaching in other universities have recently won four teaching wards and one research prize. Many staff members belong to the American Society for Engineering Education and are active in society affairs both on regional and national levels.

Current efforts to improve educational techniques include the creation and production of educational films of the "Mechanics of Materials and Structures." This series of 16 mm sound films is finding wide adoption and substantially enhances the understanding of the student as to the use of fundamental principles of mechanics in structural design. Three textbooks and two laboratory manuals written by staff members are in current use at the undergraduate level and another text is in use at the graduate level.

Experimental sections of undergraduate students have been taught with techniques of programmed instruction. Results so far compare favorably with the results obtained in conventionally taught sections.

Members of the department have been active in the development of conferences, short courses and extension teaching. For example, a conference in continuum mechanics supported by the National Science Foundation has been held each summer for the past five years and will be held in the summer of 1970. Conferences on new developments in design, and on finite element techniques (with Civil Engineering) have been successfully held. In addition, the department had strong representation in several space conferences held in the recent past (NSF, NASA, Air Force Support). Staff members have been engaged in teaching specific courses for companies such as Western Electric and General Electric.

Currently, the department is exploring the possibilities inherent in off-campus graduate training programs at several locations in the state. Depending on a number of factors, such courses may be taught by the present staff on travel, by adjunct professors, or by telewriter. At this time, the general extension service has no adequate television tape capability.

The department has maintained a strong and varied seminar program, bringing in people who are in the forefront of developments in the several fields of mechanics. In this area, the department has cooperated with other departments with parallel interests.

Professional and Industrial Activities

The faculty is quite active in professional society work, serving as national directors, national committee members, including chairmen, regional officers, and active members of local sections of a number of societies (ASCE, ASME, AIAA, SESA, ACI, ASTM, NSPE, VSPE, for example). Of course there is a significant contribution to the profession in terms of papers published in the journals of the several societies.

In the recent past, the staff has benefited from the Ford Foundation Year in Industry with two of its members visiting industry. A design engineer from industry served as a visiting professor for a year. Various staff members have spent recent summers in industry. Others have participated in programs of research laboratories (NASA, Sandia) in the summer.

Members of the department have had opportunity to perform limited consulting service during the year. Such work during the recent past concerns analyses of failure of structures, aerodynamics of suspension bridges, a stadium and some shell structures, and stress analysis of various structures of conventional materials and composites.

There is significant activity among staff members in activities related to conference proceedings, editing, review of papers for publication in professional journals and review of research proposals for different funding agencies.

Research Scope

Research currently conducted by the faculty is expanding knowledge in the several areas of machines and the resulting new information is rapidly being incorporated into advanced course offerings. Some idea of the breadth of interest may be gained from study of the faculty biographies. (It is planned to make available a publication containing title, investigators, and abstracts of progress reports of current effort.)

An abbreviated listing here of some projects would be in order, however. These would include the following topics:

1. Atmospheric Turbulence near the Ground – Application to Structures, Airplanes, Pollution Abatement
2. Fracture Mechanics as Applied to Ductile Polymers
3. Wind Tunnel Studies of Dynamic Response of Structures
4. Dynamic Non-Destructive Studies of Internal Deformation Fields by X-Ray Techniques
5. Stability of Non-Newtonian Fluids
6. Embrittlement of Materials by Hydrogen
7. Numerical Techniques Applied to Boundary Layer Theory
8. Numerical Techniques Applied to Plate and Shell Theory
9. Optimization of Shell Structures as to Weight

10. Fracture of Brittle Materials and Composites
11. Dynamic Plasticity
12. Mass and Energy Transfer for Slip Flow
13. Analysis of the Composite Beams, Plates, and Shells
14. Wave Propagation in Rate Dependent Materials
15. Failure Analysis of Wind Loaded Storage Tanks
16. Reliability of Structures
17. Application of Stochastics to Material Properties

Staff research interests are also reflected indirectly in the titles of theses and dissertations underway. A partial list follows:

1. "Experimental and Analytical Investigation of Failure Phenomena in Fiber-Reinforced Materials"
2. "Effect of Shear on the Instability of Filament Reinforced Structures"
3. "Analysis of a Cylindrical Shell of Composite Materials for Vibrations and Impact Loads"
4. "Structural Joints in Composites"
5. "New Methods of Determining Fracture Toughness Values"
6. "Photoelastic Stress Analysis of Longitudinal Cracks in Cylindrical Bending"
7. "Stresses in Infinite Strip Containing Staggered Notches of any Circular Arc"
8. "Wave Propagation in Finite Cylindrical Shells"
9. "Method of Characteristics Application to Internal Shock Propagation in Gases"
10. "Numerical Solution to Hypersonic Viscous Shock Layer Equations with Inert Gas Injection into Non-Dissociating Air"
11. "Compressible Laminar Boundary Layer Flows on Moving Continuous Solid Surfaces"
12. "Some Effects of Longitudinal and Transverse Curvature on Laminar, Compressible Boundary Layers"
13. "The Ductile Fracture of Anisotropic Materials"

Not to be omitted are the seniors working toward the B.S. As part of a course in Creative Design and Experiment, they work with staff members on suggested projects or on problems they have encountered in their co-op work. The following show some interesting examples.

1. An Optimization Study of a Single Flexible Column with Three Spring Supports
2. Finite Element Techniques in the Neighborhood of a Stress Concentration
3. Development of Educational Motion Pictures for Strength of Materials
4. Design of a Body Seal to Facilitate Lower Body Negative Pressure Testing

Research Support

The total of outside research support for the current fiscal year, July 1969 to June 1970, amounts to approximately $350,000 including contracts and grants from the

Department of Defense (THEMIS project), the National Science Foundation, Sandia Corporation, the Air Force, the Office of Naval Research, and the National Aeronautics and Space Administration. The total includes some funds from private industrial organizations.

Graduate student support derives from three sources. In terms of fellowships, (outright grants to students) the total for the year was $21,000 including an industrial fellowship (U.S. Steel), a Virginia State Fellowship, one from NSF and three from NDEA. The remaining funding came in the form of what might be called working assistantships, in the form of graduate teaching assistants ($25,000) and graduate research assistants ($50,000).

Research Facilities

The department has a significant amount of equipment for experimental investigations in the field of engineering mechanics. The list given in Appendix B indicates equipment for which the department is directly responsible. In addition, other facilities on campus are available for use. For instance, the wind tunnels of Aerospace Engineering are often used by members of the Engineering Mechanics Department. Additional facilities are available at the VPI Research Station in Rocky Mount, Virginia. The equipment there includes a large centrifuge, a large shaker, a drop tester, an altitude chamber, and other related items.

A complete computer center provides the services of an IBM 360/50 and an IBM 360/65 operating under MVT.

Technical assistance, including precision machine shop facilities and electronic equipment services, is available on a scheduled basis. The department has a three man contingent of full-time technicians to assist with experimental research.

Appendix B lists the various research (and teaching) laboratories and their approximate sixes. In addition to the major items listed, there are numerous standard accessory elements available for general use. While much of the equipment is used for specialized research, a strong general capability exists for the measurement of static and dynamic strength characteristics, the experimental analysis of stress and strain, the investigation of material defects, the study of vibrations, and the study of fluid flow.

THE DEPARTMENT IN THE FUTURE

The New Priorities

The future of any department in an engineering college is inexorably tied to the future of technology as a whole. Crystal gazing is at best a perilous pastime, but certain things seem clear at this time. The national priorities of defense and space exploration have occupied significant fractions of the total effort of engineers and this has been reflected in the educational and research activities of the engineering colleges. Now the priorities are shifting to the socio-techno-logical problems of mass transportation, housing, slum clearance, and environmental control.

The reordering of national priorities has even now produced tremendous reams of paperwork solutions relating to broad problems of water supply, waste disposal, pollution abatement, and others of such nature. Ultimately the feasibility studies must be translated into hardware in order to make any progress in problem solution. While the principles of the engineering sciences of mechanics, thermodynamics, electronics and electricity, and materials establish definite bounds in feasibility studies, these principles are vital in design of the hardware needed to solve engineering problems. Widespread availability of advancing generations of computers will permit the use of more advanced concepts of engineering science in hardware design.

It is clear then that the field of engineering mechanics will continue to be fundamental to technology. A matter of concern then is the determination of optimal methods of imparting basic knowledge of the field to students at all levels. Of equal concern are the questions of future directions of research and the relations of faculty with industry and government and private research laboratories.

Faculty Growth

Faculty growth in numbers at this university is tied to teaching load growth. As faculty members develop outside sponsorship for their research, other staff must be added to share the load. Factors having great influence on this growth include general levels of engineering enrollment, the draft situation, and the ups and downs of federal research support policies.

Faculty growth in competence and experience has been assisted materially by on-going programs such as the summer programs sponsored by the National Science Foundation. Of equal importance is summer work in industry, with possible occasional consulting contacts during the remainder of the year.

As new areas of interest are added to departmental offerings, additions to the staff of individuals with direct competence might be expected. It would also be expected that present staff members might redirect their attention to new areas of concern.

Teaching Improvement

It is not foreseen that any large increase will occur in the undergraduate student body in Engineering Mechanics in the near future. However, significant efforts will be made to increase effectiveness of teaching the service courses for all undergraduates. Innovations in programmed instruction, filmed, televised and recorded lectures, experiments and demonstrations will have to be incorporated in the technology of engineering mechanics education. The development of such techniques should form a significant part of departmental activities. The challenge here will be to increase efficiency without undergoing the depersonalization of faculty-student relations that appears to be one of the root causes of present student discontent in many areas.

In the graduate teaching area, more emphasis will be placed on use of the remote teaching methods, especially for courses at the master's level or for special work aimed at general upgrading. The work for the Ph.D. degree will require significant residence on campus although a dissertation may be completed off campus. To this end, development of a graduate co-op program should help measurably. Future needs of industry may dictate a professional degree of the Doctor of Engineering type, a step beyond the Master of Engineering now offered. Present policy is causing a phasing out or drastic reduction in the number of federal fellowships. Other sources of support will be needed to maintain a desired level of graduate training in engineering. Support for working type assistantships will be particularly useful and probably of greater value to an average graduate student and to the faculty.

Demands for continuing education and reordering of careers should lead to appropriate short courses on new developments, and condensed, high-intensity work for people with adequate background who need acquaintance with new (for them) fields. An example of this would be the presentation of adequate statistical background for understanding the basic ideas of reliability and stochastic processes by way of preparation for probabilistic design of structures and machines.

New areas of departmental staff interest will lead to new, advanced, course work. The section following discusses this.

Directions for Research

At the outset it should be stated that most of the work described previously is open-ended in the sense that all the problems in the fields listed will not be solved in the very near future. However, shifting of interests on the part of faculty can be anticipated as the fundamental work is largely finished and the remaining work, though important, is somewhat less challenging.

If any general statement may be made about the future of research by the Engineering Mechanics staff and student body, it is that it must be more concerned with the real world of behavior of fluids and solids under stress. This requires more precise mathematical models of the material, the structure or system in general, probably advanced computers, laboratory simulation of the system and observation of the final "computer," the engineering system itself. No small part of this picture is the characterization of loading on or stresses through the system during its service life.

Materials – Solid Mechanics

Considering particular areas of interest, the development of high strength-to-weight ratio materials has great promise for the future, due to the fact that it is now possible to design a material tailored to a set of structural requirements. The theoretical and experimental analysis of the mechanics of normal behavior and fracture mechanics of such systems will significantly improve their usefulness.

The understanding of composites as well as conventional materials requires the study of the micro mechanics, that is, the mechanics of the smallest constituents and their effects on their surroundings. As a result, study of anisotropic and orthotropic elasticity, visco-elasticity and plasticity will further the work in isotropic continuum mechanics. Investigation of finite deformations of both continua and particulate materials will be needed.

As noted, the future study of materials in mechanics will of necessity be related more and more to real materials than to the ideally elastic, plastic or fluid materials of the past. New materials such as polymers, crystalline metals, composites, and non-Newtonian fluids will force such a redirection. Properties of real materials will, of course, have to be determined, but this will involve more thorough knowledge of theory in order to adequately describe the constitutive laws. For example, the determination of elastic anisotropic moduli will likely involve wave propagation testing rather than the old static measurements. Other experimental innovations will be necessary in studying static and dynamic viscoelastic and plastic behavior, the behavior of composites, modern fluids, and properties of all these items under nonlinear situations. Other areas such as crack detection, non-destructive testing, in situ testing, and environmental effects relative to all materials will be important. Naturally, all efforts will need new sophistication in equipment and instrumentation.

Space Related Research

Although there will be a de-emphasis of space-related research in the immediate future, a significant level of meaningful work will continue. Foremost among the problems of interest to a mechanics group would be the study of materials and structures under vacuum, severe thermal gradients and high speed impact. Interestingly, some attention will be paid to extremely light-weight foldable and inflatable structures. The strong emphasis on returnable, reusable vehicles opens new fields in fluid mechanics and thermal protection.

Random Loading-Probability

The complexity of loads on structures of all types and the variability of material properties will increasingly require the use of probabilistic techniques in design. Random loadings produced by such things as aerodynamic turbulence, earthquake shocks, and random vibrations due to service must be considered. Additionally, combinations of random loading and severe environmental cycling must be considered for many structures; for example, various flight vehicle structures. People with mechanics backgrounds are not likely to take complete refuge in statistical definitions of loadings and responses; rather, they will continue to question the sources of disturbances. A related field of growing interest is the development of methods of structural optimization.

Bio-Engineering

A field worthy of greater penetration is the general area of bio-engineering including behavior of human and animal tissue under stress, blood flow under normal and obstructed conditions. A little considered area of bio-engineering is the study of strength of plant tissue other than wood. Crop damage caused by winds in particular might be avoided by development of varieties with sufficiently strong stems. A mechanical corn-picker is next to useless in a field leveled by a wind storm. One problem considered in the department recently was the characterization of mechanical behavior of apples at the picking stage. The information gathered has been an important step in the development of mechanical harvesting devices. Considering the economics of the agricultural field, some significant applications of mechanics theories to the study of living plant tissue with resulting improvements in production can mean much to mankind.

Fluid Mechanics

The general field of fluid mechanics is faced with many challenging, large-scale problems. A priority listing of basic needs of mankind would show air, water, food, and shelter with some question about the immediate order of the latter two, but none about the first two. Weather, atmospheric turbulence, transport of pollutants, both gaseous and particulate, are important problems that have been considered more by meteorologists than by people with the fluid mechanics training. The area badly needs an infusion of fluid mechanics experts. Water flow studies considering percolation, diffusion of sediments and diffusion of "thermal pollution" require fairly high level fluid mechanics training.

As in the case of solids, fluid mechanics in the future will need to give greater consideration to real materials that are moved as fluids. Non-Newtonian fluids, normally solid materials under high temperature conditions, particle laden fluids, slurries, multi-phase flows, chemically reacting flows all represent areas with significant problems of theoretical characterization and experimental verification. A special problem of interest is concerned with drag reduction due to polymer injection through the surface of underwater vehicles. Tailoring of fluid properties in general may be accomplished by additives and studies of interaction among the several elements will be needed. Obviously, the counter problem is important, that is, the ultimate removal of additives, pollutants and debris of all sorts. A future, long-range problem is the closed cycle system for domestic or local use.

Dynamics

The dynamics interests of a number of staff members will produce important extensions of the basic work in vibrations of lumped and continuous systems. Structural damping of materials and joints needs significant attention. Problems in wave propagation through materials under varying environmental conditions will come under attack. Nonlinear and random vibration theory need expansion along with techniques for problem solution. Celestial mechanics and control theory, which are areas of individual interest to Engineering Mechanics staff, appear to be well handled by several other departments including the Physics Department. Several graduate students in mechanics have actually worked with staff of other departments on dissertation topics – control system theory in particular.

Stability

A general area crossing all fields is that of stability. Instability of columns, compression flanges of beams, etc., probably brings about more structural failure than any other cause. Aerodynamic instability has wrecked many suspension bridges. Dynamic divergence, flutter, unstable fluid flows, and other problems will require better definition with safe bounds established for guidance of designers.

The listing of areas of prime importance could go on at greater length. Many problem areas noted above will be attacked on an interdisciplinary basis. Other broad areas of this type will certainly involve people with significant mechanics training. These would include transportation of all types, ocean exploration and subsurface exploration.

Many of the problems facing mankind can be attacked, if not solved, using existing technology. This is no excuse for a retreat from significant investment in engineering research and development. Problem solutions improve as engineers gain better understanding of basic behavior of their materials and of the interaction of elements of the systems fabricated from such materials.

Research Facilities Needed

Although the list of equipment in Appendix B appears impressive at first glance, many deficiencies exist even for present operations. Much of the equipment needs upgrading, and, in a sense, unification. Best results in measurement, recording and interpretation do not occur when non-matching electronic equipment is patched together.

Facilities producing variable vacuum, thermal, vibrational, and gravitational environments are needed. These need not be large scale, since large-scale facilities are available at Rocky Mount.

The entire field of experimental techniques and methods will need improvement. In dealing with advancements in knowledge of material behavior and in view of more stringent requirements of structures, higher order effects previously ignored become important. Experimental equipment, therefore, must be able to cope with such higher order effects. Instrument error tolerable under old assumptions will no longer be permissable.

Integrated data gathering systems with computer links should be available to staff and graduate students, particularly when the experiment generates a mass of data. Modernization of the analog computer, along with hybrid capability would facilitate much of the work in dynamics.

Experimental work in fluid mechanics is presently handicapped by lack of space. For example, the towing tank carriage and measuring system could be a powerful research tool, with some upgrading, in areas such as new means of surface vessel support and propulsion. However, it needs to be moved to a different facility where a longer, wider tank can be built.

Fortunately, much temporary trading of equipment, under proper scheduling, goes on between departments. One institutional need is a good current inventory of equipment available throughout the university.

Not least in the future needs of the department are enough competent technicians and appropriate, reliable tools to provide assistance in both teaching and research.

Conclusion

A gleaning of items from the daily news for a few days will clearly indicate thet there is no shortage of engineering problems. The staff of the department is well aware of the present horizons in Engineering Mechanics and is aware also that today's horizons are tomorrow's jumping-off points on an ever-expanding of knowledge. A general optimism prevails among the staff members over the present and future mission of the department.

It is hoped that the foregoing material has helped to put into proper framing the Department of Engineering Mechanics, its staff and its present and former student body. The department feels that it will continue to make a strong contribution to the engineering profession in terms of both staff and alumni activity. The department feels strongly that its total contribution cannot help but be greatly enhanced by initiating the developing closer relationships with appropriate industries.

APPENDIX A

FACULTY BIOGRAPHIES

ENGINEERING MECHANICS DEPARTMENT

COLLEGE OF ENGINEERING

VIRGINIA POLYTECHNIC INSTITUTE

H.F. BRINSON Assoc. Prof., B.S. (CE) N.C.S.U. '56; M.S. (CE) N.C.S.U. '61; Ph.D. (Mech.) Stanford '65.
Areas of Interest solid mechanics (elasticity, viscoelasticity, fracture), experimental mechanics, materials (polymers, metals).
Reports DTA, TGA and RGA Analysis of a Birefringent Epoxy; The Ductile Fracture of Polycarbonate; The Dugdale Model Applied to Orthotropic Materials.
Selected Publications
1. "Mechanical and Optical Viscoelastic Characterization of Hysol 4290," Experimental Mechanics, Dec. '68.
2. "The Ductile Fracture of Polycarbonate," Experimental Mechanics (T.B.P.).

RICARDO CHICUREL Prof., B.M.E., '53, Cornell; M.S.E., '57, Princeton; Ph.D., '59 Princeton.
Areas of Interest dynamics, vibrations, plates and shells, structural stability, mechanical design.
Consulting Shell Stress Analysis, Miniature Chopper Dynamics
Selected Publications
1. "Deformation of Elastic Filaments with Arbitrary Unstressed Configurations," ZAMP, vol. 13, no. 1, 1962, co-author: E.W. Suppiger.
2. "Use of Mass as a Perturbation Parameter in Vibrations," J. Engr. for Ind., ASEM, vol. 89, series B, no. 4, Nov. 1967, co-author: J. Counts.
3. "Stability of Periodic Solutions Based on Higher Order Variational Equations," to appear in Int. J. Nonlinear Mechanics.

Reviewer for ASEM, Textile Research Journal.
Patents "Gyrating Pump," U.S. Paten 3,296,975, Jan. 10, 1967.
"Internal Combustion Engine," U.S. Patent 3,315,653, April 25, 1967.

J. COUNTS Assoc. Prof., B.S., '58, VPI; M.S., '61, VPI; Ph.D., '66, VPI.
Areas of Interest dynamics, vibrations, wave propagation in solids, approximate methods of analysis.
Selected Publications
1. "Use of Mass as a Perturbation Parameter in Vibrations," with R. Chicurel, J. Eng. for Ind., Nov. 1967.
2. "The Application of Continued Fractions to Wave Propagation in a Semi-Infinite Elastic Cylindrical Membrane," with J.E. Akin, J. of Ap. Mech., Sept. 1969.
3. "On Rational Approximations to the Laplace Transform," with J.E. Akin, to appear in Soc. of Ind. and Ap. Math.

Sigma Xi, SESA, SES, ASEE.

R.T. DAVIS Assoc. Prof., B.S., '60, VPI; M.S., '61, Stanford; Ph.D. '64, Stanford.
Areas of Interest fluid mechanics, perturbation methods, numerical methods, nonlinear plate and shell theory. Director of the Center for Numerical Methods in Engineering, Member of the Editorial Advisory Board of the Int. J. for Numerical Methods in Engr., Consultant for ARO, Inc., Tullahoma, Tenn., in the field of high speed viscous flows.

Selected Publications cont. R.T. DAVIS

1. "Laminar Incompressible Flow Past a Semi-Infinite Flat Plate," J. of Fluid Mech., vol. 27, part 4, 1967.
2. "Numerical Solution of the Hypersonic Viscous Shock-Layer Equations,' Sandia Report SC-RR-840, to be published in the AIAA Journal.
3. "Boundary-Layers on Parabolas and Paraboloids by Methods of Local Truncation," to be published in the Int. J. for Nonlinear Mech.
4. "Boundary-Layer Theory for Incompressible Viscoelastic Liquids," Proceedings of the 10th Midwestern Mechanics Conference.

ASME, SES, AIAA, Tau Beta Pi, Omicron Delta Kappa, Phi Kappa Phi, and Sigma Xi.

D. FREDERICK Prof., Chairman of Solid Mechanics Technical Interest Group; B.S., VPI, '44; M.S., VPI, '48, Ph.D., Michigan, '55, P.E.

Areas of Interest continuum mechanics, constitutive theory and experimental verification, elasticity, plasticity, theory of plates and shells, including effects of shear, deformation and normal pressure, vibrations of stiffened plates, composite materials – vibration and damping of layered composites – characterization and theories of failure, finite element analysis, impact and random loading on plates and shells.

Consulting Dynamics of Ship and Submarine Structures, Stability and Vibration of Radmones, Stress and Deflection of Callender Stacks (paper), Stress Analysis – Space Vehicles, Multi-Storied Buildings, Elevated Bins, Slabs and Tanks.

Selected Publications

1. "On Some Problems in the Bending of Thick Circular Plates on an Elastic Foundation," J. of Ap. Mech., ASEM, vol. 23, no. 2, p. 195, 1956.
2. "A Simplified Analysis of Membranes Subjected to an Impulsive Loading Producing Large Plastic Deformations," Proceedings of the 4th Midwestern Conf. on Fluid and Solid Mechanics, Univ. of Texas Press, p. 18, 1959.
3. "Transient Elastic Waves in a Fluid-Filled Cylinder," co-author: W.W. King, J. of the Engr. Mech. Div., ASCE, vol. 94, p. 1215, 1968.

Texts

1. *Engineering Mechanics, Statics and Dynamics*, co-author D.H. Pletta, Ronald Press Co., N.Y., 1964.
2. *Continuum Mechanics*, co-author: T.S. Chang, Allyn and Bacon, Inc., Boston, 1965.

Reviewer, Editor, Conference Director (Cont. Mech.), active in many university and college affairs.

Tau Beta Pi, Chi Epsilon, Phi Kappa Phi, Sigma Xi, Omicron Delta Kappa, ASCE, AIAA, SES, ASEE, ASME.

H. GONZALEZ, JR. Acting Assist. Prof., B.S. (CE), Lafayette, '66; M.S. (EM), VPI, '68; Ph.D. (EM), '69.

Areas of Interest viscoelasticity, anisotropy, fracture.

Experience three years of undergraduate teaching. summer – design gas main thrust restraint devices, surveying new roads, supervise road construction.

EIT – Pennsylvania 1966, NASA three year fellowship.

R.A. HELLER Prof., B.S., '51; M.S., '53, Ph.D., '58, Columbia; P.E. (N.Y. and Va.)
Areas of Interest inelastic behavior of structures and materials, reliability and safety of structures, fatigue and failure, probabilistic mechanics, educational films, consultant to aerospace industry.
Selected Publications
1. "Structure in Architecture," Prentice Hall, N.Y., 1964.
2. Films on "Mechanics of Materials and Structures," 16 mm sound, McGraw-Hill Book Co.
3. "Interlaminar Shear Stress in Sandwich Beams," Exp. Stress Anal., Sept. 1969.
4. "Reliability Through Redundancy?", Proc. Inst. Environmental Sciences, April 1969.
5. "Mechanical Properties of Wire Reinforced Grains," Proc. 5th Naval Struct. Symp., 1969.

Chairman ASTM Comm. on Fatigue, Member ASME Reliability Comm., SESA Papers Comm., Member AIAA, Sigma Xi, AAUP.

C.T. HERAKOVICH Assist. Prof., B.S., Rose Polytechnic Institute, '59; M.S. Kansas Univ., '62; Ph.D. IIT, '68, P.E.
Areas of Interest plasticity, continuum mechanics, computational methods, structural mechanics.
Selected Publications
1. "Quadratic Programming and Plasticity," with P.G. Hodge, Jr., and T. Belytschko, *Computational Approaches in Ap. Mech.*, ASME Computer Conference, Chicago, 1969.
2. "On Numerical Comparisons in Elastic Plastic Torsion," with P.G. Hodge, Jr., and R.B. Stout, *J. Ap. Mech.*, Sept., 1968.
3. "Elastic Plastic Torsion of Hollow Bars by Quadratic Programming," with P.G. Hodge, Jr., *Int. J. of Mech. Sciences*, vol. 11, 1969, pp. 53-63.

ASCE, ASME, ASEE, Sigma Xi.

M. HOSHIYA Assist. Prof., B.S., Univ. of Tokyo, '63, M.S. Univ. of Pa., '66; Ph.D., Stanford, '69.
Areas of Interest structures, probabilistic and statistical applications in structures, bridge engineering – designed several bridges (Japan).
Selected Publications
1. "Dynamic and Eigenvalue Analysis of Stochastic Structural Systems," Stanford, Civil Eng. Tech. Report no. 107, March '69.
2. "Free Vibration of a Beam-Column with Stochastic Properties," Proceedings of EMD, ASCE, pp. 107-112 at Purdue Conf., Nov. 1969.
3. "The Effect of Cross Sectional Deformation on a Thin-Walled Beam," Proceedings of JSCE, pp.101-102, Conference at Kyoto Univ., May 1965.

Member of AIAA and Japan Soc. Civil Engr.

J.E. KAISER Assist. Prof., B.S., '62, VPI; M.S., '63, Stanford; Ph.D., '68, Stanford.
Areas of Interest fluid mechanics, viscous flow, boundary-layer theory.
Selected publications
Report: "Viscous, Hypersonic Flow Around a Blunt Body," Div. Engr. Mech. Tech. Rep. 178, Stanford Univ.
Tau Beta Pi, Phi Kappa Phi, Sigma Xi, AIAA, Omicron Delta Kappa.

V. MADERSPACH Assoc. Prof., B.S., Hungarian Engr. Mil. Academy, '39; M.S., VPI, '61; Dr. Tech. Sciences, Technische Hochschule, Vienna, Austria, '64.
Areas of Interest structures, in particular, plates and shells, and stability.
Consulting engineer for the Pittsburg Des Moins Steel Co. As a result of this work several publications were made for company use only. These publications are related to earthquake analysis of shells, reinforcing rings for shells, buckling of cylindrical shells due to wind load, etc.
Reports on Earthquake analysis of shells, reinforcing rings for shells, buckling of cylindrical shells using measured wind loading.
ASEE.

F.J. MAHER Prof., B.S., Manhattan '36, M.S., VPI, '37, P.E.
Areas of Interest structures, vibrations, damping, aerodynamics of bridges, buildings and other structures, (Stadia). Consulting structural engineer, design of buildings, dams, advising on bridges and other structures. Reports: Aerodynamics – Mackinac Straits Bridge (Prelim.) – Bosporus Bridge (Prelim.) Wm. Preston Lane Bridge (including interference studies) Bayamon Stadium and Aqueduct Race Tract Roofs. Stress Analysis of Cylindrical Tank under actual wind loads. Wind tunnel studies – inflated struc.
Selected Publications

1. "Wind Loads on Dome-Cylinder and Dome-Cone Shapes," J. Struct. Div., ASCE, Oct. 1966.
2. "Model Studies of Wind Loads on Flat-Top Cylinders (with Purdy and Frederick), Jour. of Struct. Div., ASCE, April 1967.
3. "Wind Loads on Kresge Auditorium and Traveler's Building," Jour. of Struct. Div., ASCE, Jan. 1969.

Active in university and college committee work, local prof. society, Tau Beta Pi, Sigma Xi, Phi Kappa Phi, AIAA, ASEE.

R.P. MCNITT Assoc. Prof., B.S. Penn. State, '57; M.S. Penn. State, '59; Ph.D. Purdue, '65.
Areas of Interest continuum mechanics, fracture mechanics, embrittlement of materials, dynamics and vibrations. Reports – Fracture Mechanics of Hollow Specimens, Hydrogen Embrittlement and Geometrical Effects on Fracture, Dynamic Analysis of Puse Mechanisms, Thermal Stress Analysis.
Selected Publications

1. "Irreversible Thermodynamics and Continuum Mechanics in Presence of Electromagnetic Field,' (with M. Stanisic), Acta Mechanica VII, Sept. 1969.

Selected Publications cont. R.P. McNitt

2. "Small Oscillations of a Beam-Column with Finite Electrical Conductivity in a Constant Magnetic Field,' (with J. Peddieson, Jr.) Int. J. Eng. Sci. VI, 1968.
3. "A Method of Disalignment of Titanium Hydrides," Trans. Metallurgical Soc., AIME, vol. 239, Oct. 1967.

Tau Beta Pi, Sigma Tau, Sigma Xi, SES, ASEE, Va. Acad. Sci.

D.T. MOOK Assist. Prof., B.S., '58, VPI; M.S., '61, VPI; Ph.D., '66, Michigan.
Areas of Interest hydrodynamic stability, non-Newtonian fluid flow.
Tau Beta Pi, Sigma Xi, Phi Kappa Phi, AIAA, Eng. Sci. Soc.

A.A. PAP Assoc. Prof., B.S., '43, Royal Hungarian Air Force Academy; M.S., '60, VPI; A.M., '61, Harvard.
Areas of Interest dynamics, mechanics of solids, plates, shells, structural mechanics, vibrations, structural engineer – design of buildings, bridges, industrial and training facilities. Consultant to industry – tall antenna towers (Dresser-Ideco), aerospace structures and machinery (TRW), stability of shell structures (Pittsburg Des Moins Steel Co.).
Selected Publications Testing and analysis of haunched, skewed highway bridge; analysis and design of tall guyed towers, including computer programs; evaluation studies, vibration analyses, design of thin and thick shells, airplane fuel pumps, high speed gear pumps, jet thrust reverser; stability analyses and computer programs on large thin shell containers with varying wall thicknesses under wind loads.
ASEE, Sigma Xi.

D.H. PLETTA P.E., Univ. Prof. and Head, Engineering Mechanics; B.S., '27 and C.E. '28, Illinois; M.S., '31, Wisconsin.
Areas of Interest stress analysis, structural mechanics, engineering materials. Consultant on Analysis of Multi-Story Buildings, Dams, Tanks, Drill Strings, Centrifuges, T.V. and Transmission Line Towers.
Selected Publications

1. "All-Nailed Lumber Truss of 60 to 80 ft. Span," Forest Products Journal, vol. 18, no. 2, Feb., 1968, p. 21, co-author: E. George Stern.
2. "Analysis of Non-Planar Elastic Rings," Trans. ASCE, vol. 127, 1962, p. 776, co-authors: W.C. Liessner and Y.M. Yeh.
3. "Tests of a Rigid Frame Bridge Model to Ultimate Load," Proc. ACT., vol. 58, p. 223, co-authors: A.A. Pap and C.S. Wu.

ASCE – Director 1969-1972; President Virginia Section, 1965; Chairman, Engr. Mech. Div., 1960.
NSPE – Director 1957-1965; President VSPE, 1953; President Education Foundation, 1966-1970.
ASEE – Chairman, Engr. Mech. Div., 1964, Graduate Div., 1961.
Tau Beta Pi, Sigma Xi, Chi Epsilon, Omicron Delta Kappa, Sigma Tau, Phi Kappa Phi, Phi Eta Sigma.

K.L. REIFSNIDER Assist. Prof., B.A., Western Md., '63; B.E.S., Johns Hopkins, '63; M.S.E., Johns Hopkins, '65; Ph.D., Johns Hopkins, '68.
Areas of Interest materials science, theories and methods of non-destructive testing and research, time-resolved x-ray diffraction microscopy, continuum theory of material defects. Technical translation and Materials Science consultant.
Selected Publications
1. "Dynamic X-Ray Diffraction Study of the DEformation of Aluminum Crystals," Trans. Met. Soc., AIME 245, 1615, 1969.
2. "Image Intensifier System for Dynamic X-Ray Diffraction Studies," Rev. Sci. Instr. 39, no. 11, 1651, 1968.
3. "Time Resolved X-Ray Diffraction Microscopy: Development of a New Technique," DEMVPI Rep. no. 4-2, 1969.

Sigma Xi, AIME, ASM, ASTM, AAUP, Pi Tau Sigma.

C.W. SMITH Prof., B.S., VPI, '47; M.S., VPI, '49, P.E.
Areas of Interest solid mechanics, experimental stress analysis, fracture mechanics, consulting; Stree Analysis of Glass Reinforced Plastic Structures; Deformation Analysis of Conical Dies; Stress Analysis of Rocket Motor Cases; Western Electric and General Electric Co. Graduate Engineering Training Programs; currently Principal Investigator for THEMIS Project – DD (Fracture Mechanics).
Selected Publications
1. "A Photoelastic Evaluation of the Influence of Closure and Other Effects Upon Local Bending Stresses in Cracked Plates," (in press) International Journal of Fracture Mechanics, co-author: D.G. Smith.
2. "An Experimental Investigation of Fracture Criteria for Combined Extension and Bending," ASME Trans., vol. 91, series D, no. 4, J. of Basic Engr., pp. 841-849, Dec. 1969, co-author: R. H. Wynn.
3. "Prediction of Flow of a Melted Plastic Through a Screw Extruder," ASME Trans., vol. 91, series D, no. 3, J. of Basic Engr., pp. 479-488, Sept. 1969, co-author: H. Kaiser.
4. "A thin Plate Analysis and Experimental Evaluation of Couple Stress Effects," J. of Exper. Mech., vol. 7, no. 9, Sept. 1967, co-author: R.W. Ellis. See also discussion by W.T. Koiter and author's closure, J. of Exper. Mech., July 1968.

Active in university and college committees, professional societies; reviewer for publisher and technical societies; Board of Directors, local water authority.
SESA, ASCE, ASEE, NSPE, Sigma Xi, Tau Beta Pi, Phi Kappa Phi, Chi Epsilon.

D.G. SMITH Assist. Prof., B.S., Tenn. Tech., '63; M.S., Tenn. Tech., '67; Ph.D. VPI, '69; P.E.
Areas of Interest fracture mechanics, waves in solids, elasticity, photoelasticity.
Two and a half years bridge design experience with Tennessee Highway Department.
Selected Publications
1."A Photoelastic Investigation of the Influence of Closure and other Effects Upon the Local Bending in Cracked Plates," (in press) International Journal of Fracture Mechanics, co-author: C.W. Smith

Selected Publications cont. D.G. Smith
2."Combined Mode Stress Intensity Factors from Photoelasticity," (in progress).
Held NDEA fellowship during doctoral work, Assoc. member ASCE.

G.W. SWIFT P.E., Assist. Prof., B.S. (CE), '53; M.S. (CE), '54; Ph.D. (EM) '64, VPI.
Areas of Interest continuum mechanics, structural mechanics, experimental solid mechanics. Developed courses in thermodynamics and engineering numerical analysis.
Areas of Research Structural Vibrations (M.S. Thesis '54), Numerical Methods for Analyzing Plate Bending and Extension (Ph.D. Thesis '64), (Symposium at IBM, N.Y., 1968), (Symposium, Center for Numerical Methods at VPI, 1969). Methods of investigating solid mechanics problems. (Finite Element Short Course for Practicing Engineers, VPI). Composite Materials (Lab Manual, author, 1966), (Shear strength tests, thesis supervisor, 1968), (Constitutive law of failure, thesis supervisor, 1969).
VSPE – Board of Directors, Education Committee, President Local Section. Active in civic affairs. Chi Epsilon, Sigma Xi, ASCE, NSPE, ASEE.

J.H. SWORD Prof., B.S., '50, VPI (CE); M.S., '54, VPI; P.E.
Areas of Interest solid mechanics, digital and analog computation. Consulting in structures, materials testing, computation.
Selected Publications
1. "The Construction of Influence Lines with a Mechanical Interferometer," Bulletin of the VPI Engr. Exper. Station, no. 124, co-author: D.H. Pletta
2. "An Introduction to Computers and to Elementary FORTRAN," (text) Wm. C. Brown Book Co., Des Moines, Iowa, 1969, co-author: R.C. Heterick.

ASEE, NSPE, Tau Beta Pi, Chi Epsilon, Phi Kappa Phi.

H.W. TIELEMAN Assist. Prof., B.S., Univ. of Toronto, '62; M.S., State Univ. of Iowa, '64; Ph.D., Col. State Univ., '68.
Areas of Interest structure and calculation of the turbulent boundary layer, special interest in instrumentation (hot-wire measurements of turbulence and spectral analysis), the structure of the atmospheric boundary layer, the effect of the turbulence structure of the atmosphere on obstacles such as bridges, high-rise structures, Aerolastic model studies of World Trade Center Towers.
Selected Publications
1. "Viscous Region of turbulent Boundary," Tech. Rep. CED67-68 HWT 13 Fluid Dynamics and Diffusion Laboratory, Colorado State Univ.
2. "Turbulent Spectral Data in Large-Scale Turbulent Boundary Layers, Developed Over Different types of Boundary Roughness – RM no. 10, Fluid Dynamics and Diffusion Laboratory, Colorado State Univ.

Sigma Xi, ASME.

M.J. WERLE Assist. Prof., B.S., VPI, '63; M.S., VPI, '65; Ph.D., VPI, '68.
Areas of Interest theoretical and experimental fluid dynamics of viscous flows, numerical analysis of differential equations.

Selected Publications cont M.J. Werle

1. "Simplified Expressions for Laminar Heating Rates on Isothermal Bodies," Journal of spacecraft and Rockets, p. 947, June 1966.
2. "A Critical Review of Analytical Methods for Estimating Control Forces Produced by Secondary Injection – the Two Dimensional Problem," U.S. Naval Ordnance Lab TR 68-5, Jan. 1968.
3. "Self-Similar Solutions of the Second-Order Incompressible Boundary Layer Equations," accepted for pub. in J. of Fluid Mech., co-author: R.T. Davis.

AIAA, TAU Beta Pi, Phi Kappa Phi, Omicron Delta Kappa, Sigma Xi.

APPENDIX B RESEARCH FACILITIES – CAPACITIES

	Sq. Ft.
Structural Research Lab	2350
100,000 lb. Tinius Olsen Universal Beam Machine 400,000 lb. Tinius Olsen Compression Machine 20,000 lb. Budd Dynamic Fatigue Machine 1,000, 000 lb. Test Floor 40 ft. long by 15 ft. wide	
Materials Testing Lab – No. 1	1440
120,000 lb. Baldwin Hydraulic Universal Machine 60,000 lb. Baldwin Hydraulic Universal Machine 60,000 in. lb. Tinius Olsen Torsion Machine	
Materials Research Lab – No. 2	540
120,000 lb. Tinius Olsen Universal Machine 6,000 lb. Budd Creep Machine – 10,000 hr., 2000° F	
Materials Research Lab-No. 3-Automatic Temperature and Humidity Controlled	230
20,000 lb. Instron Closed-Loop Universal Machine complete with high temperature capillary rheometer.	
Materials Research Lab – No. 4	600
MTS Closed-Loop Axial-Torsional System of 1000,000 lb. and 50,000 in. lb. static and ± 50,000 lb. and ± 25,000 in. lb. dynamic capacity.	
Non-Destructive Research Lab – No. 5	300
Siemens X-Ray Generator and Detector System – 60 KV, 80 ma Sperry Ultrasonic Pulse Generator 500 lb. Electronic Tensile Testing Machine RCA Image Intensifier for Continuous Monitoring GE Model 700 X-Ray Sensing System	
Vibrations Lab	260
10 lb. and 50 lb. Magnetic Shakers Drop Tester, 100 lb., 10 ft., 60 lb. @ 3 ft. Spectrum Analyzer – Tektronix Hopkinson Bar Impact Tester Transducers, Recorders, Electronic Counters, Oscilloscopes, etc. (Large Shakers – Mechanical Engineering or Rocky Mt. Research Station)	
Moire Analyzer Lab	130
Exacta (Delft) Moire Apparatus	
Creep and Fatigue Lab	140
6,000 lb. Budd Creep Machine – 10,000 hr., 2000° F Krause and Moore Fatigue Machines	

Photoelasticity Lab	180
12 in. Research Collimated Polariscope	
Blue-M Programmable Annealing Oven	
Allied Research Pneumatic Loading Frame	
Unitron Binocular Microscope with XY Stage and Depth Scope	
Membrane Analogy Apparatus	
Shop	1440
15 in. Cincinnatti Lathe	
Mh-2 Cincinnatti Milling Machine	
Grob Metal Cutting Band Saw	
Misc. Drill Presses, Shapers, Welders, Grinders, Gaertner Cathetometer, etc.	
Photographic Dark Room	140
Precision Cameras	
Ariflex S-16 Movie Camera	
Complete flash and developing equipment	
(High speed and cont. strip cameras – Aerospace Engineering)	
Analog Computer Lab	300
EAS Analog Computer complete with 2 XY Plotters, Oscilloscope, Amplifiers, Function Generators	
Fluid Mechanics and Hydraulics Lab	3950
100 ft. Towing Basin (4 ft. × 6 ft.)	
Towing Carriage	
Miscellaneous Ship Models	
25 ft × 25 ft. Model Basin	
35 ft. Tilting Flume	
Head Tank, Pumps, Circulating System, etc.	
DISA – 2 Hot Wire Anemometers, Linearizers, Auxiliary Units, RMS Voltmeters, 1 DC Voltmeter (shared with Mechanical Engineering)	
1 Correlator	
Miscellaneous	
Tektronic Oscilloscopes	
Optical Displacement Tracker	
Trans-Data Acquisition System with 50 Channel Digital Readout-pulsed excitation	
SR-4 Scanning Recorders	
Load Holders, Extensometers, etc.	

APPENDIX C

ENGINEERING MECHANICS COURSES

201 Mechanics of Particles
206 Dynamics of Rigid Bodies
208 Mechanics of Deformable Solids
211,221 Statics and Strength of Materials
302 Computational Methods
303 Fluid Mechanics
304 Fluid Mechanics Laboratory
306 Materials of Engineering
308 Fluid Mechanics
309 Materials Testing
3010 Structural Mechanics
3011 Introductory Engineering Reliability
402 Advanced Materials of Engineering
403 Intermediate Fluid Mechanics
405 Mechanics of Materials II
406 Experimental Stress Analysis
407 Introductory Vibrations
408 Intermediate Dynamics I
409 Numerics in Mechanics
411,421 431 Creative Design and Experiment
497 Independent Study
498 Special Study
499 Undergraduate Research

501 Experimental Solid Mechanics
502 Mechanical and Structural Vibrations
503 Advanced Mechanics of Materials
504 Theory of Plates
505 Theory of Shells
506 Limit Analysis
507 Non-Linear Mechanics
508 Intermediate Dynamics II
509 Thermodynamics of Solids and Fluids
5011 Theory of Continuous Media
5012 Introductory Compressible Inviscid Flow
5013 Introductory Viscous Flow
5014 Nondestructive Testing and Research
5015 Applied Plasticity
5026 Nonlinear Systems
5028 System Stability
511,521 Structural Mechanics
512,522 Wave Propagation in Solids
518,528 538 Graduate Seminar
597 Independent Study
598 Special Study
599 Research and Thesis
602 Symposium
603 Vibration of Continuous Media
604 Advanced Dynamics
605 Elastic Stability
606 Plasticity
607 Thermoelasticity
609 Perturbation Methods in Mechanics
6010 Theory of Turbulence
6011 Non-Linear Theory of Continuous Media
6012 Fracture Mechanics
6013 Viscoelasticity
6014 Approximate Analyses of Continua
6015 Turbulent Boundary Layers
6016 Hydrodynamic Stability
6017 Theories and Methods of Non-Destructive Research and Testing
611,621 Mathematical Theory of Incompressible Fluids
612,622 Theory of Elasticity
613,623 Applied Tensor Analysis
614-624 Mathematical Theory of Compressible Fluids
615,625 Laminar Viscous Flow
618,628 Unsteady Motion of Continuous Media
799 Research and Dissertation

APPENDIX D

DEPT OF ENGINEERING MECHANICS

Published Articles -- 1969

BRINSON, H.F., "The Ductile Fracture of Polycarbonate," Preprint No. 1513, Spring Meeting of the Society of Experimental Stress Analysis, May.

COUNTS, J., "A Note on the Use of Continued Fractions to Determine the Natural Frequencies of Elastic Members Having Variable Properties," *American Society of Mechanical Engineers, Journal of Applied Mechanics*, in press.

DAVIS, R.T. and Wingate, R., "Wave Propagation in Non-Uniform Bars by a Perturbation Method," Journal of the Acoustical Society of America, in press.

______, "The Hypersonic fully Viscous Shock-Layer Problem," AGARDOgraph on Viscous Flows, in press.

_______, and WERLE, M.J., "Self-Similar Solutions to the Second-Order Incompressible Boundary-Layer Equations," *Journal of Fluid Mechanics*, Vol. 40, pp. 343-360.

_______, "Numerical Solution of the Hypersonic Viscous Shock-Layer Equations," American Institute of Aeronautics and Astronautics Journal, in press.

_______ and WERLE, M.J., "On Solutions of the Integral Form of the Second-Order Boundary-Layer Equations," *International Journal of Engineering Science*, in press.

_______, "Boundary Layers on Parabolas and Parabolids by Methods of Local Truncation," *International Journal of Nonlinear Mechanics*, in press.

HELLER, R.A., "Interlaminar Shear Stress in Sandwich Beams," *Experimental Mechanics*, Vol. 9, p. 413.

_______, "Reliability through Redundance?" Proceedings, Society of Environmental Sciences, Apr., p. 121.

HERAKOVICH, C.T. and Hodge, P.G., Jr., "Elastic/Plastic Torsion of Hollow Bars by Quadratic Programming," *International Journal of Mechanical Sciences*, Vol. II, Jan., pp. 53-63.

_______, Belytschko, T. and Hodge, P.G., Jr., "Quadratic Programming and Plasticity," *Computational Approaches in Applied Mechanics, Proceedings*, American Society of Mechanical Engineers Computer Conference, June.

HOSHIYA, M.,. "Free Vibration of a Beam Column with Stochastic Properties," *Proceedings*, Engineering Mechanics Division, American Society of Civil Engineers, Purdue University, No., pp. 107-112.

Lang, A.R. and REIFSNIDER, K.L., "Rapid X-Ray Diffraction Topography Using a High-Gain Image Intensifier," *Applied Physics Letters*, Vol. 15, No. 8, Oct., p. 258.

MAHER, F.J., "Wind Loads on Kresge Auditorium and Traveler's Building," *Journal of the Structural Division*, American Society of Civil Engineers, Vol. 95, No. ST1, Proceedings Paper 6330, Jan., pp. 1-15.

McNITT, R.P. and Stanisis, M.M., "Some Aspects of Irreversible Thermodynamics in the Presence of Electromagnetic Fields," *Acta Mechanica*, Vol. 7, pp. 187-196.

_______ and Stanisis, M.M., "Some Aspects of Irreversible Thermodynamics and Continuum Mechanics in Electromagnetic Fields," *Acta Mechanica*, Vol. 7, pp. 287-298.

Phinney, R.E., WERLE, M.J., Knott, J. and Volz, W.C., "Slot Jet-Interaction Studies at M_∞ = 4 and 5," *American Institute of Aeronautics and Astronautics Journal*, Vol. 7, Aug., p. 1627.

REIFSNIDER, K.L. and Green, R.E., Jr., "Dynamic X-Ray Diffraction Study of the Deformation of Aluminum Crystals," *Transactions of the Metallurgical Society*, American Institute of Mining, Metallurgical and Petroleum Engineers, Vol. 245, July, p. 1615.

SMITH, C.W. and Kaiser, H., "Prediction of Flow of a Melted Plastic Through a Screw Extruder," *Journal of Basic Engineering*, Transactions of the American Society of Mechanical Engineers, Series D, Vol. 91, Sept., pp. 479-488. Discussion, pp. 488-490, Author's closure pp. 490-492.

_______ and Wynn, R.H., "An Experimental Investigation of Fracture Criteria for Combined Extension and Bending," *Journal of Basic Engineering*, Transactions of the American Society of Mechanical Engineers, Series D, Vol. 91, Dec., pp. 841-849.

_______ and SMITH, D.G., "A Photoelastic Investigation of the Influence of Closure and Other Effects upon Local Bending Stresses in Cracked Plates," *International Journal of Fracture Mechanics*, in press.

WERLE, M.J., Driftmyer, R.T., Shaffer, D.G., "Two-Dimensional Jet-Interaction Experiments – Results of Flow Field Probing and Scale Effect Studies," Paper No. 34, *Proceedings*, Eighth Navy Symposium on Aeroballistics, May.

_______ and DAVIS, R.T., "On Integral Equations for Laminar Incompressible Second Order Boundary Layers, *International Journal of Engineering Sciences*, in press.

Books and Chapters of Books -- 1969

FREDERICK, D., Editor, *Recent Developments in Theoretical and Applied Mechanics – Proceedings of the Fourth Southeastern Conference on Theoretical and Applied Mechanics*, Pergamon Press, London, 967 p., in press.

HELLER, R.A. and Salvadori, M.G. "Loads on Structures," "Behavior of Structural Materials," "Tensile and Compressive Structures," "Beams and Frames," Educational Films, McGraw-Hill Book Co., Inc.

PLETTA, D.H. and FREDERICK D., "Engineering Mechanics – Statics and Dynamics," 5th Edition, Ronald Press Company, New York, 664 p.

_______, SMITH, C.W. and SWIFT, G.W., "Experiments in Materials Testing Laboratory," (revised), Edwards Brothers, Ann Arbor, Michigan.

SWORD, J.H. and HETERICK, R.C., An *Introduction to Computers and to Elementary FORTRAN*, Revisions, Kendall/Hunt Publishing Co., Dubuque, Iowa.

Reports and Contributions – 1969

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