ENGINEERING | AND | SCIENCE

October 1961

Chemicals and temperature . . . page 11

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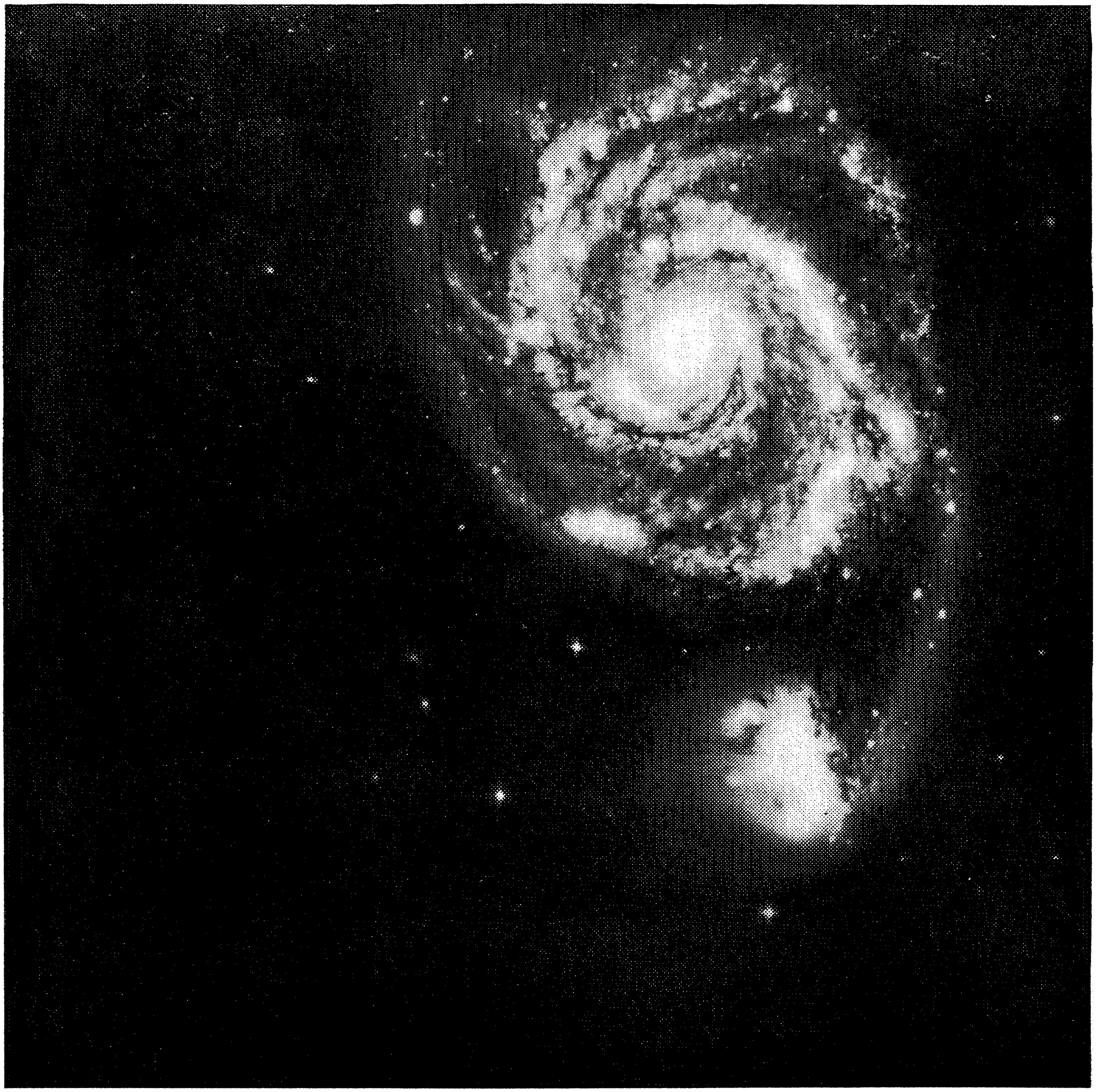

How cold is up? We know that outer space can never be colder than minus 459.72° Fahrenheit—that's absolute zero, the point at which all molecular motion ceases. We don't know what coldness like this will do to materials, but we're finding out. Scientists are using a heat exchanger to produce temperatures as low as minus 443° Fahrenheit. They test materials in this extreme cold and see how they perform. Out of such testing have already come special grades of USS steels that retain much of their strength and toughness at −50° or below; steels like USS "T-1" Constructional Alloy Steel, TRI-TEN High Strength Steel, and our new 9% Nickel Steel for Cryogenics applications. And the heat exchanger to produce the −443° Fahrenheit is Stainless Steel! No other material could do the job as well. Look around. You'll see steel in a lot of places—getting ready for the future. ■ For information about the many career opportunities, including financial analysis or sales, write U. S. Steel Personnel Division, Room 6085, 525 William Penn Place, Pittsburgh 30, Pa. U. S. Steel is an Equal Opportunity Employer. USS, "T-1" and TRI-TEN are registered trademarks.

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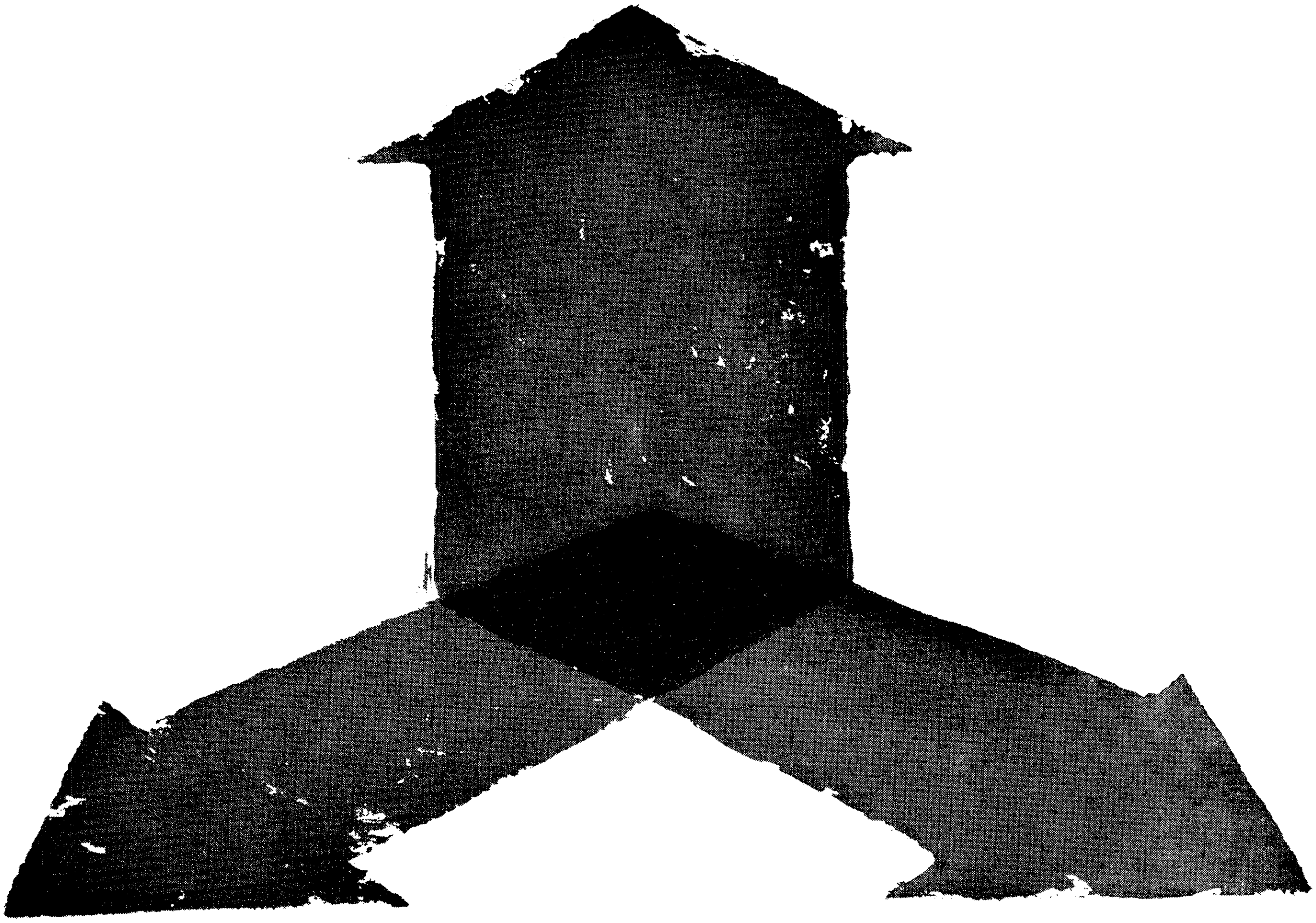
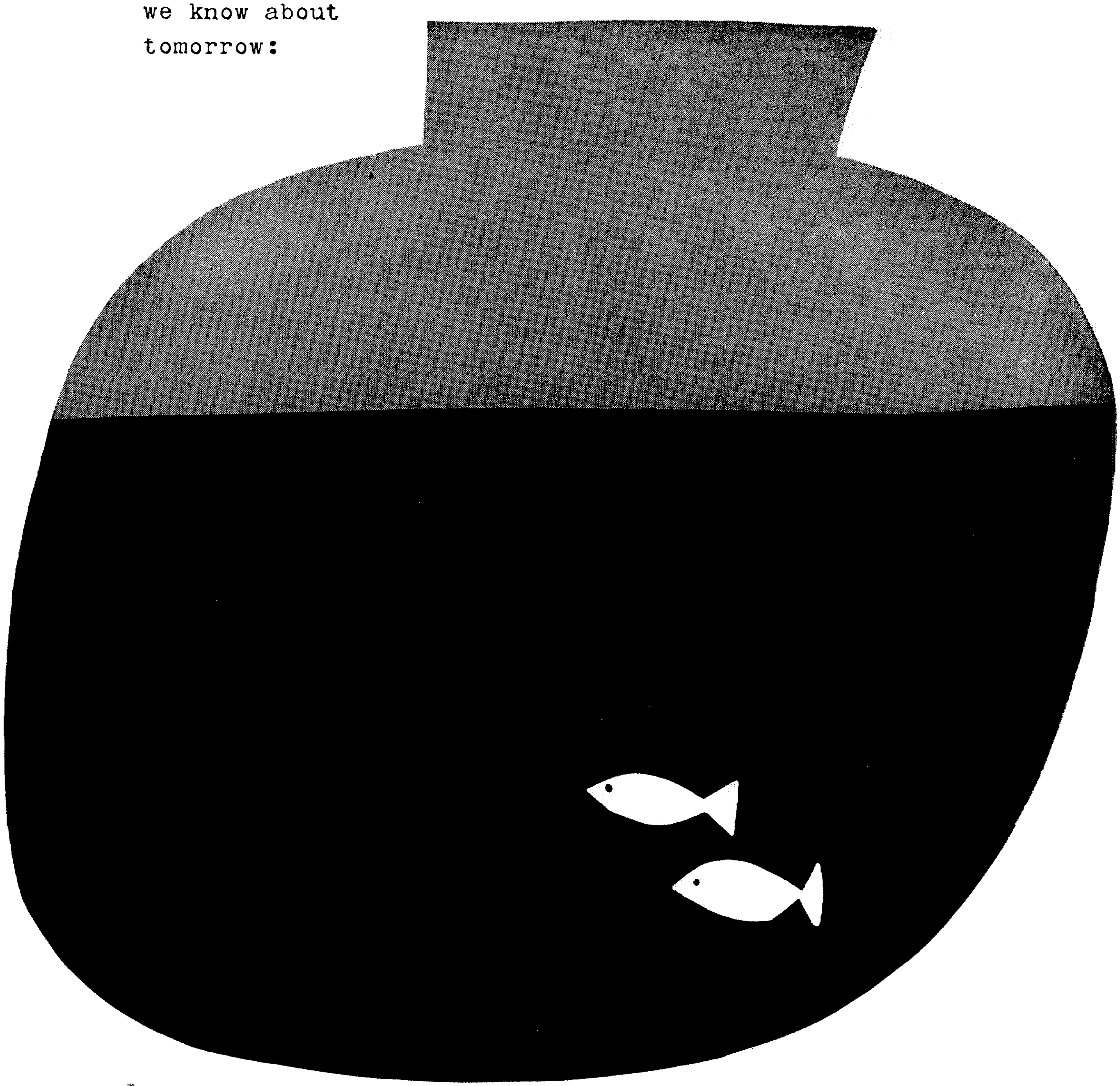


Things
we know about
tomorrow:



Man is like a Goldfish in a Bowl of Ink...His view of the "ultraviolet universe" is shut off by the blanket of air which surrounds him.

The earth's atmosphere is like the ink in a goldfish bowl. It absorbs so much of the ultraviolet light from outer space that little gets through to show us what lies out there.

But now, an electronic imaging tube, sensitive to this ultraviolet light has been developed by Westinghouse Research scientists. Westinghouse is working with the Smithsonian Institution and the National Aeronautics and Space Administration to mount these tubes in satellites so that they can "see" in outer space and radio their findings back to earth.

Every time mankind removes the limitations on human sight...with the telescope, the microscope, the fluoroscope and electronic imaging tubes...we find things which have a profound effect upon our lives.

This is just one of the exciting things going on at Westinghouse, one of the many reasons why Westinghouse is the best place for talented engineers. See our representative when he is on your campus, or write to L. H. Noggle, Westinghouse Educational Department, Pittsburgh 21, Pennsylvania.

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ENGINEERING | AND | SCIENCE

OCTOBER 1961 VOLUME XXV NUMBER 1

On Our Cover

Hendrik J. Ketellapper, research fellow in biology, and E. E. McKinzie, research aide, spray semi-dwarf pea plants with chemicals—as part of a research program in Caltech's plant laboratories to counteract the effects of undesirable temperatures on plants.

This research raises the possibility of saving crops or extending growing seasons by the use of chemical sprays. In "Chemical Attack on the Thermometer," on page 11, Dr. Ketellapper reports on the current status of this work.

Cracked Ice

Science and national defense provide increasing incentives for geological and engineering research in the polar regions – which accounts for the fact that C. J. Pings, associate professor of chemical engineering, has spent part of several summers in the crevasses of a Greenland glacier, making measurements of movement, strain, and temperature. In "Living on Cracked Ice," on page 16, Dr. Pings discusses his research and experiences. The article has been adapted from a talk given by Dr. Pings at the Annual Alumni Seminar at Caltech on May 6.

Picture Credits:

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Books

An Introduction to Spin-Spin Splitting in High Resolution Nuclear Magnetic Resonance Spectra

by John D. Roberts

W. A. *Benjamin, Inc.* . . . *$4.95*

Reviewed by Eugene I. Snyder research fellow in chemistry

In his second book on nuclear magnetic resonance spectroscopy, John Roberts, Caltech professor of chemistry, bridges the gap between a formal quantum mechanical treatment of nuclear magnetic resonance spectral analysis and its complete omission. Assuming no prior knowledge of quantum mechanics or the mathematics thereof by the reader, Prof. Roberts guides him with a gentle, but firm, touch from some simple tenets of quantum mechanics through their application to spectral analysis. This is done with the clarity, so seldom attained, which befits a worker with extensive experience in the field.

The many physical interpretations and problem sets liberally interspersed throughout the book will aid immeasurably in bringing a practical, working knowledge of nuclear magnetic resonance spectroscopy to those who are novices, and greater understanding and insight to those—particularly organic chemists – using this technique as an analytical tool.

Man and Dolphin

by John C. Lilly, M.D.

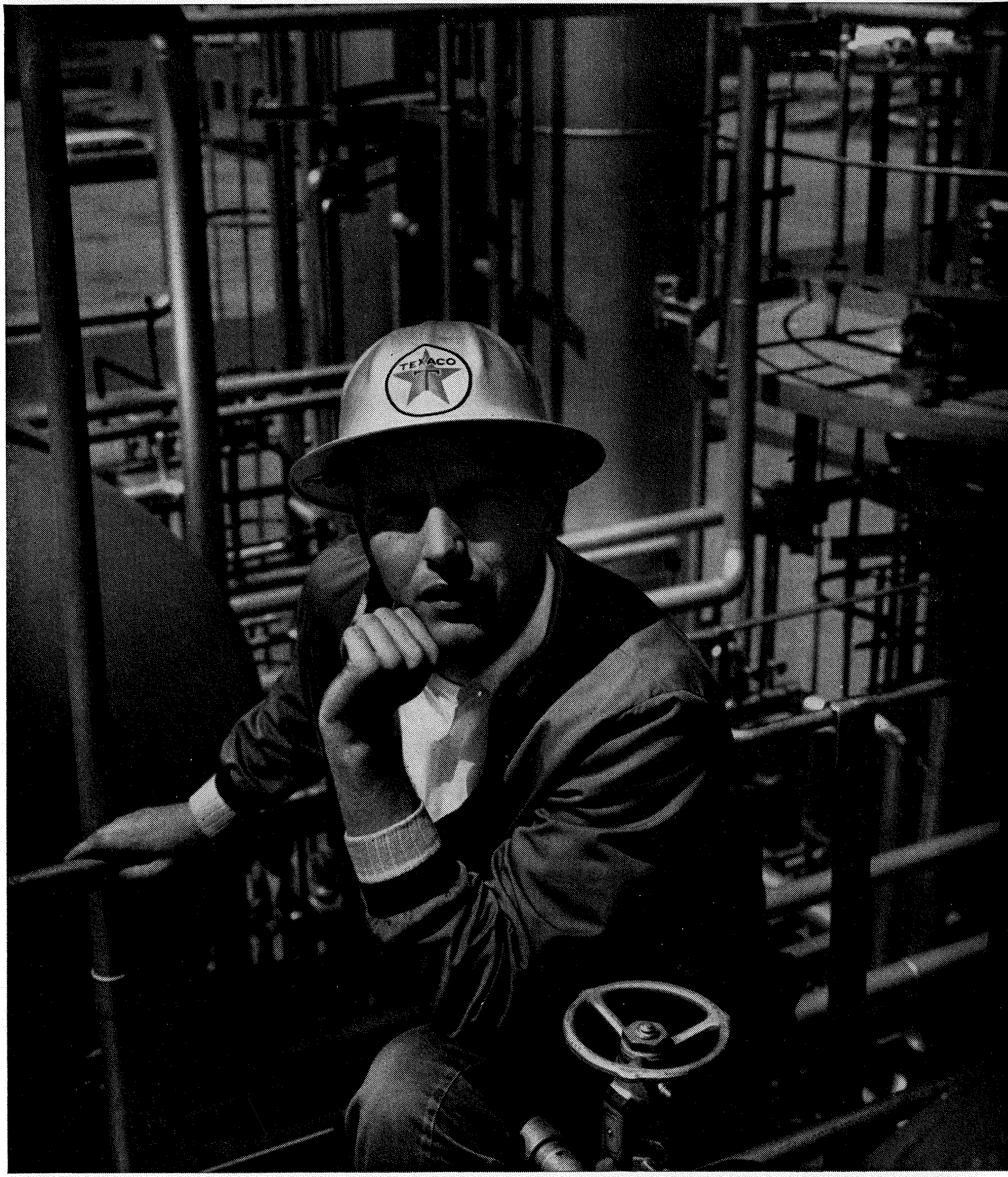
Doubleday *$4.95*

"Within the next decade or two the human species will establish communication with another species: nonhuman, alien, possibly extraterrestrial, more probably marine; but definitely highly intelligent, perhaps even intellectual. An optimistic prediction, I admit. In this book I have summarized the basic reasons for my beliefs and presented some evidence for the validity of the prediction. In a way this is a crude, elementary handbook for those humans who are interested in the realization of such communication."

This prefatory prediction sets the stage for Dr. Lilly's own absorbing account of his much-publicized research experiments with dolphins.

In searching for a species with which to attempt communication, John Lilly (Caltech '38) set out to find one with a brain equal to ours in size and complexity, with a body not too much larger than the human body, with a friendly attitude toward humans, and with the ability to vocalize within the same ranges and parametric sets of

continued on page 8


TEXACO

variables that the human uses.

The dolphin seemed to meet all these requirements, and in 1955, at Marineland, Florida, Dr. Lilly began his experiments with these creatures. In 1959 the work was transferred to the Communication Research Center, set up by Dr. Lilly in St. Thomas in the Virgin Islands.

In his book Dr. Lilly describes this fascinating project in colorful detail and in a straightforward no-nonsense manner that not only makes for fine reading, but puts this unique research back into the perspective that has been missing from most of the press accounts.

Symbols, Signals and Noise

by J. R. Pierce

Harper & Brothers $6.50

Reviewed by David Braverman
asst. professor of electrical engineering

This well-written book which discusses the origins, theoretical basis and applications of the theory of information, developed by Shannon in 1948, forms an excellent introduction to modern statistical communication theory. The book leads one from the early work in telegraphy, through the derivation of Shannon's model of the communication system, to the consequences and applications of information theory. The subject matter of the book forms the cornerstone of modern statistical communication theory.

The author has undertaken a difficult task in attempting to write a book on information theory for the general public, but for the most part he has succeeded.

Dr. Pierce received his BS (1933), MS (1934), and PhD (1936) degrees from Caltech. Because of his work in information theory and his close associations with the pioneers of the theory at Bell Telephone Laboratories, Dr. Pierce is well qualified to write an exposition of the theory.

The book is especially recommended for the scientist or lay person with a knowledge of mathematics and a desire to learn of the applications, origins, and limitations of information theory. Anyone looking for an introduction to the broad field of modern statistical communication theory would also find the book interesting.

MH COLLEGE DIVISION

PEACETIME USES OF OUTER SPACE

Edited by SIMON RAMO, Thompson Ramo-Wooldridge, Inc. 295 pages, $6.95.

This remarkable volume brings together outstanding scientists, educators, politicians, and businessmen for an examination of the coming space age. Emphasizing the peacetime, non-military aspects of space technology, the book seeks to heighten public responsiveness to the full impact of science and technology in shaping our future. Contributors include: Leston Faneuf, J. H. Doolittle, Lloyd V. Berkner, Congressman Overton Brooks, Ralph J. Cordiner, Willard F. Libby, Vice Admiral John T. Hayward, Joseph Kaplan, Morris Neiburger, Brigadier General Don D. Flickinger, Leo Goldberg, Edward Teller, and Frederick R. Kappel.

ELECTROMAGNETIC FIELDS AND WAVES

By ROBERT V. LANGMUIR, California Institute of Technology. 227 pages, $9.75.

A senior or first-year graduate text for courses in electromagnetic theory. The book covers: electrostatics, radiation including plane waves, waveguides, sperical radiation, and propagation in unusual structures such as over the surface of the earth. Eddy current problems are extensively discussed and a short treatment of traveling and standing waves is given.

GOUND SUPPORT SYSTEMS FOR MISSILES AND SPACE VEHICLES

By KENNETH BROWN and PETER B. WEISER, University of California, Los Angeles. *University of California Engineering Extension Series.* Available now.

Presenting a complete description of the systems required to support either a missile or a space vehicle. Directed toward the engineer having no prior acquaintance with ground support systems, the text approaches the system as a whole unit—assuming that the missile is merely one small portion and that each of the subsystems involved is merely an integral part of the overall system. All subsystems are considered with full discussions of recent advances.

MECHANICAL BEHAVIOR OF MATERIALS AT ELEVATED TEMPERATURES

Edited by JOHN E. DORN, University of California, Berkeley. 544 pages, $14.50.

A senior-graduate text and reference book containing a series of coordinated chapters by nationally recognized authorities on various aspects of the scientific basis and engineering application of the latest information on high temperature behavior of materials. The major intent of the book is to provide a systematic background for the scientist and engineer in dislocation theory and its application to creep and related high temperature properties.

COMPUTER-CONTROL SYSTEMS TECHNOLOGY

Edited by C. T. LEONDES, University of California, Los Angeles. *The University of California Extension Series.* 649 pages, $16.00.

This book, developed from a series of lectures offered at various centers in California, combines a unified, integrated treatment of computer-control systems technology with the presentation of a number of currently significant applications. The first sections of the book deal with the theory of digital and analog computers. Then control theory is studied. Finally these two fields are blended by considering the development of some systems of varying degrees of difficulty.

PLANNING A COMPUTER SYSTEM: Project Stretch

Edited by W. BUCHHOLZ, IBM Corporation. Available in January, 1962.

This book is primarily concerned with the selection of an instruction set and related functional characteristics of a high-speed digital computer. The specific subject of the work is the powerful and highly sophisticated computer: the IBM 7030. The authors of individual chapters have actively participated in the design project developing this computer and the text thus reflects the substance of direct personal experience. Reasons are given for various design choices and compromises between conflicting requirements are analyzed. Numerous original ideas discussed.

THERMAL REGIMES OF COMBUSTION

By L. A. VULIS; translated from the Russian by GLENN WILLIAMS, Massachusetts Institute of Technology, and others for the project SQUID, Princeton, N.J. 299 pages, $7.50.

ELECTROMECHANICAL SYSTEM THEORY

By HERMAN E. KOENIG, Michigan State University; and WILLIAM A. BLACKWELL, General Dynamics Corporation. *The McGraw-Hill Electrical and Electronic Engineering Series.* 520 pages, $14.50.

LINEAR VACUUM TUBE AND TRANSISTOR CIRCUITS: A Unified Approach to Linear Active Circuits

By A. J. COTE, JR. and J. BARRY OAKES, The Johns Hopkins University. *The McGraw-Hill Electrical and Electronic Engineering Series.* 411 pages, $10.75.

TECHNICAL REPORT WRITING, Second Edition

By FRED H. RHODES, Cornell University. 168 pages, $5.50.

RECENT ADVANCES IN HEAT AND MASS TRANSFER

Edited by J. P. HARTNETT, University of Minnesota. 404 pages, $9.75.

SYNTHESIS OF OPTIMUM CONTROL SYSTEMS

By SHELDON S. L. CHANG, New York University. 381 pages, $11.75.

FUNDAMENTALS OF HEAT TRANSFER

By GROBER, ERK, and GRIGULL; translated from the German by J. R. MOSZYNSKI, Case Institute of Technology. *McGraw-Hill Series in Mechanical Engineering.* Ready in November, 1961.

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Engineering And Science
October 1961, Volume XXV, No. 1

Chemical Attack on the Thermometer

Research in Caltech's plant laboratories shows that chemicals can prevent plant damage caused by extreme temperatures

by Hendrik J. Ketellapper

Recent experiments in Caltech's plant research laboratories indicate that the damage to plants caused by temperature extremes can be prevented – either partially or completely – by spraying the leaves of the plants with solutions of organic nutrients. These results suggest the possibility of new agricultural chemicals to protect crops during periods of adverse climatic conditions.

Environment determines the distribution of plant species as well as their growth and development. Environment, of course, consists of such things as the type of soil, the supply of nutrients and water, rainfall, temperature and daylength. Generally, temperature and water are decisive, because their extremes determine the length of time during which plants can fix light energy to be stored in the form of chemical energy. In an agricultural system, the nutritional status and water supply may be adapted to the crop grown by providing fertilizers and irrigation water. Therefore, temperature is a very important regulating factor of plant growth

A vast amount of effort has gone into the investigation of the temperature requirements and tolerances of plants. Much of this kind of work has been carried out in Caltech's climate-controlled greenhouses, the Earhart Plant Research Laboratory.

The present experiments were also carried out in the Earhart Laboratory, as part of a five-year investigation, supported by the Rockefeller Foundation, of the nature of the responses of plants to climate ("The Chemical Cure of Climatic Lesions," by James Bonner – *E&S*, March 1957).The specific purpose of this investigation was to try to answer the questions: "What goes wrong with the plant when it is grown in unfavorable temperature conditions?" and "How does the plant sense or measure temperatures?"

Plants are affected by temperature in many ways. One relatively complicated way involves rhythmic processes in the plant ("The Biological Clock," by Hendrik J. Ketellapper – *E&S*, November 1960). Another way involves the chemistry of the plant.

The first step in this chemical research consisted in the formulation of a working hypothesis – a hypothesis in two parts.

1. It is assumed that unfavorable temperature conditions affect specific biochemical events and cause a shortage of one, or a few, substances essential for the normal metabolism of plants.

2. Such essential substances can be supplied to the plants from an external source and can be utilized to make up for the shortages caused by unfavorable temperature.

Both parts of this hypothesis can be tested experimentally.

Each plant contains a great variety of compounds, so it is very difficult to find out what goes wrong in extreme temperature conditions. Therefore, as a matter of expediency, a screening technique has been used for testing the second assumption. The approach involves attempts to prevent temperature damage by applying selected chemicals to the plants grown under unfavorable temperature conditions. Positive results prove the correctness of the second assumption, and indicate the probability that temperature acts via biochemical processes, as suggested in the first assumption. Moreover, the nature of the effective chemicals indicates where to start detailed biochemical investigations, which are required for a definite proof of the first assumption.

A number of compounds have been selected for

Research fellow Hendrik Ketellapper examines pea plants, grown in artificial light, that have been damaged by high temperatures. When they are sprayed regularly with sucrose, these plants will flourish like those at the right, which have been grown at the optimal temperature.

the screening process because they are key substances in plant metabolism. In order to speed up the screening process, related compounds are applied to plants in mixtures: a mixture of the members of the vitamin B group; a mixture of the ribosides (the building blocks of ribonucleic acid); and a mixture of amino acids (the building blocks for proteins). Vitamin C has also been used, and in a few experiments the effect of sucrose has been studied.

The substances can be applied to the plants by spraying the leaves. The spray treatment is carried out every other day while the plants are growing under unfavorable temperature conditions. After a few weeks of such treatment the plants are harvested, dried, and weighed. The growth of the plant can be determined by its dry weight.

Plants that prefer warm temperatures

A wide variety of plants have been tested. Some plants prefer warm temperatures, and grow very slowly at low temperatures. Two plants belonging to this group have been selected – a crop plant, eggplant; and an ornamental, Cosmos. Groups of these plants have been grown in temperatures lower than the optimum in air-conditioned greenhouses.

The optimal temperature for Cosmos is approximately 78 degrees Fahrenheit. When Cosmos plants are grown at 55 degrees, their growth rate is only one quarter of the growth rate at the optimal temperature of 78 degrees.

Part of this growth retardation caused by temperature can be overcome by spraying the vitamin B mixture on the leaves of such Cosmos plants. The active component of the mixture is vitamin B-1 (thiamine). Cosmos plants growing at 55 degrees behave as if they are growing at a warmer temperature when they are treated with thiamine. It has been shown by analysis that the thiamine concentration in the tissues of plants grown in low temperatures is lower than that typical for plants grown at the optimal temperature.

Application of thiamine to Cosmos plants grown at 67 degrees also increases their growth rate. But application of thiamine to Cosmos grown at the optimal temperature does not have any effect at all on growth.

The optimal temperature for eggplant is also 78 degrees. At 61 degrees the growth rate of eggplant is only one quarter of that at the optimal temperature. Application of ribosides to eggplant growing at 61 degrees raises the growth rate appreciably.

Many reactions involved in the growth process will proceed more slowly at lower temperatures. However, in the case of Cosmos, the production of thiamine is more retarded than any of the other reactions. Therefore, Cosmos plants growing at lower than the optimal temperature suffer from lack of thiamine, and their growth rate may be increased by application of thiamine. In the case of eggplant, a reaction involving the metabolism of ribosides is most sensitive to temperature.

Plants that prefer moderate temperatures

Some plants prefer moderate or low temperatures for best growth, and are injured by warm temperatures. Again, two plants from this group have been selected for tests – a crop plant, peas; and a California wildflower, lupin. (This particular lupin is a species which occurs along the California coast between Santa Barbara and Santa Cruz.) These plants were subjected to warmer than optimal temperatures in the laboratory.

The pea experiments were carried out in artificial light. Peas respond very markedly to the temperature during the day. The optimal temperature for peas grown in artificial light is 62 degrees. When the day temperature is raised to 73 degrees pea plants grow more slowly; the growth rate is three quarters of that at 62 degrees. However, when a 10 percent solution of sucrose is sprayed on the leaves of pea plants growing at 73 degrees, they grow at the same rate as plants growing at 62 degrees. Sucrose has no effect on growth at the optimal temperature. Apparently the high temperature interferes with photosynthesis, and so causes a shortage of sucrose in the plants. Direct measurements have shown that the rate of photosynthesis of pea plants growing at high temperatures is lower than that characteristic for peas growing at the optimal temperature.

When the peas are grown in warmer than optimal temperatures in a greenhouse, using sunlight instead of artificial light, the application of sucrose does not stimulate growth Some pea varieties respond to vitamin C under these conditions.

The lupins grow best at 67 degrees in the greenhouse. Application of the vitamin B mixture to lupin plants grown at 78 degrees can completely prevent the high temperature damage. The treated plants behave as if they were growing in optimal temperature conditions.

Apparently high temperature inhibits growth because one particular reaction is more sensitive to high temperature than the general average. In two cases, then, it has been possible to prevent high temperature damage completely by the application of substances which are apparently in short supply.

Preventing damage

These examples (in addition to a number not yet published) show conclusively that damage caused by temperatures above or below the optimum can be partially or wholly prevented by the application of chemically well-defined substances. These compounds are composed of relatively large molecules and apparently plants can absorb such molecules when they are applied to the leaves. All of the evidence derived from this chemical research indicates that indeed the chemical cure of climatic lesions is a proven fact.

At least part of the growth reduction caused by temperature extremes seems to be the result of the interference of temperature with the biochemical processes of the plant. This interference causes a shortage in one or a few key substances.

It may be that an undesirable temperature decreases the rate of synthesis of certain compounds. The concentration of such substances in the plant will then be too low for good growth. This is probably the case in moderately low temperatures.

Extreme temperatures may even cause the destruction of the compounds. High temperature combined with a shortage of water causes the breakdown of macromolecules forming part of the plant cell. For example, proteins and starch are hydrolyzed as soon as plants are subjected to a slight shortage of water. The rate of breakdown of ribonucleic acid is also increased in young tomato plants as a result of moisture stress.

In the supra-optimal temperature range dramatic effects can be observed as a result of very small changes in temperature – changes as small as one half to one degree. Such large effects of small temperature changes suggest sudden, profound changes in plant metabolism, probably caused by the destruction of key substances or the inactivation of enzymes.

Such destructive processes involving complex cell components raise the possibility that the relationship between "curing" substance and injury is indirect. So far it has been suggested that substances active in preventing temperature damage work because their application makes up for the deficiency of that particular substance in the plant. For example, the application of thiamine to Cosmos plants grown in low temperatures prevents part of the growth retardation, because Cosmos plants growing in low temperatures do not have enough thiamine. This is a direct relationship between "curing" substance and temperature damage.

Other chemical applications

Leaf sprays are not the only method of application of chemicals. In a few cases good results have been obtained by applying substances to the roots of plants grown in sand culture or in aseptic culture in agar. Furthermore, it has been possible to overcome a large part of the retardation of early growth of tomato plants, caused by low temperature, by soaking the seeds in nicotinic acid before planting.

The major climatic "lesion" studied in this program has been the reduction in dry weight of the plant. Measuring the weight of a dried plant is one of the best ways to determine growth. Often morphological abnormalities occur as the result of extreme temperature. Such abnormalities may also be reversed by chemicals. For example, in high temperature conditions leaves are often small and withered looking. Sometimes there are dead spots or areas in the leaf. In soybeans such morphological symptoms can be prevented by the application of the amino acid mixture. In addition, growth is increased by 50 percent. In some strains of *Arabidopsis thaliana*, a European weed, leaves will be normal when biotin or cytidine are applied.

Continued research will undoubtedly provide much more detailed information on how various types of temperature injury in plants can be prevented by applying chemicals. Then it may be possible to put this information to more practical use – in terms of the protection of cash crops against sudden short periods of unfavorable conditions.

Caltech's 80-ft. shock tube — and Hans. W. Liepmann, professor of aeronautics, in charge of this research

SHOCK TUBE

A cannon-like shock tube which cost $100,000 and took two years to build is now in operation in Caltech's aeronautics laboratories. The big tube is used to produce fast shock waves with a very brief lifetime in order to obtain information about the flow of very hot and highly rarefied gases. Such information is needed as a foundation for the solution of many aerodynamic problems in space and missile technology. Typical problems include the design of foils or fins for very-high-altitude vehicles, design of drag brakes for the reentry of vehicles from space, and cooling vehicle surfaces at extremely high speeds.

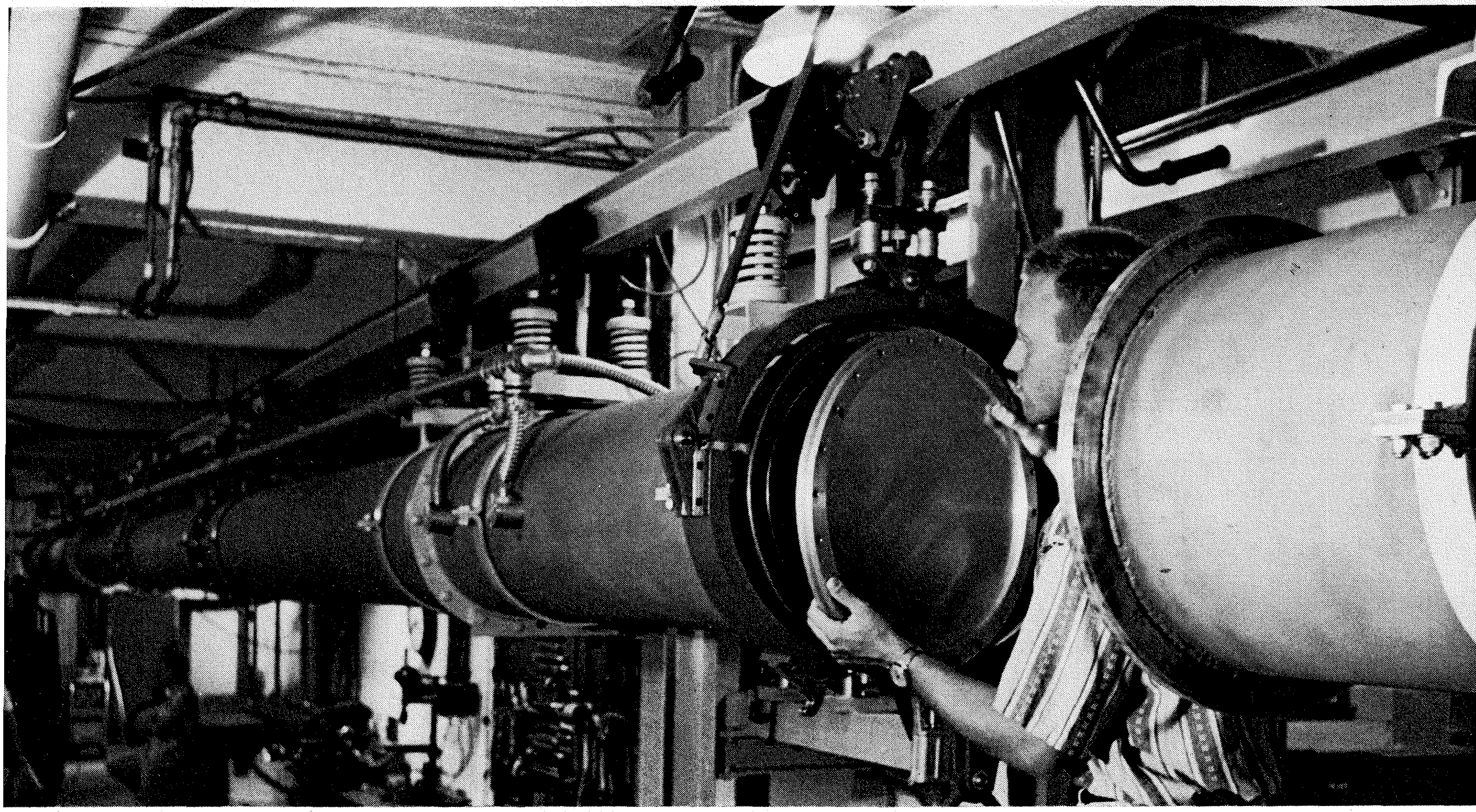
The shock tube is 80 feet long and 17 inches in diameter and fires an initial blast equivalent to that of an intermediate ballistic missile with 50,000 pounds of thrust. The shock wave, confined in the tube, packs a wallop much greater than a sonic boom created when a jet plane breaks the sound barrier, and it travels up to eight times the speed of sound.

The tube consists of seven sections of stainless steel tubing and is enclosed at each end with inch-thick steel plates. The joined sections are mounted individually on wheels on a track suspended from the ceiling, so that they may be separated and interchanged.

The tube is operated somewhat like a cannon. It consists of two parts — a driver, like the cannon's firing chamber; and a test section, similar to the barrel of a cannon. The driver is the first 12 feet of the tube, the test section the other 68 feet. Separating the two parts is the triggering mechanism, a thin aluminum diaphragm.

Firing the shock tube is more complex than loading a cannon. Air is pumped out of the test section until the pressure is equal to that existing some 60 to 70 miles above the earth — one millionth of the pressure in the ordinary atmosphere at sea level. Then helium or nitrogen is pumped into the driver up to 10 times atmospheric pressure — equivalent to the pressure 300 feet under the sea.

Building a differential ratio of one million forces the thin aluminum diaphragm to bulge like the side of a

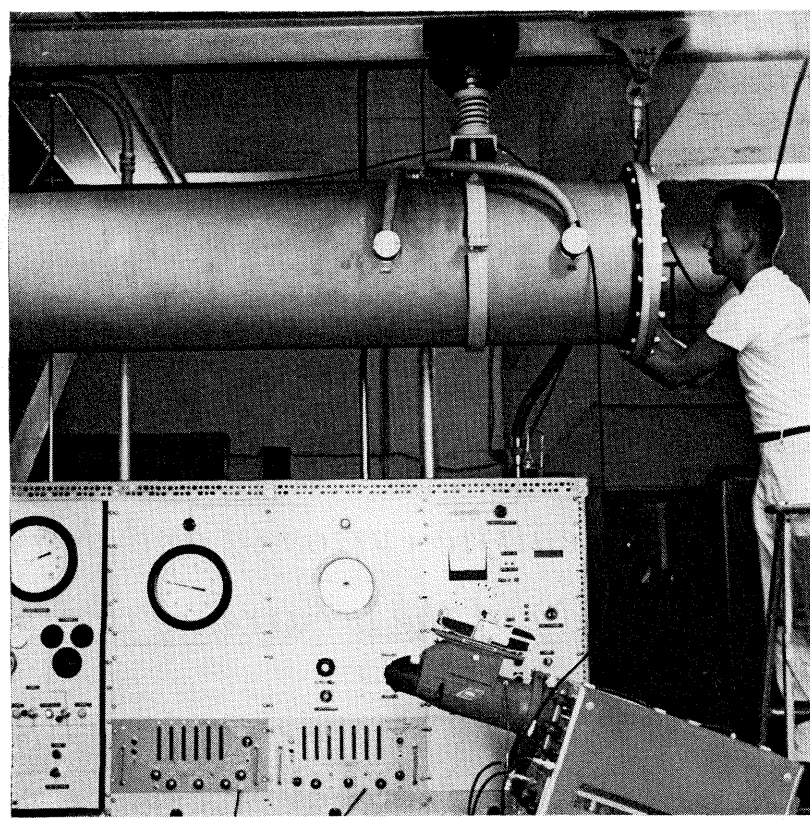


The Caltech shock tube is used to obtain information about the flow of very hot and highly rarefied gases. The shock tube is operated much like a cannon. It consists of two parts — a driver, similar to the firing chamber of a cannon; and a test section, like the cannon barrel. Above, Research Fellow Bradford Sturtevant fits a thin aluminum diaphragm between the two sections before firing the tube. Below, he removes the end plate from the test section after the shot, to inspect the instrumentation.

balloon on the test side (where there is a near vacuum). Forced by the pressure, the metal diaphragm touches a knife-edged cross that is arched to fit the curve of the diaphragm's bulge. When the pressure increases, the diaphragm presses so hard against the blades that it is sliced into four pie-shaped wedges. This instantly releases the high-pressure gas, which rushes into the near vacuum while the aluminum wedges are slammed back against the tube walls.

The released pressure creates a powerful shock wave that races the nearly 70-foot length of the test section in one one-hundredth of a second. The velocity of the wave is measured by 12 instrument stations located at intervals along the test section. All the measurements are recorded automatically, and the tube is designed to be operated by one man.

Sponsored by the National Aeronautics and Space Adminstration, the shock tube program is headed by Hans W. Liepmann, professor of aeronautics. Donald E. Coles, associate professor of aeronautics, is in charge of the mechanical design; Anatol Roshko, associate professor of aeronautics, of performance; and Bradford Sturtevant, research fellow in aeronautics, is in charge of the research program.



The interior of a crevasse is far from an ideal working location—temperatures down to −10° C., falling icicles, collapsing snow bridges, and even melt water from the surface.

Scientific curiosity and defense needs inspire a study of the occurrence and behavior of crevasses in glaciers.

Living On Cracked Ice

by C. J. Pings

During the International Geophysical Year there was considerable publicity covering the exploration and scientific activities of the United States in the Antarctic continent. Actually, of course, our nation was much involved in arctic research before the Geophysical Year, and continues to be even now, after the close of that formal program. Personnel from a number of universities, including those from Caltech's Geology Division, from the U.S. Coast and Geodetic Survey, and from several independent research institutes have a continuing scientific interest in the arctic regions. In addition, several branches of the Department of Defense support both basic and applied programs of arctic research.

Scientists are mainly interested in arctic regions because they pose an interesting collection of unsolved problems in the earth sciences. In addition, since about 1950, our defense needs have dictated the necessity for maintaining operational air bases and radar warning stations in the far North. If one takes a spherical look at the earth, the Thule air base in Northern Greenland, for example, represents one of the closest points of access to the interior of Russia, with the exception of continental Europe.

I am primarily familiar with the activities of the United States Army Corps of Engineers through their Cold Regions Research and Engineering Laboratory (CRREL) at Hanover, New Hampshire. Much of the exploration and field work of CRREL has been carried on since 1953 in various regions of Northern Greenland. The Thule Air Base at 76° north latitude in Greenland is maintained under an agreement with the Danish Government, which permits the United States to carry out glaciological activities in a substantial portion of the northwest sector of that island.

The accessibility afforded by an operational airstrip only 900 miles from the North Pole has made Northern Greenland an optimum area for arctic field research. Personnel and moderately heavy equipment can be brought in by airlift. It is possible in addition to move very heavy equipment by ship during the approximately six weeks each summer when the Thule harbor is ice-free. The airstrip has been of further value as a base for aerial reconnaissance, and particularly for helicopters for moving personnel to otherwise inaccessible areas on glaciers and snow fields.

In the early years of the Corps of Engineers' activities in Northern Greenland, the field activities were actually staged from the Thule Air Base. However, in 1954 the Corps constructed Camp Tuto at the edge of the icecap, about 13 miles inland from Thule. Every year since then Camp Tuto has grown in size, and the facilities have been improved until now it serves as an extremely useful base camp for projects operating for several hundred miles out onto the icecap. In addition to Camp Tuto the Corps of Engineers maintains at least one operational camp a substantial distance out on the ice sheet. The present icecap facility, located 100 miles out on the glacier, is the site of much of the experimental activity of CRREL.

In addition to these permanent facilities, smaller temporary camps have been set up at various locations as they were needed by the individual research projects. These are conventionally supplied and maintained from Camp Tuto, sometimes by airdrops, sometimes by surface with weasels, caterpillars, or other tracked vehicles.

The wide variety of problems that have been attacked by the personnel supported by CRREL in these various field camps, and in the laboratories at Hanover, has been dictated sometimes by scientific interest and sometimes by the need for a solution to a practical problem. Quite frequently an activity has contributed both to scientific understanding and to progress on an applied problem. One very interesting and successful engineering program carried out over a period of a number of years involved tunneling into a glacier and hewing out a number of large rooms. This was done to study the problems of tunneling in ice and to observe the strength of walls and ceilings in the shafts and rooms. However, in addition, these operations made it possible for some of the physicists to obtain samples of ice crystals which had been subjected to an unusual history of pressure and strain while present in the moving glacier. As a further bonus, one of the rooms served for a while as a very convenient field laboratory for carrying out some physical tests on ice samples without the need for elaborate refrigeration. Another activity involved setting up a drilling rig and sinking a hole into the icecap. The engineering motivation was to define the problems of drillings in ice and hopefully to find their solution. Here again, however, the scientists profited from the activity by studying the subsurface cores, resulting in definite stratigraphic correlations based on annual banding in the glacier caused by the seasonal freeze-thaw cycle.

In 1955 I was a member of a six-man group of scientists headed by Mark Meier, then a graduate student in Caltech's Geology Division, which went to Northern Greenland with the objective of carrying out some scientific and engineering studies on the occurrence and behavior of crevasses in glaciers. I returned to Greenland again twice in 1956 and once in 1957 to continue some aspects of this study. In addition to Meier, our 1955 party consisted of Jean Hoerni, then a research fellow in Caltech's Division of Chemistry and Chemical Engineering; William Melbourne, a graduate student in astrophysics; James Conel, a graduate student in geology; and the late Paul Walker, an undergraduate from Occidental College.

Concealed crevasses

Crevasses in glaciers have long been a troublesome problem to people traveling in arctic regions or over mountainous snow fields. These giant cracks in the ice presumably have developed due to the movement of the glacier. Sometimes an area will be so badly broken up on the surface by a mesh of intertwining crevasses as to make it completely impassable. However, the most insidious aspect of crevasses is that they are frequently concealed by thin bridges of snow, which may cover pits in the ice up to 100 feet deep. These snow bridges are frequently created across a crevasse during a blizzard or a high windstorm. It is quite surprising to find a crevasse five to six feet wide completely bridged over by a snow bridge only a few inches thick. These concealed cracks in the ice have claimed the lives of a number of arctic explorers, both in Greenland and in Antarctica.

As of today there is still no adequate means to detect the presence of these concealed crevasses except by the visual observation of obviously open segments of the snow bridge. Actually, when our project entered the crevassed areas, we sought the concealed crevasses by using a probe rod. This was a $\frac{3}{8}$-inch steel rod about 10 feet in length with a sharp point. If we could physically drive this rod into the snow in front of us to a depth of about 8 feet without it dropping, we could then assume that the area immediately in front of us was safe for passage. However, to proceed with any assurance of safety it was necessary to do this probing every two to three feet. Progress under these circumstances was indeed slow.

There has not been much scientific work reported on the occurrence and behavior of crevasses. It was hoped that our project would be able to make some observations and measurements that might identify areas of likely occurrence of crevasses, and give indication of their probable depths, rates of opening and closing, and perhaps something of the mechanism of the growth and collapse of the snow bridges which so often conceal them. It seemed obvious that we ought to attempt to correlate the occurrence and behavior of the crevasses with gross features such as the underlying bedrock topography, the rate of flow, the stress field at the surface of the glacier, and perhaps seasonal fluctuations in precipitation and ambient temperature. We were free in addition to make any contributions that might suggest improved methods of crevasse detection. However, at the time, this did not seem a likely prospect, since other parties had been in the field actively testing devices and schemes such as sonar, radar, and electrostatic systems.

Advanced planning

Anyone responsible for the progress of a research program in a laboratory appreciates the difficulties of anticipating all needs of equipment and supplies required for uninterrupted research. The problem is amplified manyfold if the activities are being carried out in a field camp, especially in a location as distant and as remote as a glacier in Northern Greenland. All of our instruments and supplies had to be crated and shipped ahead of us by air in early May 1955. As a matter of fact, even more advanced planning had been required in order for the Corps of Engineers to supply us with snow weasels and cargo sleds, both of which had been brought in by ship the previous summer.

Our project personnel were flown into Thule by the Military Air Transport Service in the third week of June 1955. We spent about 10 days in Camp Tuto unpacking our equipment, checking our instruments, drawing arctic clothing, and arranging for food and fuel. When we finally left to set up a field camp, our caravan consisted of two snow weasels and three wanigans. The snow weasels are small tracked vehicles about the size of an automobile; as a matter of fact, they are powered by a conventional 6-cylinder automotive engine. Although it may be merely legend, I am told that the weasel was developed late in the war for use in swampy terrain. It turned out to be quite impractical for this use, but someone discovered that it worked very well on snow fields and glaciers. The weasel is not a powerful vehicle, but it is capable of hauling about five men, and of towing a moderate load at the same time. The wanigans were simple plywood structures constructed on one-ton cargo sleds. We used two of them for sleeping quarters and the third as a field laboratory for our instruments and our records. These wanigans were primitive, but they were snug protection from the occasional blizzards. They proved vastly superior to tents.

Traffic in Northern Greenland usually avoids crevasses, and with good reason. However, our objective was to study them, so it was necessary to set up our camp in the middle of a crevasse field. From aerial reconnaissance a badly crevassed area about 15 miles out onto the icecap had been selected for study. We entered the area deliberately and carefully, and after considerable scrutiny we were able to pick a safe campsite between the crevasses.

Our party contained some expert mountaineers and some complete novices, including myself. Therefore, even after we had set up a secure camp, we deferred scientific activity for several days while Meier conducted class to acquaint us with safety procedures in moving about the crevasse field, and to teach rope techniques which would be necessary when some of us started to enter the crevasses. We also discussed techniques and procedures that would be necessary should there be an accident requiring a rescue from a crevasse. These precautions paid off, since we spent the entire summer living and working in the crevasse field without a single accident.

In order to make any progress we had to narrow the scope of our investigation. We decided finally that we would pick out one crevasse and concentrate our detailed studies upon it. This was coupled with examination of the bedrock profile, velocity measurements, and general superficial observations on an area of considerable extent on both sides of this crevasse. We did make enough control measurements on several other crevasses to convince ourselves that we had not selected a freak for our detailed study.

Assorted investigations

Although there were some activities shared by all of the party, for reasons of intrinsic scientific interest, various members of the party concentrated on different investigations. Meier and Conel measured the velocity of the surface of the glacier over a considerable area embracing the study crevasse plus several parallel crevasses on each side. As early as possible in the summer of 1955 they set out a grid of vertical stakes in the glacier surface, forming as nearly as possible a rectangular grid. After these stakes had been positioned approximately, their location was precisely established by triangulation with a theodolite. The stakes were surveyed a second time late in August of 1955, and the measured changes in position were sufficient to make a fairly detailed mapping of the strain vectors on the surface of the glacier.

The results confirmed that the glacier was not only moving, but that, at the surface, movement was definitely non-uniform. The occurrence of the crevasses seemed to be well explained in terms of the measured stress concentrations. From these observations Meier noted that, parallel to the existing crevasses, there existed a locus of stress concentration which indicated a likely future crevasse. As a matter of fact, a new crevasse was indeed discovered at this location in 1959, when personnel reentered the area.

With the assistance of a seismological crew from the Air Force Cambridge Research Center, Meier planned and carried out a series of seismic shots in order to establish the location and configuration of the bedrock underlying the study area. Interpretation of these data was assisted somewhat by the availability of a few gravitometer studies obtained in a previous season. These measurements seemed to indicate some slight undulations in the bedrock surface under the study area. Although the data were too sketchy to be absolutely convincing, they appeared compatible with an often quoted model for crevasse formation which suggests that the surface of the ice checks or cracks as the glacier stretches over a slightly rounded region on the bedrock.

Bill Melbourne and I spent much of the summer clambering in and out of the study crevasse. He was making strain measurements in order to establish the rate of opening of the crevasse, while I was conducting some thermal studies. To our knowledge there had never been any careful quantitative measurements of the rate of opening and closing of crevasses, though there were some interesting legends of gaping crevasses suddenly opening in front of skiers' eyes, and the converse tales of crevasses suddenly snapping shut, much to the embarrassment of anybody who happened to be in them.

Rate of opening of crevasses

Melbourne was able to get some interesting and conclusive data on the rate of opening of the crevasses by application of a strain gauge technique. He stretched strain gauge wire across the width of the crevasse and anchored it very securely with ice pitons in each wall. He strung a number of these wires at various depths in a vertical plane and then ran lead wires from the two ends of each of these wires to the surface of the glacier. One by one these could be hooked into a bridge circuit which measured the resistance of the wire. With appropriate calibration, changes in the resistance of each wire gave the changes in lengths, and hence a measure of the widening of the crevasse.

The crevasse studied in detail seemed to be opening as a wedge about an apex 65 feet below the surface, with a rate which was equivalent to a movement of the walls of about 2 inches per week at the surface of the glacier. From another nearby crevasse Melbourne obtained evidence that the crevasses also close with comparable rates.

In addition to those measurements, in 1955 we observed what appeared to be a new crevasse of substantial length, but apparently only several inches wide at the surface. This particular crevasse was observed again in 1956 and 1957, and each time it showed a considerable increase in width until it was

As of today the only adequate way to detect the presence of concealed crevasses is by visual observation of open sections of the snow bridge.

several feet wide in 1957. We are thus rather firmly inclined to reject as old-wives' tales the legends of catastrophic opening or closing of crevasses.

I was personally assigned the job of making some temperature measurements in the walls of the crevasses. We thought it would be informative to better understand the heat flow characteristics in the glacier near the crevasse, especially since there had been some speculation that transient thermal expansion might have some effect on the collapse of the thin snow bridges. We drilled thermocouple wells up to 15 feet back into the sides of the crevasse. In each of these wells we installed a number of thermocouple junctions, the leads from which were all run to the surface of the glacier. Additional thermocouples were mounted at assorted locations on the walls of the crevasse and in the snow bridge.

The interior of the crevasse was not exactly an ideal working location. It was moderately cold, with temperatures ranging to $-10°$ C. There was a considerable hazard from icicles falling from the wall and from fragments of snow and ice falling from a snow bridge or over the edge of the crevasse. In addition, on a warm day, considerable melt water from the surface ran over the edge of the crevasse. It is particularly unpleasant to be showered with water while working in an environment that happens to be about 10 degrees below freezing!

Some of the strain gauge and thermocouple installations were made at the bottom of the crevasse, where we could stand on reasonably solid ice while working. However, we were anxious to install both types of instruments at a number of assorted depths between the surface and the bottom of the crevasse. At the beginning of the summer we attempted to do this work while clinging to a rope ladder anchored at the surface. This proved to be difficult to the point that productivity was negligible. Therefore we were particularly pleased when the Corps of Engineers was able to supply us with a 15-foot aluminum assault bridge, long enough to straddle the crevasse in which we were working. This bridge included a small hand-operated hoist works which permitted us to position a bos'n chair at any desired depth within the crevasse. Either Melbourne or I spent much of the summer strapped in that chair dangling in the crevasse while we installed our instruments.

Altogether we installed about 65 thermocouples at various locations in and near the crevasse. These were arranged so that we could read the temperature by using a potentiometer at the surface. Sufficient readings were obtained in 1955, and again in the summer of 1956, to permit us to map the temperature distribution around the crevasse, including the transient response to seasonal changes in the ambient temperature. These data were sufficient for computation of the heat flux vectors near the crevasse and in the snow bridge.

As an interesting illustration of the results that sometimes come out of scientific measurements, our temperature data provided the incentive for some of the personnel of CRREL to investigate a new scheme of crevasse detection. While inspecting our data, Lyle Hansen of that organization noted that our results indicated differences between the temperature of the snow surface over the undisturbed glacier and the temperature of the snow bridge over a crevasse. This temperature difference was slight, but it appeared that it might be sufficient to be detected by some recently developed infrared cameras. This has led to further studies and development of a thermal crevasse detector which exploits an infrared camera mounted in an aerial mapping plane. Although this work is still in progress and is partially classified, I can report that there is some prospect of a crevasse detector that may eventually replace the 10-foot probe rod.

Although our party obtained a few useful results, our efforts were brief and provided only a mere beginning to a better understanding of the mechanism of occurrence and growth of crevasses. As with many other problems involving arctic phenomena, a combination of scientific curiosity and defense needs will motivate still further productive research on crevasses and their detection.

The Summer at Caltech

Faculty Changes

New members of the Institute's staff of instruction and research for 1961-62 include:

Joseph Blau, visiting associate professor of philosophy, from Columbia University, where he is associate professor of religion.

Arthur Boucot, associate professor of paleontology, from MIT, where he was associate professor of geology.

David J. Braverman, assistant professor of electrical engineering, from Stanford, where he received his PhD in June.

Charles J. Brokaw, assistant professor of biology, from the University of Minnesota, where he was assistant professor of zoology. He received his BS from Caltech in 1955 and his PhD from Cambridge University in 1958.

James Burdon, visiting associate in chemistry, from Birmingham University in England, where he is a lecturer in chemistry.

K. Das Gupta, senior research fellow in engineering, from the University of Calcutta, where he is a Reader. He received his MS from the University of Calcutta in 1940 and his PhD from the University of Liverpool in England in 1952.

John D. Dixon, instructor in mathematics, from McGill University in Montreal, Canada, where he received his PhD in June.

Olin J. Eggen, professor of astronomy and staff member of the Mount Wilson and Palomar Observatories, from the Royal Greenwich Observatory in Sussex, England, where he was chief assistant to the Astronomer Royal. He received his BA in 1940 and his PhD in 1948 from the University of Wisconsin.

Robert F. Howard, staff member of the Mount Wilson and Palomar Observatories, from the University of Massachusetts, where he was assistant professor of astronomy. He received his BS from Ohio Wesleyan University in 1945 and his PhD from Princeton in 1957.

Icko Iben, Jr., senior research fellow in physics, from Williams College, where he is assistant professor of physics.

Karl R. Johansson, associate professor of environmental health, from the Virology and Rickettsiology Study Section of the National Institutes of Health at Bethesda, Md., where he was executive secretary. He received his BS in 1942, his MS in 1946, and his PhD in 1948 at the University of Wisconsin.

Milton Lees, assistant professor of mathematics, from New York University, where he was assistant professor of mathematics. He received his PhD from the University of California in 1958.

Robert W. Long, visiting associate in chemistry, from El Camino College, where he is an instructor in chemistry. He received his AB from Indiana State Teachers College in 1938 and, his PhD from the University of California in 1941.

Oscar Mandel, visiting associate professor of English, from the University of Nebraska, where he is associate professor of English.

Edwin S. Munger, professor of geography, who has been a lecturer on the American Universities Field Staff. He received his MS in 1948 and his PhD in 1951 from the University of Chicago.

Minoru Nishida, senior research fellow in astrophysics, from Kyoto University in Japan, where he is assistant professor of astrophysics.

Paul Orlov, M.D., lecturer in Russian, from Georgetown University, where he was lecturer in Russian at the Institute of Languages and Linguistics.

Major Lorrin C. Peterson, professor of air science and tactics, from the Air America Plant Office of the Air Materiel Force in the Pacific Area.

Robert A. Phinney, assistant professor of geophysics, who received his PhD at Caltech last June.

Lenard O. Rutz, visiting associate in chemical engineering, from the University of Iowa, where he is assistant professor of chemical engineering. He received his BS in 1952 and MS in 1953 from the University of Wisconsin and his PhD in 1958 from the State University of Iowa.

Alan Sharples, instructor in mathematics, from the

University of Liverpool, England, where he is an assistant lecturer. He received his BS in 1956 and his PhD in 1960 from Manchester University.

Stewart W. Smith, assistant professor of geophysics, who received his PhD at Caltech in June.

Ronald Soohoo, associate professor of electrical engineering, from the Lincoln Laboratory at MIT, where he was a research physicist and staff member. He received his BS in 1948 and MS in 1952 from MIT, and his PhD from Stanford in 1956.

Alvin Walz, visiting associate in chemistry, from Mankato State College in Wisconsin, where he is a professor of chemistry.

Gerald Whitham, visiting professor of applied mechanics, from MIT, where he is professor of mathematics. He received his BS in 1948, his MS in 1949, and his PhD in 1953 from Manchester University in England.

DEPARTURES:

Daniel G. Dow, assistant professor of electrical engineering, to the Central Research Laboratories of Varian Associates in Palo Alto.

Albert E. J. Engel, professor of geology, resigned to be professor of geology at the Scripps Institute of Oceanography at La Jolla.

Lester Field, professor of electrical engineering, to the Hughes Aircraft Company as head of the Microwave Tube Division.

Major F. W. MacKenzie, professor of air science and tactics in the ROTC, to the ballistic missile division of the Air Force in Inglewood as an orientation officer.

Elliot Pinson, instructor in electrical engineering, received his PhD at Caltech in June and has now joined the staff of the Bell Telephone Laboratories in Murray Hill, N.J.

Calvin H. Wilcox, associate professor of mathematics, resigned, to the University of Wisconsin where he is professor of mathematics.

ON LEAVE OF ABSENCE:

Allan J. Acosta, associate professor of mechanical engineering, to Imperial College in London for a year, to do research on fluid mechanics.

Max Delbruck, professor of biology, to the University of Cologne in Germany, for two years as director of a new Institute of Genetics.

Robert P. Dilworth, professor of mathematics, to the Institute for Defense Analysis, at Princeton University for one year.

William A. Fowler, professor of physics, to St. Johns College, Cambridge University, England, for one year, to collaborate with Plumian Professor Fred Hoyle in the preparation of a manuscript on the origin of nuclear species.

David R. Smith, assistant professor of English, to lecture at the Universities of Lille and Toulouse in France for one year.

HONORS AND AWARDS:

Stanford S. Penner, professor of jet propulsion and mechanical engineering, has been named by the Air Force Office of Scientific Research to the newly-formed Research Advisory Committee on Engineering Sciences.

Ernest H. Swift, chairman of the Division of Chemistry and Chemical Engineering, has received the 1961 honor scroll of the American Institute of Chemists' western chapter "for the many years devoted to teaching and for the promotion and development of his profession and for his concern and attention for those within the profession of chemistry."

Rudolph Minkowski, who retired from the Mount Wilson and Palomar Observatories last year, has been named recipient of the 1961 Bruce Gold Medal of the Astronomical Society of the Pacific.

Ernest E. Sechler, professor of aeronautics, has been appointed a member of the National Academy of Sciences-National Research Council Committee on Basic Research Advisory to the U. S. Army Research Office. The appointment is for three years. Dr. Sechler is also chairman of the NASA Committee on Missile and Spacecraft Structures.

PROMOTIONS:

To Professor:

Felix H. Boehm—Physics
Eugene W. Cowan—Physics
Dino A. Morelli—Engineering Design
G. Wilse Robinson—Physical Chemistry
Rolf H. Sabersky—Mechanical Engineering
David W. Wood—Mechanical Engineering
Theodore Y-T. Wu—Applied Mechanics

To Associate Professor:

James K. Knowles—Applied Mechanics
John H. Richards—Organic Chemistry
J. Beverley Oke—Astronomy
Robert W. Oliver—Economics
David F. Welch—Engineering Design

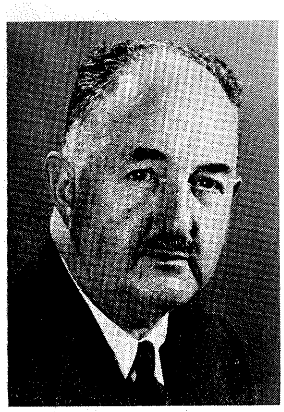
To Senior Research Fellow:

Rudolf L. Mossbauer—Physics
Arthur F. Messiter—Aeronautics
Sten Samson—Chemistry
Richard L. Sears—Physics
John D. Smith—Biology
Paul O.P.Ts'o—Biology

To Assistant Professor:

Peter V. Mason—Electrical Engineering

In Memoriam



HOWARD P. ROBERTSON, professor of mathematical physics, died on August 28 of injuries sustained in a traffic accident. He was 58 years old. At a memorial service held on the campus on August 30, President L. A. DuBridge paid tribute to Bob Robertson as "a unique figure in the world of science and education—unmatched for the breadth of his interests and talents, unsurpassed in the depth of his knowledge both of the physical universe and of the world of men.

"Bob was born in Hoquiam, Washington, on January 27, 1903," said President DuBridge, "received his bachelor's degree from the University of Washington at the age of 19 and his doctor's degree from Caltech at the age of 22. After study in Europe, he came back to spend his professional life on the faculties of Princeton University and the California Institute of Technology.

"As a mathematician and physicist, he devoted his attention to the fields of differential geometry, relativity theory and cosmology . . . Professor Paul Epstein has given the following summary of Robertson's chief contributions to science:

" 'The scientific personality of H. P. Robertson was characterized by exceptional mathematical powers, coupled with a deep insight into physical processes. His chief interests lay in general relativity, in which field he will be mainly remembered for two contributions of outstanding importance.

" '(1) Early in his career he gave the solution of Einstein's cosmological equations for the case of a homogeneous and isotropic universe. This solution served ever after as the basis for most of the vast number of papers written by other authors on relativistic cosmology.

" '(2) By bringing to bear his great mathematical skill on the two-body problems in general relativity he succeeded in obtaining its solution, a task which before him had been unsuccessfully tried by almost all the best specialists.

" 'Of his work on subjects other than relativity, the most important is perhaps that relating to the quantum-dynamical principle of indetermination. Instead of restricting himself to the theory of measurement of a *coordinate* and of the associated *momentum*, Robertson asked about when and to what extent *any* two physical observables whatever can be simultaneously measured, and in a simple and elegant way he set up the conditions for this. In all modern textbooks the principle of indetermination is now presented in this generalized form.'

"Dr. Robertson's achievements as a physicist were recognized by his election to the National Academy of Sciences in 1951, and in 1958 he was elected foreign secretary of the Academy. . . . Yet the astonishing thing about Bob's career—and the phase which may have had the greatest impact — was the way in which, during World War II and after, he turned from abstruse subjects like relativity to the practical problems of military strategy. . . . He quickly won the respect of both scientists and military officers in his grasp of war problems, his keen analytical ability and his skill in bringing the results of scientific analysis into useful and understandable form.

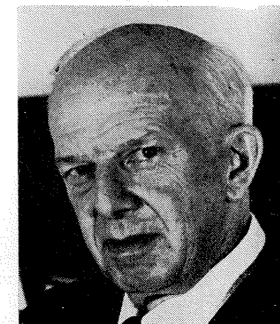
"In the years after World War II he was heavily engaged in military advisory tasks. He spent two years as scientific adviser to the Supreme Commander of the Allied Forces in Europe while General Alfred Gruenther held that post and General Norstad was United States Air Commander. He served two years as Director of the Weapons System Evaluation Group in Washington, working directly with the Joint Chiefs of Staff. He was on every important science advisory board—the Defense Science Board, the President's Science Advisory Committee, the Advisory Committee for the Mutual Weapons Development Program, the Science Advisory Group to NATO, and many others.

"However, Robertson's extracurricular activities were not confined to government service. He was a trustee of the Systems Development Corporation, the Institute for Defense Analysis, and the Carnegie Endowment for International Peace; and he was a director of the Northrop Corporation. . . .

"But it is for his work closer to home that most of us here will remember Bob—as a teacher, as a devoted faculty member, and as a loyal, thoughtful and generous friend. . . .

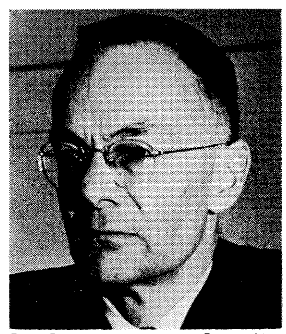
"No one can ever replace Bob—as a scientist, as a citizen, as a faculty member or as a friend. His tragic and untimely death leaves an aching void. Yet we can comfort ourselves that he did spend 14 active, fruitful years here—years which were happy and stimulating for him and years which will leave permanently a respected and a fond memory of a great man. . . ."

Among the many telegrams of condolence received by the Robertson family was this from President John F. Kennedy: "Your tragic loss is shared by the many in government who have been fortunate to benefit from Bob Robertson's wise counsel and warm friendship. He gave unselfishly of his great talent and energy in serving the nation's needs. As a scientist and teacher, foreign secretary of the National Academy of Sciences, member of the President's Science Advisory Committee, chairman of the Defense Science Board, scientific advisor to SHAPE, and in other key roles he has left an enduring contribution at home and abroad. Please accept our deepest sympathy."



STUART JEFFERY BATES, professor emeritus of chemistry, died on July 28 at the age of 74. One of the oldest members of the Caltech faculty in point of service, Dr. Bates taught physical chemistry to undergraduates for 42 years until his retirement in 1956. He wrote papers Number 1 and 2 of the now more than 2700 published by workers in Caltech's Gates and Crellin Laboratories of Chemistry.

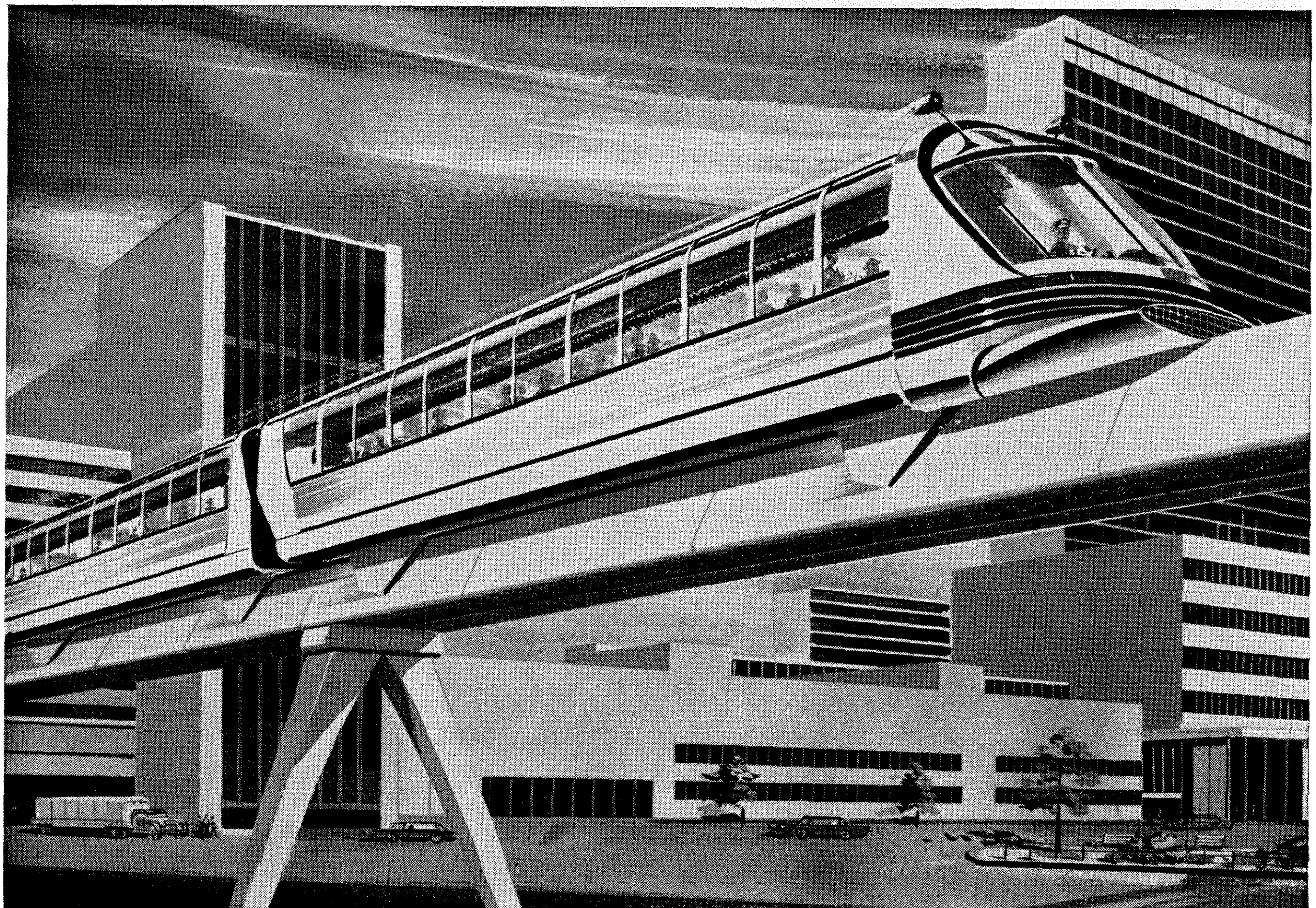
Born in Toronto, Canada, on May 9, 1887, Stuart Bates received his AB and AM degrees from McMaster University there. He got his PhD in 1912 from the University of Illinois, where he served as instructor in physical chemistry until he came to Caltech in 1914.



HUNTER MEAD, professor of philosophy and psychology, died on July 2, following surgery for a brain tumor. He was 54 years old. Dr. Mead came to Caltech in 1947. In addition to his teaching he was director of musical activities on the campus. He built a mammoth 950-pipe organ in his home, where he held occasional concerts for students and faculty.

Born in Sierra Madre, he was graduated from Pomona in 1930, received his MA from Claremont College in 1933, and his PhD from USC in 1936. Author of *An Introduction to Aesthetics*, and *Types and Problems of Philosophy*, he was at work on a comprehensive history of philosophy at the time of his death.

PAUL WILLARD MERRILL, retired from the staff of the Mt. Wilson and Palomar Observatories, died on July 20. He was 73 years old. Dr. Merrill's specialty was stellar spectroscopy and he was one of the foremost authorities on spectrum analysis. Born in Minneapolis on August 15, 1887, he was graduated from Stanford University, and received his PhD from the University of California at Berkeley in 1913. He joined the Mt. Wilson Observatory staff in 1919. Though he retired officially in 1952, he continued his research at the observatory's offices in Pasadena until the time of his death.



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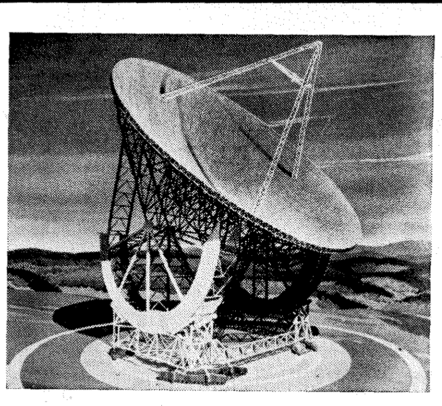

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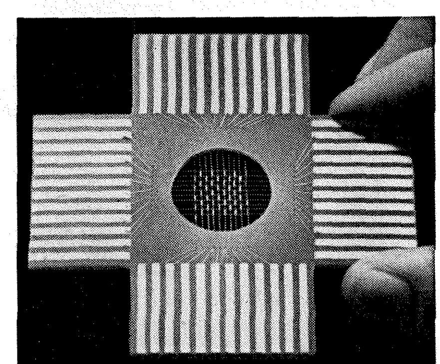

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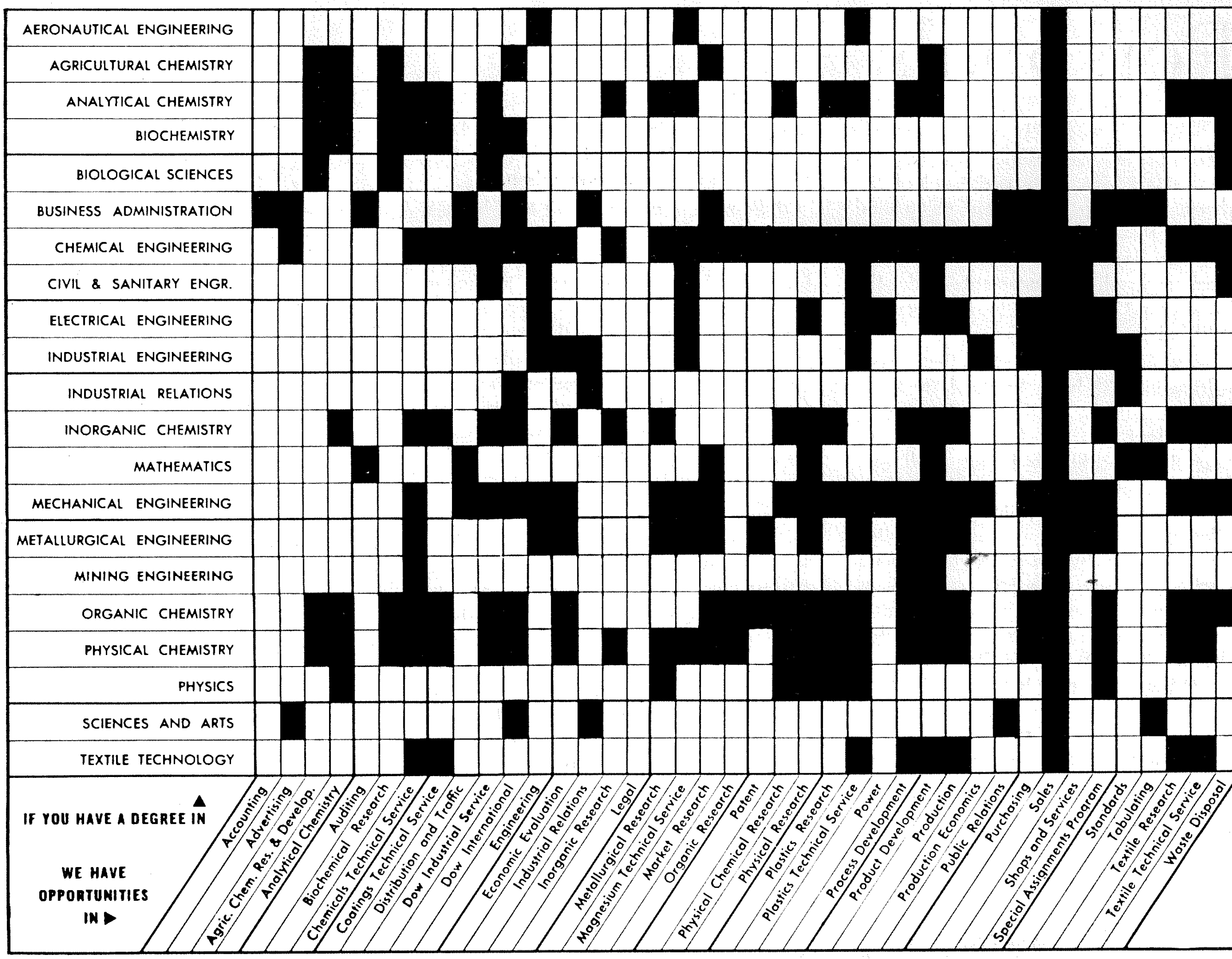

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We call this an 'opportunities chart.' It shows some of, but by no means covers all, the professional positions available at Dow for college graduates. What the chart cannot show is the keen interest that Dow management takes in the individual. Here, sound technical background and qualities of leadership are soon rewarded. Opportunities abound—on the job and through graduate study.

Dow is currently serving 200 industries varying from medicine to mining, paper to paint, tires to textiles, farming to foundries. Dow has major manufacturing operations in 23 locations in the United States in addition to associated and subsidiary companies. Exploration goes on endlessly at 50 separate laboratories. In addition, Dow has rapidly expanding marketing and manufacturing operations in 28 foreign countries.

Behind every product (and Dow has more than 700) is a story of achievement that comes with *opportunity*. Opportunity for individual and independent work by the people who created the product; by those who developed and engineered its manufacture; by the ones who produced, sold, and serviced it; and by those who continue to improve it.

Dow's fringe benefits are excellent also . . . life and hospitalization insurance . . . a yearly salary review plan (salaries are reviewed at least once a year, and the emphasis is on merit rather than length of service) . . . a pension and profit-sharing plan . . . an educational refund plan (provides financial assistance for employees who want to increase their job effectiveness through continued education) . . . and by participating in past stock purchase plans offered periodically, about 45 per cent of Dow's employees have become shareholders in the company.

For more detailed information about Dow, we invite you to visit or write the Technical Employment Manager at any of the locations listed below.

California—Pittsburg
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Michigan—Midland
Missouri—Allied Laboratories, Inc., Kansas City
Ohio—Dobeckmun Company, Cleveland
Dow Industrial Service, Cleveland
Oklahoma—Dowell, Tulsa
Texas—Freeport
Virginia—Williamsburg

THE DOW CHEMICAL COMPANY DOW Midland, Michigan

Personals

1923

Donald H. Loughridge, BS Ch, BS Ph, PhD '27, physicist and head of the physical research department at General Motors Research Laboratories for the past five years, is now director of applied research management with the Aerospace Corporation in El Segundo, California.

Walton E. Gilbert writes that "since retiring in 1958 from the Shell Oil Company operations abroad, I have conducted four three-week seminars in my home in Princeton, N.J., for Shell production engineers and superintendents. Apart from this vestigial activity, my wife and I are rediscovering the United States. So far this year we have made a trip by car to San Diego, Pasadena, Seattle and return, with frequent way-stops for golfing purposes. Ponte Vedra, Florida, is next on the list. I beg to report that retirement is fun."

1924

F. Douglas Tellwright retired from the Pacific Telephone Company in San Francisco on September 1. For the past three years he was executive vice president handling regulatory, tax and legislative matters in California. The Tellwrights, who live in Carmel, have one daughter and four grandchildren.

Rolland S. Thomas writes that he has resigned from his position with the Long Beach Unified School District. During his years of service, he was an instructor in 3 different high schools, city college, war training program, and then department head of the Industrial Arts Department. Tommy will continue to serve as a member of the board of directors, and also as president of a mutual water company in Garden Grove.

1928

Tomizo Suzuki is currently working on construction of the Tokai Nuclear Power Station for the British General Electric Company. The Japan Atomic Energy Research Institute, with three reactors, and the Japan Nuclear Fuel Corporation are located in the same area – near the city of Mito, about 90 miles northeast of Tokyo. "Our home is still in Tokyo," writes Tomizo, "and I return there once a month. In our garden we have two dogwood trees from our Seattle friends, and the pink ones bloomed for the first time last spring. We also have California poppies."

1929

M. Howard Nagashi, MS '31, died last November of cancer. He had been an engineer with the Kawasaki Aircraft Company in Yokohama.

1930

Warren Arnquist, PhD, is now assistant to the director of advanced research for the Douglas Aircraft Company in Santa Monica. He was formerly assistant director of engineering research at the System Development Corporation.

1933

John R. Pierce, MS '34, PhD '36, director of research in communications principles of the Bell Telephone Laboratories, received an honorary degree of Doctor of Engineering from the Newark, (N.J.) College of Engineering last June.

1935

Kenneth S. Pitzer, professor of chemistry at UC, has been named president of Rice Institute in Houston, Texas His appointment was effective on July 1. He was formerly director of research for the Atomic Energy Commission. The

continued on page 30

Pitzers have three children: Ann, 24, an employee of the extension division of the University of Hawaii; Russell, 23, a graduate student at Harvard; and John, 19, a junior at UC Riverside.

1937

Robert S. Schairer, MS, PhD '39, has been named chief scientific advisor to the commander of the Pacific Missile Range at Point Mugu, Calif. He was formerly assistant director of development planning at the Lockheed Corporation in Burbank.

1938

Charles F. Robinson, MS, PhD '49 has been elected vice president for research at the Bell and Howell Company in Pasadena, and chairman of their research planning board.

Howard S. Seifert, PhD, has held a joint appointment as professor of aeronautical engineering at Stanford, and director of advanced planning at the United Technology Corporation, since April, 1960. Last March he was elected a member of the International Academy of Astronautics, with headquarters in Paris. The Seiferts have a daughter who is a freshman at Stanford, and a son who is in high school.

1945

LCDR Mark M. Macomber, U.S.N., is now working in the astronautics division of the Bureau of Naval Weapons – Project Transit, the satellite-borne Doppler navigation system, and Project Anna, a tri-service, Navy-managed geodetic satellite program. He was formerly hydrographic and operations officer on the USS Tanner in Bombay, India. The Macombers have two boys, 8 and 4, and a girl, 1.

Richard A. B. Knudsen writes that he is still vice president and in charge of sales at FITTINGS That FIT, Inc., in Alhambra. The Knudsens have four children: Eric, 7; Craig, 3; Lesley (a daughter) 4; and Scott, 2.

1948

Hugo Schwartz, MS, writes from Israel that "about 8 years ago, my brother and I founded an industry for friction material and asbestos textiles – by now our factory is of sizable dimensions with about 200 workers and plenty of business including export in Europe. I am married and have two children: a girl, 7 and a boy, 6. I am also acting as councillor at the Chilean Embassy to Israel."

1950

Arent H. Schuyler, Jr. is now director of Polytechnic Upper School in Pasadena. He is also teaching 11th and 12th year courses in chemistry and physics. He had been teaching at Midland School in Los Olivos.

Norman F. Jacobson, PhD '56, heads a new department, the program engineering section, at Caltech's Jet Propulsion Laboratory. He has been at the lab since 1956.

1951

Charles Bates is development engineer in the process development department of the food products division of Proctor and Gamble in Cincinnati. The Bates' have two sons – Charles, Jr., and Richard – and a daughter, Pricilla.

Herbert M. Hull, PhD, is a plant physiologist with the USDA at the Arizona Agricultural Experiment Station in Tucson. The Hulls have two children: Laurie, 6, and Danny, 4.

Ronald T. Caldwell, MS '55, systems engineer at AiResearch in Phoenix, writes that he is working on the design of space vehicle power conversion systems (nuclear and solar). The Caldwells have two sons: Norman, 5, and Billy, 1.

Dallas L. Peck, MS '53, is a geologist with the U.S. Geological Survey in the Menlo Park office. He's mapping the geology of an area that includes Mt. Lyell and the Clark Range in the High Sierras near Yosemite. Dallas received his PhD from Harvard last year. The Pecks have two children: Ann, 8, and Steve, 5.

William Whitney is assistant professor of physics at MIT. The Whitneys live in Winthrop, Mass., and have two children; Steve, 7, and Diane, 3.

1953

Robert Spencer is now senior research engineer at JPL after 8 years in industry in the L.A. area.

Kimball L. Hamberger, assistant professor of engineering at San Francisco State College, died from complications after major surgery for an abdominal aorta aneurysm last summer.

After Kim left Caltech, he prepared maps for the U.S. Army in Alaska. He received his MS in petroleum engineering from the University of Oklahoma in 1957, then started his PhD in engineering at U.C. Berkeley. His work was supported by Ford Foundation grants.

Kim leaves his wife, Anne and two children: Chris, 2, and Karen, 8 months.

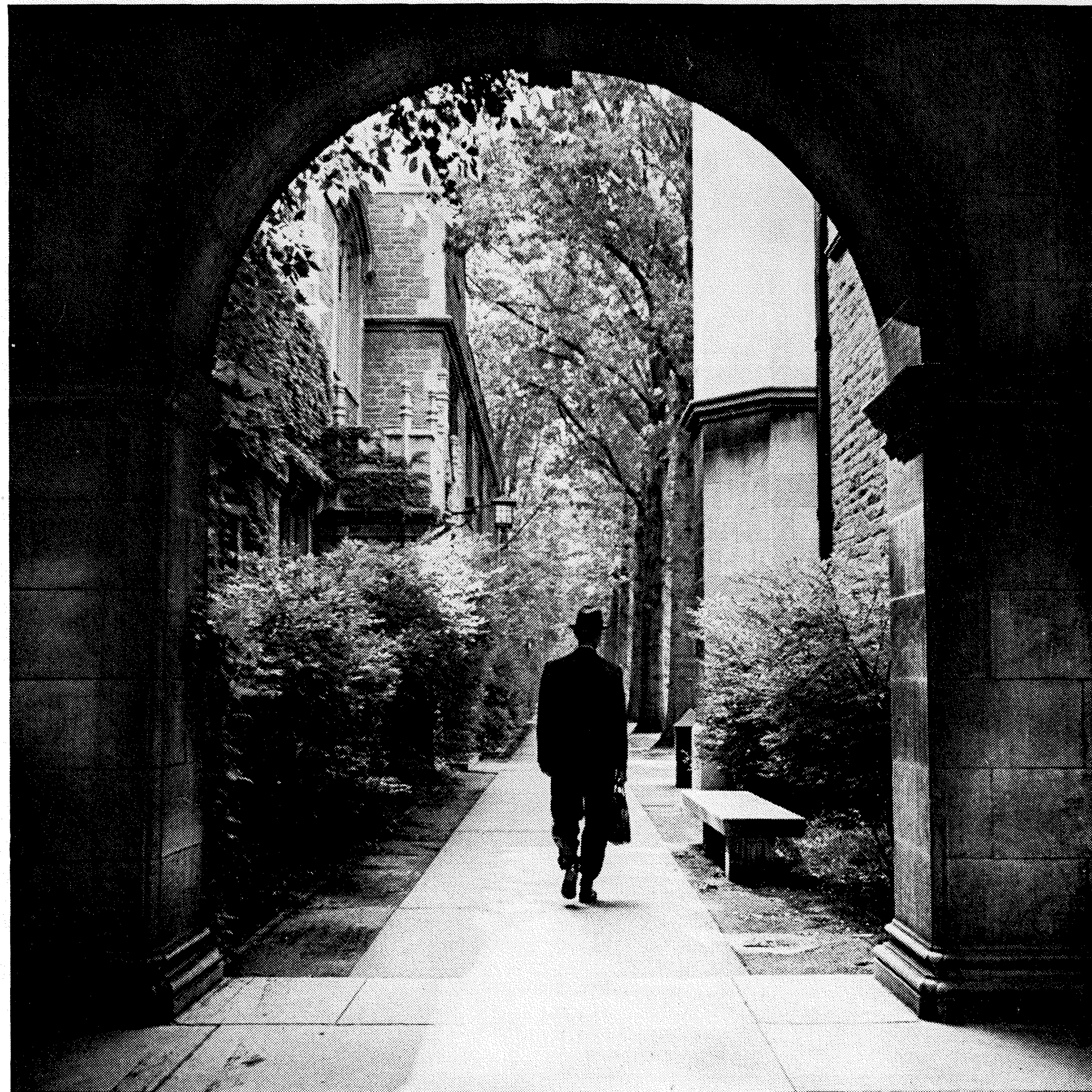
1954

Edward Bryan is now with the RAND Corporation in Santa Monica, after being with the Bell Labs in Murray Hill, N.J., for 6 years. His group is working on giant electronic brains.

1955

William B. Lindley, MS '58, is now a staff associate at General Atomic Corporation in La Jolla. He was formerly a physicist at the Radiation Laboratory in Livermore.

continued on page 32



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Personals . . . *continued*

Gerald Z. Lippey, MS '56, associate engineer at the IBM Corporation in San Jose, Calif., announces the birth of a son, Barry, on July 7, 1961.

Major Manley E. Rogers, MS, is now with the Alaska Engineer District of the U.S. Army in Anchorage. He has been in the Army since June 1950.

1956

Robert L. Shacklett, PhD, associate professor of physics at Fresno State College, is spending 1961-62 at the Institute of Physics in Uppsala, Sweden, doing research and studying on a NSF fellowship.

Frederick M. Trapnell, Jr., MS '57, has been appointed acting director of the IBM World Trade Laboratories Limited in Great Britain. He has been with the IBM World Trade Corporation, a wholly-owned subsidiary of IBM, since 1960, when he became systems engineer in the Development Engineering Department assigned to Paris. Before that he spent three years with the domestic organization in Poughkeepsie, N.Y.

1957

Gerald Klaz received his MD from UCLA Medical School last June and is now interning at L.A. County Hospital. He has also "added a wife to my collection named Anita."

1958

Philip D. Thacher writes that "after graduation I spent the academic year as a Fulbright Fellow studying theoretical physics in Paris at the Institut Henri Poincaré. After a tour through Europe that summer, I got back to the U.S. in time to enter Cornell for the fall term. Last year (1960-61) I had a research assistantship under Professor Sproull, with whom I shall stay on to do my thesis in experimental solid state physics."

Philip Reynolds, MS '59, chemical engineer at the Aerojet-General Corporation in Sacramento, was married on April 8 to Elizabeth Porter of Visalia.

1959

Kenneth M. Mitzner, MS, Caltech graduate student in electrical engineering, is studying at the Technological University at Eindhaven, The Netherlands, on a Fulbright grant.

John R. Stevens, MS, a graduate student at Caltech in physics, is studying at the Universities of Heidelberg and Marburg in Germany. He received the Deutscher Akademischer Austauschdienst Award of the German Government.

1961

James L. Aronson, MS, graduate student in geology at Caltech, is studying at the Dominion Laboratory, Dept. of Scientific and Industrial Research, in New Zealand, under a Fulbright grant.

Thomas B. Smith is spending a year at Kings College in Cambridge, England, on a Fulbright grant.

Peter R. Vogt is studying at the University of Innsbruck in Austria on a Fulbright grant.

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Visiting alumni cordially invited—no reservation

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U. S. Navy Electronics Laboratory

"CHARGED PARTICLES"

Accelerators on the Research Frontier

We keep rewriting copy on this theme, and properly so. The needs of science for charged particles in nuclear structure research continue to create dynamic interest in Van de Graaff and microwave linear accelerators, and intensive development is leading to performance in energy and current that could not be considered even a short while ago. All the uses for higher energy, greater intensity, and more exacting specifications of stability and pulsing are not clearly known, but consideration of attainable accelerator performance may stimulate action on research programs lying dormant for lack of appropriate apparatus. The advanced characteristics here outlined can be contemplated now, due to recent technical advances in the design of accelerator components.

Energy

The capability of the Tandem Van de Graaff to reach into the range well above 20 Mev with precisely stabilized positive ions is a reality. Currents will be more than adequate for useful nuclear structure research.

New linacs of proven design extend high pulsed currents of electron beams to hundreds of Mev. They open up great areas of neutron physics and monoenergetic gamma work for physicists. The high power capabilities are now matched by sophisticated analyzing, deflecting and collimating systems which are as important to experimental work as the linacs themselves.

Intensity

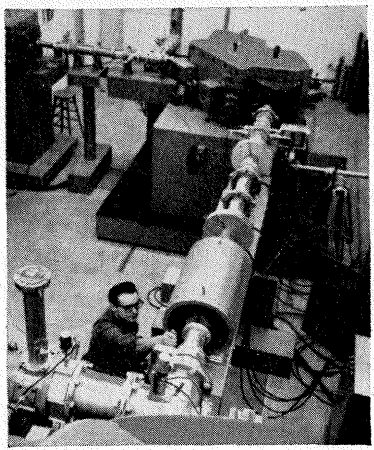
Electron or ion-beam currents in the one-ampere range at a few Mev can now be considered seriously. A specially-designed accelerator has shown excellent life performance at 1 Mev and 20 milliamperes of electrons as part of High Voltage Engineering's continuing test program to reduce the cost of ionizing radiation energy at high power levels.

The X-ray and neutron outputs from these beams are indeed heroic: X-rays — millions of rads per minute at a few centimeters distance. Neutrons — 10^{15} neutrons per second from a "point" source.

Pulsing

New techniques enable Van de Graaffs to be pulsed from a few nanoseconds to a millisecond. Instantaneous intensities as described above make feasible the consideration of hundreds of rads per pulse, or more than 10^{11} neutrons per burst.

High-energy linacs, now being supplied to physics laboratories, provide intense neutron pulses for time-of-flight studies. Typical of these machines are several built under AEC-sponsorship, which yield as high as 10^{17} fast neutrons per pulse at a rate of 1.5×10^{14} fast neutrons per second. The thermal neutron flux attainable with these machines is 10^{12} n/sec/-cm^2.



High-energy end of 12-Mev Tandem Van de Graaff Accelerator.

Photo courtesy University of Wisconsin

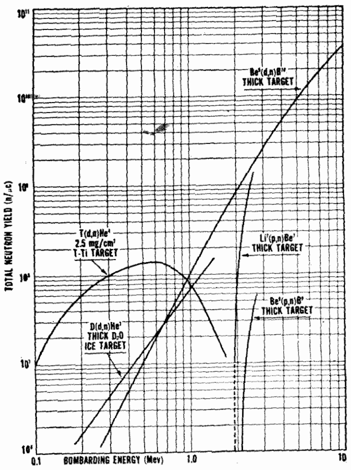
Energy Stability

It is now possible to consider stabilizing systems to a limit imposed primarily by the thermal motion of nuclear targets. With little effort, continuous particle-energy stabilities of a few tens of electron-volts can be provided.

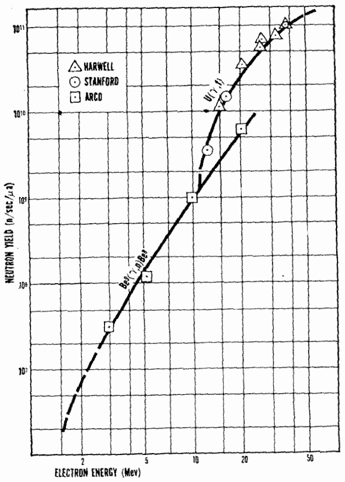
Among the research fields in which these particle-accelerator characteristics may make a considerable contribution are: nuclear physics, biology, solid state, radiation damage, plasma physics, ignition of thermonuclear systems, and space-environment studies.

Physicists and radiation chemists at High Voltage Engineering are prepared to explore on an individual basis, long-range and immediate research problems that could utilize our accelerator systems.

This is part of a series of which reprints are available on request to: Technical Sales Department.



Neutron yields versus positive ion bombarding energy.



Photodisintegration neutron yields from X-rays produced in electron bombardment of large-atomic-number targets.

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When there is a choice of employment opportunities, most graduating engineers and scientists make some sort of list of the advantages offered by each prospective employer.

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TWO-MINUTE BRAINWASH

"On three? . . . O.K. . . . Hullo?. . . Well! I was wondering when you were going to call. How's things, George? What's new?

"Boy! I left myself wide open for *that*, didn't I? Alright, what's new b'sides the 'lumni Fund?

"Just what I figured – *What?*

"Whaddaya mean have I thought about giving to the Fund? It sure hasn't kept me *awake* nights – but I've thought about it. I'm sure not gonna *bankrupt* myself just because Tech needs more endowment, but I'll give *something* – just to get you off my back.

"WHAT? Oh c'mon now. You mean I have to give *and* have the right attitude too? You must have lost your mind, George. It's not going to be so much money that–

"Why isn't it? George, there are people after me for money that I haven't even *earned* yet. There's a guy from Red Cr– Alright then, ask a silly question, get a silly answer. . . .

"Sure I'm busy . . . Two minutes? O.K. A two-minute brainwash, huh? Synchronize watches. Go!

"I'm with you . . . Endowment is the purpose of the Fund . . . fine . . . my gift will *never* be spent . . . good . . .

"You say Tech can't get along without 'lumni support? Hold on there George, I think you're way off base . . .

"Yes, 'lumni *are* the product of the Institute, but–oh, I see. If they don't support the school, people figure–what? O.K. *Corporations* and *Foundations* and people will figure it's not worth supporting? Will they really?

"They assume that the alumni are doing their share 'til they find out otherwise, huh? So what would happen if we had no 'lumni Fund at all?

"We could lose a good part of two million five hundred thousand bucks annually? *Every year?* . . . Well, maybe I . . . But wait, George; if Tech gets that much in gifts what's the reason for a bigger endowment? We must be loaded!

"All that money amounts to only 17% of Tech's annual expenditures? I'll bet you're sneakin' JPL in there and *that's* not fair. No? . . . You mean the campus stuff alone costs *$14 million* a *year?* Well, how about the endowment income? . . . Only 23% of annual expenditures and going down? How come? . . .

"The big additions to endowment are from bequests . . . that makes sense, but what if no one dies–no one with money, interested in Tech? . . . Oh! That's the point? And with the cost of education 'way up, endowment income can't keep pace with increased costs.

"So what you want, my friend, is what you call your 'live additions' to endowment–in short–MY GIFT. Simple. Wait a minute though, you're makin' me sell *myself* . . . Marge can't do that, and I've never won an argument from *her, either.*

"George, you're a fine man, a real salesman . . . money's never going to be spent . . . It'll be workin' forever . . . Boy! . . . You know what? I'm convinced! Tell you what I'm gonna do . . . I have a bunch of bills this month, but *next* month I'll put the Endowment Fund at the top of the list . . .

"I know it's deductible, boy . . . Sure you can count on me. Nothin's too good for old Tech, I always say. And when I say I'll give, I mean I'll . . . give . . ."

The Caltech Alumni Endowment Fund Has Begun. Your Alumni Fund Directors Respectfully Suggest That You Do Not Wait For George's Friend.

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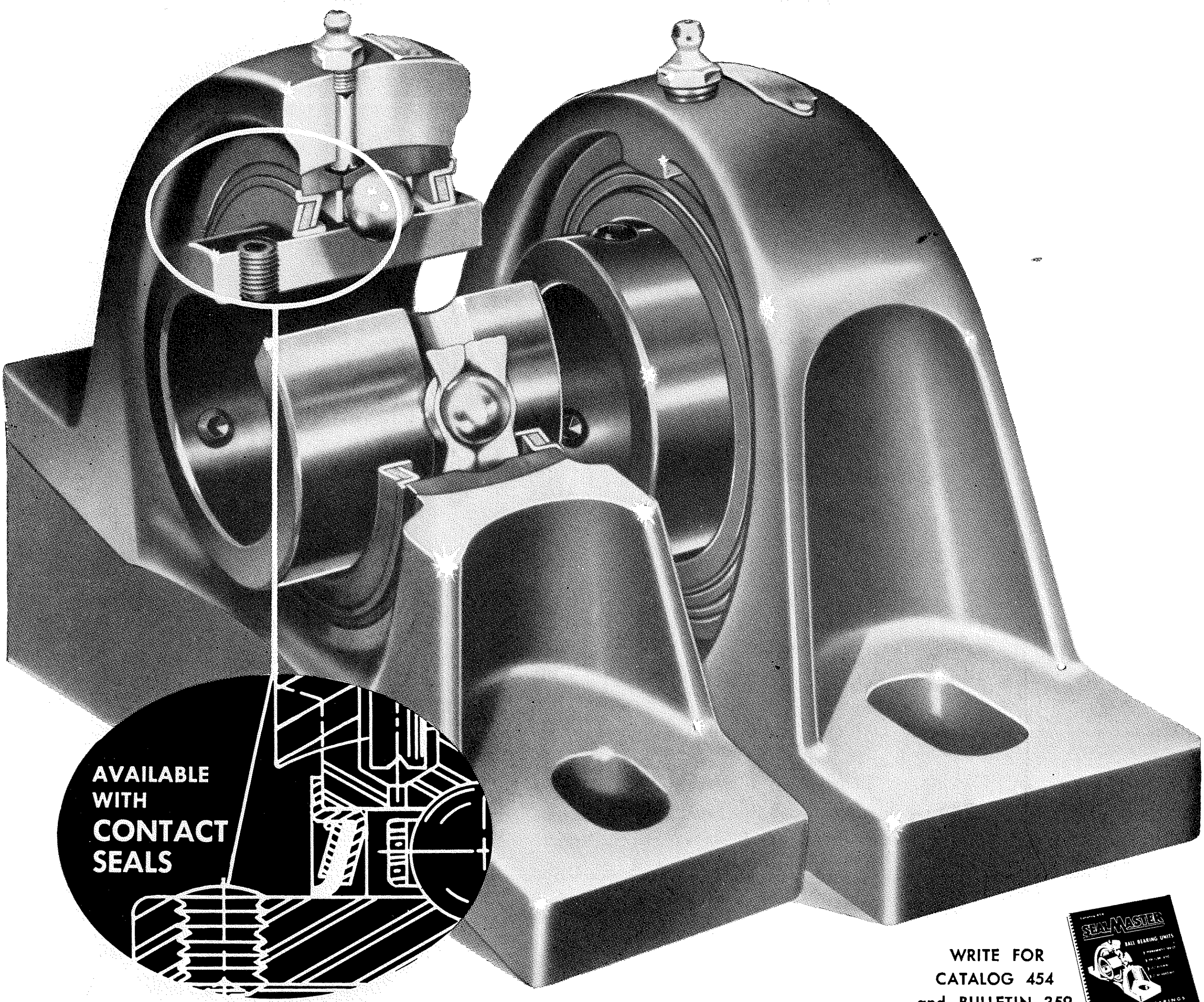

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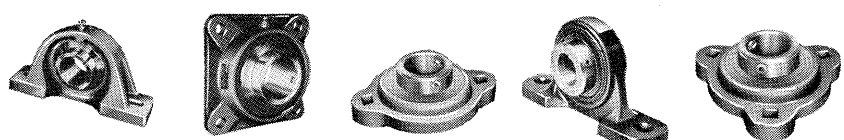

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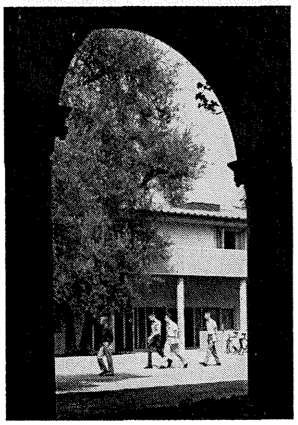


CALTECH CALENDAR

ALUMNI EVENTS

November 11
Interhouse Dinner and Dance

ATHLETIC SCHEDULE

WATER POLO

October 10
L.A. State at L.A. State

October 13
UCLA at UCLA

October 17
Claremont-H. Mudd at Caltech

October 20
Pomona at Pomona

FOOTBALL

October 14
Pomona at Pomona

October 21
La Verne at Caltech

SOCCER

October 14
UC Riverside at Riverside

October 21
UCLA at UCLA

FRIDAY EVENING DEMONSTRATION LECTURES

Lecture Hall, 201 Bridge, 7:30 p.m.

October 20
On the Trail of Ancient Man
—William Miller

October 27
San Gabriel Mountains – Man and Nature in Conflict
—Henry Hellmers

November 3
Problems of Armament in the Modern World
—David Elliot

ALUMNI ASSOCIATION
CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, California

BALANCE SHEET
June 30, 1961

ASSETS

Cash in Bank			$ 2,459.33
Investments:			
Share in C.I.T. Consolidated Portfolio		$ 67,038.39	
Deposits in Savings and Loan Associations		19,840.43	86,878.82
Investment Income Receivable from C.I.T.			3,786.76
Postage Deposit			141.76
Furniture and Fixtures, at nominal value			1.00
Total Assets			$ 93,267.67

LIABILITIES, RESERVES AND SURPLUS

Accounts Payable			$ 1,286.64
Deferred Income:			
Membership Dues for 1961-62 paid in advance		$ 10,045.25	
Investment Income for 1961-62 from C.I.T. Consolidated Portfolio (earned during 1960-61)		3,786.76	13,832.01
Life Membership Reserve			57,000.00
Reserve for Directory:			
Balance, July 1, 1960	$ 193.60		
1960-61 Appropriation	2000.00	$ 2,193.60	
1960-61 Directory Expense		108.70	2,084.90
Surplus:			
Balance, July 1, 1960		$ 14,750.52	
Share of Profit on Disposal of Investments of C.I.T. Consolidated Portfolio for 1960-61		3,319.74	
Excess of Income over Expenses for 1960-61		993.86	19,064.12
Total Liabilities, Reserves and Surplus			$ 93,267.67

STATEMENT OF INCOME AND EXPENSES
For the Year Ended June 30, 1961

INCOME

Dues of Annual Members		$ 15,850.22
Investment Income:		
Share from C.I.T. Consolidated Portfolio	$ 3,449.80	
Interest on Deposits in Savings and Loan Associations	940.56	4,390.36
Annual Seminar		4,983.90
Program and Social Functions		3,652.70
Miscellaneous		29.16
Total Income		$ 28,906.34

EXPENSES

Subscriptions to Engineering and Science Magazine:		
Annual Members	$ 11,095.00	
Life Members	2,933.00	$ 14,028.00
Annual Seminar		4,696.30
Program and Social Functions		3,717.28
Administration:		
Directors' Expenses	$ 165.90	
Postage	1,166.70	
Printing	118.03	
Supplies	657.20	
Miscellaneous	430.17	2,538.00
Directory Appropriation		2,000.00
Membership Committee		519.25
ASCIT Assistance		400.00
Fund Solicitation Committee		13.65
Total Expenses		$ 27,912.48
Excess of Income over Expenses		$ 993.86

AUDITOR'S REPORT

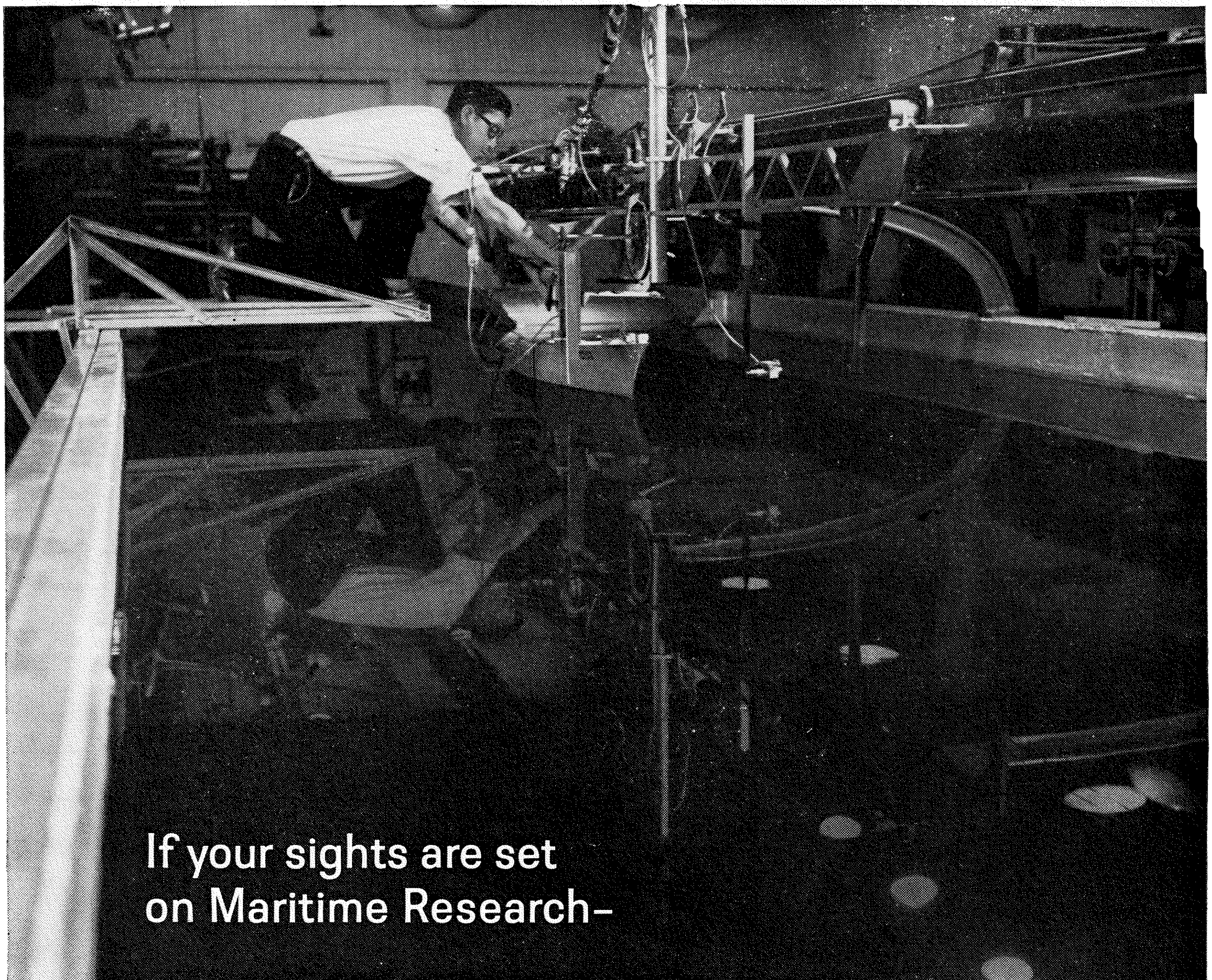
Board of Directors, Alumni Association, California Institute of Technology
Pasadena, California

I have examined the Balance Sheet of the Alumni Association, California Institute of Technology as of June 30, 1961 and the related Statement of Income and Expenses for the year then ended. My examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as I considered necessary in the circumstances.

In my opinion, the accompanying Balance Sheet and Statement of Income and Expenses present fairly the financial position of the Alumni Association, California Institute of Technology at June 30, 1961, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

CALVIN A. AMES, Certified Public Accountant
1602 West Thelborn St., West Covina, California

September 26, 1961



Technician preparing for motion-picture studies of a model in the testing tank at Stevens Institute of Technology.

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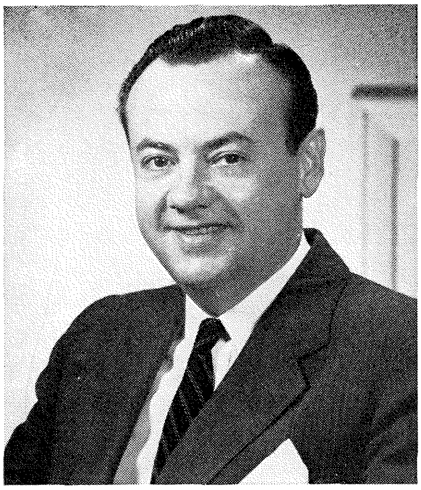
Interview with General Electric's Dr. J. H. Hollomon



Manager—General Engineering Laboratory

Society Has New Needs and Wants—Plan Your Career Accordingly

DR. HOLLOMON is responsible for General Electric's centralized, advanced engineering activities. He is also an adjunct professor of metallurgy at RPI, serves in advisory posts for four universities, and is a member of the Technical Assistance panel of President Kennedy's Scientific Advisory Committee. *Long interested in emphasizing new areas of opportunity for engineers and scientists, the following highlights some of Dr. Hollomon's opinions.*

Q. Dr. Hollomon, what characterizes the new needs and wants of society?

A. There are four significant changes in recent times that characterize these needs and wants.

1. The increases in the number of people who live in cities: the accompanying need is for adequate control of air pollution, elimination of transportation bottlenecks, slum clearance, and adequate water resources.

2. The shift in our economy from agriculture and manufacturing to "services": today less than half our working population produces the food and goods for the remainder. Education, health, and recreation are new needs. They require a new information technology to eliminate the drudgery of routine mental tasks as our electrical technology eliminated routine physical drudgery.

3. The continued need for national defense and for arms reduction: the majority of our technical resources is concerned with research and development for military purposes. But increasingly, we must look to new technical means for detection and control.

4. The arising expectations of the peoples of the newly developing nations: here the "haves" of our society must provide the industry and the tools for the "have-nots" of the new countries if they are to share the advantages of modern technology. It is now clearly recognized by all that Western technology is capable of furnishing the material goods of modern life to the billions of people of the world rather than only to the millions in the West.

We see in these new wants, prospects for General Electric's future growth and contribution.

Q. Could you give us some examples?

A. We are investigating techniques for the control and measurement of air and water pollution which will be applicable not only to cities, but to individual households. We have developed, for example, new methods of purifying salt water and specific techniques for determining impurities in polluted air. General Electric is increasing its international business by furnishing power generating and transportation equipment for Africa, South America, and Southern Asia.

We are looking for other products that would be helpful to these areas to develop their economy and to improve their way of life. We can develop new information systems, new ways of storing and retrieving information, or handling it in computers. We can design new devices that do some of the thinking functions of men, that will make education more effective and perhaps contribute substantially to reducing the cost of medical treatment. We can design new devices for more efficient "paper handling" in the service industries.

Q. If I want to be a part of this new activity, how should I plan my career?

A. First of all, recognize that the meeting of needs and wants of society with products and services is most important and satisfying work. Today this activity requires not only knowledge *of science and technology* but also of economics, sociology and the best of the past as learned from the liberal arts. To do the engineering involved requires, at least for young men, the most varied experience possible. This means working at a number of different jobs involving different science and technology and different products. This kind of experience for engineers is one of the best means of learning how to conceive and design—how to be able to meet the changing requirements of the times.

For scientists, look to those new fields in biology, biophysics, information, and power generation that afford the most challenge in understanding the world in which we live.

But above all else, the science explosion of the last several decades means that the tools you will use as an engineer or as a scientist and the knowledge involved will change during your lifetime. Thus, you must be in a position to continue your education, either on your own or in courses at universities or in special courses sponsored by the company for which you work.

Q. Does General Electric offer these advantages to a young scientist or engineer?

A. General Electric is a large diversified company in which young men have the opportunity of working on a variety of problems with experienced people at the forefront of science and technology. There are a number of laboratories where research and advanced development is and has been traditional. The Company offers incentives for graduate studies, as well as a number of educational programs with expert and experienced teachers. *Talk to your placement officers and* members of your faculty. I hope you will plan to meet our representative when he visits the campus.

A recent address by Dr. Hollomon entitled "Engineering's Great Challenge — the 1960's," will be of interest to most Juniors, Seniors, and Graduate Students. It's available by addressing your request to: Dr. J. H. Hollomon, Section 699-2, General Electric Company, Schenectady 5, N.Y.

GENERAL ELECTRIC

All applicants will receive consideration for employment without regard to race, creed, color, or national origin.