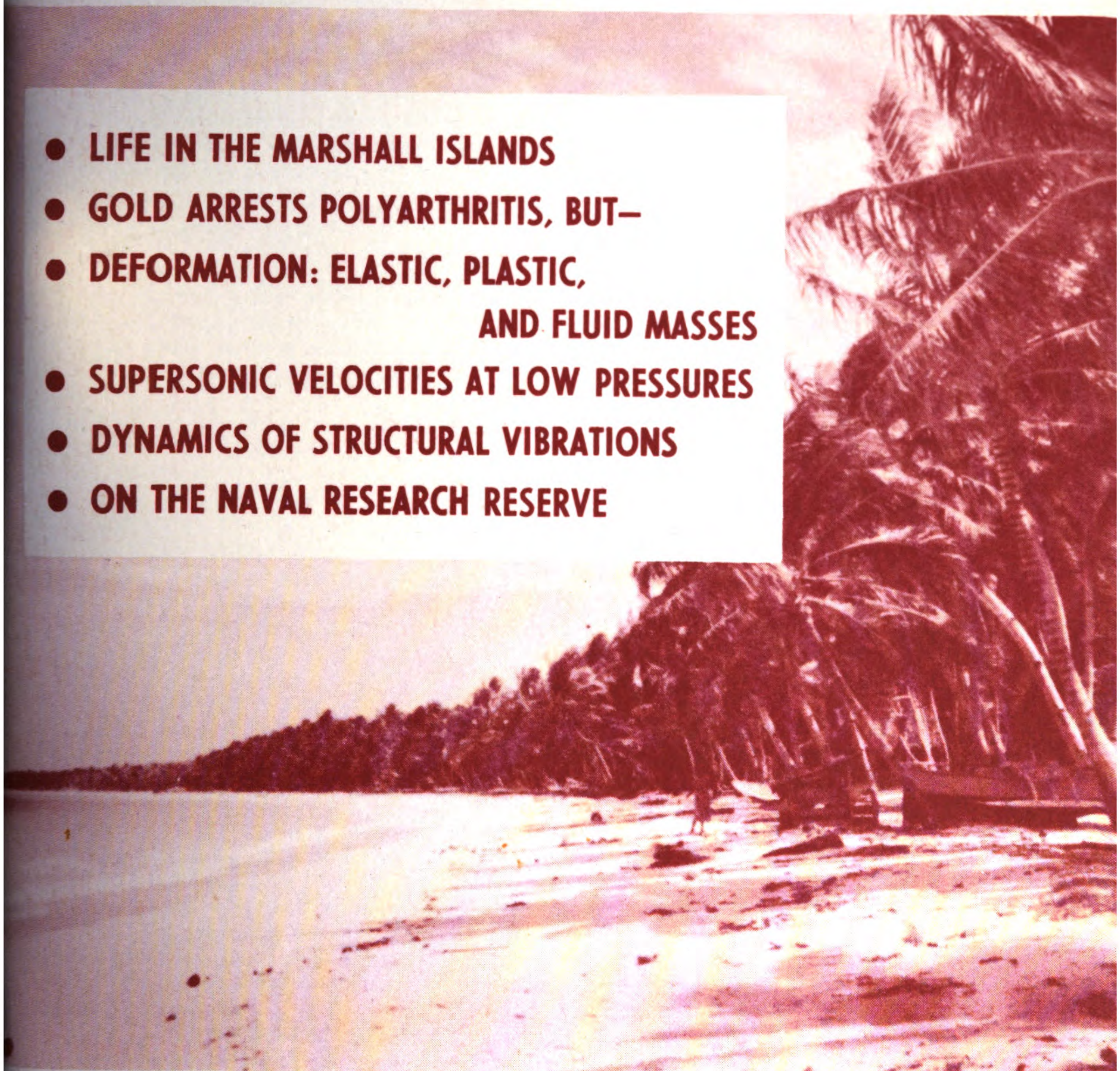
• APRIL 1949

FOR OFFICIAL USE ONLY

RESEARCH REVIEWS



- LIFE IN THE MARSHALL ISLANDS
- GOLD ARRESTS POLYARTHRITIS, BUT—
- DEFORMATION: ELASTIC, PLASTIC, AND FLUID MASSES
- SUPERSONIC VELOCITIES AT LOW PRESSURES
- DYNAMICS OF STRUCTURAL VIBRATIONS
- ON THE NAVAL RESEARCH RESERVE

OFFICE OF NAVAL RESEARCH
DEPARTMENT OF THE NAVY
WASHINGTON, D. C.

NAVEXOS P-510

COVER PHOTO: Village Beach, Majuro Atoll, Marshall Islands, 1947.

CONTENTS

Approved by Bureau of Budget, 13 April 1948.

RESEARCH REVIEWS

Informs the Fleet of ONR-sponsored Research

Editorial Musings

Research Reviews aims to play a spotlight on the variegated research pattern of the Office of Naval Research. This pattern is a strong component in the defense effort, but it is not generally realized that the scientists working in their laboratories all over the country are the scouting outposts of this effort. The scientists do research because it's fun, seeking to identify a new virus, applying the engineering know-how to the development of a machine, which will reveal hitherto undisclosed relationships in the realms of biology, medicine, and nuclear physics, or seeking to uncover the meaning of the meson in atomic structure. All the time the scientist is enjoying his pursuits, he is aware of the importance of his research. He may not be the one to interpret the meaning of his research -- often it is a colleague or the philosopher who adds the final interpretation or a reinterpretation of the original facts. But he is aware of the historical background of his research. He has studied the evolution of his problem before he devotes his efforts to it. He takes up where someone else has left off. History has shown that stemming from the original discovery there is often a chain of events leading to the final interpretation of the investigation.

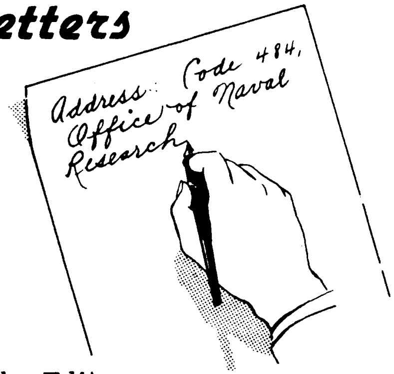
A striking example of a chain of events leading to an understanding of the importance of a discovery is found in the field of bacteriology. During the nineteenth century one of the most important problems confronting bacteriologists was the identification of bacteria causing infectious diseases. These studies required the isolation of bacteria in a pure culture medium. Pasteur, Cohn, and Koch had been seeking a medium which was at once solid, transparent, and sterile. Gelatin was fluid at 37° C which was not satisfactory for pathogens requiring heat. The man who passed the information on to Koch was Walther Hesse. His wife, Fannie Eilshemius Hesse, had been born of German immigrant parents in Laurel Hill, New Jersey, and had emigrated to Germany where she married Walther Hesse. When her husband discussed his problem with her, she suggested the use of agar-agar which she had been using for years in her kitchen in the preparation of fruit and vegetable jellies. While in America she had received the recipe from her mother who had obtained the formula from some Dutch friends who had lived in Java. In the East Indies, where the source of agar-agar, Japanese seaweed (Gelidium corneum), also abounds, this material had been used for generations as a jellifying agent and as a thickening for soups. This medium permitted Dr. Hesse to prepare a substrate, solid, transparent, and sterile, which could retain these properties at all temperatures. In 1881 he communicated the discovery to the famous bacteriologist, Robert Koch. It is now the standard culture medium for studying organisms of infectious diseases.*

So the constant reader of Research Reviews will look beyond the short accounts of individual efforts and realize that a new bit of information uncovered today may be the significant missing link to be added tomorrow to the chain of events.

---

*Hitchens, A. P. and M. C. Leikind, "Introduction of Agar-Agar Into Bacteriology." J. Bact. 37, 5, 485-493, May 1939.

Letters



To the Editor:

"....material (in Research Reviews) is usually covered in cognizant departmental publications."

USS PRINCETON (CV-37)
M. E. Arnold,
Capt., USN, Commanding

Since Research Reviews carries accounts of work supported by the Office of Naval Research, no other government agency is in a position to publish accounts of this research.

The subjects discussed in Research Reviews are covered in technical and final reports of the scientists who are working on ONR-sponsored research, but these reports are highly technical and reach a limited audience. The number of copies of these contractors' technical and final reports is generally much less than one hundred.

The Office of Naval Research believes, therefore, that Research Reviews must necessarily be unique in that the accounts of research are not disseminated elsewhere to reach a wide audience and to be understood by many readers.

The Editors

Code 484
Office of Naval Research

". . .You certainly are doing splendid work.

"I tentatively make a few suggestions. . ."

"1. Perhaps Research Reviews should have volume and number designations, so reference can be made to the volume. The page numbers should be continued consecutively until the volume is completed.

"2. . . .reprint copies should be made available for distribution.

A. Packchanian

Professor of Bacteriology and Parasitology
Director, Laboratory of Microbiology
University of Texas--Medical Branch
Galveston, Texas

The Editors thank Dr. Packchanian for his comments and suggestions. Now that the publication of Research Reviews has been established on a smooth working basis, the editors plan to adopt a volume and number designation system, if not during this year, then at the beginning of the new year.

With regard to the second suggestion, reprints may be procured by authors.

Because of the method of reproduction used in Research Reviews, the cost of reprints is nominal and this Office assumes the charge.

The editors desire that maximum use be made of the individual articles; therefore, they are glad to supply reprints upon request.

The Editors

LIFE IN THE MARSHALL ISLANDS

Alexander Spoehr
Chicago Natural History Museum

In 1947 the Pacific Science Board of the National Research Council initiated a formidable-sounding project called the Coordinated Investigation of Micronesian Anthropology, dubbed CIMA for short. The aim of the project was relatively simple--to obtain a basic, up-to-date anthropological knowledge of the peoples of the Micronesian islands which were taken over from Japan and now form the U. S. Trust Territory of the Pacific Islands.

Fig. 1. Limotin's house, an old style thatch structure, Majuro Village, Majuro Atoll, Marshall Islands, 1947.

Alexander Spoehr, Curator of Oceanic Ethnology, Chicago Natural History Museum, did his undergraduate work at Stanford University and in 1940 he received his Ph. D. in anthropology from the University of Chicago. He has been on the staff of the Chicago Natural History Museum since 1940. During World War II he served as Air Combat Intelligence Officer, U. S. Navy. In his anthropological work for the University of Chicago and for the Chicago Natural History Museum he has studied American Indian tribes and tribes in Micronesia. His field of specialization is social anthropology on which he has written many reports, articles, and monographs.

Unfortunately, the Japanese had written little about their native charges. A series of German reports based on conditions during the German regime in Micronesia was available, but lacked much essential information and naturally gave no indication of recent changes. On the whole, the published material was far from adequate. With the responsibility of administering the Trust Territory on its shoulders, the Navy was in need of accurate information concerning many phases of native life. On their part, anthropologists have long been curious about Micronesia and were only too happy to be given the means of carrying out field investigations. Out of this need and desire for knowledge of the Micronesian peoples the CIMA program grew[1]. The project was carried out in 1947 and 1948 by civilian scientists from universities and museums, with the Pacific Science Board as the coordinating agency. A grant from the Office of Naval Research, the Viking Fund of New York, and additional support from participating institutions made the project possible.

With this introduction, we can jump to the Marshall Islands. Until my return in 1947, my last glimpse of those atolls was from the flight deck of a homeward bound carrier in 1945. At that time I admit I was not sorry to see the last of Kwajalein, which would be difficult to include among the beauty spots of the world. On the other hand, Majuro brought back pleasanter memories, for it certainly had one of the most liveable of the war-time Navy bases in the Pacific. Also, for many years beyond the memory of living men, Majuro has had a Marshallese village on a large island at one end of its spacious blue lagoon. Today the people of this village continue to follow their daily routines of life. It was to this community that I came in 1947 to conduct anthropological field work for the Chicago Natural History Museum, under the CIMA program.

What was the aim of this field work; how was it carried out; and what were the results? This is not the place for a detailed report, but we can here comment briefly on some of the more significant aspects of the project.

The aim of the field work at Majuro was to determine the principal features of the social organization of a contemporary Marshallese community. With this goal in mind, certain kinds of questions became relevant. Among those that the investigator asked himself were: What are the local divisions of people--such as districts, neighborhoods, and households--in this community; how are they held together through community activities; and what are the focal points of interest for such activities? What is the relation of the community to its local natural resources? What is the composition and organization of household and family? What is the form and function of larger kinship groupings, such as lineage and clan? Is there a well-defined class structure, and what is its relation to the distribution of political power? What is the system of land tenure, and what are the factors that control the exchange of goods and distribution of income? How are these related to the kinship system and the class structure? What is the relation of introduced institutions, such as the church or the dispensary, to indigenous ceremonial and magical practices?

---

[1]For further information on the CIMA project, see Coolidge, Harold J., "The 1947 Invasion of Micronesia," Research Reviews, 15 June 1948.

Fig. 2. King Langlan, Majuro Atoll, Marshall Islands, 1947.

By investigating a series of questions such as these, the anthropologist working on a problem of the kind with which I was preoccupied gradually builds up a carefully worked out body of observation that allows him to put together a picture of the community and its culture. He comes to his study with a wide background of comparative knowledge that provides him with some insight into the probable kinds of social segments, their associated functions, and their inter-relations--family organization, for instance--that he can expect to find. So he does not approach his data "cold," but sees it as varieties of similar categories of observed facts from other cultures of the world. His primary job is to keep reformulating questions in more precise and penetrating terms as his field investigations carry him toward his major goal.

To someone of a different occupation, the anthropologist's field work among living peoples seldom looks like work at all. It is true that maps must be constructed, census figures obtained, some formal interviewing done, and documentary materials utilized--all of which call for procedures most people think of as "work." However, a large share of an anthropologist's most valuable data is derived from casual discussion and informal meetings with the people he is studying, and from day to day observation of the ordinary life that goes on about him. I well remember the skeptical attitude toward my efforts at Majuro expressed by a Navy friend who visited the village one day on an official field trip. During the day he encountered me (1) at the village store, swapping

Fig. 3. Making handicraft. Majuro Village, Majuro Atoll, Marshall Islands, 1947.

stories and jokes with the group always found there; (2) drinking coffee with some friends at their house; and (3) sitting on the beach in the shade of a tree gossiping with some old women. This indeed does not sound like work, but it actually can be work of a very exhausting kind. For all the conversation and discussion that one enters into, all the trivia of daily life that one observes, must be jotted down in one's mind or in a notebook, and must be sorted out, analyzed, and evaluated for its worth in showing how human relations in the community are organized and patterned. During evening hours when the villagers have long since gone to bed, the anthropologist will still be working by the light of his lantern, recording the day's events, sifting them to find the critical gaps in his knowledge, and preparing for his work for the morrow.

The Marshallese are a group much affected by contact with the west, and accordingly they possess a culture that is a blend of traditional and recently introduced elements. This fact is reflected in their social organization. Thus the bonds of kinship are very important and are widely extended beyond the immediate family, while two kinds of groupings based on kinship--the maternal lineage and the larger maternal clan--have important functions. The lineage is the principal vehicle for the transmission of land rights, while both lineage and clan are determinants of the still important class structure that divides the community into nobles and commoners. This emphasis on kinship stems from the traditional culture. On the other hand, the Protestant Church has supplanted the organized, indigenous ceremonial life, and the village stores are new agencies for marketing trade goods among the people and signify the participation of the Marshallese in a larger world economy. Both church and store are recently introduced elements in the old pattern of native culture.

For the anthropologist, the kind of information just noted is important for several reasons. One of his jobs is to know the overall cultural characteristics of major world areas outside of modern America and western Europe. Micronesia is an area the culture of which has not been well known, and its historical relations with surrounding areas need further clarification. Also, the knowledge obtained by the CIMA program will aid in defining the principal social and cultural types that are emerging among the Pacific peoples today and help us to discern the direction of culture change in Micronesia. And this knowledge bears on comparative problems, such as the nature and function of kinship groupings, the processes of social change, and the relations of different kinds of communities to their local natural resources.

For administrative purposes, the information is likewise significant. If the extension of local self-government is an aim of administrative policy, then the prevailing form of local political organization should be considered in implementing such policy and gauging its success. If improvement in economic conditions is an aim of policy, then the prevailing way in which local natural resources is controlled and

Fig. 4. Canoe on beach, Majuro Atoll, Marshall Islands, 1947.

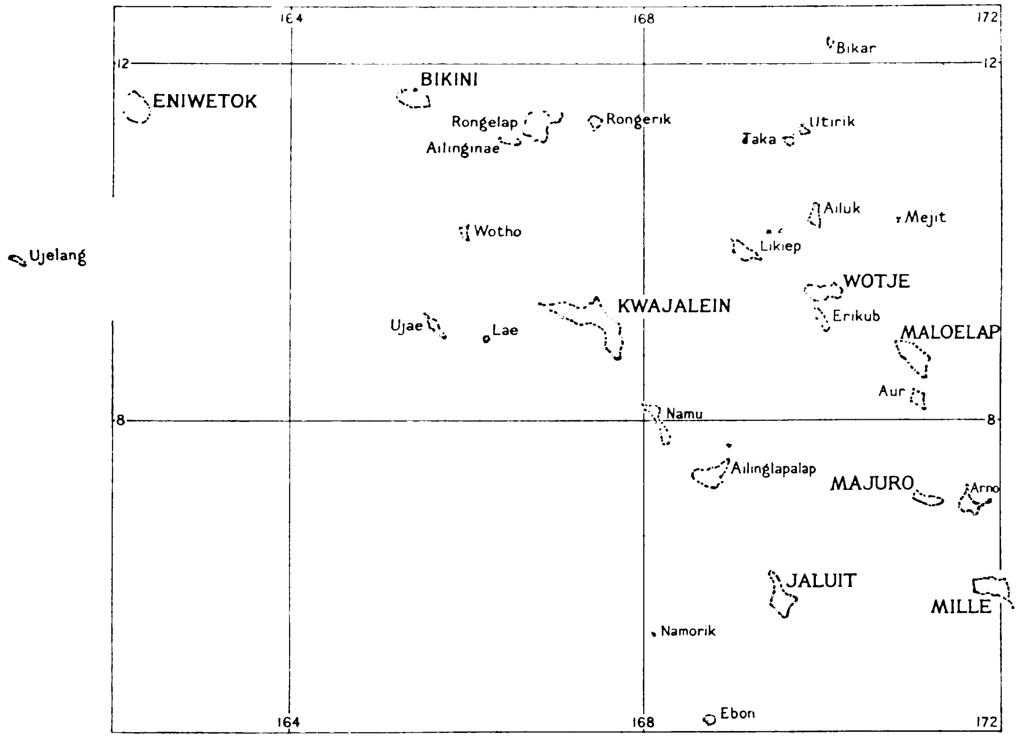


Fig. 5. Marshall Islands. Taongi, the most northerly island in the group is not shown.

used, how production is organized within the village, and the extent to which money is a factor in exchange and distribution are all important questions. If it is desired to promote an acceptance and use of western medical practice, then such programs must be viewed in conjunction with traditional forms of therapy--many of them admittedly magical--that partly control the villagers' degree of acceptance of new ideas relating to health and disease. In other words, it is impossible to administer humanely and effectively, no matter how lofty basic policy is, unless one knows the cultures of the people with which one deals. It is to the Navy's credit that it has realized this fact, and accorded support to the Coordinated Investigation of Micronesian Anthropology, of which the field work in the Marshalls was a part.

GOLD ARRESTS POLYARTHRITIS, BUT—

W. C. Kuzell and P. J. Hanzlik
Stanford University

Research in the rheumatic diseases has been hampered by the failure to produce in animals the counterpart of the various forms of human arthritis. Rheumatoid arthritis, the great crippler of thousands, is often treated in part with gold salts. The exact mode of action of the gold salts is unknown, and there is a calculated risk in the employment of gold since toxic reactions are frequent.

There is an arthritis of rats and mice which is readily and constantly produced experimentally by the L-4 strain of pleuropneumonia-like organisms, other strains of which occur in human secretions. The constancy and ease of reproducibility of this polyarthritis make it especially attractive for investigational purposes. Although the type of joint involvement in this experimental disease is not identical with that of rheumatoid arthritis in man, there is the similarity that, when left untreated, the experimental disease progresses to fibrous and bony ankylosis of joints, as in clinical arthritis. Furthermore, the disease in rats and mice can be prevented by injection of gold salts prior to the introduction of the infecting microbes, or once the disease is established, the use of gold will arrest its development.

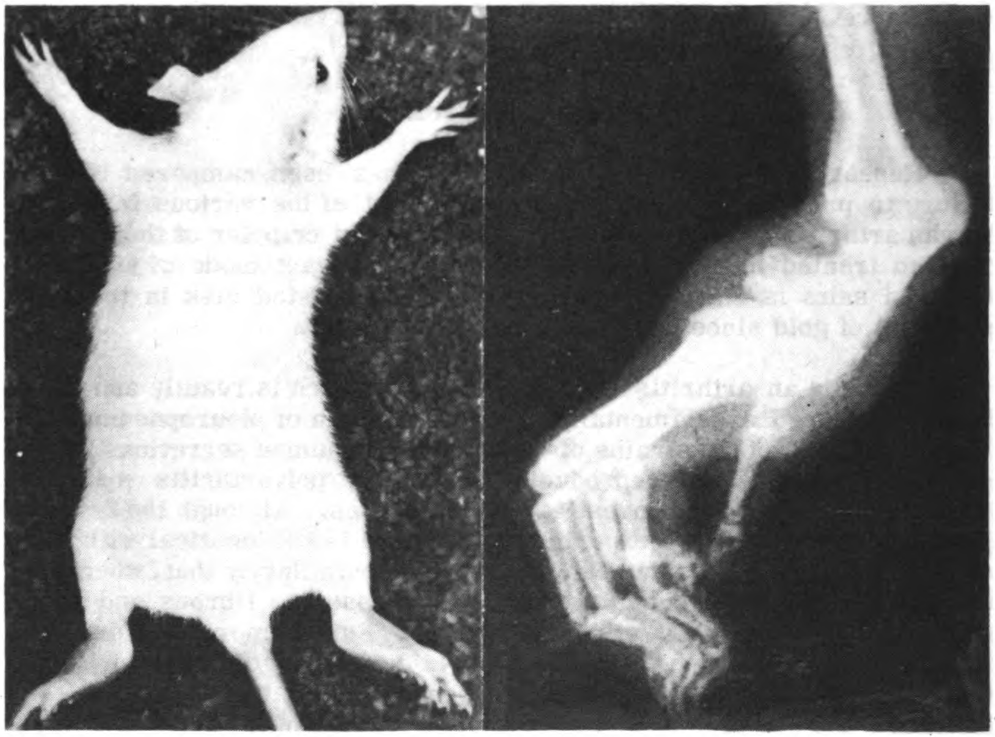
Since we have a type of polyarthritis which responds readily to gold therapy, there is an opportunity to make therapeutic trials with

---

William C. Kuzell is Research Associate in Therapeutics and Clinical Instructor in Medicine, Stanford University School of Medicine, San Francisco. He received his B.A. degree in 1936 and M.D. degree in 1941 from Stanford University. From 1940 to 1942 he was on the house staff of the San Francisco Hospital. From 1942 through 1945 he was on active duty in Africa and Europe in the Medical Corps, U. S. Army. In 1945 he did special work in cardiology at the University of Paris, France. Returning to Stanford in 1946 as Fellow in Therapeutics, he was appointed to his present position at the end of that year. He is a member of the American Rheumatism Association and is assistant editor of the Stanford Medical Bulletin.

Paul J. Hanzlik is professor of pharmacology and Executive of the Department of Pharmacology and Therapeutics, Stanford University School of Medicine, San Francisco. He received his A.B. and A.M. degrees from the University of Illinois, Ph.D. from the University of Iowa, and M.D. degree from Western Reserve University. He was a member of the Western Reserve teaching staff for 9 years and has been at Stanford over 27 years. For one year (1914) he did research in the Pharmacological Institute and Physio-Chemical Biological Institute of the University of Vienna and visited research centers in Europe. He served in the U. S. Army Medical Corps and was in charge of the Skin Irritation Unit, C.W.S., American University, Washington, D. C., investigating war gases in World War I. He instructed in war gases Army, Navy and civilian groups in the San Francisco Bay Region during World War II. He has been consultant to federal, state, local, public health, and private agencies on status of medicinal agents, poisons, and treatment of poisoning. He is author of several books in his field.

831005 O - 49 - 2



A B

Fig. 6. Albino rat showing (A) polyarthritis 2 weeks after intraperitoneal inoculation of 2 cc broth culture of L4 strain pleuropneumonia-like organisms, and (B) x-ray film showing arthrodesis of tarsal joints 2 months after inoculation.

other agents, and use gold as a standard for comparison. When and if agents are discovered which act as favorably as gold and are less toxic or objectionable they may be tried in patients. At the same time until therapeutic agents as efficient as gold are found, means of controlling gold toxicity must be studied.

Our work has followed 3 general lines: (1) therapeutic trials in experimental polyarthritis of rats, (2) possible contributory factors to the polyarthritis, and (3) means of decreasing gold toxicity.

(1) Therapeutic Trials. Therapeutic trials have been made with the following compounds: sodium hexavanadate, salazopyrin, copper salts, cinchophen, oral bismuth and citrinin (antibiotic) compared with gold salts as controls. Thus far only salazopyrin (combination of sulfapyridine and salicylic acid) and cupralene (copper-allylthiourea sodium benzoate) have shown some promise, but no substance tested to date has been as efficient as gold in preventing and arresting the arthritic process.

Factors which are sometimes believed to influence the course of rheumatoid arthritis in man have been applied to this experimental polyarthritis of rats. Effects of long continued exposure to ultra-violet light, heat, and cold have been shown not to alter materially the course of the disease, but this may perhaps have something to do with the fact that fur-bearing animals can tolerate greater changes in environment than man.

(2) Contributory Factors to Polyarthritis. The influence of underactivity of the thyroid gland has been determined by removal of the gland and also by administration of thiouracil, a substance used to suppress thyroid overactivity. The arthritis was not made worse in animals from which the thyroids had been removed but was definitely worse in those receiving the thiouracil, which implies that some peculiar intrinsic action of this substance was responsible for the aggravation of the condition. It was also shown incidentally that prolonged administration of thiouracil produced an increase in size of the thyroid glands and caused the formation of nodules in them.

(3) Decreasing Gold Toxicity. 2,3-dimercaptopropanol, which is commonly known as British Anti-Lewisite or BAL, was developed during World War II to combat the effects of the poison gas, lewisite, and was used by us in studies of gold toxicity and the elimination of the metal. BAL was found to protect animals against lethal doses of gold and to cause a greater urinary excretion of gold combined with BAL in a less toxic form.

Since BAL (contains sulfur as dithiol) is also a toxic substance, other possible gold antagonists were tested, among which were methionine, choline, cystine and sulfur. It was found that methionine (sulfur-containing amino acid) used as a dietary supplement will protect rats against lethal doses of gold, but that in so doing the urinary gold excretion is not increased. The protective effect is, therefore, caused by some as yet unexplained mechanism. Cystine (another sulfur-containing amino acid) and sulfur were irregular or ineffective and choline was ineffective as antagonists of gold toxicity.

A point of considerable interest has been the demonstration that the simultaneous administration of methionine in the diet and BAL by injection will permit rats to survive single doses of gold, which would be surely fatal if either substance were used alone. This combination may have applications not only in mitigating the clinical toxicity of gold but also in treating toxicity caused by other metals.

Since BAL removes gold from the body, it is possible that as a result of this, arthritis may be aggravated. We have observed that BAL aggravates the polyarthritis of rats not treated with gold. Studies of these phenomena may lead to an understanding of how gold acts in the experimental polyarthritis of rats as well as the rheumatoid arthritis of man. This work is partially supported by contract with the Office of Naval Research, and partially by the Stern Fund for Research in Arthritis.

DEFORMATION: ELASTIC, PLASTIC, AND FLUID MASSES

C. A. Truesdell
Applied Mathematics Section, Mechanics Division
Naval Research Laboratory

DEFORMABLE MASSES

Most naval situations involve deformable masses. If a projectile is fired from one vessel and strikes another, the first ship's launching mechanism and plates are deformed by the recoil, but if the plates and mechanism are sufficiently strong, they quickly return to their original shapes; the theory of such deformations is elasticity. The missile is propelled by the explosion or burning of various gases, and travels through the air or water; the theory of these deformable media is fluid dynamics. When the missile strikes the second ship, a permanent deformation results; the theory of such deformations is plasticity. Separate theories of elasticity, several branches of fluid dynamics, and various types of plasticity have been studied for 300 years, under a variety of simplifying assumptions. These classical theories have been very successful. Not a ship nor a plane reaches even the drawing board until after extensive and careful calculations by engineers well grounded in the principles of mechanics. Most of these principles were established over 100 years ago by mathematicians and physicists, and have gradually been properly interpreted, assimilated, approximated, and applied by the practical designers.

One of the reasons for the splendid successes of the classical theories is their mathematical simplicity, so that they can easily be learned and their basic equations can easily be solved in a variety of cases. This simplicity enables them to be used widely. At the same time, it limits their value (great as it is), because today there are many problems of the greatest naval importance to which they fail to apply because the approximations upon which they rest are not physically justified.

C. A. Truesdell was born in Los Angeles, 1919. He trained in pure and applied mathematics, rational mechanics, and theoretical physics at California Institute of Technology (B. S. '41, M. S. '42), Brown, and Princeton (Ph.D. '43); after some teaching, and work at the Radiation Laboratory, Mass. Inst. of Technology, he became chief of the Theoretical Mechanics Subdivision at Naval Ordnance Laboratory, where his work on the subject of the present article was begun under ONR sponsorship. He is now Consultant in the Applied Mathematics Section, Mechanics Division, Naval Research Laboratory, and Associate Professor of Mathematics, University of Maryland. He has lectured at Harvard and Toronto, and will give a series of lectures at the Institut de Mécanique of the Sorbonne (Paris) this spring. His papers deal mainly with three subjects: (1) calculation of stresses in elastic shells (domes, tanks, turrets, etc.); (2) special functions (A Unified Theory of Special Functions, Princeton University Press, 1948); and (3) the subject of the present article.

AIMS OF THE PROGRAM

For these reasons we decided to review and extend the classical theories. Our aims are (1) to state in as general a fashion as possible the fundamental principles governing the mechanical behavior under all sorts of load of all continuous masses such as air, water, and steel, and to deduce as many properties as possible from these general principles, and (2) to give the clearest possible and most general definitions of the separate types of deformable continuous bodies, such as elastic bodies, fluids, and plastic bodies, and to deduce their main properties.

This program is valuable for several reasons:

(1) An economy of thought and simplicity of approach result by paring off extraneous details and approximations;

(2) the scientist is enabled to go at once to the heart of a mechanical problem, when he has decided the main effects to be considered, and to find the most general equations set up for him;

(3) as a by-product, specific and correlating contributions are made to the separate sciences embraced by the program;

(4) not the least value of a general, accurate theory extending classical methods is that it clarifies the known procedures and enables the scientist to know what he is neglecting when he uses them.

MATHEMATICAL LANGUAGE

The mathematical language selected as of the generality suitable to this project is Riemannian geometry, which was discovered by the mathematician Riemann, who predicted shock waves mathematically before they were observed in experiments, and was employed by Einstein as the only suitable expression for his general theory of relativity. Because of its basic economy, generality, and simplicity (once one has learned it), today it is becoming more and more a common tool for physicists, mathematicians, and research engineers.

NEW DIFFERENTIAL EQUATIONS?

It may be objected that the known differential equations of fluid mechanics and elasticity are so difficult to solve that it is useless to discover new differential equations even more complicated. Such a statement is wrong, whether viewed from the point of view of the mathematician, the physicist, or the practical engineer. Even today we cannot solve exactly all the differential equations governing the motion of a Civil War cannon ball; yet our new missiles fly through rarefied atmospheres and will not wait for old fashioned scientists who insist on solving all the problems of the traditional fields before opening new ones. It is possible also that automatic computing machines may yield numerical solutions of differential equations of great complexity, providing they are first properly understood and formulated by mathematicians; our attitude is changing from "what approximations can be made so as to solve these equations?" to "what are the right equations to solve?" Finally, a great deal can be learned from equations without solving them at all. The general properties of solutions, the general phenomena which can be expected to occur, are often of greater value to the progress of science and its practical applications than are specific numerical solutions. From the aerodynamic research of twenty years ago, for example, it is not the firing range and wind tunnel data then accumulated which the designers now use. While of course these details were necessary for the development of the weapons they concerned, today they have lost their value because the particular weapons are obsolete. It is the general principles of aerodynamics, as discovered partly through experiment and partly through mathematics by Prandtl, Karman, Mises, and others, which today are as important and valuable as at the day of their discovery, and which apply equally to the old and to the new weapons.

PHYSICAL PRINCIPLES SELECTED

As the physical principles governing all mechanical problems we selected the conservation of mass, the conservation of momentum, and the conservation of energy. The first principle states that in mechanical problems no new matter is created and no old matter is destroyed. The second principle states a general formulation of the familiar law of recoil of a gun when a shot is fired. The third principle states that energy is neither created nor destroyed in any mechanical process. These laws of course are familiar, but we have attempted to give them a mathematical form of new generality and usefulness.

ELASTIC BODIES AND FLUIDS

To study elastic bodies and fluids we began by discarding all previous equations and approximations and returning to the simplest basic concepts of springiness and of fluidity, as we first grasped them from practical experience in the nursery.

To define an elastic body, consider a rubber band. When we stretch it any amount below the breaking point, it will return to its original shape upon release. If we stretch it very rapidly or very slowly, retain it in extension for a long or for a short period, and perform the experiment in a hot room or in a cold one, within a wide range of conditions, it will nevertheless return to its original shape. When we formulate this simple and general idea in mathematical equations, we obtain the most general theory of elasticity yet discovered. A notorious defect of the classical theory was that being restricted to small strains, it could not predict most of the behavior of rubber, the first example of an elastic body which comes to mind.

To define a fluid, consider a basin of water. The water completely assumes the shape of the basin, but if we pour the water into a glass, it quickly assumes the shape of the glass, showing no tendency whatever to return to that of the basin. It would be quite wrong, however, to attribute to water any lack of resistance to being deformed, as we may readily observe by dragging our hand through it. Similarly, if we turn a bottle of honey upside down, the honey runs out rather slowly because it resists rapid deformation; ultimately, however, it too will assume the shape of its new container. The resistance of a fluid depends upon the rate at which it is deformed, and is quite independent of the final deformation which takes place. The motion set up by the disturbance dies rather quickly, and hence by the principle of conservation of energy there must be an attendant heating of the fluid. If now we take the basin and heat it upon a stove, we find that currents are set up because the bottom of the basin is hotter than the top surface.

Therefore, we may expect the rate at which the mechanical energy of a fluid is converted into heat to depend upon the rate of deformation and the differences of temperature existing. These very simple and general ideas when expressed mathematically lead to a more general theory of fluid mechanics than any previously known. It includes as a special case certain proposed equations for air flow at an altitude of 100,000 ft, which had previously been deduced by a very lengthy calculation in the kinetic theory of gases.

MATHEMATICAL TECHNIQUES

The general equations, of course, are quite complicated and abstract in appearance. One must remember that the now familiar classical theories necessarily were created by mathematicians using all the apparatus of pure mathematics then available, so that to the engineers of that day they seemed abstract, difficult, and impractical. Euler's basic equations of fluid dynamics waited 150 years, often being maligned as representing an "ideal" rather than a real fluid before they were shown to imply the greater part of the theory of the airplane. Cauchy's ideas of stress and strain in elasticity were introduced so as to explain optical phenomena, for which they are now no longer employed, and 50 years passed before their usefulness was fully realized by engineers. It is worth noticing that Euler and Cauchy were the best pure mathematicians of their respective periods. While the present project is specifically directed toward applications, we attempt to achieve the generality and clarity which result from a full use of modern mathematical techniques.

PROPERTIES OF CLASSICAL THEORIES

Having set up these general theories, we began to study their properties. We shall mention only three specific results here. The first concerns elasticity. The classical theory states that a shaft can be twisted without suffering a change of length. The general theory shows that if a long shaft be twisted through a large angle, it will grow shorter unless at the same time its ends be drawn out. Thus a designer employing a long flexible shaft would need to provide bearing clearance to permit the contraction, or if he needed to keep the length constant, he would have to provide suitable extending members. The second example concerns plasticity. An experimental group studying the plastic flow of armor plate when struck by a missile found difficulty in presenting and interpreting their results. Although an appropriate theoretical treatment seemed out of range, our general studies suggested a better type of empirical equation for fitting the experimental data, so as to make it easier to understand. The third example concerns fluid dynamics. Although the equations governing high altitude aerodynamics are extremely complicated, we can use them (without trying to solve them) to guide and evaluate experimental work. One conclusion is that if the designer wishes to use data measured in a flow about a small model, he must arrange matters so that the number $\underline{T}$, defined by

$$T = \frac{\text{(viscosity) (typical rate of deformation)}}{\text{(pressure)}},$$

has the same value for the flow about the model as for that about the full scale missile. While this number is negligibly small in flight conditions at low altitudes, for high altitudes where the pressure is very low it can be of predominant importance.

RELATED STUDIES

After our work had gotten well under way, we learned that these same problems were being studied also in England, Israel, Germany, Italy, and Russia. Although rather different ideas and methods were employed by the various scientists, all can be included in our general framework, as will appear in the survey article "Recent Continuum Theories of Elasticity and Fluid Dynamics," now being written for Advances in Applied Mechanics, 1949.

WHERE DO THESE STUDIES LEAD?

The reader will have gained from this account a notion of the fundamental nature of this re-evaluation of classical work and attempt to unfold new information. He will also have drawn the obvious conclusion that all these studies are pertinent to the ultimate development of new or improved ships, airplanes, and guided missiles.

Among the ONR Contractors

F. F. Nord, professor of chemistry at Fordham University, is the principal investigator on three ONR contracts in the field of chemistry. He received the third Carl Neuberg Medal of the American Society of European Chemists and Pharmacists at a meeting of that society January 27. The Neuberg medal was established by the ASECP in 1947, to honor Carl Neuberg of New York University, who in 1906 during his time on the faculty of the University of Berlin founded the famous publication, Biochemische Zeitschrift.

Professor Nord in addressing the meeting, devoted a considerable portion of his talk to the subject of wood chemistry. He stressed the need for a re-examination of the foundations of this subject in the light of new concepts which have arisen during the past few decades. The conventional assumption, he said, is that wood consists of cellulose, hemicellulose, and lignin. The latter is richer in carbon than the sugars, and is obtained from the wood by the use of sulfurous acid, oxidizing agents, or alkali. Further, lignin does not split down to simple sugars as the cellulose and hemicelluloses do upon treatment with mineral acids.

This situation has posed a dilemma for the wood chemist, concerning which Prof. Nord said he was undecided whether or not to assume a stable chemical linkage between cellulose and lignin in nature. Equally controversial is the assumption that lignin exists in the wood in a preformed state. He believes that a chemical linkage between cellulose and the lignin of wood in a preformed state would mutually exclude each other.

The second part of the medalist's address was devoted to a discussion of his investigations of the Fusarium type of mold, some members of which have good abilities to convert carbohydrate to fats. He presented data to show the type of fatty acids produced by various members of the genus and the effect that some outside agents had upon mold growth.

SUPERSONIC VELOCITIES AT LOW PRESSURES

R. G. Folsom and E. D. Kane
University of California

Investigation of the unknown is the objective of scientific research. Often development and research are not clearly defined and much confusion exists with respect to these separate phases of scientific work. Development is usually associated with the application of known scientific principles, methods, and materials to achieve a given end. As an example, the design of an amphibious craft would be considered development because fundamental ideas and principles that would be applied are already known and the materials and equipment are known or available. The advances to be achieved by such a development would be a new combination of variables in a different way so that the resulting project, the amphibious craft, would have improved performance over any available at present. In such work, the objective is clearly defined and all efforts can be expended in a given direction. With research which has to do with the development of new ideas and fundamentals, such a definition and completeness of understanding of the objective are usually not possible.

The investigations in fluid flow and heat transfer at low pressures being undertaken at the University of California at Berkeley are scientific research. The objective is to enlarge the field of knowledge concerning these subjects by appropriate theoretical and experimental studies. The actual application of the results to be obtained is somewhat uncertain at the present moment, but it is safe to state that as the importance of vacuum systems increases, such as those developed at Oak Ridge, the importance of understanding fluid flow and heat transfer under such pressure conditions increases. It should be noted that there

---

R. G. Folsom, professor of mechanical engineering, University of California, Berkeley, received his B.S., M.S., and Ph.D. degrees in mechanical engineering from the California Institute of Technology (1924, 1928, and 1932).

He has published numerous articles in the field of fluid mechanics, particularly flow metering problems and pumping machinery. During the war period, he was in charge of several classified projects under U.S. Navy, U.S. Army Air Corps, OSRD, and NDRC auspices, including a period at the Jet Propulsion Laboratory, California Institute of Technology, 1943-44. He is currently supervisor of ONR-sponsored research on fluid flow and heat transfer problems in gases under low-pressure conditions.

E. D. Kane, formerly assistant professor, now lecturer in engineering design, University of California, received his B.S. degree from the University of California (1938) and his M.S. from Kansas State College (1939). He has been on the University of California staff since 1940; he was with Radiation Laboratory, Berkeley, and later at Oak Ridge on the Manhattan District Project, 1942-1945, on development and design problems. He is currently co-supervisor with R. G. Folsom on the research problem described in this article.

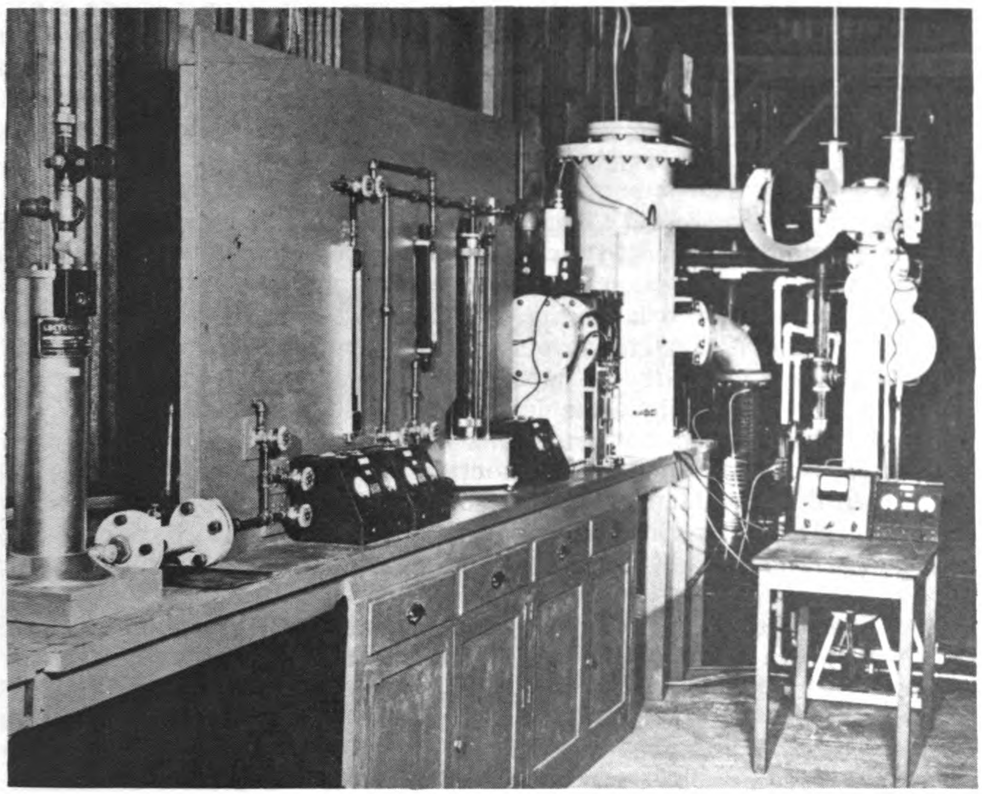
is a large body of theory and experimental information on the subsonic flow of gases in pipes under low pressure conditions. On the other hand, there are virtually no experimental data nor theoretical treatments available for supersonic flow of a gas at low pressures. This latter phenomenon appears in the scientific literature under such varied headings as "Superaerodynamics," "Rarefied gas dynamics," and the "Mechanics of flow at low pressures." Low pressures in this connection are usually defined as absolute pressures at less than about 1 mm of Hg. A knowledge of the flow at supersonic velocities under low pressures is necessary to understand completely the problem of flight at extreme altitudes such as those attained by the present V-2 rockets (approximately 115 miles).

Under normal conditions for flow of a liquid or a gas, the molecules of the fluid in contact with a solid surface have the same velocity as the surface. Since the fluid at some distance from the surface may have a velocity appreciably different from that at the surface, a velocity gradient will exist in the fluid. This velocity gradient or change of velocity with distance determines the frictional forces on a solid surface. For example, to move a ship through water requires a thrust from the propeller to overcome the fluid skin friction losses of the hull and the wave making resistance. The fluid in contact with the hull moves with the velocity of the ship, but the fluid at some distance from the ship has a zero velocity. The velocity gradients in the vicinity of the hull are a measure of the skin friction resistance.

When low pressures in a gas are achieved, the molecules apparently in contact with the solid surface no longer have a velocity corresponding to the solid surface. These molecules have a relative velocity with respect to the surface which has been designated "slip." Conditions under which "slip" will occur in flow in normal straight pipes at low pressures are well understood. Present available experimental data indicate that the start of the "slip" phenomenon will occur at higher pressures when the solid body concerned has some curvature and a pressure gradient exists. Thus in the flow about objects at extreme altitudes the "slip" phenomenon may occur at a lower altitude than would be predicted on the basis of "slip" as determined in pipe flow experiments.

When the pressures become very low, the molecules act as individual particles and may be likened to ball bearings spaced at intervals that are large with respect to the ball diameters. For such conditions the heat transfer and fluid flow associated with a solid boundary will depend upon the type of reaction occurring between the molecule and the surface at the time of impact and immediately following. When a molecule strikes a surface it may be reflected like a ball bearing striking a smooth metal surface with the angle of reflection equal to the angle of incidence. Experimental data, on the other hand, indicate that for the region of fully developed molecular flow, the molecules strike the surface and are re-emitted in a diffuse fashion which is independent of the angle of incidence. This type of impact might be considered as inelastic followed by a re-emission. The proportion of molecules, kinds of molecules, and surfaces for which these types of impact occur are of importance in determining the performance characteristics of any object passing through such an atmosphere.

The University of California investigations include the "slip" phenomena as well as the surface phenomena when fully developed molecular flow takes place. "Slip" is being investigated in specially constructed wind tunnels designed for test section pressures of about 10^{-2} mm of Hg. The fully developed molecular flow is being investigated in an apparatus known as a molecular beam, a type of equipment which directs a stream of molecules against a given surface when the surrounding pressure is in the neighborhood of 10^{-6} mm of Hg. In order to use these two types of basic equipment, many special instruments are necessary. Among the most important are means of flow visualization and means of detecting the molecules reflected from a surface in the molecular beam apparatus.



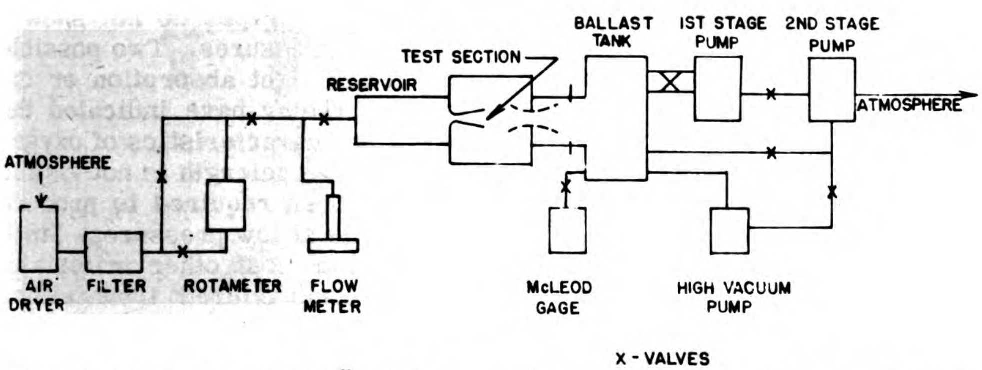


Fig. 7. Medium-sized tunnel has a test section 1 in. x 1 in. and a pressure of 10^{-2} mm Hg.

The wind tunnels being used may be defined as continuously operating once through supersonic tunnels. Air is drawn through a dehumidifier into a settling chamber from which it passes through a De Laval type of converging-diverging supersonic nozzle into a test section, from there into a reservoir and through the vacuum pumps back to the atmosphere. The smallest tunnel has a rectangular test section of 1 in. x 3/8 in. and a test section pressure of about 1 in. of Hg. The driving pump is a single stage steam ejector. The medium-sized tunnel, shown in a general view in Fig. 7, has a test section of 1 in. x 1 in. and a pressure of 10^{-2} mm Hg. It is driven by an oil jet pump, backed by a mechanical vacuum pump. The large tunnel now under construction will have a test section of approximately 150 square inches in area at a test section pressure of about 5×10^{-2} mm of Hg, and a capacity of approximately 7 pounds of air per hour (equivalent to 23,000 cubic feet per minute). The drive unit is a 5-stage steam ejector. The ejector pump type of drive has been used because of its economical application in the particular situation and its flexibility for operation of the tunnel throughout a wide range of test section pressures. Commercial oil jet pumps could be used for this purpose, but were not found suitable in comparison with the ejectors.

In operating a wind tunnel it is desired to have a maximum area of the test section filled with velocity of a given constant value. At low pressures a viscous boundary layer exists and the thickness of this layer may become so large that only a small portion of the middle of the stream has a constant velocity and is available for test purposes. It is necessary to re-design nozzles and other equipment on rather new bases in order to achieve the desired results. A close-up of one type of supersonic nozzle for the 1 in. x 1 in. tunnel is shown in Fig. 8. It will be noted that the approach section is much more abrupt than one usually sees in wind tunnels and the diverging portion has straight walls. This procedure was found necessary in order to reduce, as far as possible, the thickness of the laminar boundary layer at the test section.

In order to take pictures showing details of flow such as shock waves, a new system of photography has to be developed. The normal system of taking photographs of shock waves involves the principle of refraction of light. Equipment based on this principle includes the shadowgraph, Schlieren, and interferometer procedures. When the pressure becomes low, the number of molecules available for refraction of light becomes so few that no appreciable refraction takes place for reasonable path lengths, and thus the photographs do not show a distinction between regions of air at different pressures. Two possible basic methods of attack on the problem are light absorption or the after-glow phenomena. Experiments at Berkeley have indicated the practicability of making use of the absorption characteristics of oxygen for 1470 Å wavelength radiation. Light of this wavelength is not visible to the human eye and special lamps have been required to produce such a wavelength. These lamps use xenon gas at low pressures. Since 1470-Å light is absorbed by glass, quartz, and most other materials, the optical system, including lenses, is manufactured from either calcium or lithium fluoride. A general view of the experimental xenon lamp is shown in Fig. 9. It will be noted that the discharge in the capillary tube provides the source of light which passes through a fluoride window into a test chamber in which the oxygen content can be controlled and on to a fluorescent screen. This screen has the ability to fluoresce as a visible green light when excited by the invisible 1470 Å light. By using a photo tube, it is possible to measure

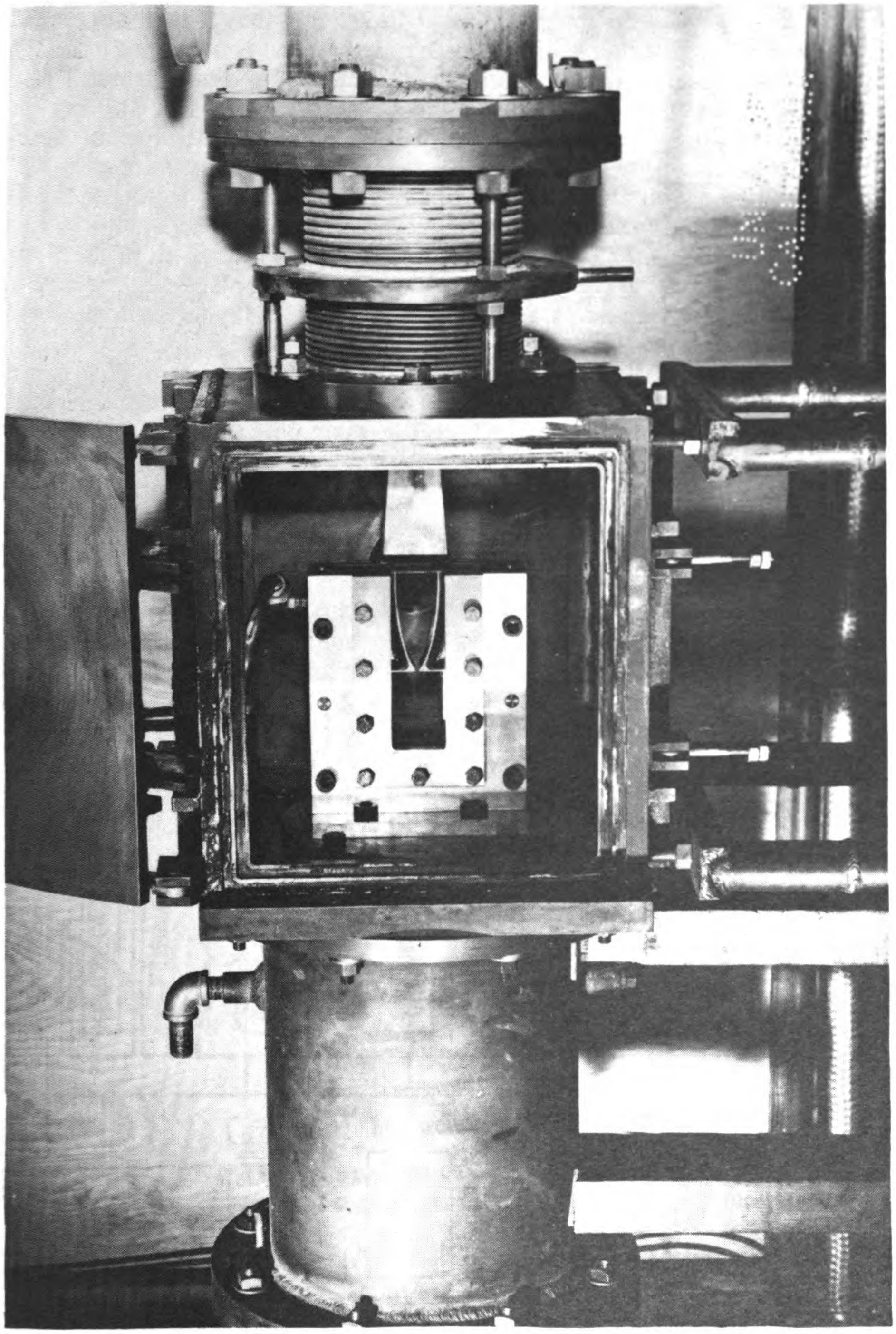
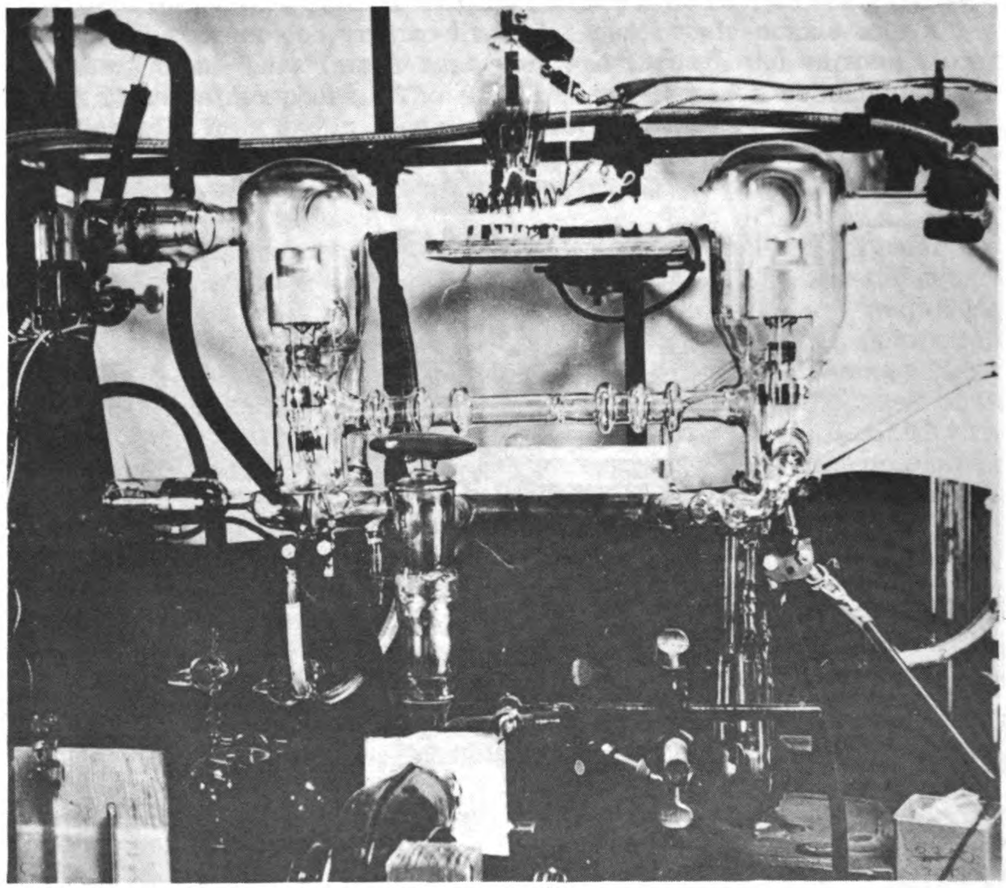


Fig. 8. One type of supersonic nozzle for the 1 in. x 1 in. tunnel.



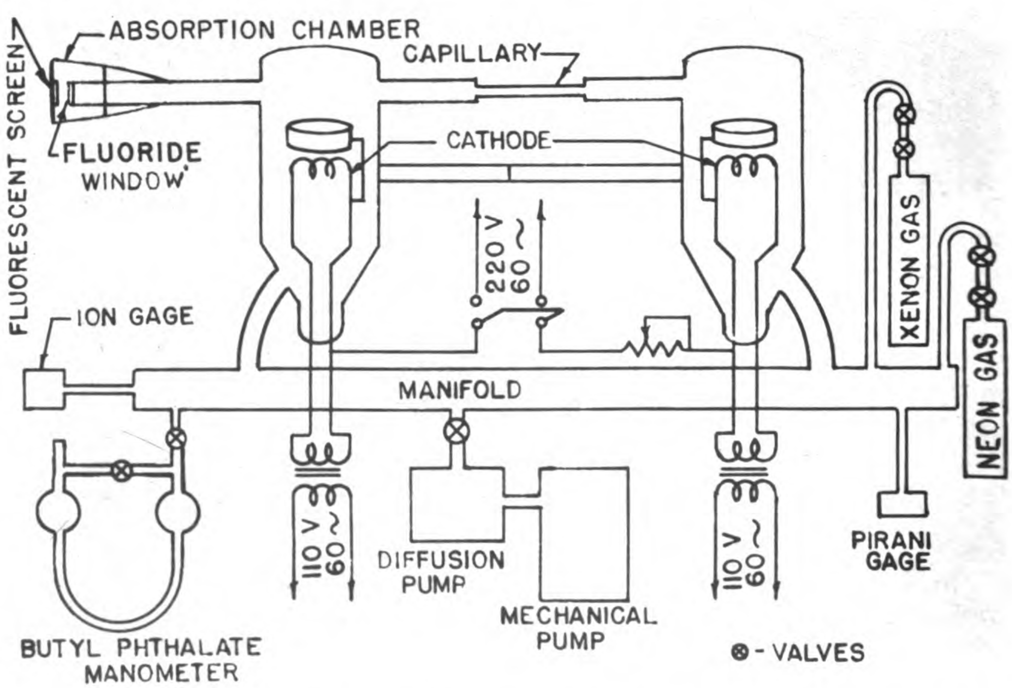


Fig. 9. Experimental xenon lamp. The discharge in the capillary tube provides the source of light which passes through a fluoride window into a test chamber in which the oxygen content can be controlled and on to a fluorescent screen.

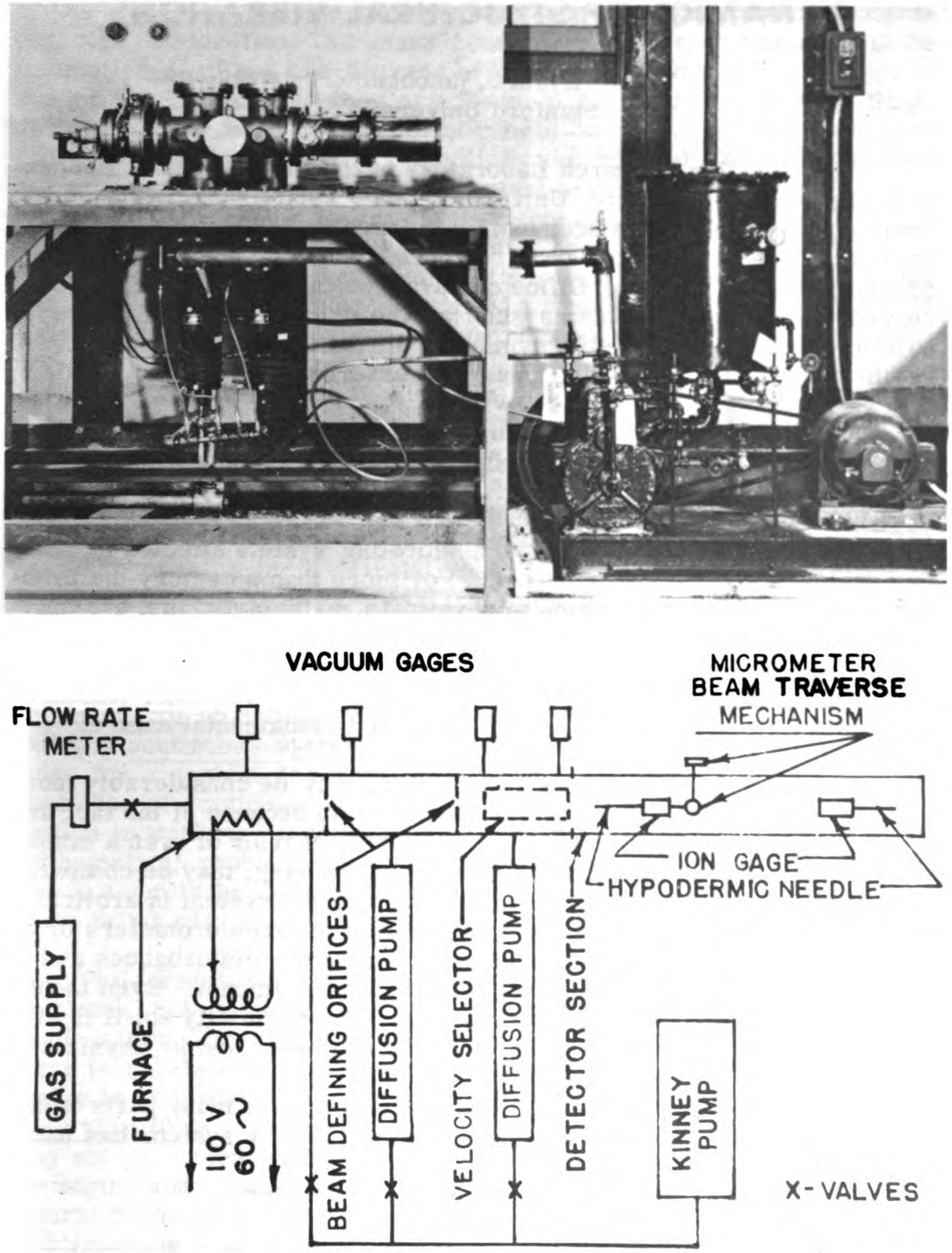


Fig. 10. Molecular beam equipment.

the amount of light transmitted through the oxygen chamber. Since the size of this chamber is the same order of magnitude as the cross-section of the medium tunnel, design data are being obtained for an optical system of this type to be operated in the experimental wind tunnels. Greater sensitivity may be obtained by using oxygen instead of air in the wind tunnel. No pictures of fluid flow have yet been taken.

The molecular beam equipment is shown in Fig. 10.

A full understanding of the phenomenon of fluid flow must be gained before we can tackle the basic investigations in heat flow.

DYNAMICS OF STRUCTURAL VIBRATIONS

Lydik S. Jacobsen
Stanford University

The Vibration Research Laboratory of the Department of Mechanical Engineering, Stanford University, was established with private funds about twenty years ago, mainly to investigate the fundamentals of the effects of earthquakes on structures. Prior to the advent of the present contract with the Office of Naval Research, the work was concerned mainly with problems such as the dynamics of multi-storied buildings, mass and elastic symmetry in buildings, the dynamics of earth-filled dams, and hydrodynamic pressures against a moving dam.

The effect of transient disturbances on structures is the subject of the investigation now being conducted at this Laboratory under ONR-sponsorship.

The fundamental problem of a vibrating system affected by some external disturbance is an old one. For more than a century the problem has attracted the attention of physicists, mathematicians, and engineers. Mathematical and experimental methods of dealing with problems regarding the disturbances of structures are well known, especially if the problem is mainly what is known as <u>linear</u>. The Vibration Research Laboratory is exploring new applications of a fundamental nature.

The dynamics of a particular system may be considerably more complicated than the statics of the same system because of the fact that time is an important variable. The dynamical behavior of even a simple system, for example, a weight suspended by a spring, may be comparatively complicated if the disturbance acting on the system is arbitrary. Systems of this nature find wide application as accelerometers or as displacement meters in the recording of seismic disturbances and of vibrations caused by unbalanced machinery and impact. Even though this application appears to be simple, and it is essentially so, it is still the subject of considerable study both by engineers and by physicists.

To go to another extreme, consider a system of many parts which are connected elastically with one another. Such a system has many

---

<u>L. S. Jacobsen</u> began his career in vibration research with Westinghouse in 1921. He is in charge of the Department of Mechanical Engineering at Stanford. He came to Stanford in 1924 and began his Stanford studies of structural vibrations in 1926. These studies have resulted in a number of theoretical as well as experimental papers that have influenced the aseismic design of buildings, bridges, and dams. He has been associated with the Seismological Division of the U. S. Coast and Geodetic Survey since 1930. In 1932 he held a Guggenheim Fellowship by which he became acquainted with the foremost structural laboratories in this country and in Europe. During the thirties a number of model experiments were undertaken at the Stanford Laboratory, resulting in practical modifications of building theory. His experience as a Commander in the U. S. N. R., from June 1943 to December 1945, has augmented his knowledge of vibration phenomena. He was in charge of vibration and noise reduction of all Navy vessels touching the Pacific Coast.

degrees of freedom and consequently many natural modes and frequencies of vibration. As many coordinates are required to describe the motion as there are degrees of freedom. Examples of this type of system are numerous; they are found in some of the delicate firing devices in ordnance, in instrument panels on airplanes, and in engines and their mountings. Even a building may be analyzed as a vibrating system, particularly if it is of the steel or reinforced concrete frame type with non-bearing walls. In the general case the dynamical behavior of a system of many degrees of freedom is complicated even though the disturbance acting on the system is simple. Assume, for example, that a particular system has five degrees of freedom. Five coordinates will be required to describe its motion and consequently five differential equations of motion will be involved. The system will have five natural modes of vibration and corresponding to these, five natural frequencies. A disturbance acting on the system will, in the general case, excite all five natural modes. The degree of excitation of each mode depends on the ratio of the frequency of the disturbance to the natural frequency of the mode and on the direction of the disturbance. If the disturbance is a simple harmonic motion or force, the response of the system is relatively simple, but if the disturbance is arbitrary or composed of many frequencies, as is often the case, then a quantitative analysis may be extremely laborious.

In the limiting case the system of many degrees of freedom becomes one of an infinite number of degrees of freedom. The latter is called a continuous system and mathematical methods different from those for a system of a finite number of degrees of freedom are used. Examples of continuous systems are found in beams and plates. If the system is uniform in distribution of mass and elastic properties, the mathematical problem may be comparatively simple, but if there is non-uniformity the mathematical solution may be hopelessly complicated. In the latter case resort must be made to model experimentation.

The foregoing has introduced some of the more general types of problems, but there are additional factors. A vibration problem may be classified either as transient or as steady-state. For example, if there is unbalance in the engine or in the propeller of a ship and if the engine is turning over at constant speed the ship is subjected to steady-state vibrations. These vibrations may be felt by personnel, or they may not be, depending on the magnitude of the unbalance, the speed of the engine and on the ratios of the disturbing frequencies to the various natural frequencies of the ship's hull. Moreover, when the engine is started or stopped or is in any way changed in speed, transient vibrations occur. The transient vibrations will eventually die out because of the inherent damping of the system. Transient vibrations are also caused by seaway and especially when a part of the rotating propeller is lifted out of the water.

A different type of system and disturbance is found in an aircraft-launched torpedo. When the torpedo strikes the water a violent impact occurs. The major forces acting to retard the torpedo on its entrance into the water last only for a very short period of time, but this disturbance is sufficient to excite all of the natural modes of vibration of the torpedo and its component parts. The impact problem is a problem in transient vibrations, and it can be a very complicated one. Steady-state vibrations are in general much simpler than transients. The analysis of the former can often result in rather simple expressions for recurrent maximum dynamic loads, but analysis of the transient state generally can go no further than to indicate the distortions as a function of time.

Another major classification, a most fundamental one, is the distinction between systems which are linear and those which are nonlinear. The basic difference lies in the form of the differential equations of motion. The principle of superposition holds for linear systems but does not hold for those which are nonlinear. Linear systems are much simpler to analyze than nonlinear systems and very much more is known about them. There are of course not many practical systems which are exactly linear, but many are sufficiently close to being linear, particularly if the displacements and stresses are "small." On the other hand, there are practical systems that cannot be assumed linear, even to a first approximation. These lie within the field of what is known as nonlinear mechanics. Nonlinearity may arise in the mass, in the restoring elements or elasticity, and in the damping of a system when the coefficients describing any one of these characteristics in the differential equations are functions of the motion itself. One of the most important forms of nonlinearity in a mechanical system is elastic nonlinearity. For example, a vibrating system with snubbing-springs or stop-springs, which act only when the distortions of the system exceed some designed values, is nonlinear; a beam vibrating so violently that its stresses pass beyond the elastic limit is also nonlinear.

The program of the Vibration Research Laboratory is mainly concerned with the transient state in linear problems, although some classes of nonlinear problems are also being investigated. The following is a resume of the problems which are now in progress or which have recently been completed under the Navy contract:

Problem 1: Steady Forced Vibration of a System with Varying Mass. The mass of the single-degree-of-freedom system varies in a stepwise or sudden manner with change in the sign of velocity, that is, when the velocity is positive, the mass is a constant m_1 and when it is negative the mass is a constant m_2. Furthermore, when the velocity is positive the system does work in lifting a weight. The external disturbance acting on the system is a simple harmonic motion of constant frequency which acts on the restoring element or elastic member.

The system is a highly idealized version of a reciprocating pump, but the results are not directly applicable to a deep-well pump since the long sucker rod and fluid column of the latter are continuous systems and since certain other factors have been omitted. The purpose of our studies is to reduce the system to its bare essentials in order that attention can be focused on the nonlinearity of the problem and on the various types of motions which are possible. Analytical solutions for four distinct classes of motions have been derived. Work is now in progress on checking these solutions by mechanical-experimental methods. While the problem is, in a sense, a steady-state phenomenon it actually consists of two repeated transients.

Problem 2: Response of an Elastically Nonlinear System to Transient Disturbances. The problem is that of an undamped, elastically nonlinear, single-degree-of-freedom system subjected to transient disturbances in the form of ground or base motions. The ground motions have been limited to single pulses of various shapes. The nonlinearity of the system's restoring element is symmetrical with respect to the instantaneous position of the moving ground and involves an abrupt but constant increase in stiffness at a given relative displacement between the ground and the mass of the system. Systems of this general type are common enough in practice.

A rather complete quantitative survey of the response of the system has been made using graphical and experimental (mechanical) methods. The graphical method is an adaptation of the rotating vector method of representing the vibration of a single-degree-of-freedom system. It is theoretically exact for systems with stepped variation in "spring constant" which are subjected to external disturbances composed of rectangular, arbitrary shapes. The method is not new, but the simplicity and directness with which a wide variety of problems can be solved do not seem to be appreciated generally.

Problem 3: Transverse Vibration of a Two-Span Beam Under the Action of a Moving Force. The two-span beam is symmetrical, continuous, and restrained at the three supports only against transverse displacement (a simply-supported beam). Its proportions are slender, and damping is assumed to be negligible. The external disturbance is a transient one. It consists of a constant transverse force which moves across the beam with uniform velocity.

The problem divides into two parts, first, to find the shapes and frequencies of the natural modes of vibration, second, to apply a "forcing function" which describes the progression of the disturbing force along the beam and to determine either the deflections or the stresses caused by this force. When the velocity with which the force moves along the beam is low, there is no appreciable dynamic effect and the stresses correspond to what are known as "crawl stresses." However, as the velocity is increased the dynamic stresses increase until they reach values of the order of 2.5 times the crawl stresses when the velocity is in the neighborhood of resonance with the beam's fundamental natural mode. For greater values of velocity the stresses are in general less than this first maximum, but other lesser maxima are reached as the velocity is increased through values causing pronounced excitation of the higher natural modes.

An exact analytical solution has been completed; it is supplemented by mechanical-electrical experimentation. The experimental apparatus has been used as a "computing machine"; it performs automatically the laborious calculations involved in adding the terms of the infinite series of the analytical solution.

Two new problems (4 and 5) relating to Problem 3 but involving different forcing functions are in progress.

Problem 4: Transverse Vibration of a Two-Span Beam Under the Action of a Moving Oscillating Force. Instead of a constant force, a sinusoidally varying force moves with constant velocity across the beam. Such a force arises, for example, in unbalanced driving wheels of locomotives. The methods and general conclusions are similar to those for Problem 3 except that in Problem 4 relatively higher stresses may be expected and large magnifications of stress occur at lower values of velocity. An exact analytical solution has been completed and experimental work is in progress.

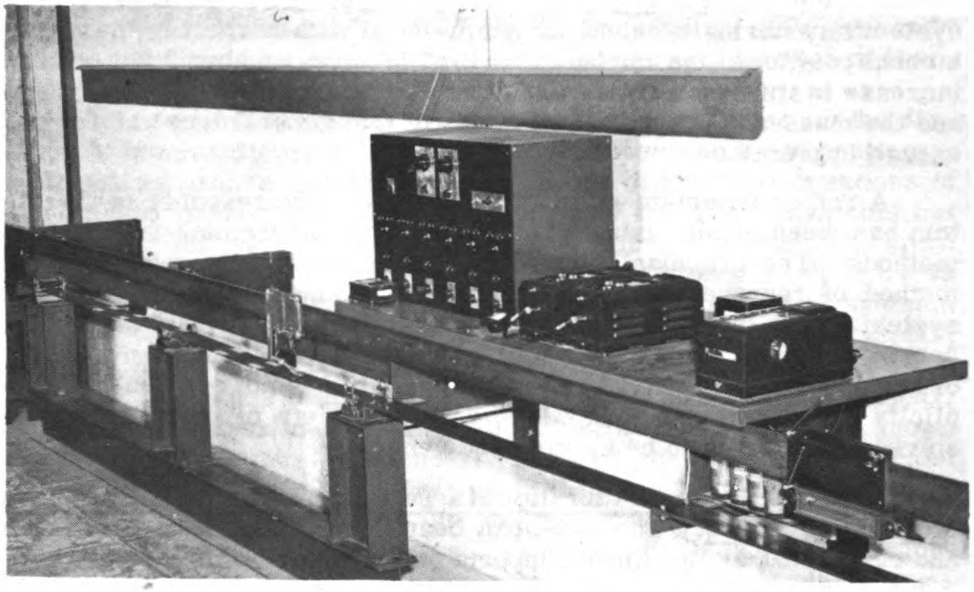


Fig. 11. Part of the equipment for Problem 3. The two-span beam appears at left center. Five sets of stress pick-ups (wire-resistance strain gages) are distributed along the beam. The outputs from the pick-ups are fed into the selecting and balancing circuits contained in the large box and thence into the amplifiers and oscillograph. The carriage which transports the moving force along the beam appears at about the center of the first span of the beam. The carriage is accelerated by means of an elastic cord (nylon mono-filament), dynamometer, and winch system. Immediately prior to the instant at which the carriage enters the test section, the nylon cord disengages itself and the carriage proceeds at nearly uniform velocity across the beam. After crossing the beam the carriage enters a frictional arresting device seen in the left background. Velocities up to about 7.0 feet per second can be attained. The same equipment is used, with some modification, in Problems 4 and 5.

Problem 5: Transverse Vibration of a Two-Span Beam Under the Action of a Moving Mass Load. The very important difference between this problem and Problem 3 is that the moving load is a mass load rather than a simple force without mass. The force exerted by the moving mass on the beam is composed of two parts, a gravity force and an inertia force which is proportional to the mass of the load and to the transverse acceleration of the beam. The natural frequencies and modes of vibration of the beam-load system are not dependent on the beam alone but are functions also of the position of the load along the beam, that is, they are functions of time. The solutions cannot be superimposed on those for Problems 3 and 4. It is not expected that exact analytical solutions can be developed for this problem, but experimental solutions can be obtained rather readily with the apparatus on hand and from them it should be possible to arrive at approximate analytical solutions. The first step will be to study the changes in the beam's natural frequencies and modes of vibration as the position of the load and the ratio of the weight of the load to the weight of the beam are changed.

Problems 3, 4, and 5 are extensions to the two-span case of work done on the forced vibration of single-span beams by Kryloff, Timoshenko, Inglis and others.

ON THE NAVAL RESEARCH RESERVE

Secretary of the Navy John L. Sullivan addressed officers and guests of the U. S. Naval Reserve Battalions, North Hollywood, California recently. A few of his remarks regarding the Naval Reserve and particularly those concerning the Naval Research Reserve and the Office of Naval Research will be of interest to our Research Reserve readers:

> "At the end of the last war, two out of every three men in the naval establishment were technicians. Many had to know how to operate radar and sonar. Many were specialists in hydrodynamics and aerodynamics. Others learned how to fire rockets, operate jet and diesel engines, launch guided missiles. Most of them were trained by synthetic devices which simulated the actual conditions they were to meet in combat. On board ship, they lived surrounded by the most ingenious machinery and equipment ever assembled in the field of electricity, metallurgy, optics, mechanics, radio and sound.
>
> "Today your Navy is keeping pace with current developments in these fields and we are leaning very heavily upon our Reserve components and on outstanding technicians and scientists who are members of the Naval Reserve for assistance.
>
> "The Office of Naval Research has sponsored more than twelve hundred research projects in a majority of the major academic, government and industrial laboratories in the nation. Last year we organized the Naval Research Reserve, which has a proposed strength of five thousand men and women. Its mission is to provide an adequate trained force of Reserve personnel now in civilian jobs who would in the event of emergency be available for immediate assignment to activities under the control of the Office of Naval Research.
>
> "The first Research Reserve unit was activated in Washington last year and soon afterward two more units were organized here in California -- one at San Francisco and the other at the University of California at Berkeley. We have now activated 26 of these units; our eventual goal is to organize 100 of them. I am sure you all appreciate their importance to the Navy and to the security of our country."

News of meetings having come in from several of the units. A random sample of some of the topics discussed or scheduled for discussion are given, to stimulate the other units in making their plans.

Volunteer Reserve Unit 3-1 heard an address recently by Capt. W. H. Leahy, USN, Assistant Chief for Research, ONR. The meeting of the New York Naval Research Reserve group was held at Cornell University Medical College. The group comprises former Naval officers currently engaged in civilian scientific pursuits. Cdr. James D. Hardy, USNR, of the Department of Physiology, Cornell University Medical College, is commanding officer of the New York unit.

Capt. Leahy's subject was "The Navy in Research." He spoke of the Navy's stake in science, of its dependence on scientific accomplishments, and of the establishment of ONR at the war's end because of this dependence. Most of his talk was devoted to a description of specific

Naval problems on which work is now under way and in which the Naval Research Reserve might assist the Navy.

Four such problems described by Capt. Leahy were antisubmarine warfare, atomic warfare defense, new materials to withstand high temperature demands, and protection of men against the severe environments demanded by modern warfare. He called upon the reserves to take an active interest in the solution of these and other urgent Navy problems. He indicated as one of the advantages of the Navy's research program the large number of scientists it attracts to the Navy team, and that through the Naval Research Reserve this number is increased.

Volunteer Reserve Unit 12-4, Fresno, California, Cdr. Ralph Ajack, USNR, Commanding Officer, heard Lt. Comdr. B. M. Fisher, USNR, speak recently on "Psychological research on the effect of environmental variables." He covered such topics as the effects of high humidity and temperature and high concentrations of carbon dioxide in the atmosphere. The same unit held a seminar on the subject of radioactivity where the geiger counter was demonstrated. "U. S. Naval Research Laboratory" was discussed at another meeting by Lt. Owen F. Foin, USNR, associate professor of physics at Fresno State College. "Engineering department of a large carrier" was the subject of another meeting. The speaker, Capt. George M. Bowman, USNR, is city electrical engineer for Fresno and was engineering officer on USS Saratoga during World War II.

Volunteer Reserve Unit 12-1 at San Francisco, having a sub-unit at the University of California, Berkeley, Cdr. J. E. Laurance, USNR, Commanding Officer, and, as Secretary Sullivan mentioned, one of the first units to be organized, has likewise reported meetings scheduled on similar subjects. Mr. Paul William, chemist and metallurgical engineer with Eitel-McCullough, San Bruno, spoke on the subject of "Vacuum tubes, materials, and problems." Techniques of war-damage analysis was the topic of an address by W. E. Strope, Head, Engineering Applications Division, Naval Radiological Defense Laboratory. Mr. Strope discussed such work as fire-fighting on aircraft carriers.

Volunteer Reserve Unit 12-3, Stanford University, Palo Alto, Calif., Cdr. L. S. Jacobsen, USNR, Commanding Officer. This unit heard a discussion on radioactive carbon in cancer metabolism by Prof. H. B. Jones, Professor of medical physics, and assistant director of the Donner Laboratory, University of California. The use of radioactive carbon labeled compounds was discussed in the study of actively growing cancer.

Human Servomechanisms and their reactions in response to starvation, thirst, and injury was the subject discussed by Prof. J. M. Crismon, Professor of Physiology, Stanford University.

Exploring the upper atmosphere by radiodetection of meteors was discussed by Prof. O. G. Villard, Assistant Professor of electrical engineering, Stanford University.

A recent Princeton meeting of Volunteer Reserve Unit 4-1 gets under way. Left to right: Ensign George Boswell, USNR, New York Branch Office, Cdr. R. S. Woodbury, Director of Research Reserve, Capt. F. M. Eggers, Commanding Officer, New York Branch Office, ONR, and Lt. Cdr. Paul Busse, Commanding Officer, Princeton Unit 4-1.

Volunteer Reserve Unit 4-1, Princeton, N. J., Lt. Cdr. Paul Busse, USNR, Commanding Officer, lists a number of interesting topics, "Project Skyhook Movies," "ONR and the Navy," "Navy Patents and Inventions Policy," "Operational Readiness-Evaluation and Research," "An Administrator Looks at Research," "Joint Research and Development Board," "Feasibility Projects," "Human Engineering and CIC," "Atomic Energy for Power," "Jet Propulsion and Guided Missiles," and "Pro and Anti Sub-surface Warfare.

NEW RULING ON RESERVIST RETIREMENT

Defense Secretary Forrestal said on 15 March the controller general had ruled that a member of the armed forces Reserve with 20 years' satisfactory service is entitled to retirement benefits at the age of 60 regardless of his status then.

This is, in effect, a reversal of the controller general's office's previous stand in regard to members of the National Guard and the Organized Reserves.

VOLUNTEER RESEARCH RESERVE UNITS

DESIGNATION	TYPE	LOCATION	COMMANDING OFFICER
1-1	Composite	Navy Headquarters Boston, Mass.	Capt. J. W. Hammond, USNR
3-1	Composite	Cornell University Medical College 1300 York Ave. New York 21, N. Y.	Cdr. James D. Hardy, USNR
3-2	Special Devices	Special Devices Center Sands Point, Port Washington Lond Island, N. Y.	Cdr. Len E. Yoder, USNR
3-3	Composite	Stromberg-Carlson Corp. Rochester, N. Y.	Cdr. Henry C. Sheve, USNR
4-1	Composite	Princeton University Princeton, N. J.	LCdr. Paul Busse, USNR

DESIGNATION	TYPE	LOCATION	COMMANDING OFFICER
4-2	Composite	Franklin Institute Electronics Section Philadelphia, Pa.	LCdr. William G. Amey, USNR
W-1	Composite	Dept. of the Navy Washington, D. C.	Cdr. F. C. Wiesner, USNR
5-1	Composite	University of Virginia Charlottesville, Va.	Lt(jg) P. B. Buck, USNR
5-2	Composite	Virginia Polytechnic Institute Blacksburg, Va.	LCdr. E. D. Harrison, USNR
6-1	Composite	Georgia Institute of Technology Atlanta, Ga.	Cdr. James E. Boyd, USNR
6-2	Composite	Alabama Polytechnic Institute Auburn, Ala.	Lt. James E. Land, USNR
6-3	Composite	Oak Ridge, Tenn.	LCdr. David J. Mallon, USNR
6-4	Composite	University of Florida College of Engineering Gainesville, Fla.	Lt. J. S. Johnson USNR
9-1	Composite	Technological Institute Northwestern University Evanston, Ill.	Capt. George G. Lamb, USNR
9-2	Composite	University of Illinois Urbana, Ill.	LCdr. A. C. Williams, USNR
9-3	Composite	University of Michigan Ann Arbor, Mich.	Cdr. Charles M. Davis, USNR
9-4	Composite	Ohio State University Columbus, Ohio	LCdr. Karl E. Krill, USNR
9-5	Composite	Iowa State College Dept. of Mathematics Ames, Iowa	LCdr. O. C. Kreider, USNR
9-6	Composite	University of Minnesota Minneapolis, Minn.	LCdr. J. A. Wise, USNR
9-7	Composite	Purdue University Biological Annex Lafayette, Ind.	Lt. L. M. Baker, USNR
11-1	Special Devices	510 W. 6th St. Los Angeles, Calif.	LCdr. H. J. Pedersen, USNR
11-2	Composite	680 E. Colorado Drive Pasadena, Calif.	LCdr. J. H. Biggar, USNR
11-3	Composite	University of California Los Angeles, Calif.	Cdr. L. P. Delsasso, USNR
12-1	Composite	801 Donahue St. San Francisco, Calif.	Cdr. J. E. Laurance, USNR
12-1 (sub)	Composite	University of California Berkeley, Calif.	Cdr. Carl J. Vogt, USNR
12-2	Biological Sciences	University of California Berkeley, Calif.	LCdr. Nello Pace, USNR
12-3	Composite	Stanford Univ. Stanford, Calif.	Cdr. L. S. Jacobsen, USNR
12-4	Composite	Fresno State College Fresno, Calif.	Cdr. Ralph A. Jack, USNR
13-1	Composite	University of Washington Seattle, Wash.	Cdr. H. S. Bennett, USNR
13-2	Composite	95 Atkins Ave. Richland, Wash.	Lt. W. W. Gonder, USNR

U. S. GOVERNMENT PRINTING OFFICE : O—1949

LIST OF FIGURES

Note to Contributors

Manuscripts received for Research Reviews sometimes spell trademark names without the initial capital letter. Owners of some trademarks have lost their rights by allowing this practice to continue until the name became a common noun. Two familiar examples are vaseline and cellophane. As a result of such a situation, the word, nylon, was given to the world as a common noun. In recognition of owners' rights and for the information of readers, the initial capital should never be omitted in trademark names (even if foreign). In doubtful cases, the author may mark the manuscript with a query for the Editorial Branch, ONR.


SHARE
THIS
COPY