ENGINEERING | AND | SCIENCE

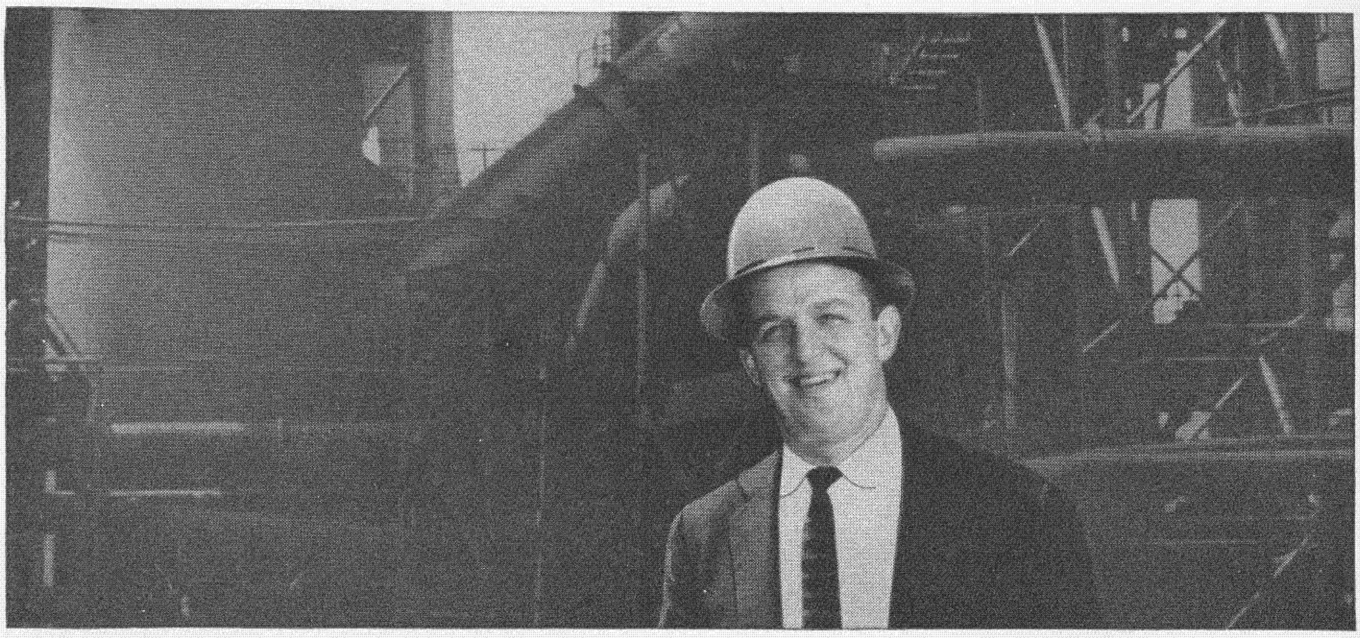
DECEMBER/1956

Students' Day . . . page 48

PUBLISHED AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY

Thomas A. Beattie, class of '47,
speaks from experience when he says:

"At U. S. Steel one has a great amount of varied experiences. There is truly never a dull moment."



After receiving his B.S. in Mechanical Engineering in 1947, Mr. Beattie entered the employ of U. S. Steel as a student engineer. That was on September 22, 1947, and included service in the United States Navy from 1943 to 1946.

Mr. Beattie's progress from that date onward is typical of that of many engineering graduates who plan their future with U. S. Steel. For, within two years, we find Mr. Beattie advanced to the position of Process Engineer, Maintenance Department. Then on April 16, 1951, he was promoted to Relief Foreman, Shops, Maintenance Department. On March 1, 1952, he was made Turn Foreman, Blooming and Bar Mills, Mechanical Maintenance Department. And on January 1, 1955, he was promoted to his present post of Assistant Superintendent, Maintenance Department, of U. S. Steel's National Tube Division's National Works.

In this position, Mr. Beattie's responsibilities are numerous. They include the Service Power House and Skelp Mill area; maintenance of four blast furnaces and blast furnace auxiliaries, plus a sintering plant; maintenance of two blooming mills and soaking pits; maintenance of one bar mill; maintenance of three Bessemer converters, three open hearth furnaces, three open hearth auxiliaries, and seventy overhead cranes ranging from two to 200 tons. He supervises 680 men.

As Mr. Beattie remarks: "A steel plant includes all departments . . . every craft known to industry. In the space of three years, a U. S. Steel engineer can obtain experience that may take three times as long under different employment circumstances. One meets all types of problems and personnel. Each day is varied, certainly not dull, and yet no problem is insurmountable. Certainly, there is no possibility of getting 'into a rut' here."

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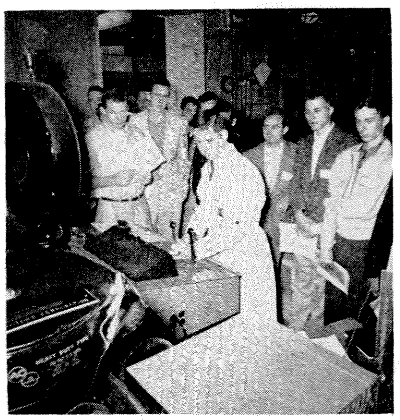
ENGINEERING AND SCIENCE

IN THIS ISSUE



On our cover this month—a picture of one of the colorful demonstrations set up by Caltech students for the edification of the hundreds of high school students who swarmed onto the Caltech campus for the annual Students' Day held this year on Saturday, December 1.

In our cover picture, Jon Harford, a senior in mechanical engineering, is demonstrating how research is conducted on a high compression test engine in the mechanical engineering laboratory.

For other views of Students' Day—see page 48.

Warren Weaver's article on page 27 of this issue has been extracted from a talk he gave at the Athenaeum on November 15, on the occasion of the dedication of Caltech's new Norman W. Church Laboratory of Chemical Biology.

Dr. Weaver, who is now vice president for the natural and medical sciences of the Rockefeller Foundation in New York, served as assistant professor of mathematics at Caltech from 1917 to 1920—when the school was known as Throop College. Which explains why Dr. Weaver calls his talk "Pasadena Revisited."

In 1917, as Dr. Weaver explains, this was a slightly different school. His salary at the time was $1,800 a year—though the Weavers only paid $17 a month rent for a cottage on Mentor Avenue. They couldn't afford a

CONTINUED ON PAGE 6

PICTURE CREDITS

Cover	David Groce '58
pps. 16-23	Muriel and Thomas W. Harvey
pps. 24, 25, 30 (top)	Thomas W. Harvey
pps. 30-31	Graphic Arts, Caltech
p. 48	David Groce '58

DECEMBER, 1956 VOLUME XX NUMBER 3

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CONTENTS

In This Issue 3

Books 10

A Portfolio of Faculty Portraits 15
by Thomas W. Harvey

The Month at Caltech 24

Pasadena Revisited 27
An abstract of a talk given at the dedication of the Norman W. Church Laboratory for Chemical Biology.
by Warren Weaver

Dedication of the Church Laboratory 30
A pictorial record

What's Happening to the Automotive Powerplant? 32
A forecast for the next 25 years
by Peter Kyropoulos

Student Life 48
Students' Day, 1956

Alumni News 52

Personals 56

Lost Alumni 66

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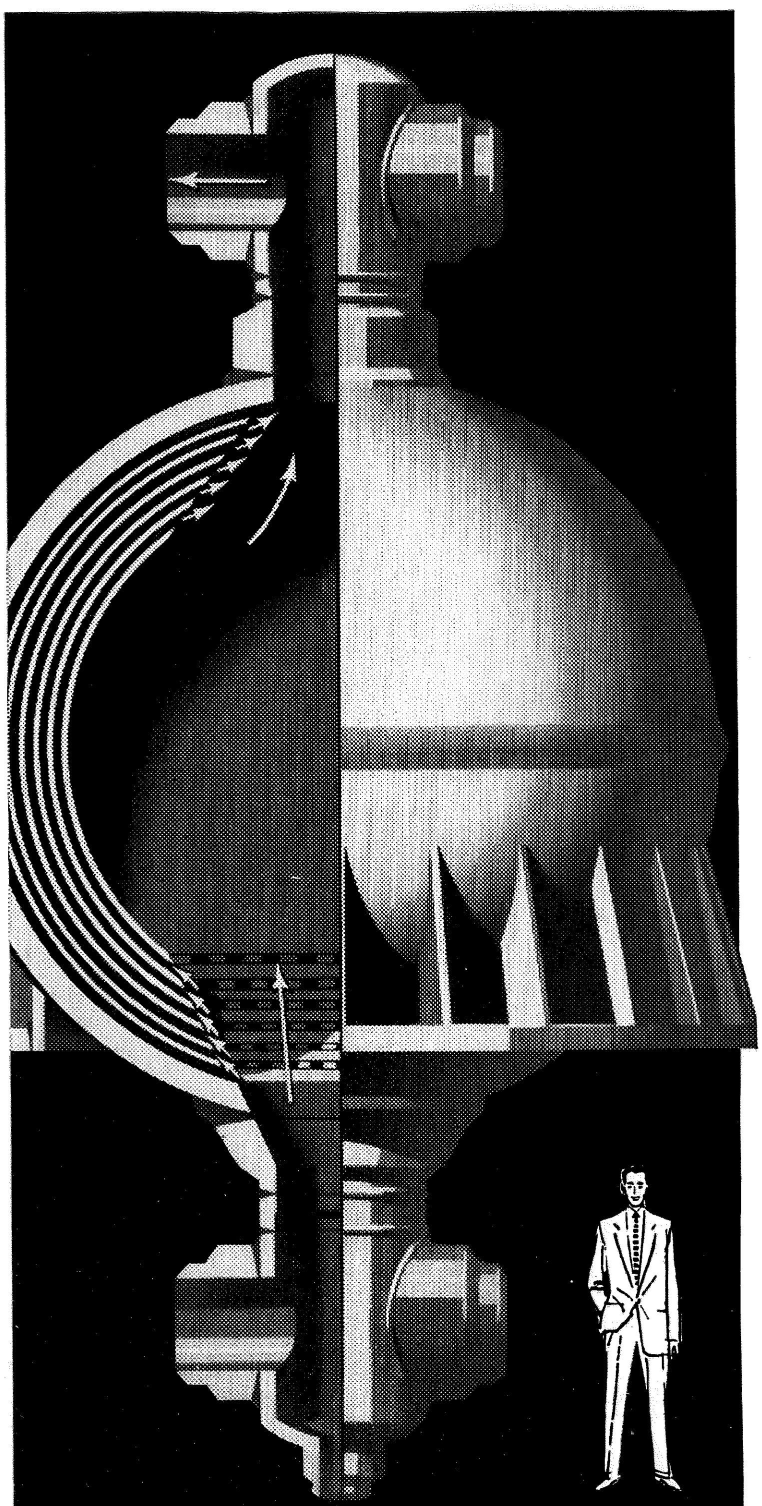
Printed in Pasadena PP 6

Building the first large liquid-fuel reactor for a utility power plant.

. . . A PROBLEM IN ATOMIC POWER



Possible design for homogeneous reactor vessel.

The first large homogeneous reactor for a utility power plant is now being designed by Westinghouse engineers and scientists, in partnership with the Pennsylvania Power and Light Company, for whom the plant will be built. The plant will have a capacity of 150,000 kw.

Liquid fuel will be circulated throughout the nuclear power plant and carry heat to steam generators.

This is only one of many daring research and engineering projects young engineers can work on at Westinghouse.

Here you can work in your chosen field . . . electrical, mechanical, chemical and industrial engineering; physics; mathematics; metallurgy and many others. And, you can pick the type of work you prefer.

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Write: Mr. M. L. Winter, Regional Educational Co-ordinator, Westinghouse Electric Corporation, 410 Bush Street, San Francisco 8, Calif.

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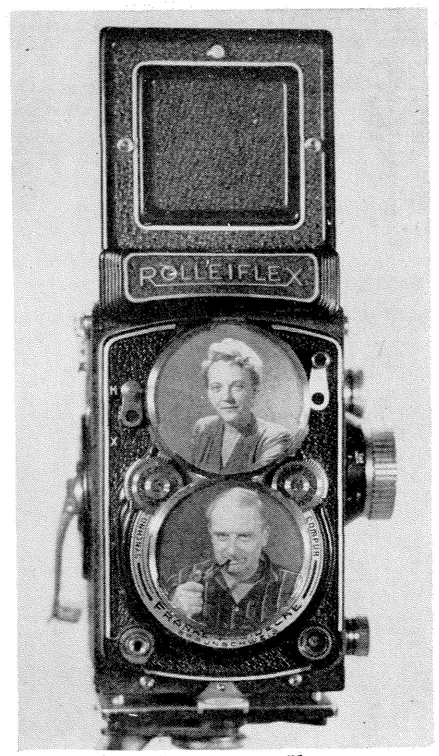
Westinghouse

In This Issue . . . CONTINUED



Muriel and Tom Harvey

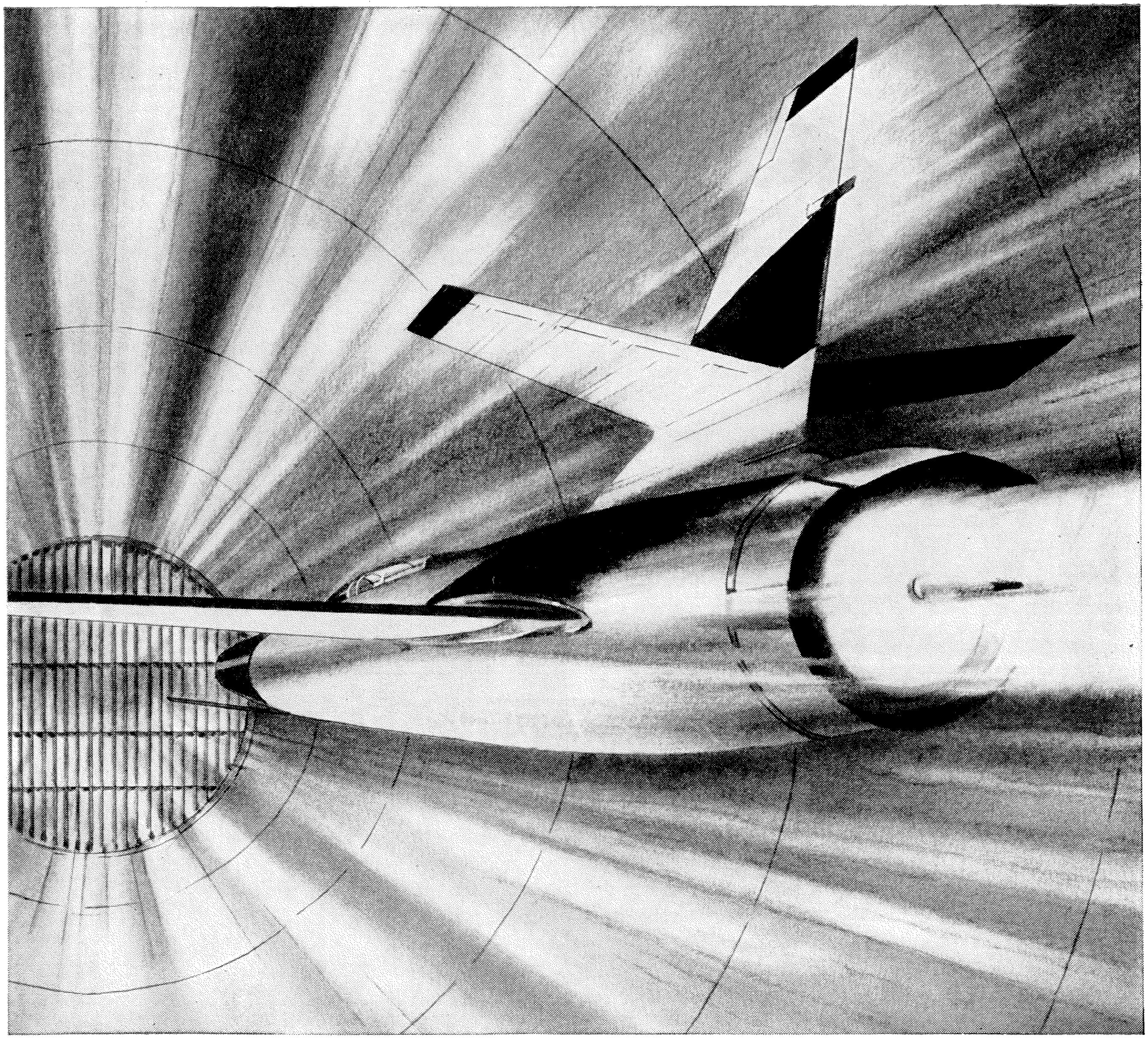
car, of course, but Dr. Millikan had one (known, for some reason as "Sir William") which could be—and was—borrowed fairly freely.

In his article Dr. Weaver not only revives some warm memories of the early days of the Institute, but traces the growing partnership between the physical sciences and the biological sciences—which has now been so firmly established in the new Church Laboratory.

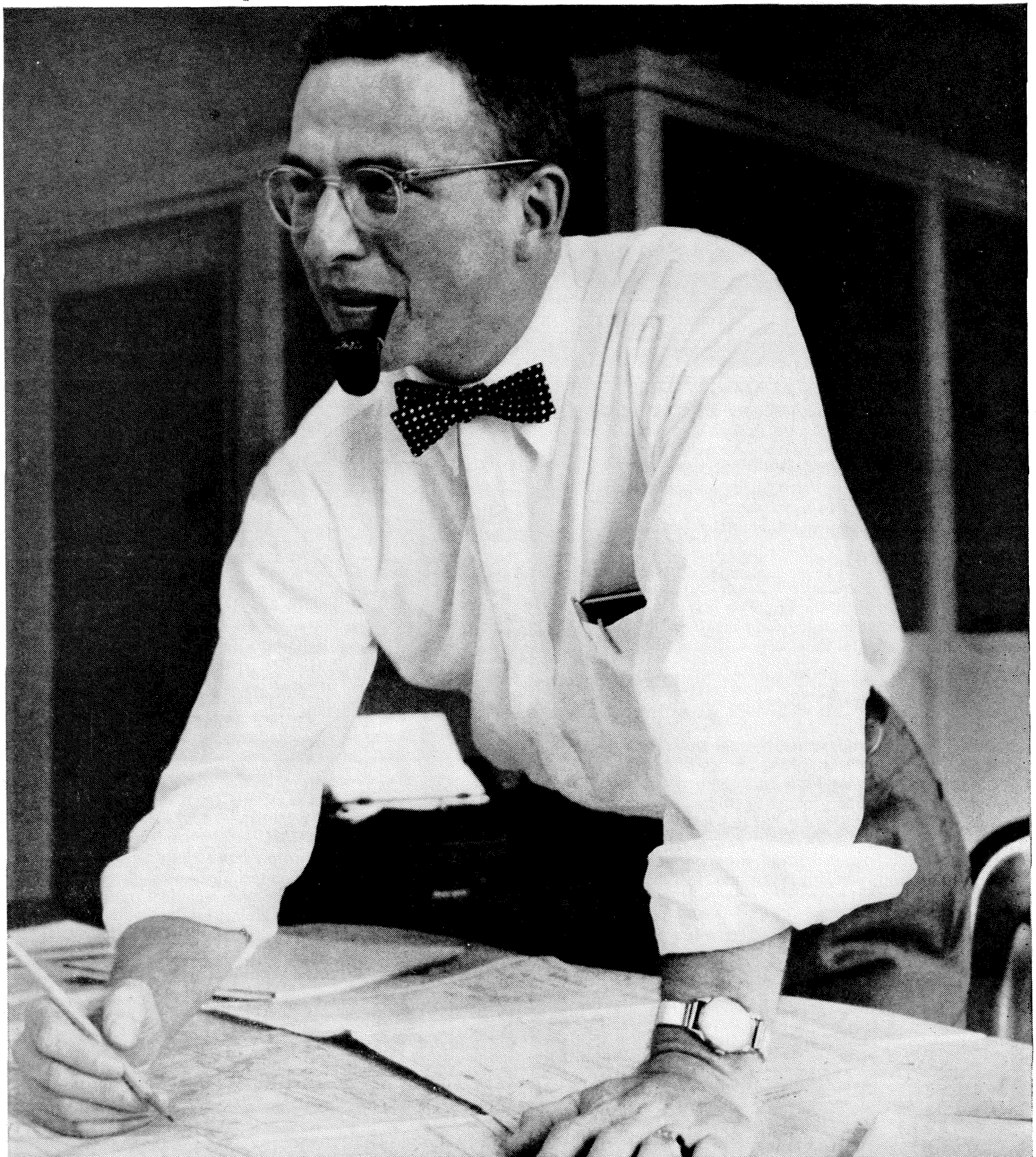
When we say, on page 15, that Thomas W. Harvey took the impressive faculty portraits on pages 16 to 23, we are telling a half-truth, because some of the portraits—and only the Harveys know which—were taken by Tom's wife, Muriel.

Tom Harvey's interest in portrait photography goes back 25 years, when he was 14 years old. Muriel's dates, roughly, from the day, just a few years back, when her husband made her a present of a Rolleiflex. Tom now confesses that he expected his wife to have a brief romance with photography—and then to turn the camera over to him. Instead, Muriel developed a permanent attachment to photography and Tom had to buy himself another camera.

The Harveys have worked together on portrait photography ever since. To get a relaxed portrait they shoot a minimum of 24 exposures, in about 30 minutes. They can usually count on the first 12 being worthless because it takes this much time for most subjects to loosen up. Out of the 24 shots they usually get one or two worth printing—and some of these prints can be found on pages 16 to 22 of this issue.



the top of your chosen field!



BOOKS

MEN AND MATERIALISM
by Fred Hoyle
Harper & Brothers, N.Y. $2.75

Reviewed by Hunter Mead
Professor of
Philosophy and Psychology

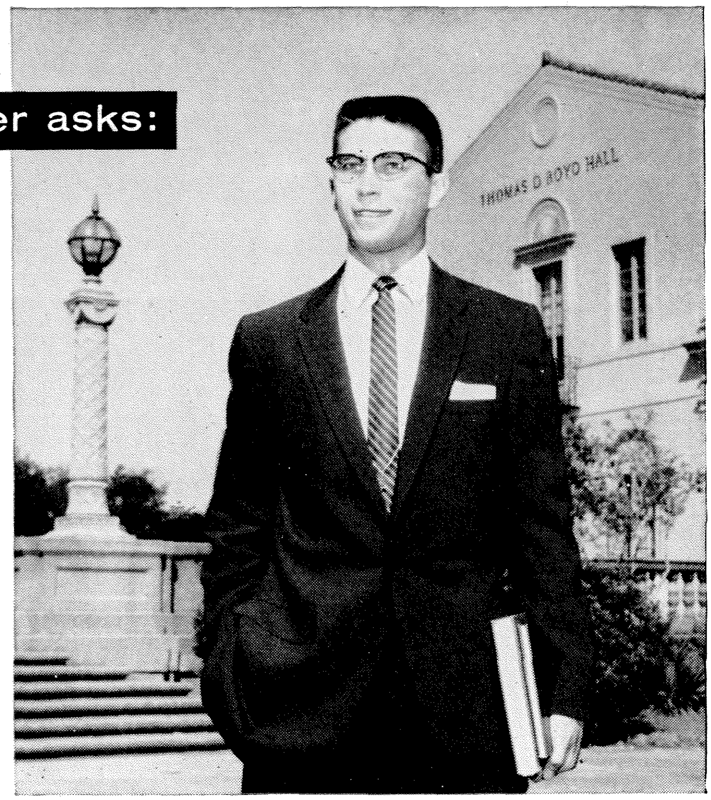
THIS SMALL volume is one of a well-intentioned series entitled "World Perspectives." Some eight or ten books in the series have already been published and another fifteen are announced.

Personally I found the book disappointing. Its subtitle, "A Commentary on Human Affairs," and the author's declaration in his opening chapters that the problems of modern civilization are too complex to be dealt with in such a small volume, necessarily rob the critic of much of his ammunition. However, the book can still be criticized on two grounds.

In the first place, it seems to me that Mr. Hoyle's handling of the enormously difficult problems facing modern man is not only brief, but cavalier and even casual. Again and again as I read the chapters I found myself saying, "Here is the boy scientist behaving in typical boy-scientist fashion: making the world over in his own rational image in less than one hundred and sixty pages." At first this seemed amusing; soon it became irritating. In short, I feel that Hoyle tried to cover far too much in such a small space, and then compounded his original mistake by covering it in a casual let's-make-the-world-over-some-weekend fashion. I feel a better subtitle for the book would have been, "Random Jottings on Human Affairs from the Desk of a Busy Scientist."

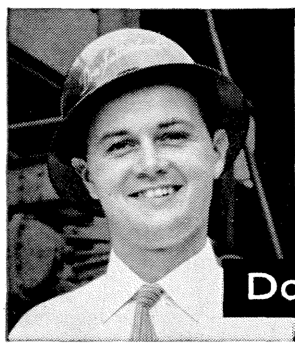
I feel Hoyle's second mistake was his attempt to adapt strictly technical terms to non-technical uses, thereby confusing the non-technical reader, and thereby giving readers who are completely at home in this terminology a false impression that the problems are as definite, well understood and soluble as most technical problems eventually become. One example will suffice. Hoyle states that the chief difficulty in understanding human behavior with any precision comes from the fact that "human behavior is controlled by an interlocking system of nonlinear feedback loops." He then gives a short para-

Oran Ritter asks:



Does Du Pont hire men who have definite military commitments?

Oran A. Ritter, Jr., expects to receive his B.S. in chemical engineering from Louisiana State University in June 1957. He's now editor-in-chief of the "L.S.U. Engineer," local president of Tau Beta Pi, and senior member of the Honor Council of his university. Oran's question is on the minds of many men planning a technical career.



Don Sutherland answers:

Donald G. Sutherland graduated from Virginia Polytechnic Institute in 1953 with an M.S. degree in chemical engineering and an R.O.T.C. commission. He was hired by Du Pont's plant at Victoria, Texas. After two years in the service, Don returned to his career in engineering, and is now doing plant-assistance work in the technical section at Victoria.

YES, Oran, we certainly do! We've employed quite a number of college graduates with definite military commitments, even when we knew they could work no more than a few weeks before reporting for duty. Take my own case. I was hired in November of 1953 and worked for only four weeks before leaving for the Army. Two years later I returned to Du Pont.

You see, we're primarily interested in men on a long-range basis. The fact that they're temporarily unavailable, for a good reason like military service, isn't any bar to their being considered for employment. After working only one day, an employee is guaranteed full re-employment rights—that's the law. And if a man works for Du Pont a full year before entering the service for two or more years, he receives an extra two months' salary. If he goes into the service for six months, he's paid a half month's salary. When he's entitled to a vacation but doesn't have time to take it before leaving, Du Pont gives him equivalent pay instead.

Even if present employment is impossible, Oran, we definitely recommend your talking with Du Pont's representatives as well as those of other companies. The very least you'll gain will be valuable background and some contacts of real benefit to you when you leave military service.

WANT TO KNOW MORE about working with Du Pont? Send for a free copy of "The Du Pont Company and the College Graduate," a booklet that tells you about opportunities for work in all departments of the Company. Write to the Du Pont Company, 2521 Nemours Building, Wilmington, Delaware.

DU PONT
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BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

Watch "Du Pont Theater" on television

graph, consisting mostly of an analogy drawn from the stock market, explaining what he means by "linear" and "nonlinear" and "feedback." After this extremely brief (and to my mind, inadequate) explanation of these technical terms, he uses them freely throughout many sections of the book. Now to a technically trained person who has never seen the relation between human behavior and feedback systems, this might be helpful. But this book was intended for laymen, not technicians, and I am certain Hoyle confuses more readers than he ever enlightens by utilizing this misplaced technical vocabulary. It may be quite exact to describe human behavior as controlled by an interlocking system of nonlinear feedback loops, but the statement is not helpful to most of the persons for whom the book was supposedly written.

To my mind the best thing in the book is the author's frank acceptance of materialism, which he defines very well along these lines: "The essence of materialism lies in its refusal to separate Man and his environment into the mutually exclusive categories of 'spiritual' and 'material'." This statement comes on the first page and looks promising of some good discussion. But on page two we come to those nonlinear feedback loops, and most readers will find themselves tangled therein for the remaining hundred and fifty pages.

Fred Hoyle, lecturer in mathematics at Cambridge University, is now at Caltech as visiting professor of astronomy.

ELEMENTS OF PURE AND APPLIED MATHEMATICS
by Harry Lass
McGraw-Hill, N.Y. **$7.50**

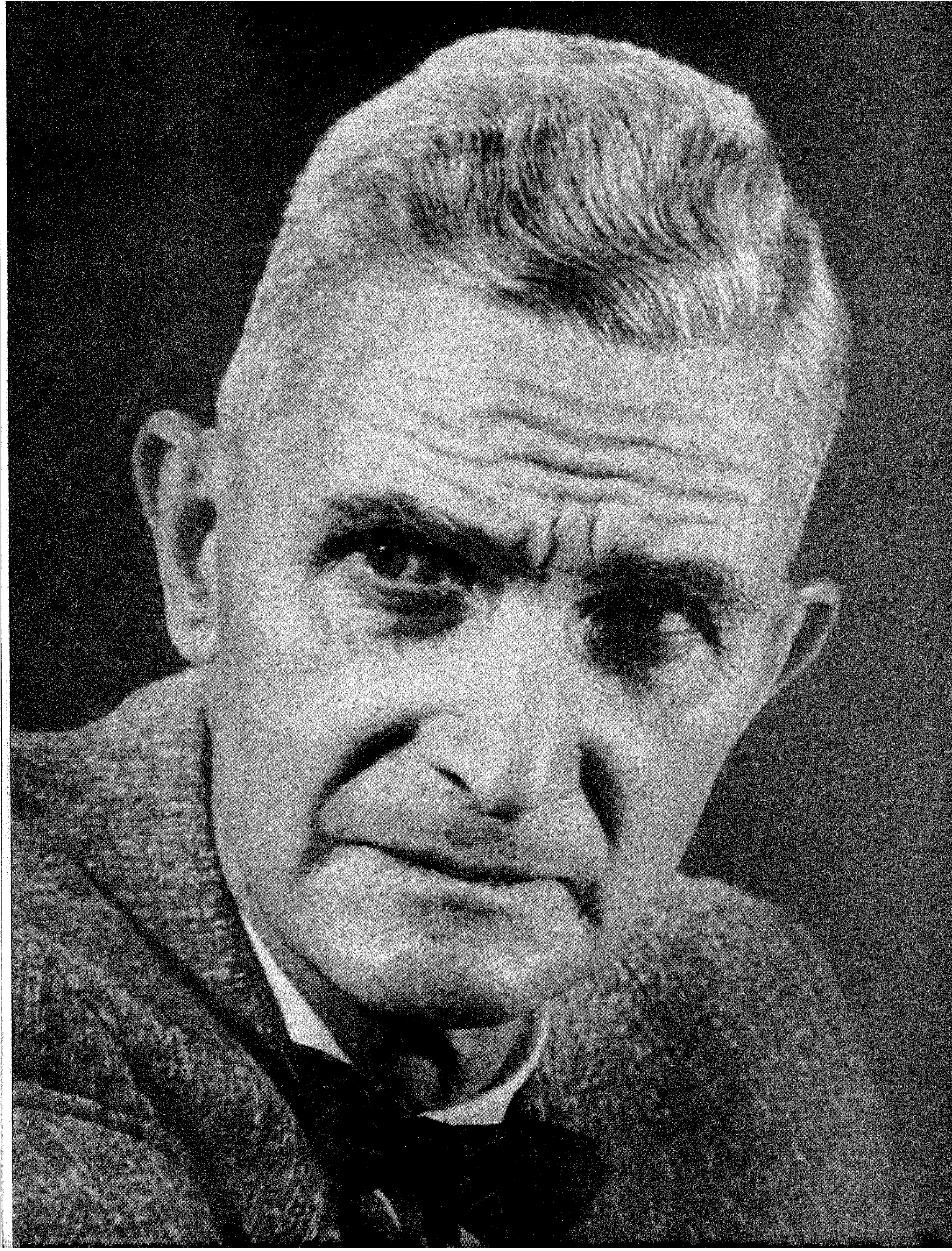
THIS WORK is intended as a reference book for all readers and a text for upper-division undergraduate courses for physical science, engineering, and math majors. There is a short treatment of nonlinear mechanics and game theory, a chapter on group theory and algebraic equations, and material on vector and tensor analysis, probability theory and statistics, as well as a treatment of orthogonal polynomials. Dr. Lass, who received his PhD from Caltech in 1948, is a research specialist at Caltech's Jet Propulsion Laboratory.

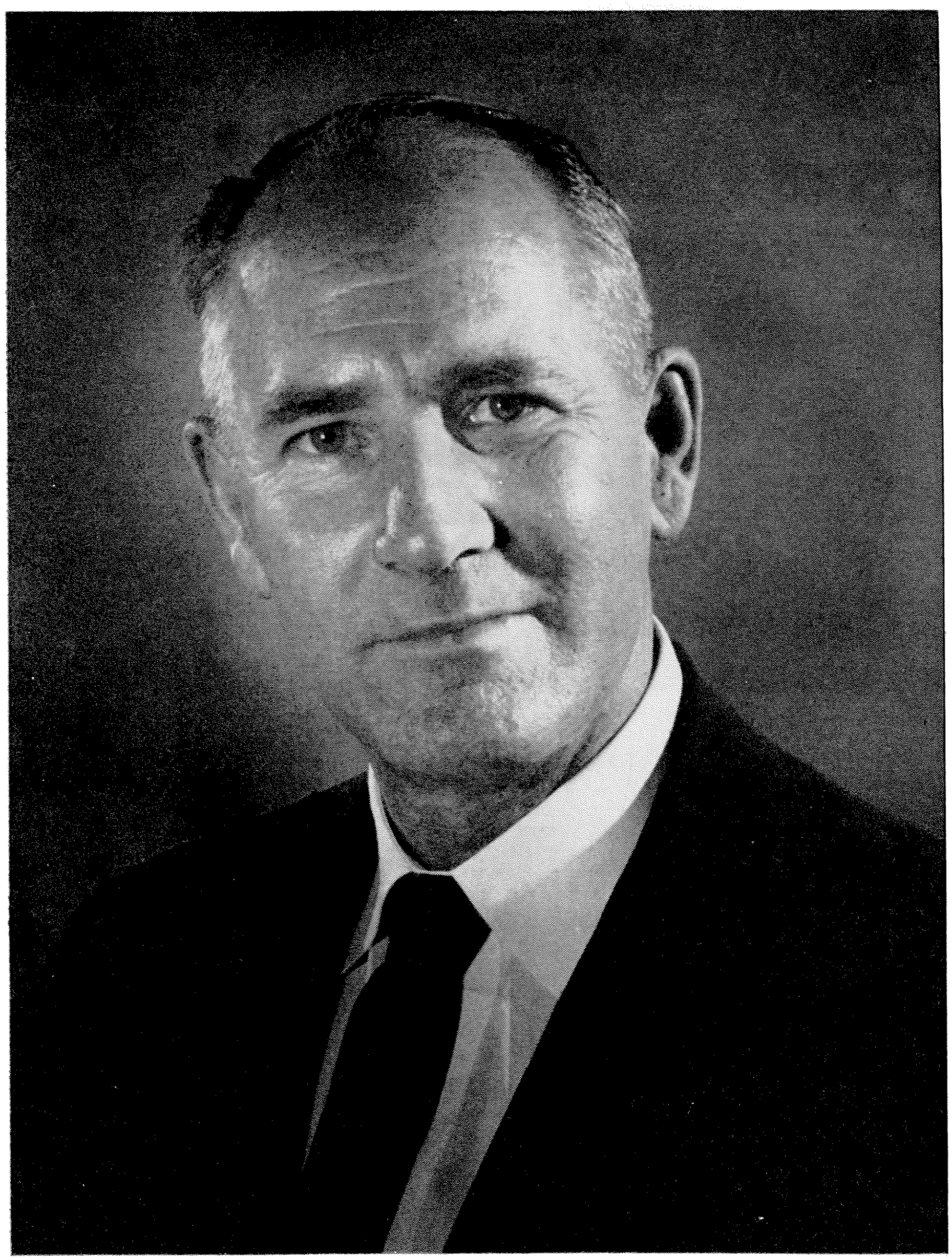
A PORTFOLIO OF FACULTY PORTRAITS

by THOMAS W. HARVEY

THE PHOTOGRAPHS on the next eight pages were taken by Thomas W. Harvey, administrative assistant of physics at Caltech. Among other things, Tom Harvey runs the physics stockroom (more commonly known as "Harvey's Dime Store") and, in the course of a normal year, can produce enough miscellaneous equipment to set up approximately 300 laboratory experiments for freshmen and sophomore classes and for the renowned Friday Evening Demonstration Lectures.

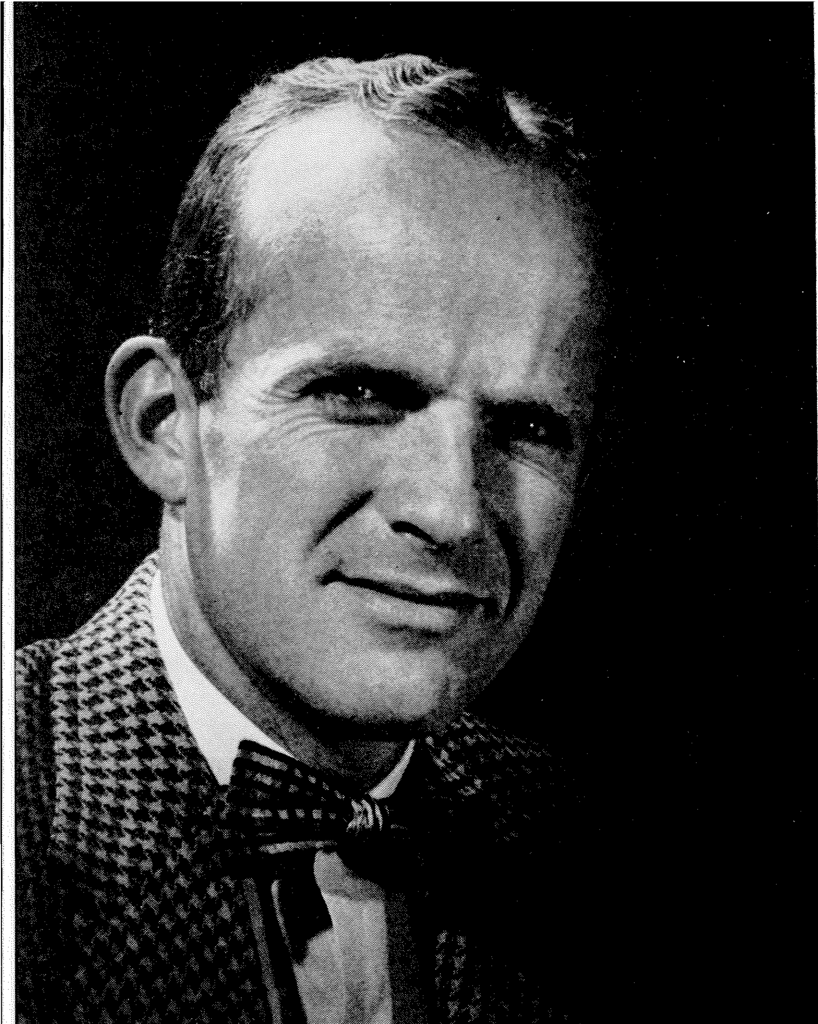
After hours, Tom Harvey is a photographer. He's been one for 25 years, since he was 14, and his chief photographic interest has always been in portraits—in trying to record, as honestly as possible, the character in a face. Since he came to Caltech in 1947, faculty members have been some of Tom Harvey's favorite subjects. Some of the favorite faces in his collection are on the following pages.





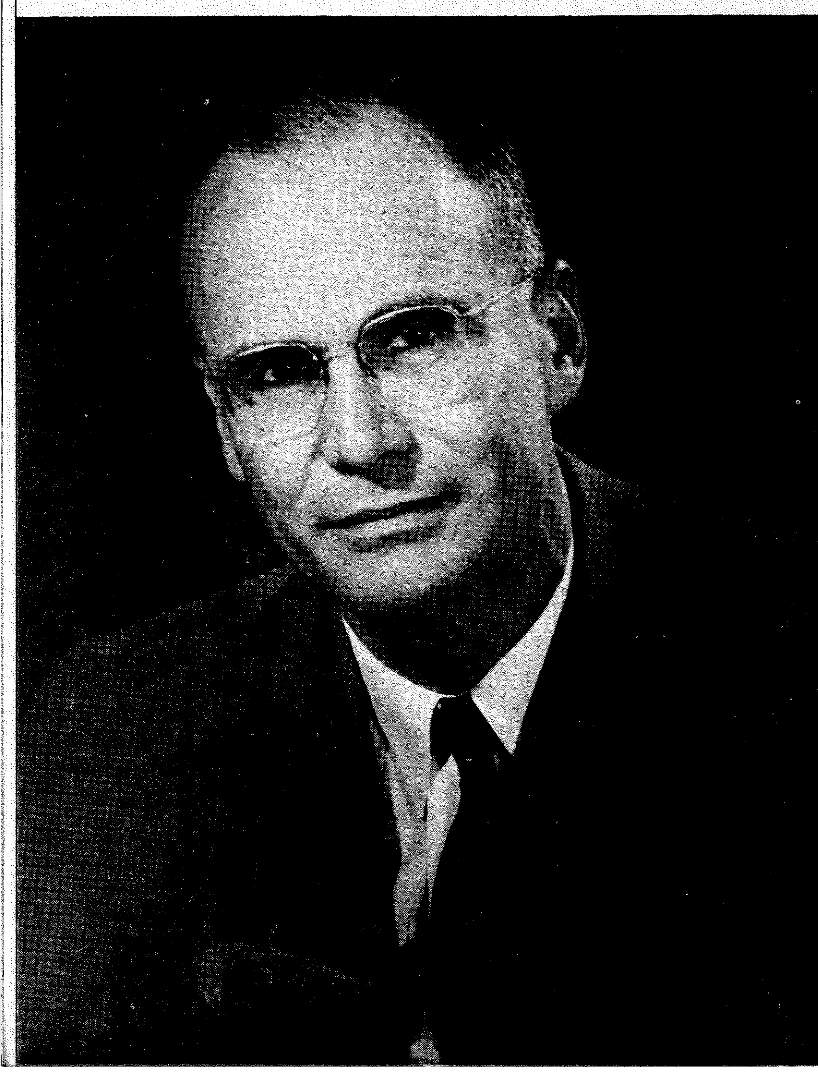
George W. Beadle, professor of biology, and chairman of the biology division

William R. Smythe, professor of physics

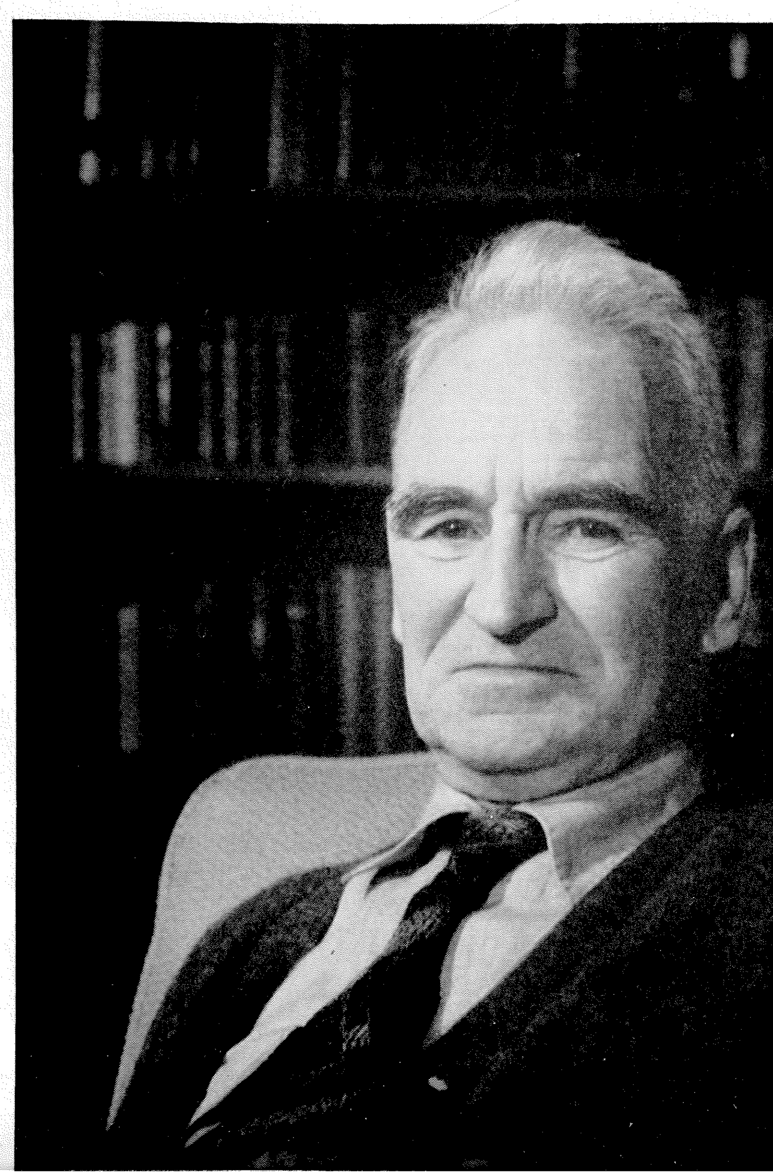


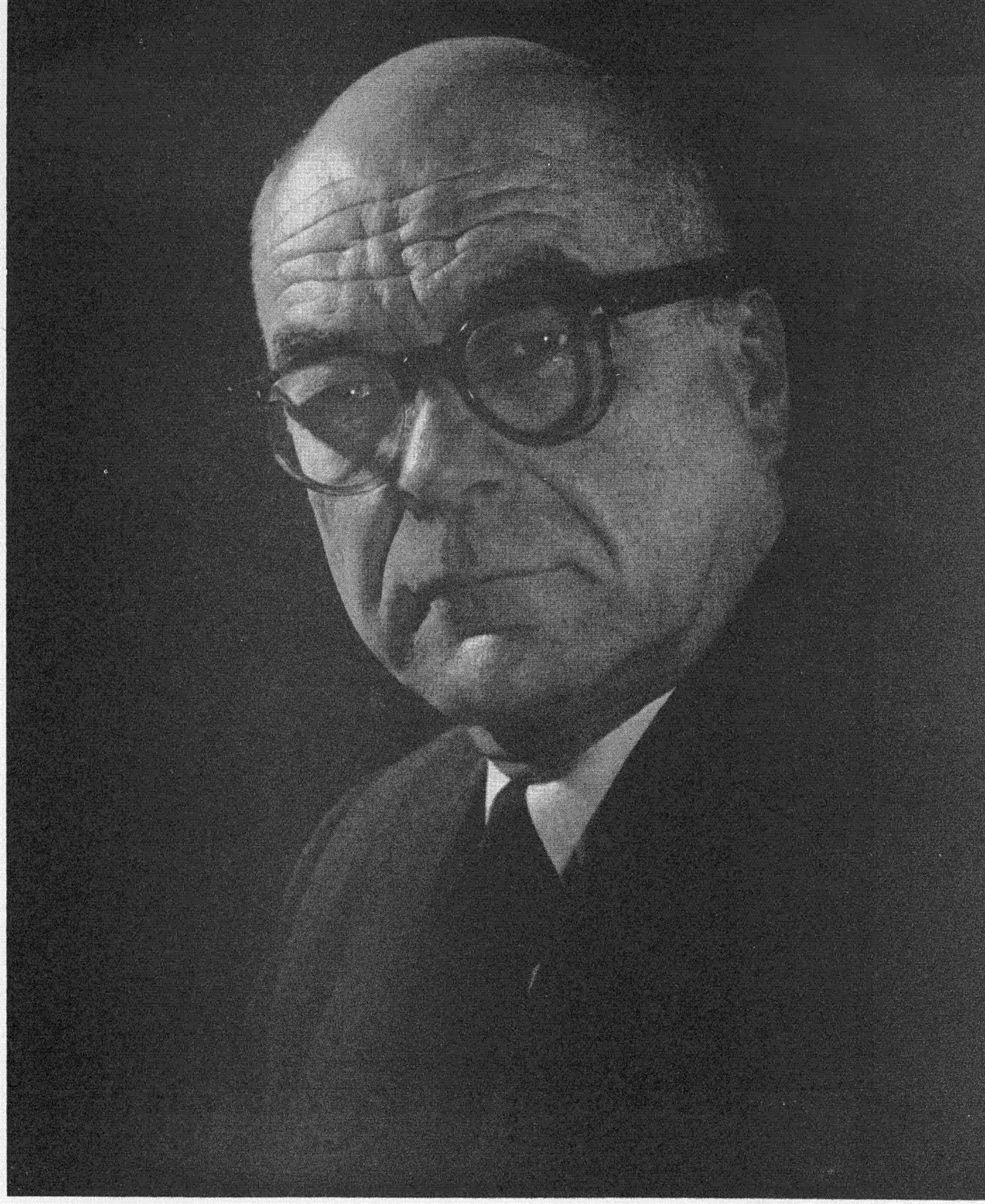
Gunnar Bergman,
assistant professor of chemistry and mechanical engineering

Robert B. King,
professor of physics



Eric T. Bell,
professor of mathematics, emeritus

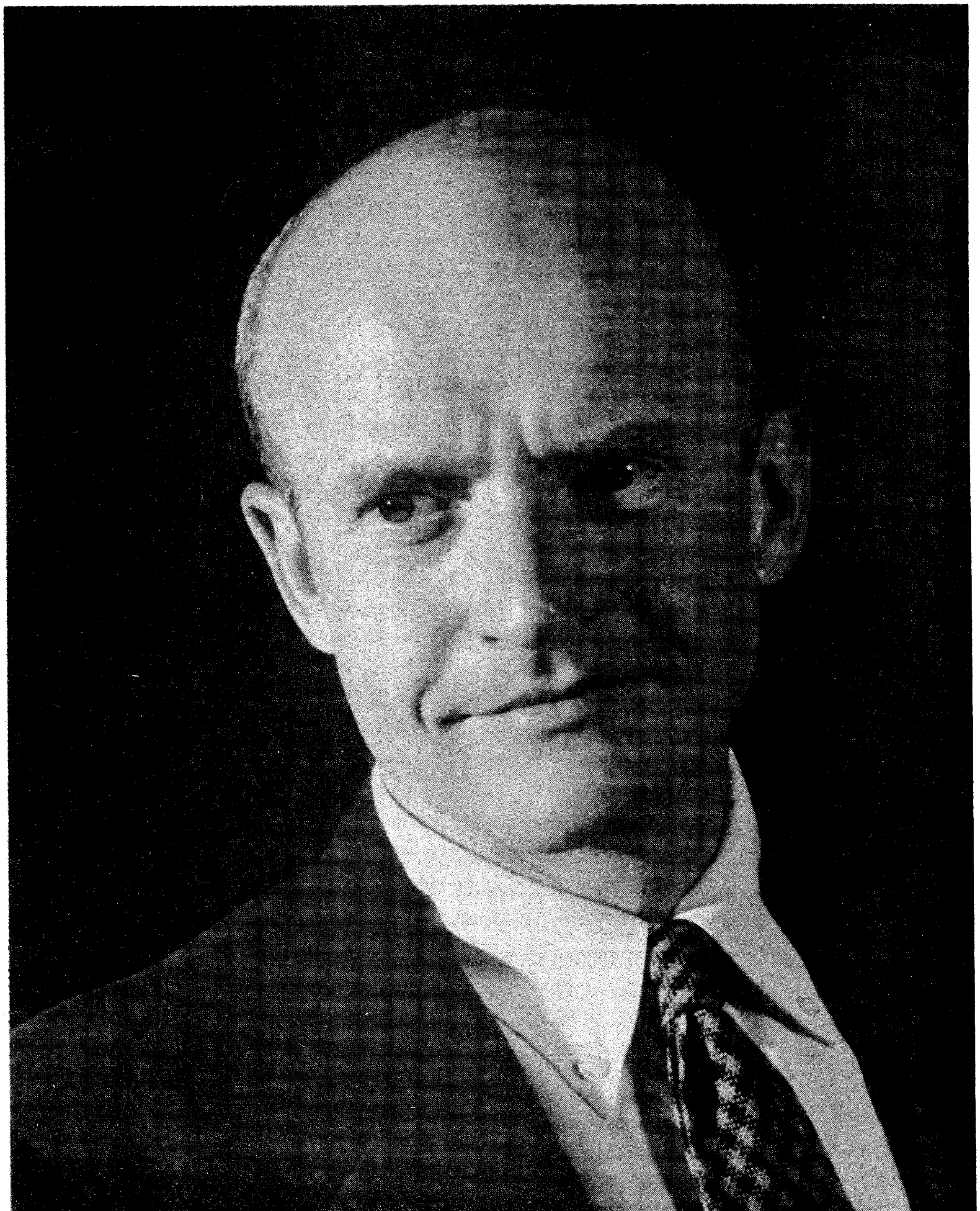




Harvey A. Eagleson, professor of English

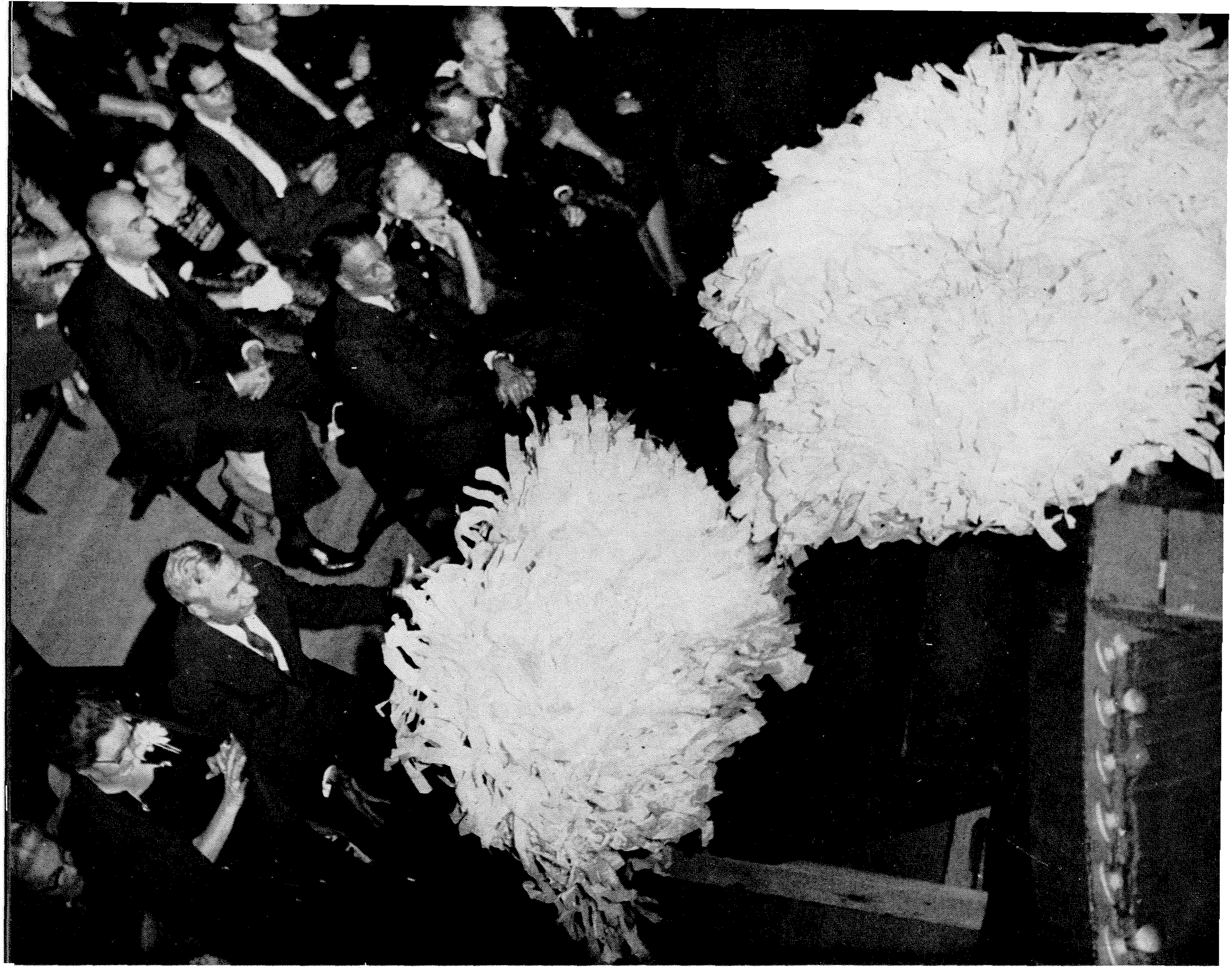
Peter Kyropoulos, associate professor of mechanical engineering

James C. Davies, associate professor of political science



Richard H. Jahns, professor of geology

Richard P. Feynman, professor of theoretical physics



President and Mrs. DuBridge receive a volley of pom-poms from Culbertson stage at tenth anniversary celebration

THE MONTH AT CALTECH

Anniversary

DR. L. A. DUBRIDGE celebrated his tenth anniversary as president of Caltech this month, and the faculty and trustees of the Institute honored him at a dinner in the Athenaeum on December 7.

The anniversary celebration included brief tributes to President DuBridge by Albert Ruddock, chairman of the board of trustees, and by Dr. Robert Bacher, chairman of the division of physics. Dr. Clark Millikan, professor of aeronautics and director of the Guggenheim Aeronautical Laboratory, was master of ceremonies during the evening, and faculty members presented a musical skit, "Who Is This Guy DuBridge?"

One of the high points of the anniversary occasion was a telegram received by President DuBridge, which read:

"Please give my greetings to the students, faculty and the Board of Trustees of the California Institute of Technology on the occasion of the tenth anniversary of the administration of their president, Dr. Lee Alvin DuBridge, scientist, educator and public servant. Dr. DuBridge has contributed repeatedly and significantly to the strength of the nation. I join his friends in wishing him many more years of service to his countrymen. Best wishes to you all."

(signed) Dwight D. Eisenhower

On January 12 Mr. and Mrs. DuBridge will leave Pasadena for a trip around the world, to visit universities, engineering schools and scientific research centers under the auspices of the Ford Foundation.

The chief purpose of the trip is to exchange ideas with scientists and educators, principally in the countries of Southeast Asia, and to report to the Ford Foundation on the various activities in which they are interested or are supporting.

After brief stops in Honolulu and Manila, the DuBridges will spend about ten days in Indonesia, then ten days in Burma, slightly over three weeks in India, and two weeks in West Pakistan. The visits to the Middle Eastern countries will be determined by conditions which exist there at the time of their arrival. It is expected, however, that they will spend two days in Teheran, a few days in Beirut, Lebanon, and several days in Istanbul. From that point on, their trip will be occupied by vacation and sightseeing in Greece and Italy. They will return home on the Queen Mary, leaving Cherbourg on April 18, and will be back in Pasadena on April 25.

Mutual congratulation society—Elliott Davis, who wrote music for anniversary skit, and the DuBridges.

New Appointments

William H. Corcoran, associate professor of chemical engineering, and Norman H. Davidson, associate professor of chemistry, have now received appointments as professors at the Institute.

Dr. Corcoran, whose appointment will become effective on January 1, has been on the Institute staff since 1953. He received his BS from Caltech in 1941 and his MS in 1942, then joined the research staff of the Cutter Laboratories in Berkeley. In 1943 he returned to Caltech to serve as development engineer on the rocket development program. After the war he resumed his graduate studies at the Institute, and was awarded a National Research Council fellowship. In 1948 he was one of the first men to receive a PhD degree with a major in chemical engineering. From 1948 until he joined the Caltech faculty in 1953, he served as head of the Cutter Laboratories' technical development division.

Dr. Davidson has been a member of the Caltech faculty since 1946. He was graduated from the University of Chicago in 1937, then spent two years at Oxford, as a Rhodes Scholar. He received a BSc at Oxford in 1938, and a PhD degree from the University of Chicago in 1941. He worked on the uranium separation project at Columbia University, then served as an instructor at the Illinois Institute of Technology before joining the staff of the University of Chicago plutonium project, where he remained until 1945. From 1945 to 1946 he worked at the RCA Laboratories in Princeton, N.J., on electron microscope research and studies of electron diffraction by solids.

Faculty members and wives serenade the president on his tenth anniversary, during musical skit, "Who Is This Guy DuBridge?"

At Caltech his research has mainly involved studies of the rates of very fast chemical reactions, and in 1954 he received the California Section Award of the American Chemical Society for this work.

Dr. Davidson's appointment as professor will become effective on July 1, when he returns to Caltech from a year's leave of absence as visiting professor of chemistry at Harvard University.

Geographos

On August 31, 1951, Dr. Albert G. Wilson and Dr. Rudolph Minkowski, staff members of the Mt. Wilson and Palomar Observatories, discovered a small new planet while they were working on the National Geographic Society-Palomar Observatory Sky Survey.

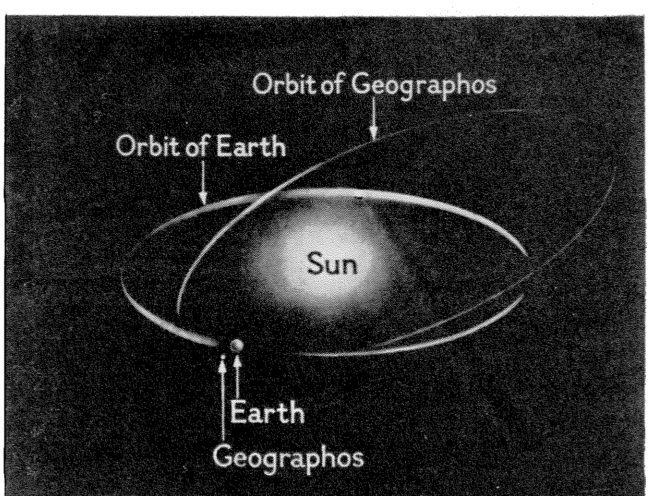
Now, after more than four years of checking, the planet's existence has been officially confirmed. Its discoverers have named it Geographos, after the National Geographic Society. Dr. Wilson is now director of the Lowell Observatory in Flagstaff, Arizona; Dr. Minkowski is still in overall-charge of the Sky Survey.

Small as it is (probably no more than a mile in diameter) Geographos is especially interesting to scientists because, with the exception of the moon, it comes closer to the earth than any other celestial object with a known orbit. In 1969 it will come within less than four million miles of us.

Aid to Hungary

Caltech undergraduates last month donated $1,000 to help Hungarian students who have fled to Austria to escape reprisal for their part in the Hungarian revolt against Russian domination. The gift, which will be administered by the World University Service, was voted at a meeting of the student body board of directors, and the action followed receipt of a cable from the general headquarters of the World University Service in Geneva, Switzerland, appealing for funds to aid the students. The World University Service operates in conjunction with the International Red Cross and the International Rescue Commission.

After making their donation, the Caltech students contacted student body officers of other southern California colleges and universities to get their support for the project too.



New planet, Geographos, as it will appear in relation to earth in 1969, when it will be 4,000,000 miles away.

Honors and Awards

Bruce H. Sage, professor of chemical engineering, has been named the 1956 recipient of the American Rocket Society's C. N. Hickman Award for solid propellants advancement in the jet propulsion field. Dr. Sage was presented the award at the Society's eleventh annual meeting in New York on November 29.

Bruce Sage was graduated from Texas A & M College in 1929, and received his MS from Caltech in 1931, and his PhD in 1934. He has been associated with the Institute ever since. In 1945 he was made head of the explosives department of the Naval Ordnance Test Station at Inyokern, California, and since 1950 has been senior consultant for NOTS.

From 1941 to 1946 Dr. Sage served as a consultant to the Division of Rocket Ordnance of the National Defense Research Committee of the Office of Scientific Research and Development, and later as investigator and supervisor of the Propellant and Interior Ballistics Division of the National Defense Research Council's rocket program at Caltech.

He played an important role in the development of rockets for military purposes, and in 1948 received the Medal for Merit, the outstanding civilian award for contributions to the war effort, for his studies on rocket ballistics.

Since the war Dr. Sage has led the development of solid rockets as a propulsion medium. In addition he is credited with the development of a propellant "blacking" process which greatly increased solid propellant reliability by counteracting radiation phenomena, and the creation of successful extrusion methods for propellants.

John D. Roberts, professor of organic chemistry, has been elected chairman of the American Chemical Society's Division of Organic Chemistry for 1957. Dr. Roberts, who has been a member of the Caltech faculty since 1953, received the American Chemical Society Award in Pure Chemistry for 1954 for his research achievements in theoretical organic chemistry.

R. R. Martel, professor of structural engineering; and Theodore von Karman, professor of aeronautics, emeritus, will be made life members of the American Society of Civil Engineers at the January meeting of the society's Los Angeles section.

PASADENA REVISITED

by WARREN WEAVER

IT WAS THIRTY-NINE years and a few months ago that a young assistant professor of mathematics walked into the entrance of the main building of Throop College, stepped up to the desk of the college book store (which was then just to the left of the entrance), and asked the attendant what textbook was to be used in calculus. She said, perfectly reasonably, "I would suggest that you wait until tomorrow and ask that question of your teacher." I must, at that moment, have looked very young and green.

Life in those days for the fledgling professor was rather different from what I imagine it is now.

Physically speaking, Throop College consisted of the chemistry building now known as the Gates Laboratory, the central building now known as Throop Hall, and a few assorted sheds spotted around in the rear. Will Lacey had joined the staff the year before, Stuart Bates two years before, Howard Lucas three years before. Earnest Watson was to come the next year.

There are not many of us left of that vintage. Linus Pauling was a senior in high school that year, and George Beadle, if I calculate correctly, had just graduated with honors from the seventh grade. Biology at CIT was, at that moment, not even a gleam in father's eye.

In the basic sciences, there then were, of professorial rank, one in physics, two in mathematics, and three in chemistry. We were so small in numbers that faculty meetings were held in President Scherer's office—a small room which has now become part of President DuBridge's present office. But it was entirely clear, even at that early moment, that something strange and wonderful was astir here.

We had an early and clear vision of a new and special sort of institute which would be intellectually compact; which would be imaginative, flexible, and superb in quality; which would be dedicated not to size or noise or to the routine levels of technological training, but rather to outstanding quality and to the supreme adventure of advancing basic knowledge about nature.

Most important of all, we had the leadership that could not only dream such dreams, but could turn them into reality. I count it one of the great good fortunes of my life that I had the privilege of knowing Dr. Millikan, Dr. Noyes, and Dr. Hale. It is a tradition of American academic life to speak with deserved reverence about Mark Hopkins at one end of a log and a student at the other. When, a hundred years from now, there is talk about the development in this country of graduate education in science, I suspect there will be even more frequent reference to those three unselfish and inspired men who created and made manifest the concept of this great institution.

It may have occurred to some of you that I have, at this point, created a dilemma of explanation. If this institution, just then at its chrysalis stage, presented so challenging and so attractive an opportunity, why didn't I stay here?

I could claim that I never have officially left. For I treasure a handwritten letter from Dr. Millikan in which he said that he couldn't restrain me from leaving, but that the Institute could and did refuse to accept my resignation; that I would continue indefinitely to be a member of the faculty, and that I needed only to inform them when I wished to return. I have, on several occasions, warned Lee DuBridge and the trustees that I still hold this document.

But the real reason for my departure is one that Caltech people can understand. I went back to Wisconsin, and then to the Rockefeller Foundation, because Max Mason asked me to. I am sure that there are many persons here who have fallen under Max's spell, and

"Pasadena Revisited" has been adapted from a talk presented at the dedication of the Norman W. Church Laboratory of Chemical Biology, November 15, 1956. Mr. Weaver, who is now vice president for the Natural and Medical Sciences of the Rockefeller Foundation in New York, was assistant professor of mathematics at Caltech from 1917 to 1920.

who realize just why I have considered it one of the major joys and excitements of my life to be a friend and a working colleague of Max Mason. The more detailed reason for the shift to the Rockefeller Foundation is, moreover, closely related to our proper subject here.

For Max Mason and I, although both trained in the physical sciences, shared an enthusiasm for the biological sciences, and both had certain articles of faith and conviction concerning the interrelationship of the biological and physical sciences. It seemed clear that the century from 1825 to 1925—the century from Ampère and Oersted to Einstein and Schrödinger, from the first laws of the electric current and of electromagnetism to relativity and quantum theory—had been a great century of upsurge for the physical sciences. One was not so foolish as to think that this rate of progress would necessarily decrease; but it was surely evident that the physical sciences had developed a tremendous momentum; that support for the physical sciences was in general assured from federal, industrial, and other sources; and that, perhaps most important of all, our knowledge of physical laws and our capacity to control physical nature were advanced far beyond our knowledge of the mechanisms of behavior of the living creatures who held all this power in their fumbling hands.

It also seemed evident that the physical sciences—chemistry most notably, but physics and mathematics as well—had developed many experimental procedures and many techniques of theoretical analysis which could undoubtedly be applied with profit to biological problems —and which had, as yet, not been generally so applied.

Thus it was our shared privilege to help develop, in the Rockefeller Foundation, a program which, though labeled "Modern Experimental Biology," was in essence a program of attack on basic biological problems using all the theoretical and experimental armament of the physical sciences, it being of course absolutely essential that this effort be dominated by the biological viewpoint —by a constant recognition of the essential complexity, the essential subtlety, and the essential wholeness of living organisms.

Merger of the sciences

When one compares the status today of the interrelationship of the physical and the biological sciences with what the situation was 25 years ago, the change is substantial. It would of course be ridiculous to suggest that the Rockefeller Foundation is in any large measure responsible for this change. But one may, I think, take reasonable satisfaction in the fact that we were privileged, over that period, to give modest aid to many of the productive scientists who have done the real work.

Some early aspects of this development occurred in Europe, with the Bohr-Hevesy-Krogh-Rehberg group in Denmark; the Kluyver-Ornstein-Milatz group in Holland; with Astbury, and later the Randall group in England; with the Hammarsten-Svedberg-Tiselius-Theorell-Caspersson-Engstrom galaxy in Sweden; with the organic chemists devoted to natural substances, the enzyme chemists, the biochemical geneticists, the physical chemists concerned with macromolecules, the X-ray crystallographers, the virus experts, the submicroscopic anatomists—one cannot even hint at the range and excitement of the old fields which were brought to new life, and of the new fields which were opened up.

Rather than attempt any detailed technical discussion I would like to suggest in rather general terms what has been involved in this grand merger of the physical and biological sciences.

It would be entirely unfair to the great record of biology to intimate that it suddenly got smart, some quarter of a century ago. The earliest Italian anatomists realized the importance of, and bravely served, the experimental method. The bewildering variety of plant and animal life clearly made it necessary for biology, over long patient years, to describe, to classify, and to invent unambiguous terminology. A knowledge of form naturally precedes a knowledge of function—and an *explanation* of function quite inevitably comes later. The systematic and morphological approach to the living world has led to great triumphs of insight and interpretation, as illustrated by the theory of evolution itself.

A new viewpoint

But it remains true that the time had now come when biological phenomena could be analyzed on a new and more detailed and deeper level. To a great extent this resulted from the growing and releasing intellectual conviction that vital processes were not necessarily and inescapably mysterious, that one did not need to speak in terms of an *élan vital*, that the happenings in a cell and eventually even important aspects of the behavior of man are analyzable, are understandable, are describable, in the same sort of dependable and precise terms that has served so well for the atom and the star.

To an important extent, also, this new viewpoint was made feasible by a variety of new experimental techniques. I will speak of these, in general terms, under the heading of *new ways of seeing* and *new ways of separating*.

Until the microscope was invented, some 350 years ago, man had to observe nature only with his unaided eyes. Until the turn of the present century, there occurred only improvements in the power of the optical microscope, finally resulting in the fact that today one can usefully examine in that way objects whose dimensions are as small as about one-half a micron—that is to say, about five one hundred thousandths of a centimeter. But this is, for inescapable theoretical reasons, about as small as one can usefully see with ordinary light: and this leaves totally unexplored the world of the smallest bacteria, the still smaller animal viruses, and the still, still smaller plant viruses, to say nothing of the macromolecules, the molecules, and even the atoms with which the modern biologist must deal.

Ultraviolet microscopy has helped materially, as has phase contrast and fluorescent microscopy. But it was the electron microscope, a quite new device developed by the physicists, which decreased the size of observable objects by a factor of 100 or even, under specially favorable circumstances, by a factor of 500.

New kinds of seeing

Even this, however, is but a small part of the gain we have made in seeing. For there are new *kinds* of seeing—methods which are broadly analogous to seeing because they reveal the details of form and structure, and which are often better than ordinary seeing because they also give some evidence concerning constitution. There is the whole range of methods in ultraviolet and infrared spectroscopy, and the newer magnetic resonance methods, which give information about the details of chemical structure and about the mechanisms of chemical reactions. There are the cytochemical methods which permit the exploration of the detailed chemical organization within single cells. There are—which should be mentioned with special pride and emphasis here at CIT—the methods of X-ray and electron diffraction, which permit examination and analysis down to the actual level of individual atoms.

Coupled with these new ways of *seeing*, there are powerful new ways of separating. From one point of view any living organism—a single-celled protozoan as well as a man—is an almost incredibly and intolerably messy affair. It is a conglomeration of a vast number of exceedingly complicated substances and structures, all pretty thoroughly interdependent (which is almost a defining characteristic of an organism), and all thoroughly and subtly mixed up. To an old-fashioned physicist, used to a few variables and six-figure accuracy, or to an old-fashioned inorganic chemist, used to the purity of crystalline compounds, a bit of living protoplasm is more or less a shovel-full of guck.

So it has been of the greatest value that there have emerged, over the last quarter or third of a century, new and delicate methods of separating, out of messy mixtures, components which are relatively homogenous and thus suitable for study. The ultra-centrifuge of Svedborg, and the electrophoresis apparatus of Tiselius; column chromatography, to which Professor Zechmeister here at CIT contributed in so critically important a way, and the powerful later developments of paper chromatography; the newer Tiselius methods of charged carbon and starch; the Moore-Stein refinements in experimental procedures; counter-current methods; the employment of enzymes to break up and deliver desired fragments of molecules, the use of specially trained microorganisms which can report the presence or absence, in a messy mixture, of certain substances: all these are, in a broad sense, separation tools, most of which the physical sciences have furnished to the biologist.

This problem of separation is a very special one with biological material. On the one hand the chemical details of an organism may be very delicately characteristic. There are, for example, sub-species of snails that are so completely alike in all their morphological characteristics that not even the leading world experts can tell them apart. Yet one of these two sub-species is an intermediate host for the parasite which causes schistosomiasis, whereas the other is not. And these two sub-species do differ in certain details of their internal chemistry, and one can be told from the other by chromatographic techniques. There are of course numerous other instances in which biochemistry furnishes the only satisfactory discrimination between creatures which, on ordinary taxonomic criteria, are alike.

On the other hand, it is one of the remaining mysteries of biology that a vast variety of mixed-up material may be fed into an organism without in any way disturbing the basic and massive fact that this organism keeps on, so to speak, being itself. As Walter de la Mare remarked in "Peacock Pie":

"It's a very odd thing—
As odd as can be—
That whatever Miss T eats
Turns into Miss T."

In addition to these new methods of seeing and new ways of separating, there have been new ways of measuring. Perhaps most important of all, there has been a developing sense of active intellectual unity and comradeship between all the sciences, and a healthy emphasis on problems rather than on the compartments of the classical disciplines.

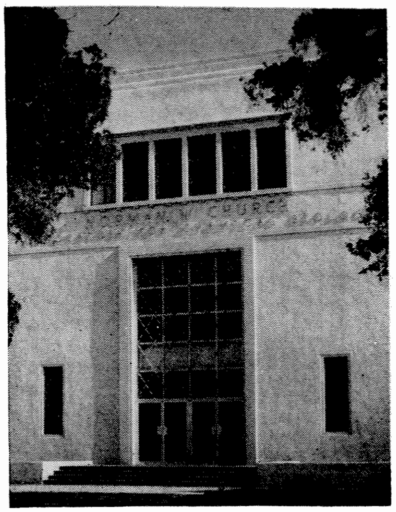
A fruitful union

I wish finally to relate the present situation at CIT to these remarks about the new partnership between the physical and the biological sciences: and I think that it should be clear to you that I have, up to now, been talking of the play without mentioning Hamlet. For in the fruitful union of chemistry and biology, the California Institute of Technology stands quite clearly in the very front rank. Nowhere else in the world, at least to the best of my knowledge, is there combined leadership such as is furnished here by George Beadle and Linus Pauling.

The wonderful new laboratory which is now being dedicated represents an act of inspired and unselfish faith on the part of the donor. It is a structure which, intellectually speaking, rests on a solid foundation of past and proved performance. It will, we are all confident, reach up into new heights of future activity.

To the Trustees, to the Associates, and to the Administration of CIT I say that it is your great opportunity and your great duty to see to it that there is kept preserved here the vision of Millikan, Noyes, and Hale.

Your heritage from the past is clear. Your faithfulness to that heritage has been superb. It is up to you to keep CIT compact, flexible, and imaginative. It is up to you to continue your marvelous record of providing a climate for leadership.



DEDICATION

Biologists and chemists hold open house in the newly-completed Norman W. Church Laboratory of Chemical Biology

James Bonner, Caltech professor of biology; Mrs. George Laties; and Harlan Lewis, UCLA professor of botany

Ernest Anderson, Caltech professor of genetics, and his daughter, Jean—absorbed in the exhibits

Mrs. Arthur McCallum, donor of the McCallum scholarships and fellowship fund; Linus Pauling, chairman of Caltech's chemistry division; Warren Weaver, vice president for the natural and medical sciences of the Rockefeller Foundation; and George Beadle, chairman of the Caltech biology division.

Mr. and Mrs. George Mitchell (first and third from left), associates of the Institute, look over Dr. Pauling's new quarters with the Paulings. Focal point of the office is the 25" x 55" rock sculpture shown below. Designed by Pasadena artist Susana Mueller, it is called "Professor Pauling and His Students." High-flying objects are "new ideas."

Mr. and Mrs. George Beadle, with Mr. and Mrs. Arnold Beckman. Mr. Beckman is a Caltech trustee.

Anton Lang, UCLA professor of plant physiology, and Linda Pauling, daughter of Linus.

What's Happening to the Automotive Power Plant?

A forecast for the next 25 years

by PETER KYROPOULOS

FOR the next 25 years there seems to be no indication of an early return to horses, nor any probability that steam or electric power will become attractive for use in the automotive powerplant. Too little is known about the miniaturization of nuclear reactors to even take a guess as to whether this might become a practical source of power—and this is also true for the direct utilization of solar energy.

Indications are that a summarization of present ideas on automotive powerplants would give us a better clue to what's in the future. For this forecast we might ask: How many people? How many cars? How much fuel?

	People	Cars	Gasoline
	10^6	10^6	10^9 gallons/year
1940	130	27	21
1950	150	40	35
1960	180	60	55
1970	200	80	75
1980	210	90	85

Since the table brings us to a formidable figure of 90,000,000 powerplants, the next question might be: How are these automobile powerplants going to work? The term automobile powerplant indicates that we are concerned with the whole propulsion system; the engine, transmission, drive line, differential and rear wheels.

As far as the engine is concerned, we have three choices, the piston engine, gas turbine, or the gas turbine with a free piston gas generator.

The forecast also lists gasoline consumption. Whether or not it will be gasoline or another liquid hydrocarbon is an important question. Whatever the type of fuel will be, the quantity should be about 85 billion gallons per year, and this, as the saying goes, "ain't hay."

Before we can discuss types of powerplants, we should establish the desirable and probable output required. Let us consider a typical passenger car traveling on a superhighway at 70 mph. The power required adds up as follows:

Air and rolling resistance			**40 hp**
(No headwind, summer temperature. This figure would be 60 hp with a 13 mph headwind at 30° temperature.)			
Transmission efficiency			**.88**
Rear end efficiency			**.96**
Engine power required	$= \dfrac{40}{.88 \times .96}$		$=$ **47.5 hp**
Accessories		hp	
Power steering		1	
Generator, charging		2	
Air conditioner		6	
Fan		3	
Total accessories		**12**	
Total engine power required for cruising:		**47.5 + 12**	$=$ **59.5**

This indicates only the minimum required. Acceptable acceleration can be obtained with an engine of 200 to 250 hp.

Although engines with considerably more power are common today, this trend may be eventually reversed. Acceleration at low speeds can be had from high torque at low speeds, without requiring very high peak power. The very high peak powers which are advertised are, in themselves, not very meaningful. The peak occurs at engine speeds which can be utilized only infrequently, if at all, because they correspond to high road speeds. It is doubtful whether cruising speeds over 75 mph will be practicable. If fully automatic steering and control systems become available, cruising speeds of around 100 mph on superhighways may be feasible. This would require about 160 hp at the rear wheels. This is easily available in many of our present engines.

Commercial vehicles such as trucks and off-the-road equipment are in quite a different situation. Here full load uphill operation is critical. A 65,000 pound truck going up a 6 percent grade at 45 mph requires about 1100 hp. There is at present no powerplant which will

An abstract of a paper presented at the annual meeting of the Western Engine Rebuilder's Association in Palm Springs, California, on November 2, 1956.

deliver this amount of power and which will fit into a truck.

The torque needed for low speed acceleration is not only a characteristic of the engine but depends on the correct *matching of the engine and transmission.* This matching has a twofold objective:

(1) Performance (meaning smooth and rapid acceleration over a wide speed range) and

(2) Economy (meaning an acceptable miles per gallon vs speed relation).

Meeting the requirements

Both these requirements can be met by a transmission with an infinitely variable gear ratio, automatically controlled. Basically the hydrodynamic transmission (commonly called a *torque converter)* is such a transmission. Actually, present torque converters still fall short of our requirements.

The chart, right, shows typical curves for two converters. One is designed for high stall torque ratio (4.3) at low speed, i.e., designed for high acceleration at low speed.

At a speed ratio of about .62 the stator is allowed to free-wheel (intersection of heavy and broken line). This is called the "clutch point." The torque ratio becomes 1 and the converter degenerates into a coupling. Efficiency peak is at a speed ratio of about .4. Between this peak and the clutch point, the converter efficiency is quite low, hence performance is unacceptably low.

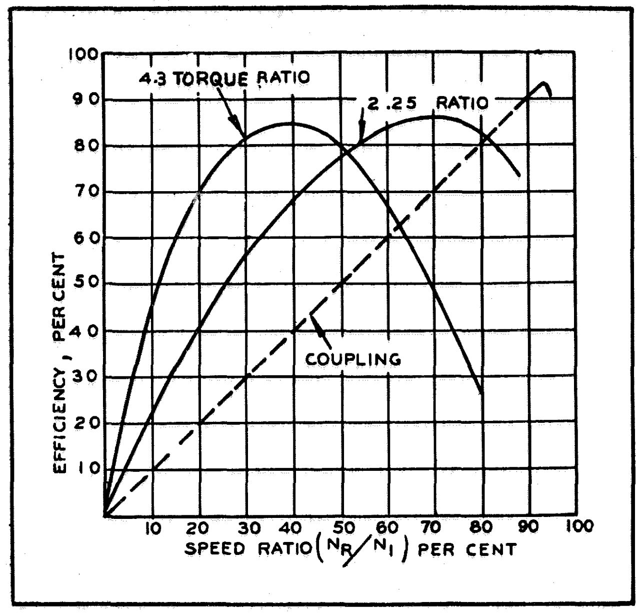
The second converter has a stall torque ratio of only 2.25, an efficiency peak at high speed ratio and atrocious efficiencies at lower speeds, hence no performance.

With fixed blade angles, the torque converter is essentially a single speed machine. We will need torque converters with continuously controllable blade angles. This would give us a transmission with high stall torque and high efficiency over a wide range of speed ratios.

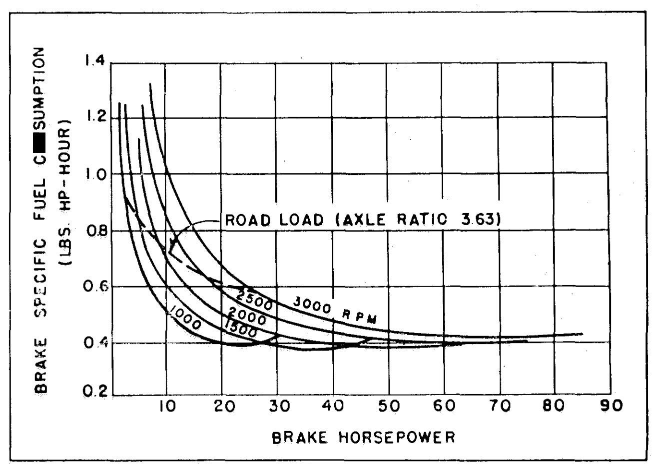
The second requirement—Economy—demands, first of all, high transmission efficiencies over the widest possible range of speed ratios. This is strictly a matter of converter development. Besides, the transmission should automatically seek the most economical operating point of the engine, compatible with speed and load requirements. This is illustrated in the center chart.

This plot shows fuel consumption vs power for a typical piston engine (spark ignition). The broken curve represents operation at road load for a typical passenger car with fixed gear ratio transmission. It is evident that the engine is forced to operate considerably above its optimum fuel consumption. The transmission should permit us to operate on the envelope around the minima of the consumption curves. What this means in terms of miles per gallon is shown in the bottom chart, where we have designated the latter case as "ideal transmission."

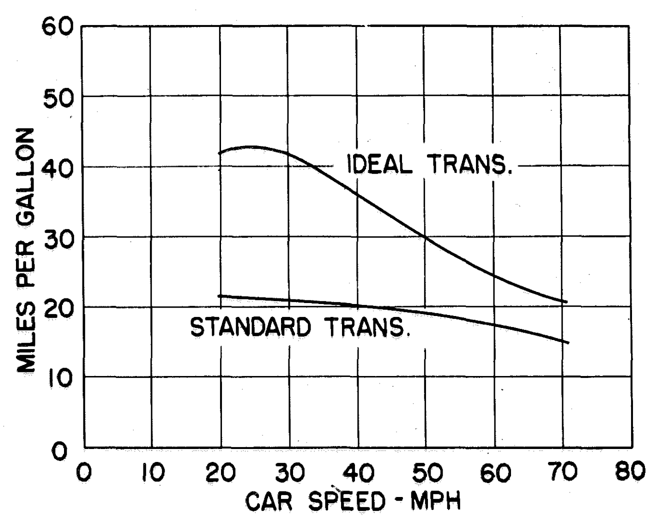
It is within the capability of the variable pitch trans-



Efficiency vs speed for two converters with different design points (Ref. 6). Speed ratio = output speed/input speed.



Typical piston engine curves of fuel consumption vs power (Ref. 5).



Comparison of economy for fixed gear ratio (standard) transmission with optimum within the capability of the engine (Ref. 5).

mission to utilize the large potential gain in economy.

The transmission problem in one form or another is common to all propulsion systems and is not limited to the piston engine. It is, therefore, considered ahead of an evaluation of engine types.

Pistons or pinwheels?

It has been said that, had we been driving around with turbine engines for the last 35 years, and someone had just now invented the piston engine, he would be considered quite a genius.

Just what is the status now and what is the potential? For passenger cars, the maximum practicable power is somewhere between 400 and 500 hp. Considerably less is most likely sufficient, as has been demonstrated earlier in this report. The objective of future development will be to

(1) improve economy without sacrifice in performance;

(2) increase specific output (bhp/cu.in.) while, at the same time, decreasing the weight of the powerplant (lbs/bhp).

Piston Engines: The first objective clearly indicates continuation of the trend towards increased compression ratios. At present it is estimated that we shall use compression ratios of 12:1 and premium fuels of 110 octane number. The potential gains were established as far back as 1949 (Ref. 7). Raising compression ratio from 8:1 to 12:1 decreases the specific fuel consumption from .53 to .44 lbs/bhp-hr. In the meantime fuel technology and research in combustion chambers have progressed to the point where 12:1 compression ratios will be practicable.

The effect of combustion chamber shape on octane requirement (mechanical octanes) is illustrated in the charts below. Each point on the curves is a maximum i.m.e.p. obtained with a fuel as denoted by the octane number above the curve. Design A has the i.m.e.p. of 99 percent maximum of 141 psi and requires a 95 O.N. fuel. Design B has a corresponding i.m.e.p. of 136 psi and requires only a 73 O.N. fuel.

We have witnessed a gradual increase in displacement volumes. There is a definite limit to this, dictated primarily by the amount of space and weight allotted to the powerplant. We will have to make smaller engines do more work per cubic inch and per pound of engine weight. This can be accomplished by the use of (1) *turbo-charging* and (2) *lightweight materials.*

Active research is being carried out in both areas. (1) shows promise for commercial engines, rather than passenger cars. Both types will profit from (2). Aluminum die casting offers not only weight advantages but also appreciable savings in manufacturing cost. A die casting machine exists which produces a complete crankcase-block combination requiring a minimum of machining. The crankcase of the Volkswagen engine is a magnesium casting. The variable blade angle transmission which we need is heavy and offers only limited opportunity for weight saving. The engine crankcase and block offers the biggest single component which can reduce powerplant weight effectively. A better appreciation of weight will become more and more necessary.

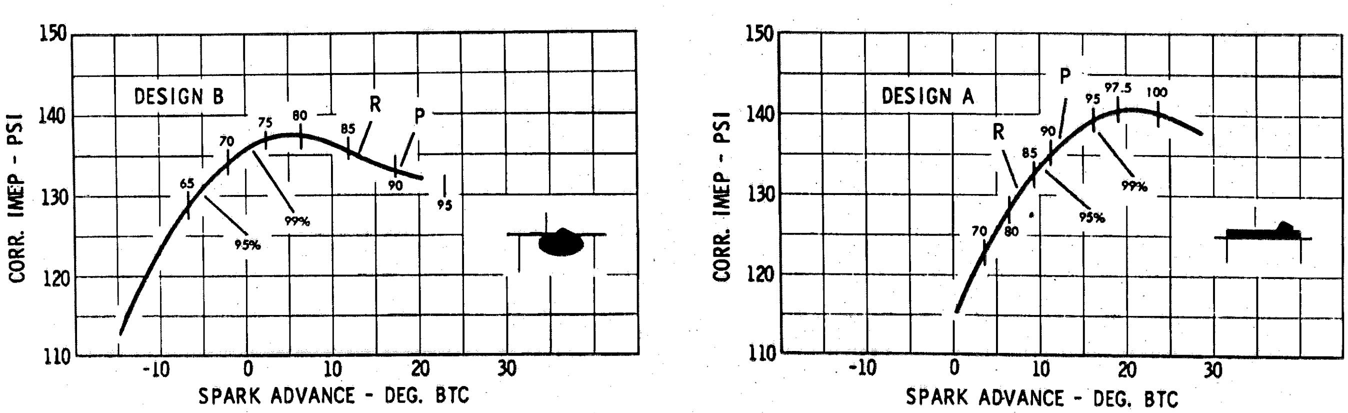
Heavy equipment

Turbo-charging of spark-ignition engines has a considerable potential for trucks and earthmoving equipment and will be fully investigated and utilized before very long. It will be used with fuel injection.

Fuel injection *(into the cylinder rather than the manifold)*, will be closely investigated, especially in conjunction with turbo-charging. There are some fundamental difficulties in applying cylinder injection to engines of small displacement (compared with aircraft engines) and operating over a wide range of speed and loads (compared with constant speed in aircraft). This has all been

CONTINUED ON PAGE 38

The effect of combustion chamber shape on octane requirement (mechanical octanes)



Comparison of flat (Design A) and compact (Design B) combustion chamber .9:1 compression ratio; 1,000 rpm. R = Regular, P = Premium (1954 level) 99 percent = 99 percent of maximum i.m.e.p. (indicated mean effective pressure) (Ref. 9)

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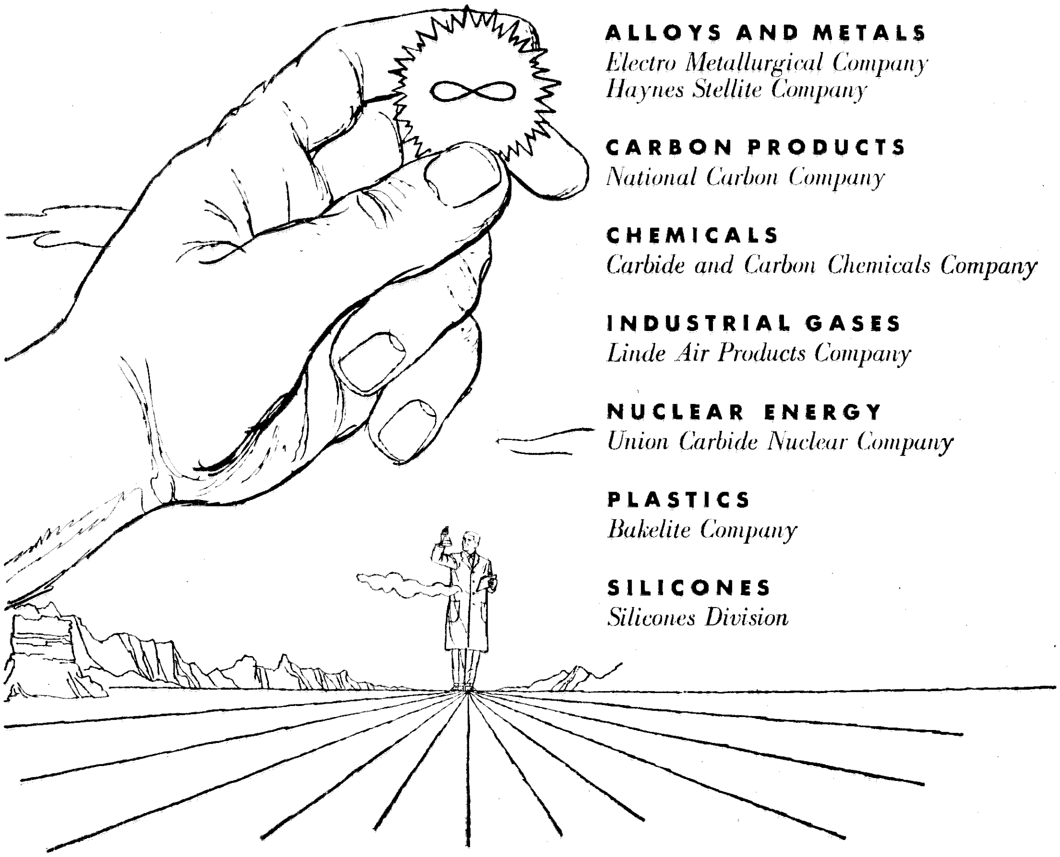

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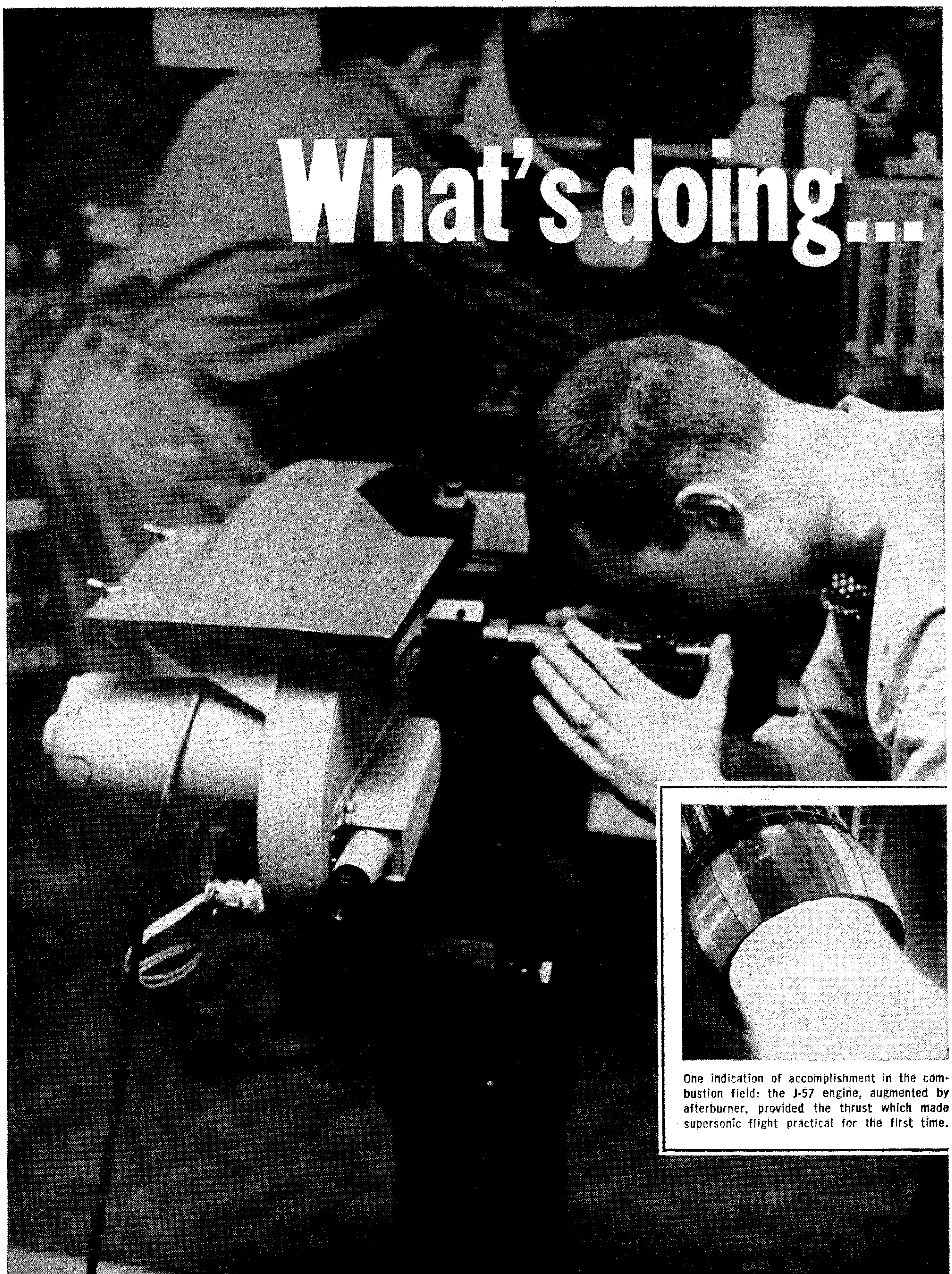
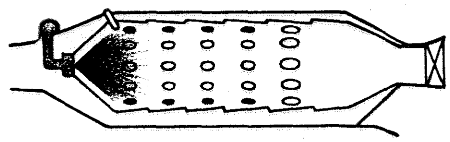


One indication of accomplishment in the combustion field: the J-57 engine, augmented by afterburner, provided the thrust which made supersonic flight practical for the first time.

This special periscope gives Pratt & Whitney Aircraft engineer a close-up view of combustion process actually taking place within the afterburner of an advanced jet engine on test. What the engineer observes is simultaneously recorded by a high-speed motion picture camera.

at Pratt & Whitney Aircraft in the field of Combustion*



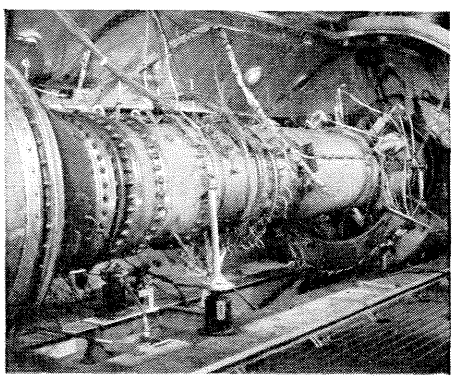
Historically, the process of combustion has excited man's insatiable hunger for knowledge. Since his most primitive attempts to make use of this phenomenon, he has found tremendous fascination in its potentials.

Perhaps at no time in history has that fascination been greater than it is today with respect to the use of combustion principles in the modern aircraft engine.

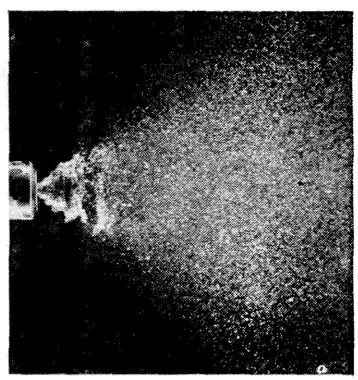
At Pratt & Whitney Aircraft, theorems of many sciences are being applied to the design and development of high heat release rate devices. In spite of the apparent simplicity of a combustion system, the bringing together of fuel and air in proper proportions, the ignition of the mixture, and the rapid mixing of burned and unburned gases involves a most complex series of interrelated events — events ocurring simultaneously in time and space.

Although the combustion engineer draws on many fields of science (including thermodynamics, aerodynamics, fluid mechanics, heat transfer, applied mechanics, metallurgy and chemistry), the design of combustion systems has not yet been reduced to really scientific principles. Therefore, the highly successful performance of engines like the J-57, J-75 and others stands as a tribute to the vision, imagination and pioneering efforts of those at Pratt & Whitney Aircraft engaged in combustion work.

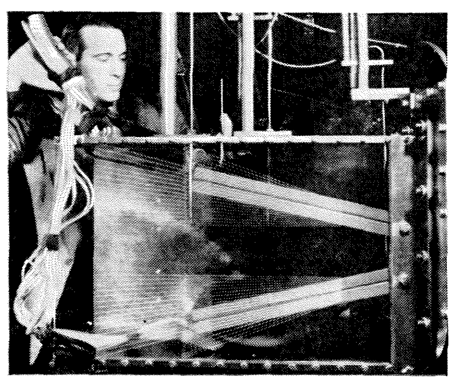
While combustion assignments, themselves, involve a diversity of engineering talent, the field is only one of a broadly diversified engineering program at Pratt & Whitney Aircraft. That program—with other far-reaching activities in the fields of instrumentation, materials problems, mechanical design and aerodynamics — spells out a gratifying future for many of today's engineering students.



Mounting an afterburner in a special high-altitude test chamber in P&WA's Willgoos Turbine Laboratory permits study of a variety of combustion problems which may be encountered during later development stages.



Microflash photo illustrates one continuing problem: design and development of fuel injection systems which properly atomize and distribute under all flight conditions.



Pratt & Whitney Aircraft engineer manipulates probe in exit of two-dimensional research diffuser. Diffuser design for advanced power plants is one of many air flow problems that exist in combustion work.

**Watch for campus availability of P & WA color strip film on combustion.*

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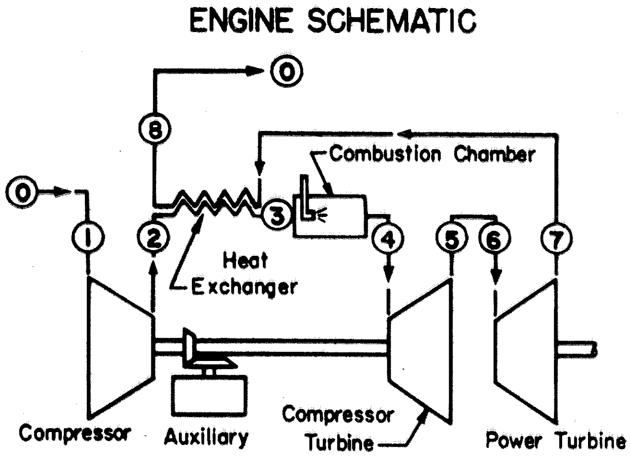
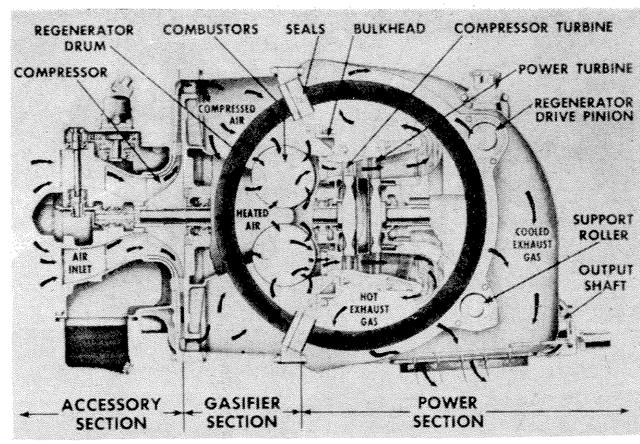


Schematic diagram of a regenerative turbine (Ref. 12) (Ford)



Section through a Whirlfire regenerative gas turbine (Ref. 13) (G.M.)

spelled out (Ref. 18) but is not clearly understood by everybody who is talking about the subject.

So far, nothing has been said about the diesel engine. Since diesel and spark ignition engine compression ratios have approached each other, the thermodynamic advantages of the diesel have gradually diminished. High speed diesels require carefully controlled fuels, which decreases the cost advantage of diesel fuel over gasoline.

First cost of diesels is higher than that of gasoline engines. In the passenger car field there is no real incentive for the use of diesels. In the truck and heavy off-the-road field the diesel predominates today, but seems to offer little capability for future growth. Its weight and size are unfavorable as compared with the gasoline engine. Increase in displacement and hence engine size is limited as much as in the gasoline engine. It therefore cannot offer the trucker the 1000 hp engine for which he is hoping.

Turbines: The *automotive gas turbine* has progressed faster than was expected. At the left, above, is a schematic of a regenerative turbine. At the right is a section through the actual engine—which in this case, is a Whirlfire regenerative gas turbine.

The regenerator is of the rotating matrix type. Regenerator efficiencies are of the order of .80 at low loads, dropping to .60 at high loads.

Typical performance curves are shown below for a truck turbine.

Since vehicle turbines operate predominantly at variable load and speed, the part load performance is particularly interesting and significant.

Cruising power fuel consumption is far from good. Best miles per gallon for the engine in the charts below is 3.7 mpg as compared with 7.0 for comparable piston engine. The turbine utilizes a cheaper fuel and hence

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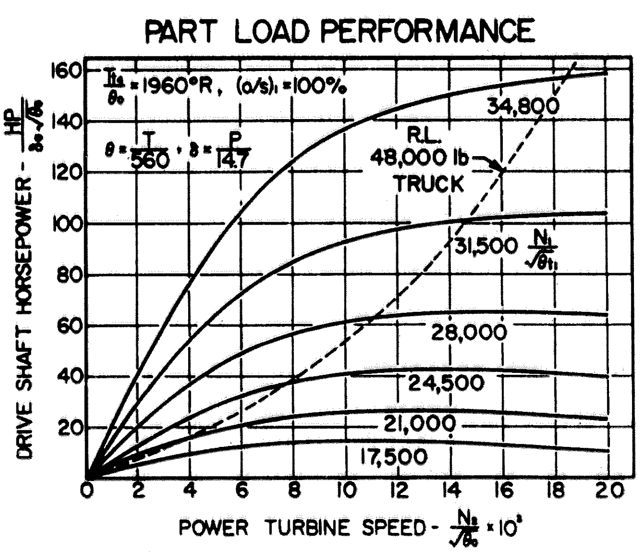
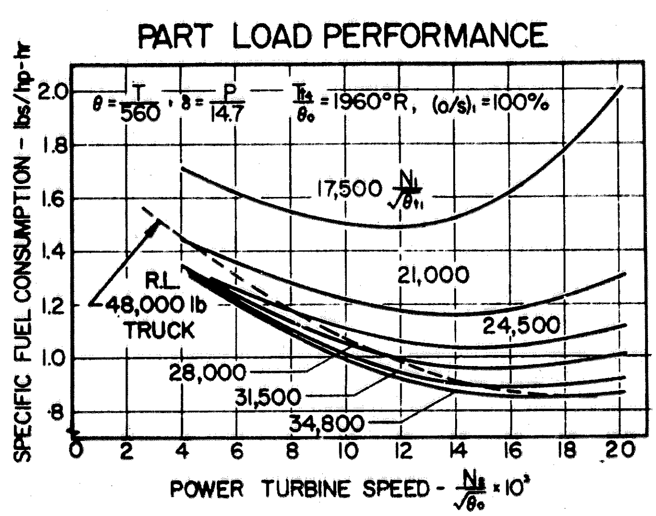
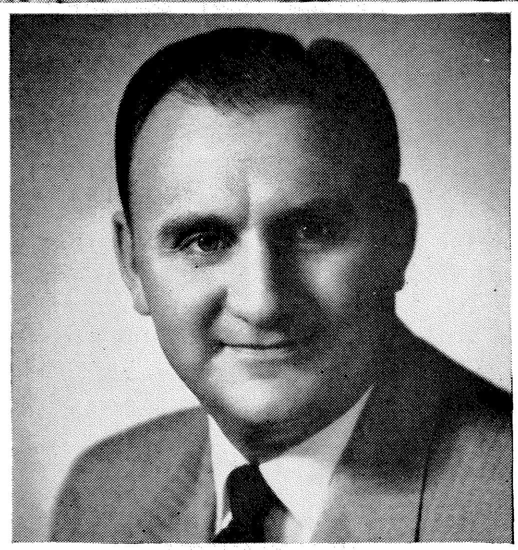


Output vs power turbine speed. R.L. = road load. Numbers on curves are compressor speeds (Ref. 12) (Ford)



Fuel consumption vs power turbine speed. Turbine inlet temperature 1,500°F. (Ref. 12) (Ford)



Charles C. Ingram, Jr. became Vice President of Oklahoma Natural Gas Company in less than 15 years

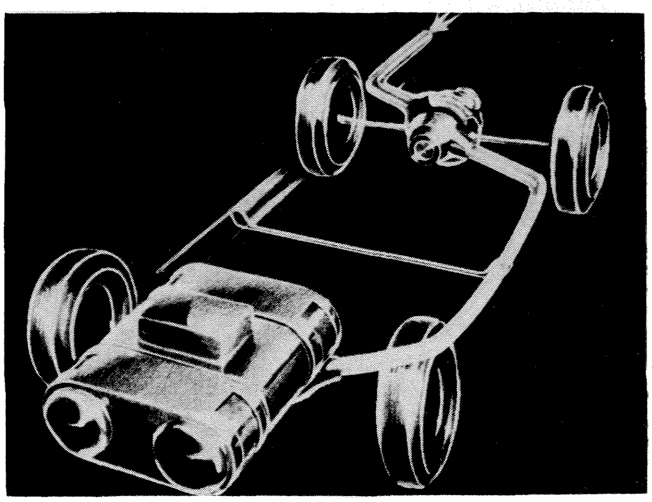
CHARLES C. INGRAM, JR.
B.S. in Petroleum Engineering, 1940
University of Oklahoma

Charles Ingram has been Vice President of the Land and Geological Department of Oklahoma Natural Gas Company since June of 1955. Mr. Ingram joined the company immediately after his graduation from Oklahoma, and was soon called into service. Following his discharge, 5 years later, he rejoined the Engineering Department in Tulsa. He was quickly promoted to Assistant Chief Engineer and then took over the position of Superintendent of Gas Purchase and Reserves, and by 1954 was District Superintendent of the Oklahoma City district.

After 6 years with Lone Star Gas, Bill Collins took over a new job in a new field for the company

WILLIAM A. COLLINS, JR
B.S. in Mechanical Engineering, 1947
A & M College of Texas

Bill Collins is employed by the Lone Star Gas Company in Dallas as Coordinator of Air Conditioning and Utilization. Bill operates over 400 square miles in North Texas and Southern Oklahoma. Since joining Lone Star, Bill has worked primarily in the design, sales and installation of air conditioning equipment, with some time devoted to industrial gas applications. When it was found that a large scale air conditioning program requires close attention to design and installation as well as sales and service policies, a special department was organized in 1955. Bill was put in charge.



Free piston gas generator and turbine installation for an automobile (GMR Hyprex. Ref. 16). The gas generator consists of two parallel cylinders.

the difference in cents per mile is not as great as that in mpg.

Cost of and availability of high temperature materials is, at present, a serious handicap for the turbine.

The following table compares the cost of some materials used in turbines with the cost of cast iron:

Cobalt	2.70
Nickel	.65
Molybdenum	1.50
Vanadium	3.10
Tungsten	3.45
Manganese	.30
Chromium	.37
Aluminum	.23
Cast Iron	.05

At present, large amounts of nickel are used (75 lbs in a 700 lb engine). A typical automotive turbine blade material (GMR 235, Ref. 19) is as follows:

Carbon	.10 - .20
Manganese	.25 max
Silicon	.60 max
Chromium	12.00 - 17.00
Molybdenum	4.50 - 6.00
Aluminum	2.50 - 3.50
Titanium	1.50 - 2.50
Boron	.025 - .100
Nickel	Balance

Nevertheless there seem to be excellent prospects for the development of inexpensive materials which will meet the needs of the vehicle turbine.

Manufacturing techniques will have to be developed for high production of such parts as turbine wheels (single casting). This, likewise, should not prove an unsurmountable obstacle. In spite of the fact that the split turbine arrangement (power turbine drives the rear wheels, is not connected to the gas generator turbine) has some of the characteristics of a torque converter, a transmission is needed. The stall torque ratio is of the order of 2.3, which is not enough.

The feasibility of the turbine has been amply demonstrated. Will it replace piston engines? I don't think so. It will rather fit in where the piston engine has nothing to offer, i.e., in the range from 400 - 1500 hp. Trucks need this power range badly. Passenger car turbines will be produced and used if for no other reason than to be different. They do not offer any fundamental advantage.

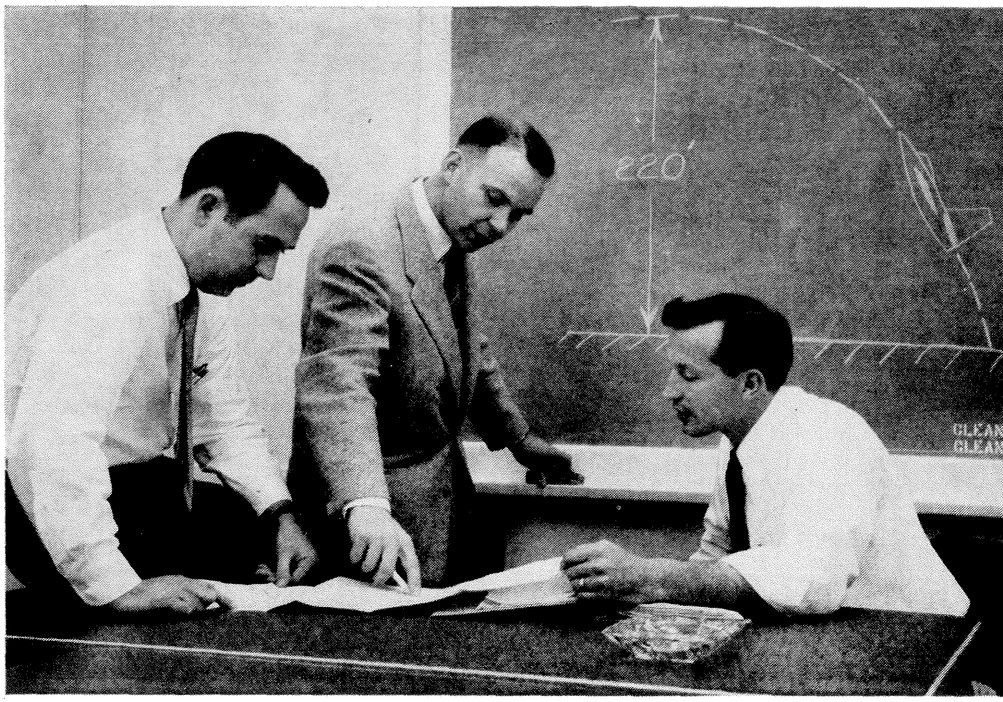
The free piston engine

By itself, the free piston engine is not a propulsion unit but an air compressor. In conjunction with a gas turbine it becomes a *free piston gas generator.* Its thermodynamic merits have been discussed (Ref. 15). The schematic drawing above shows a twin cylinder free piston engine and gas turbine installed in a car. The turbine operates at a relatively low temperature and does not require expensive materials. Experience with this type of powerplant is limited (Ref. 17) but it looks as though it fits in between the piston engine and the turbine, overlapping both ranges.

To sum up the comparison of existing and future powerplants, the pertinent parameters are listed (Ref. 17) in the table below.

Comparison of automotive powerplants

	Fuel Consumption Lb/bhp/hr @ Max. Power	Fuel Consumption Lb/bhp/hr @ Best Econ.	Weight Lb/hp	Size Cu.ft/100hp	Fuel
Spark Ignition Piston Engine Cast Iron 9:1 Comp. Ratio	.48	.41	3.6	9.1	95 Octane
Spark Ignition Piston Engine Aluminum 12:1 Comp. Ratio	.44	.38	2.2	8.4	110 Octane
Spark Ignition Piston Engine Aluminum 8:1 Comp. Ratio Turbocharged - 30% Boost	.49	.43	2.1	7.3	95 Octane
Gas Turbine - Regenerative	.75	.75	3.6	7.2	Kerosene
Gas Turbine - (Projected) Regenerative	.60	.60	3.0	7.2	Kerosene
Diesel Engine 4-stroke cycle	.41 - .47	.38	12.7	26.0	#2 Diesel
Diesel Engine 2-stroke cycle	.42	.40	12.1	14.8	Kerosene
Diesel Engine 2-stroke cycle Exhaust Turbo Blower	.42	.41	11.7	13.6	Kerosene
Free Piston Engine	.48	.48	3.6	7.0	Kerosene Gasoline, Diesel



N. T. Avant, aerodynamicist (left), R. R. Heppe, Aerodynamics Department head (center), and C. F. Branson, aerodynamicist, discuss wind tunnel tests to determine transition height of a supersonic superiority fighter.

Hovering to High Speed Flight:

Lockheed aerodynamics projects offer advanced problems

Master's Degree Work-Study Program

The program enables graduates in Engineering, Mathematics and Physics to attain a Master's Degree at the University of California at Los Angeles or University of Southern California while gaining important practical experience on the engineering staff of Lockheed Aircraft Corporation in Burbank, California.

Additional information may be obtained from your Placement Officer or Dean of the Engineering School or by writing E. W. Des Lauriers, Employment Manager and Chairman of the Master's Degree Work-Study Program.

Aerodynamics Engineers at Lockheed are working on advanced problems that cover virtually every phase of aircraft. The full scope of their work can be seen in the wide range of aerodynamics problems encountered in Lockheed's diversified development program.

Among the advanced problems are:

1. Determine means of controlling a supersonic vertical rising aircraft through the transition flight stages from horizontal to vertical flight.
2. Determine the dynamic response of supersonic aircraft in high rate rolls by application of five degrees of freedom analysis procedures.
3. Study optimum operating descent procedures to minimize costs on a new turboprop commercial aircraft.
4. Conduct and analyze wind tunnel research on new and radically different external radomes to be carried at high speed by early warning aircraft.
5. Perform generalized aeroelastic analysis combining structural and aerodynamic knowledge to determine optimum lateral control devices for use on very high speed, low load factor aircraft.

These—and many other—significant problems have created new positions for experienced Aerodynamics Engineers and Aerodynamicists in Lockheed's expanding program of diversified development.

You are invited to contact your Placement Officer for a brochure describing life and works at Lockheed in the San Fernando Valley.

LOCKHEED

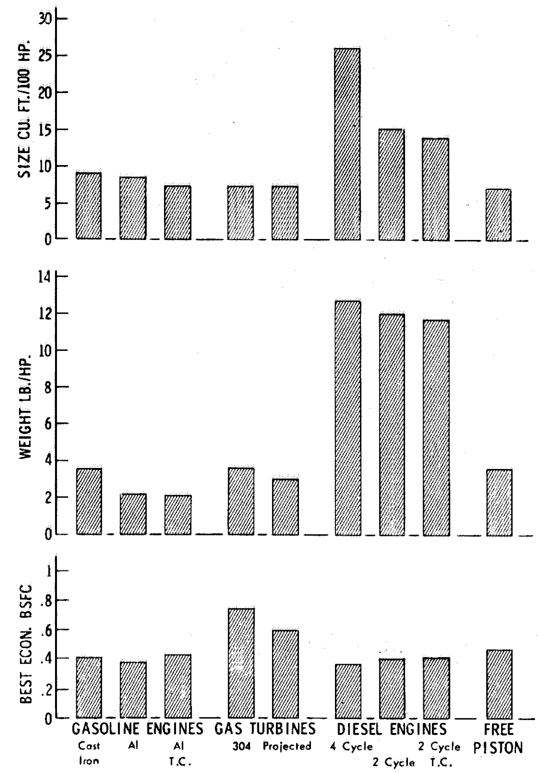
California Division • AIRCRAFT CORPORATION • BURBANK

CALIFORNIA

The same data are shown here in a bar chart (Ref. 1). It becomes apparent that the diesel is out of line as far as size and weight are concerned, which makes its contiued use in vehicles questionable. The turbine has been treated with optimism in the fuel consumption column. No one powerplant shows a vast superiority over the others, except for the large power range, 400 hp and up, where the turbine is the only practicable engine.

There is, at present, no reason why any one powerplant type should replace the other. The turbine as well as the free piston engine-turbine combination will supplement the piston engine in the areas of their optimum suitability.

Comparison of automotive powerplants



Comparison of fuel consumption, weight, and space requirements for different powerplants (Ref. 1). On the chart, Cast iron = cast iron cylinder block; Al = aluminum cylinder block; and Al T.C. = aluminum engine with exhaust turbo-charger.

Whence come these pearls of wisdom?

In any prediction there is necessarily a lot of guesswork; as the saying goes—"based on incomplete data, rumor and prejudice." The following list of references contains the background information on which my prejudices are based. Anyone with enough stamina to read through the references is entitled to pick my line of reasoning to pieces.

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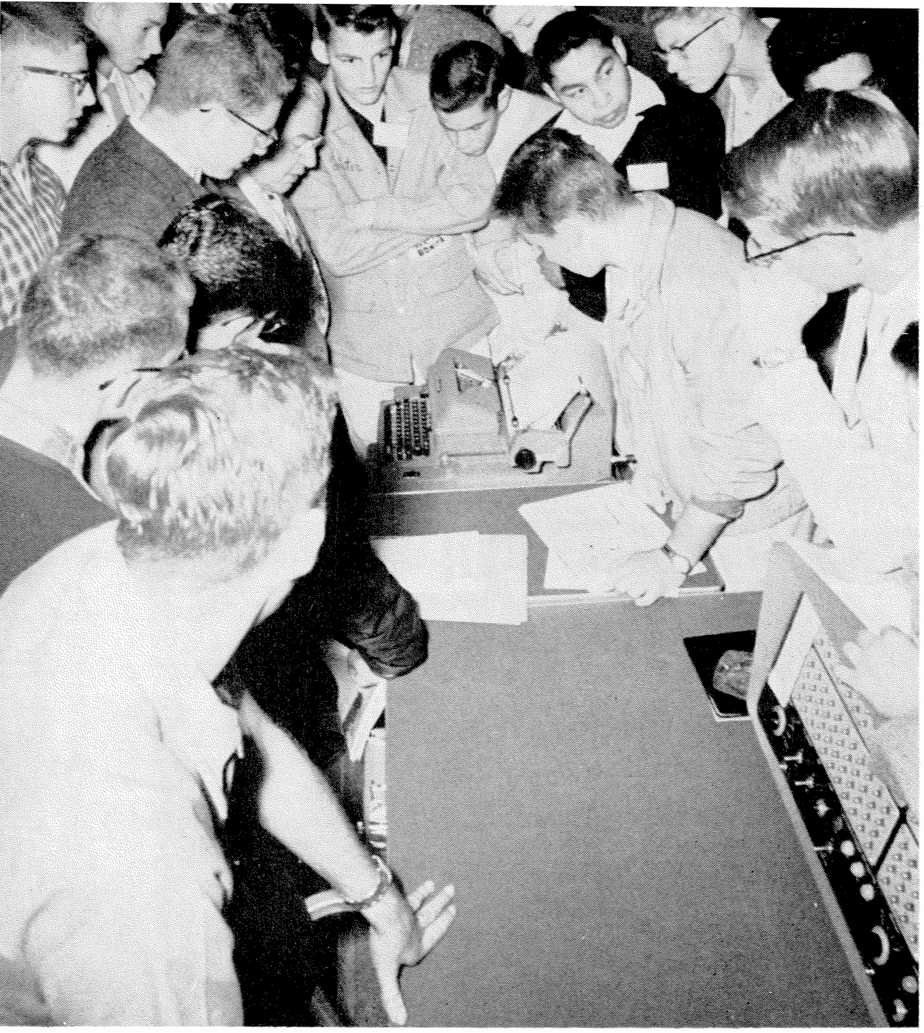
(16) "The GMR 4-4 Hyprex Engine," by A. F. Underwood, *SAE preprint no. 765*, SAE Meeting, Atlantic City, June 1956.
(17) "Observations on 25,000 Hours of Free Piston Engine Operations," by G. F. Flynn, Jr. *SAE preprint no. 802*, SAE National West Coast Meeting, San Francisco, August 1956.
(18) *Verbrennungskraftmaschinen*, by F. A. F. Schmidt. Oldenbourg Verlag, München, 1951, chapter 4, p. 194-213.
(19) "Development of a New Gas Turbine Super Alloy, GMR-235," by D. K. Hanink, F. J. Webbere and A. L. Boegehold. *SAE Transactions*, vol. 63, 1955, p. 704.

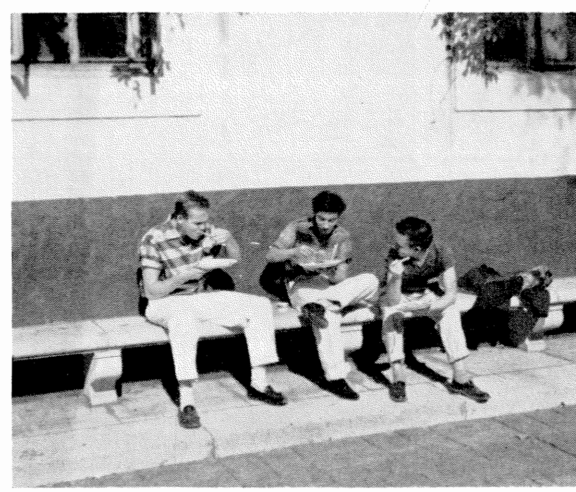
CREDITS: CHARTS AND DIAGRAMS:

Pages 32, 33, 34, 38—from publications of the Society of Automotive Engineers, Inc., New York City.
Page 32—from reprint by Automotive Industries; Philadelphia, Pennsylvania.
Pages 38, 42—from preprint by A. L. Boegehold, General Motors Corporation, ASTM meeting, Cleveland District.

STUDENTS' DAY



Computer works out a problem

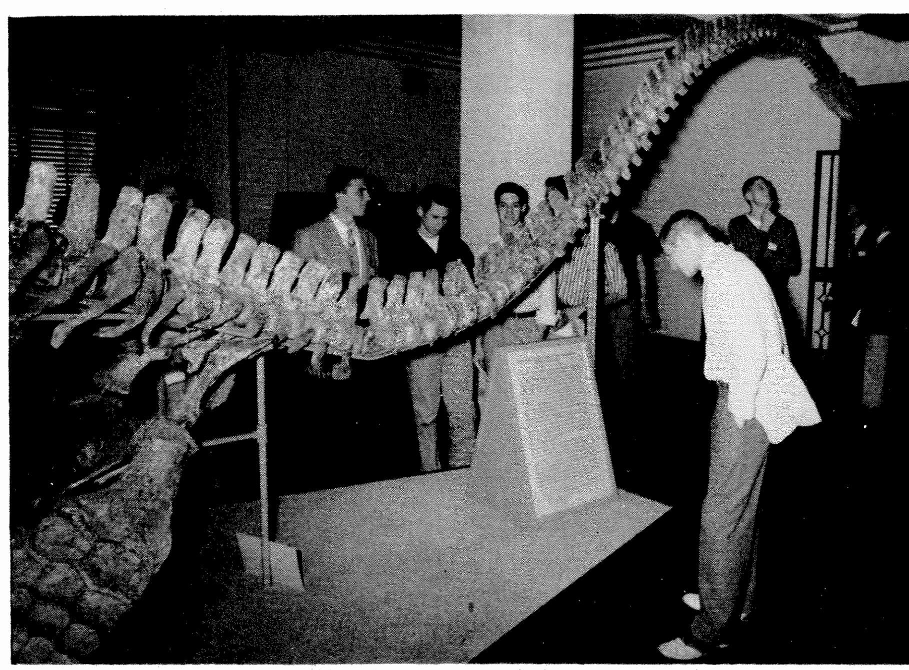


Box lunch—al fresco

MORE THAN a thousand high school and junior college students descended on the Caltech campus for the seventh annual Students' Day on December 1.

The visitors came from all over the southern California area—and were joined this year by four enterprising students from Milwaukie Union High School in Portland, Oregon, who flew their own plane down for the event.

The all-day program included campus tours, laboratory exhibits, lunch in the student houses, demonstration lectures and a talk by President DuBridge.



California sea serpent draws a crowd

A man can take just so much

ALUMNI NEWS

Alumni Directory

CALTECH'S NEW Alumni Directory will be ready for mailing sometime in the early spring. Information is now being compiled from postcards received from the 7,108 people who have received degrees from Caltech. The Directory will list all names alphabetically, with home and business addresses, degrees and options, and will have geographical and class lists wherever possible. Richard Stenzel, '21, MS '30, heads the Directory committee, and has Francis E. Odell, '44, assisting him, with Kenneth Russell, '29, acting as advisor. The Directory will be available to all paid alumni.

Dinner Meeting

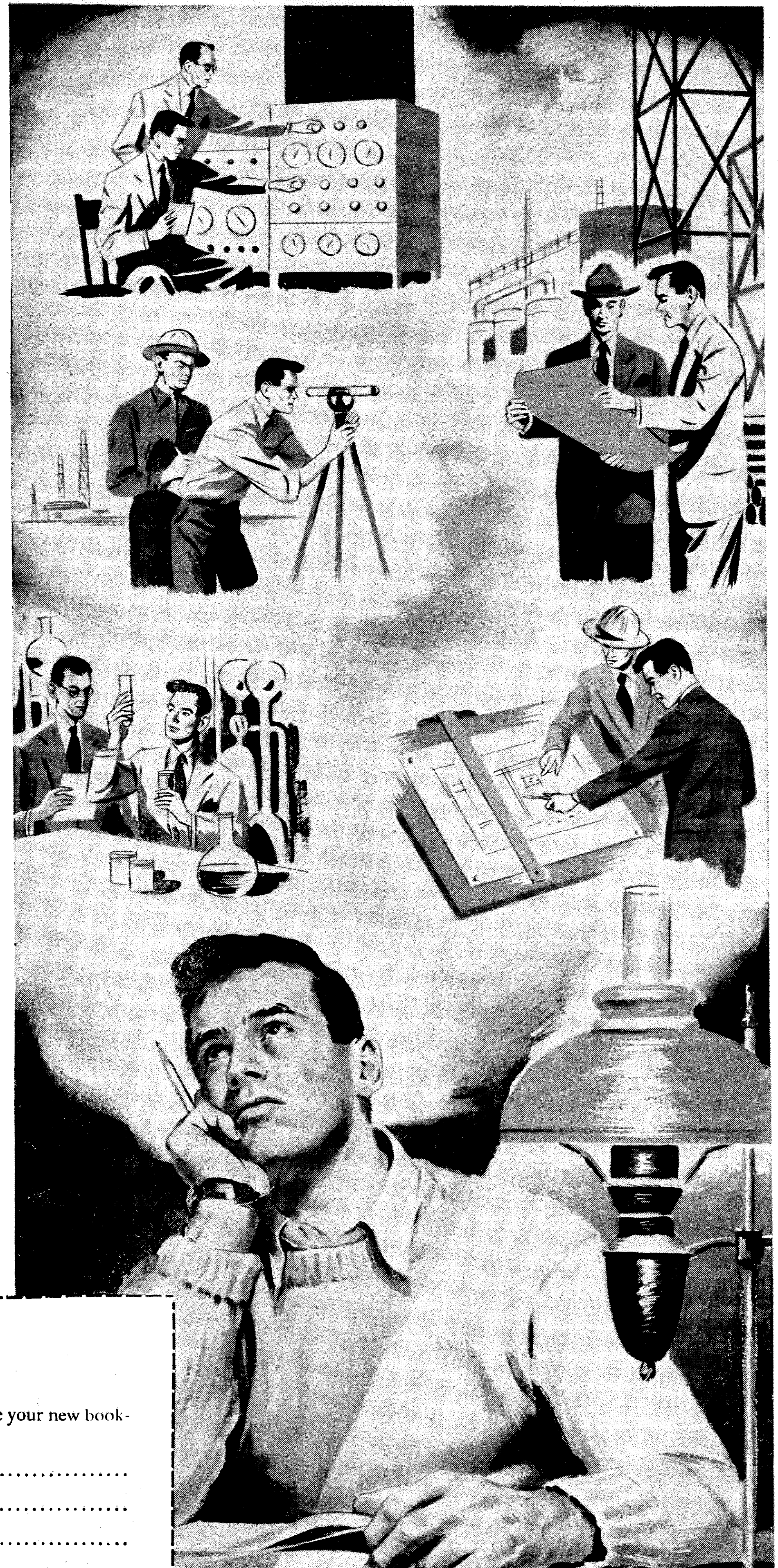
PHILIP S. FOGG, chairman of the board of Consolidated Electrodynamics Corporation in Pasadena, will be the speaker at the Winter Dinner Meeting of the Caltech Alumni Association on January 17. Mr. Fogg, who was registrar and professor of business economics at Caltech from 1930 to 1941, will talk about "Some Problems in Business Management—or How to Make a Buck in Business." The place is the Rodger Young Auditorium, 936 West Washington Boulevard, Los Angeles—the time is 6:30 for cocktails and 7:00 for dinner.

—*George R. Watt, '46*
Chairman

Dinner Dance

THE 21ST ANNUAL semi-formal dinner and dance of the Caltech Alumni Association will be held on February 9, at the Oakmont Country Club, Country Club Drive, in Glendale. Dinner will be served at 8 p.m., with dancing to the music of La Verne Boyer and his orchestra from 9:30 to 12:30. Reservations should be in the Alumni Office by Thursday, February 7. Let's all attend and make this annual gala affair the best yet.

—*Robert E. Covey, '51, MS '52*
Chairman



PERSONALS

1927

Col. Vernon R. Jaeger, chaplain in the U.S. Army, reports that "at this station in Fort Gordon, Georgia, I've been able to use a good deal of my engineering basic training recently, since as senior chaplain I am monitoring the planning and will soon monitor the construction of a new Post Chapel Center. We are also engaged in renovating and air conditioning the old wartime chapels. In another connection, I have been engaged in piloting the chaplain's phase of the new Army Command Management System which this station was selected to test and improve."

1928

Huston W. Taylor writes that he is the owner of the Taylor-Drake Company, insurance adjusters and surveyors, with a main office in Los Angeles and branches in Pasadena and Long Beach.

1931

Rev. Oscar M. Newby took up new duties in Monrovia, California, as pastor of the First Methodist Church last month. He had been in Las Vegas since 1954 and in two years there had organized a church, built a new building and had a full working program with a membership of 300. The Newbys have four children—Richard, 16; Kenneth, 13; Mary, 12; and Elizabeth, 9.

1932

E. Nelson Harshman, MS '33, writes from Denver that he is still with the U. S. Geological Survey and is now chief of their Defense Minerals Exploration Administration work in Region III. The work consists of appraisal of mining properties. The Harshmans have four children—three girls and a boy.

1933

Robert C. Kendall, MS, senior geophysicist in the Denver area exploration department of the Shell Oil Company, has just completed 20 years with the company. Bob, his wife, and their 16 year old twins, Robert and Elizabeth, live in Lakewood, Colorado.

John A. Randall writes that "in July, 1955, I returned to my first employer, the Southern California Edison Company in Los Angeles, where I first worked in 1923. My present job in the engineering department of the civil division involves planning and specifications for new construction for their rapidly expanding hydro and steam generation facilities and high voltage transmission lines." John was formerly sales engineer with The Austin Company in Los Angeles.

1934

Robert B. Brown, engineering coordinator and consultant of foreign licenses for the International Dresser Equipment Company in Long Beach, keeps on the move in his job. So far he's been to Venezuela, Colombia, England, France, Germany and Holland. The Browns have a daughter, 15, in high school and a son, 18, in college.

1935

Hsia-Chien Huang, MS, PhD '38, has been working for the past year with the American Institute of Aerological Research in Denver. The work consists of long-range (anywhere from several months to a year) weather forecasting. One long range forecast, aimed at the origin of a hurricane in the Gulf of Mexico, turned out especially well, he notes, as far as timing and intensity was concerned.

1936

Louis Ridenour, Jr., PhD, director of research for the Lockheed Missile Systems Division, was inducted into Tau Beta Pi at UCLA last month.

Holley B. Dickinson, MS '37, is the new assistant to the president of the Consolidated Electrodynamics Corporation in Pasadena. Holley was with Lockheed Aircraft for 11 years before this.

1937

W. Gordon Wylie reports: "I entered the U.S. Weather Bureau in October, 1937, at Fresno, California. Transferred to Burbank in January, 1940, then to UCLA in September for a year's study in meteorology (no degree). The next nine years were spent in Seattle as aviation forecaster, and for the past six years I've been in Honolulu as district forecaster and international aviation forecaster.

"While in Hawaii I have traveled to all the major islands of the group and last April I made a week's trip to Japan via MATS. These trips have afforded ample opportunity for indulging in one of my favorite hobbies—color photography.

"I was married in June, 1938 to Pauline Blackwood of Newton, Iowa. Our family consists of a boy, 16, and three girls, 13, 8 and 5."

1938

Arnulfo G. Gutierrez, MS, reports that tearing down or rebuilding old structures has turned out to be a safe and sound business for him. Arnulfo lives in Mexico City, is married and has 4 daughters (whose ages are 10, 8, 6 and 3), and a year-old son.

1940

Newton C. Stone, MS '41, is executive vice-president of Irving P. Krick Associates, Inc., in Denver. He reports that one of the most interesting parts of his work consists of supervising an electronic technique for developing long-range weather forecasts.

1941

Fred W. Billmeyer, Jr., research chemist at the DuPont Experimental Station in Wilmington, Del., specializes in color in plastics and the molecular structure of polymers. Fred is also a lecturer in high polymers at the University of Delaware and has completed a "Textbook of Polymer Chemistry", to be published by Interscience Publishers in December.

1942

Warren Gillette, MD, writes from Boulder, Colorado, that he recently put a 1500-square-foot addition on their house —probably to make room for his three boys, 10, 4 and 2. Warren had a short visit recently with *Alan Bell*, '42, who is an ophthalmologist in Pensacola, Florida. "If anyone wants to join me in a trip to the 1960 Olympic Games in Italy," says Warren, "just let me know."

Charles M. Brown, formerly chief engineer with Electromec, Inc., in Los Angeles, is now engineering manager for the Remler Company in San Francisco.

Hugh A. Baird, MS '46, writes that he is in his tenth year with C. F. Braun & Co. in Alhambra. For the last couple of years he was in charge of chemical engineering work on the process units for a refinery for the Tidewater Oil Company in Delaware City, Del. At present Hugh is project engineer on a new chemical plant that Braun is building for the Shell Chemical Corporation in Louisiana. The Bairds, who live in Pasadena, have two children—a girl, 11, and a boy, 8.

John T. Bowen, MS '46, PhD '49, has been with Preco, Inc., in Los Angeles for a year now. His work is concerned with developing control systems for earth-working equipment.

1944

Comdr. Albert B. Furer, MS, AE, writes from Brunswick, Georgia, where he has command of the U.S. Naval Air Station Glynco. This has been a base for blimps since 1943, but recently became the new home of the Navy's CIC school (Combat Information Center), and is growing rapidly, Al says. The Furers live in quarters on the station with their two daughters—Susan, 10, and Pamela, 5.

Douglas G. Dethlefsen is now on the administrative staff of the Ramo-Wooldridge Corporation in Los Angeles. Doug had formerly worked at the Stanford Research Institute.

Alan Andrew, MS, PhD '49, is now head of technical services for Atomics International, a division of North American Aviation, Inc., in Canoga Park. Al has been with the company since 1950.

Frederick T. Sadler is now a patent examiner in the U. S. Patent Office in Washington, D.C. He was formerly a mechanical engineer with the Civil Service.

1945

Billy F. Burke is celebrating his 10th year with the Carter Oil Company in Tulsa, Oklahoma, where he is senior engineer. The Burkes have a daughter, Brenda Lee, 3½ years old.

Ralph D. Winter is now employed by the Presbyterian Board of Foreign Missions and will be working in Guatemala with Indians of Mayan stock.

Alan R. Stearns, managing partner of A. C. Stearns Company, manufacturers' representatives in Glendale, writes that he is married, has a daughter and a son, and lives in the Hastings Ranch section of Pasadena. Alan's company specializes in aircraft and electronic components.

1946

Eberhardt Rechtin, PhD '50, is now chief of the electronics research section at the Jet Propulsion Laboratory in Pasadena. He's working with *C. R. Gates*, PhD '51, *Henry Richter*, '52 PhD '56, *R. J. Parks*, '44. *W. F. Sampson* '51, and *C. I. Cummings* '44, the division chief, on ex-

treme-range missiles. Eberhardt has been married 5 years to the former Dorothy Denebrink who graduated from Scripps in 1951 and they have three daughters.

1947

Andrew W. McCourt, MS, project manager in the engineering department of the Westinghouse Air Arm Division in North Linthicum, Maryland, received his PhD from the University of Pittsburgh last June. Andy has been with the company since 1947. The McCourts have three children.

Joe Rosener, Jr., is now division manager of the controls division of the G. M. Giannini Co. in Los Angeles. The Roseners and their two children, Lynn and Doug, live in Pasadena.

1948

John J. Attias, MS '49, has been working for the Ramo-Wooldridge Corporation since January, 1955, and has recently moved from Pasadena to the Westchester area in Los Angeles. The Attias family now includes two sons—Christopher, 2½ and Thomas, 1.

Joseph W. Wechsler, MS '49, AE '50, is an engineer in the aeronautics department of the RAND Corporation in Santa Monica, where he has been working since he left Caltech. The Wechslers live in Los Angeles and have two children—Ruth Nancy, who will be 4 next March (and who answers to "Cookie" or any Mouseketeer name)—and Philip Stuart 1, (who seems to be content with the name he has).

1949

Comdr. O. Scott Dwire, after three years in the Bureau of Ordnance in Washington, D.C., is now commanding the U.S.S. Wilkinson DL-5, based at San Diego. The Dwires have three daughters—Janet, 10, Susan, 4, and Betty, 1,—and are living in Somis, California, near Oxnard.

John M. Andres, MS '50, will be married to Anne MacLeod on December 29 in Riverside, California. John is a member of the technical staff of the Ramo-Wooldridge Corporation in Los Angeles.

Gene D. Six, mathematics instructor at Pasadena High School and also instructor for the extended day division of Pasadena City College, received his MS in education from the Claremont Graduate School last June. The Sixes live in Pasadena and have a son, Brian David.

Hardy C. Martel, assistant professor of electrical engineering here at Caltech, announced the arrival of a daughter last month. The Martels already have a son, Jeffrey, 1½.

Fred D. Ordway, Jr., PhD, was appointed director of the Portland Cement Association Fellowship at the Bureau of Standards in Washington, D.C., last July. The fellowship's staff is engaged in basic research on the constitution and properties of Portland cement. Fred has been with Portland since 1948.

Murray S. Bornstein, MS, who has been in the Army since September, 1954, is now a specialist second class in France, where he is assigned to the 541st Engineer Detachment.

James D. Young was appointed assistant professor of English at Georgia Tech this fall. Jim was formerly at Rice Institute in Houston, Texas, as an instructor in English.

1950

Michel Gossot sends news of his activities from France: "I am a naval constructor in the French Navy and have been stationed in Brest in French Brittany, for the past four years. The city was entirely wiped off the surface of the earth in 1944 but has been rebuilt and is far better than before the war. It would be a fine place to live in if it was not for the climate — constant temperature, constant rain and constant wind.

"My wife, Genevieve, and I have two children—a son, Dominique, and a daughter, Anne, two months old.

"I spent the entire month of September in the States. I was very sad not to be able to go to California but I was busy in Washington, D.C. and Charleston, S.C., and had no opportunity for traveling.

"We say in France that happy people have nothing to tell. So this is all about me and my family."

Bain Dayman, Jr., MS '51, AE '53, was married last July to Evelyn Mills Waggener of South Pasadena at Oneonta Congregational Church. Bain is a research engineer on the wind tunnel staff at JPL.

Dr. Peter T. Knoepfler is doing a residency in psychiatry at the Bronx Municipal Hospital in New York after having graduated from Cornell Medical College.

Palmer E. Hakala, MS, is now in the guided missile research division of the Ramo-Wooldridge Corporation in Los Angeles.

1952

Ernst Gehrells, a graduate student in Stanford University's Radio Propagation Laboratory, is now in Punta Arenas, Chile, at the southern tip of South America, where he is installing and operating the receiving equipment of a new radio listening post. The Stanford project was set up to attempt to learn more about conditions in outer space and to obtain a better estimate of the amount of matter in space.

Gordon E. Zima, MS, PhD '56, is research engineer for the International

Nickel Company in Bayonne, New Jersey.

1953

Carl A. Anderson, Jr., was married to Lillian Johnson in Santa Maria on October 7. *Donald Moore*, '50, was his best man. Carl is an analytical chemist in the control lab of the Stauffer Chemical Company in Vernon, California. The Andersons are living in Norwalk.

1954

Comdr. Chester W. Gates, Jr., AE '54, was killed on July 10 in a jet plane crash while on active duty with the Navy. He was serving at the time as commanding officer of Attack Squadron VA-86 at Oceana, Virginia.

Don E. Rogers, a member of the technical staff of the Ramo-Wooldridge Corp. in Los Angeles, will begin a two-year stint at the second semester, as assistant professor of aeronautical engineering, on half time, at the University of Michigan.

1955

John I. Lauritzen Jr., PhD, is now on the staff of the newly organized Dielectrics Section of the National Bureau of Standards in Washington, D.C. John has worked at the Bureau every summer from 1947 to 1950.

Mervyn L. Barman is now working in the Control Systems Division of the Ramo-Wooldridge Corporation. He was formerly with the National Bureau of Standards, where he conducted studies in solid state physics. Mervyn lives in Los Angeles.

Bruce J. Rogers, PhD, is now assistant professor in plant physiology at Purdue University, where he is doing research on the effect of various chemicals in producing chlorosis in plants.

Vincenzo M. Cestari, BS, MS, reports that last summer, after he left Computer Engineering Associates, he and his wife took a two-month trip to Italy to see his parents and relatives. After his return he went to work as an associate engineer in the development engineering department of Consolidated Electrodynamics Corporation in Pasadena.

F. Blake Wallace announced the arrival of a son, Bruce Edward, on November 10. Blake is an experimental test engineer with the Pratt & Whitney Aircraft Corporation in Rockville, Connecticut.

1956

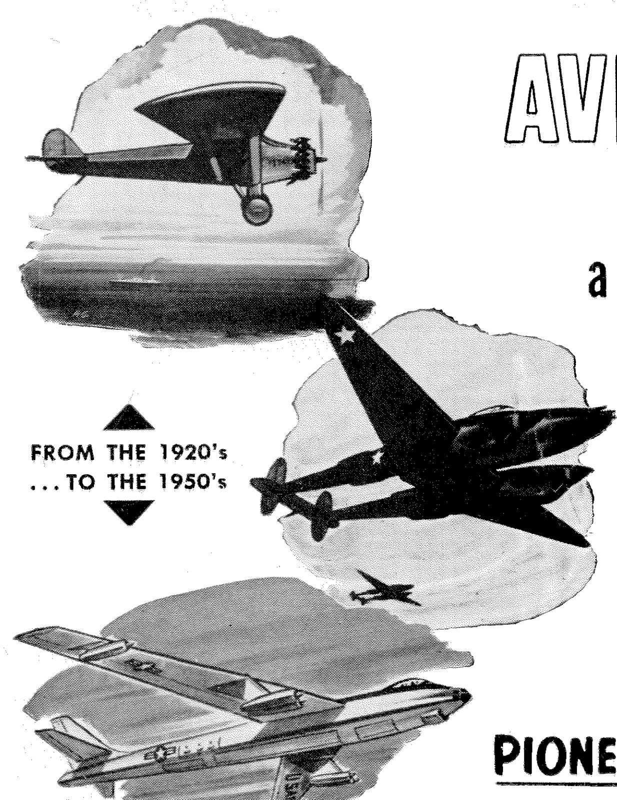
Eugene Epstein, now an astronomer at Harvard College Observatory in Cambridge, Massachusetts, reports as follows: "Foremost news is the marriage of *Harold Mark Goldenberg* to Tracy Haussman on October 21 in Boston. Several Tech men were in attendance at the wedding. Mark is working for his PhD in physics here.

"The large number of Tech graduates here makes for frequent impromptu sessions of reminiscence and exchange of news from back home—and we're all wondering if Caltech is becoming a football school. Among those seen around are *Will Richards*, '54, *Gary S. Gayron*, '55, *Big Jim Pinkerton*, '54, *Fred Anson*, '54, *Jerry Mitchell*, '54, *Tom Bergeman*, *Kyle Bayes*, *Ted Johnson*, *John Young* and *John Myers*, all '56 and *Jerry Dudek*, '54.

"Lest my friends fear that the New England weather has curtailed my shot-putting activities, I should like to report that my efforts in the indoor track area have been improving steadily and that I have vowed to clear 50 feet by the time I get my PhD."

AVIATION

owes this veteran furnace a deep bow



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1906
Norton, Frank E.

1911
Lewis, Stanley M.

1917
Poole, Fred L.

1921
Wulff, Robert G.

1922
Beman, Willard J.
Garfield, Arthur J.
Taylor, William T.

1923
Skinner, Richmond H.

1924
McKaig, Archibald
Mercereau, James T.
Tracy, Willard H.

1925
Aggeler, William F.
Smith, Dwight O.

1926
Huang, Jen-Chieh
Huang, Y. H.
McCarter, Kenneth C.
Schueler, Alfred E.
Yang, Kai Jin

1927
Evjen, Haakon M.

1928
Hicks, Hervey C.
Martin, Francis C.

1929
Nagashi, Mashahiro H.
Nelson, Julius
Reed, Albert C.
Robinson, True W.
Sandberg, Edward C.

1930
Chao, Chung-Yao
Douglass, Paul W., Sr.
Janssen, Philip
Russell, Lloyd W.
White, Dudley
Zahn, O. Franklin, Jr.

1931
Crossman, Edward B.
Hall, Marvin W.
Ho, Tseng-Loh
Voak, Alfred S.
West, William T.
Woo, Sho-Chow
Yoshaka, Carl K.

1932
Fraps, A. W.
Marshall, Donald E.
Oulton, Thomas D.
Schroder, L. D.
Wright, Lowell J.

1933
Applegate, Lindsay M.
Ayers, John K.
Downie, Arthur J.
Hsu, Chuen Chang
Kitusda, Kaname
Larsen, William A.
Lockhart, E. Ray
Michal, Edwin B.
Murdock, Keith A.
Perrine, Charles D., Jr.
Plank, Dick A.
Rice, Winston H.
Shappell, Maple D.
Smith, Warren H.
Solomon, Hyman

1934
Becker, Leon
Core, Edwin J.
Harshberger, John C.
Liu, Yun Pu
Lutes, David W.
Radford, James C.
Read, John
Vosseller, A. B.

1935
Ehrenberg, Gustave, Jr.
Gelzer, John R.
Huang, Fun-Chang
Obatake, Taneimi

1936
Barnes, Sydney U.
Bassett, Harold H.
Chu, Djen-Yuen
Creal, Albert
Kelch, Maxwell
Kurihara, Hisayuki
Nichols, Robert M.
Obashi, George Y.
Onaka, Takeji
Rector, Eugene M.
Weber, Bruce T.

1937
Burnight, Thomas R.
Davis, Roderic C.
Easton, Anthony
Jones, Paul F.
Lotzkar, Harry
Maginnis, Jack
Munier, Alfred E.
Nojima, Noble
Park, Noel R.
Penn, William L., Jr.
Rechif, Frank A.
Servet, Abdurahim
Shaw, Thomas N.
Tsubota, George Y.
Yin, Hun Chang

1938
Gershzohn, Morris
Goodman, Hyman D.
Kanemitsu, Sunao
Lowe, Frank C.
Ofsthun, Sidney A.
Okun, Daniel A.
Stone, William S.
Tilker, Paul O.
Tsao, Chi-Cheng
Van Horn, James W.
Velazquez, Jose L.
Watson, James W.
Wong, Tsun-Kuei

1939
Asakawa, George
Brown, William L.
Burns, Martin C.
Easton, R. Loyal
Fan, Hsu Tsi
Jackson, Andrew M., Jr.
Jones, Winthrop G.
Kyte, Robert M.
Liang, Carr Chia-Chung
Matthew, Tyler R.
Neal, Wilson H.
Robertson, Francis A.
Tatom, John F.
Tsien, Hsue-Shen

1940
Batu, Buhtar
Green, William J.
Hsu, Chang-Pen
Menis, Luigi
Nagle, Darragh E.
Paul, Ralph G.
Payne, Charles M.
Tajima, Yuji A.
Tao, Shih Che
Ustel, Sabih A.
Wang, Tsung-Su

1941
Blake, Charles L.
Bruce, Sydney C.
Clark, Morris R.
Damberg, Carl F.
Dieter, Darrell W.
Easley, Samuel J.
Farquhar, John P.
Feeley, John M.
Geitz, Robert C.
Green, Jerome
Frank-Jones, Glyn
Jones, John W.
Kuo, I. Cheng
Robinson, Frederick G.
Standridge, Clyde T.
Stephenson, William B.
Taylor, D. Francis
Tiemann, Cordes F.
Tyra, Thomas D.
Waigand, LeRoy G.
Whitfield, Hervey H.
Yui, En-Ying

1942
Bebe, Mehmet F.
Bergh, Paul S.
Carr, Earle A.
Chastain, Alexander
Hughes, Vernon W.
Levin, Daniel
MacKenzie, Robert E.
Martinez, Victor H.
Sternberg, Joseph

1943
Angel, Edgar P.
Bethel, Horace L.
Bryant, Eschol A.
Burlington, William J.
Carlson, Arthur V.
Daniels, Glenn E.
Enikeieff, Oleg C.
Hamilton, William M.
Hewson, Lawrence
Hillyard, Ray L.
Hilsenrod, Arthur
King, Edward G.
Koch, Robert H.
Kong, Robert W.
Lee, Edwin S., Jr.
Leeds, William L.
Lobban, William A.
Lundquist, Roland E.
Mampell, Klaus
McNeil, Raymond F.
Mixsell, Joseph W.
Mowery, Irl H., Jr.
Nesley, William L.
Neuschwander, Leo Z.
Newton, Everett C.
O'Brien, Robert E.
Patterson, Charles M.
Pearson, John E.
Rambo, Lewis
Rivers, Nairn E.
Roberts, Fred B.
Rupert, James W., Jr.
Scholz, Dan R.
Shannon, Leslie A.
Tindle, Albert W., Jr.
Vicente, Ernesto
Walsh, Joseph R.
Washburn, Courtland L.
Weis, William T.
Wood, Stanley G.
Yung, Chiang H.

1944
Alpan, Rasit H.
Andrew, Alan H.
Barriga, Francisco D.
Bell, William E.
Benjamin, Donald G.
Berkant, Mehmet N.
Birlik, Ertugul
Burch, Joseph E.
Burke, William G.
De Medeiros, Carlos A.
Dodge, Willard A.
Freeman, James R., Jr.
Fu, Ch'eng Yi Fu
Harrison, Charles P.
Hu, Ning
Johnson, William M.
Kern, Jack C., Jr.
Labanouskos, Paul J.
Leenerts, Lester O.
Marshall, John W.
Rempel, John R.
Shults, Mayo G.
Stanford, Harry W.
Stein, Roberto L.
Sullivan, Richard B.
Sunalp, Halit
Taylor, Garland S.
Trimble, William M.
Unayral, Nustafa A.
Wood, George M.
Writt, John J.
Yik, George.

1945
Anderson, Kenneth G.
Carter, Truland H.
Gibson, Charles E.
Knox, Robert V.
Jenkins, Robert P.
Kuo, Yung-Huai
Leydon, John K.
Mendelson, Burton G.
Pooler, Louis G.
Rodgers, Bertram J., Jr.
Romney, Carl F.
Tatlock, William S.
Taylor, Robert W.
Werme, John V.

1946
Barber, John H.
Burger, Glenn W.
Childers, Kenen C., Jr.
Conradt, Robert H.
Dethier, Bernard
Dyson, Jerome P.
Esner, David R.
Hayne, Benjamin S., III
Hoffman, Charles C.
Lang, Serge
Lewis, Frederick W.
Lowery, Bryon O.
Lowery, Robert H.
MacDonald, Norman J.

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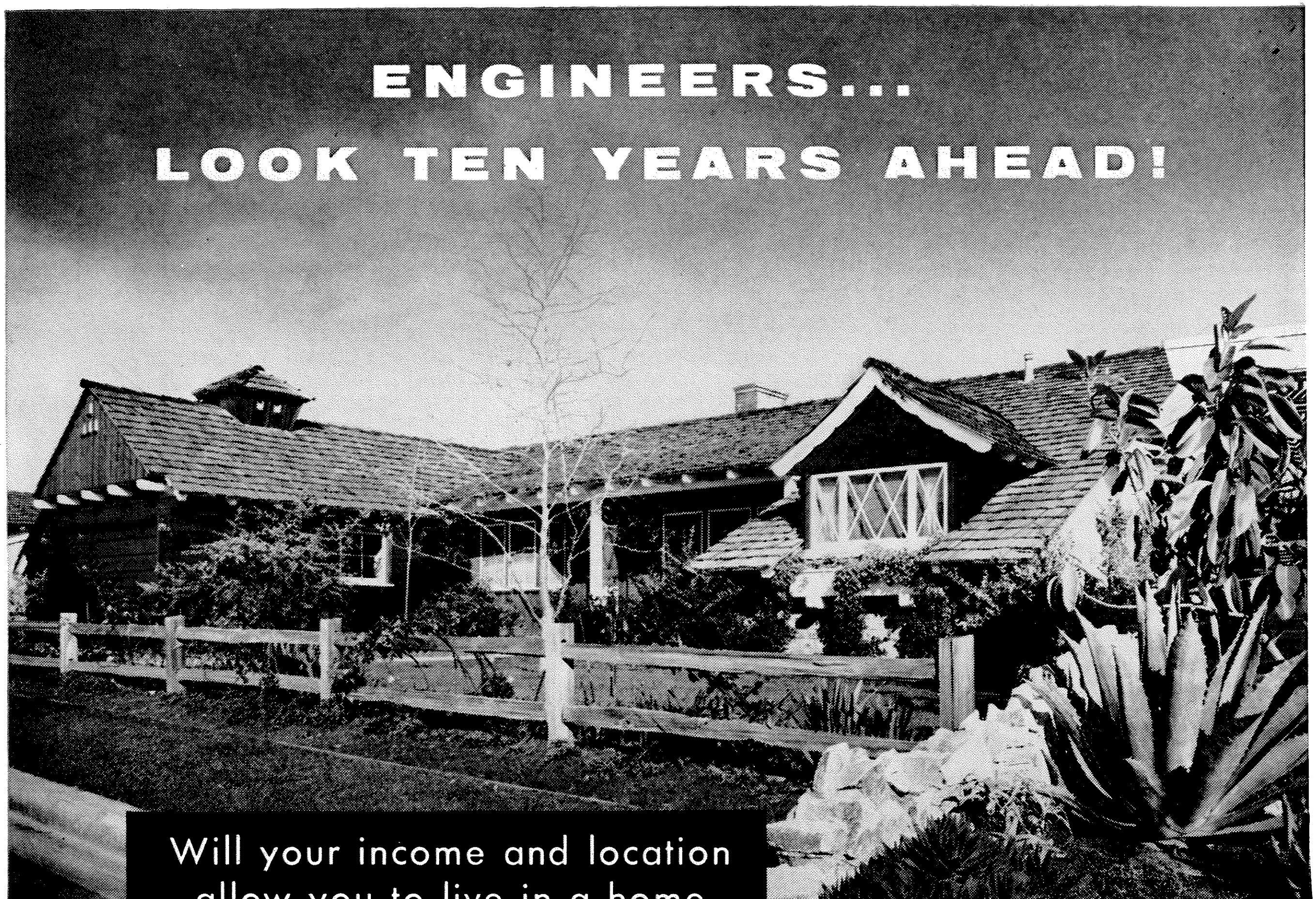

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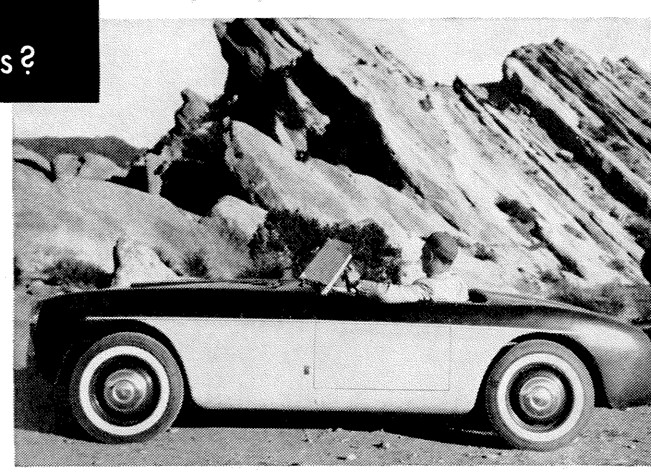

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Miller, Jack N.
O'Meara, Donald J.
Prasad, K. V. Krishna
Simmons, George F.
Smith, Harvey F.
Stone, Dean P.
Tung, Yu-Sin
Uberoi, Mahinder S.
Weldon, Thomas F.
Weitzenfeld, Daniel K.
Williams, Ralph C.
Yaun, Chen Ke

1947

Atencio, Adolfo J.
Dagnall, Brian D.
Hsu, Chi-Nan
Hsueh, Chi-Hsun
Huang, Ea-Qua
Kamath, Mundkur V.
Leo, Fiorello R.
MacAlister, Robert S.
McClellan, Thomas R.
Molloy, Michael K.
Monoukian, John
Moore, Charles K.
Moorehead, Basil E. A.
Nelson, Conrad N.
Rosell, Fred E., Jr.
Sanders, Lewis B.
Sappington, Merrill H.
Shackford, Robert W.
Swatta, Frank A.
Vanden Heuvel, George R.
Veale, Joseph E.
Wan, Pao Kung
Wimberly, Clifford M.
Wellman, Alonzo H., Jr.
Ying, Lai-Chao

1948

Agnew, Haddon W.
Bingham, Andrew T.
Blue, Douglas K.
Browne, Charles I., Jr.
Bunce, James A.
Collins, Burgess F.
Crawford, William D.
Eldin, Hamed K.
Holser, Alexander F.
Hsiao, Chien
Hsieh, Chia Lin
Mason, Herman A.
McCollam, Albert E.
Morehouse, Gilbert G.
Oliver, Edward D.
Rhynard, Wayne E.
Stewart, Robert S.
Swain, John S.
Swank, Robert K.
Talmadge, Richard B.
Walters, James W., Jr.
White, Harvey J.
Wilford, David B.
Winniford, Robert S.
Yanak, Joseph D.

1949

Barker, Edwin F., Jr.
Baumann, Laurence I.
Blazina, Thomas D.
Chandler, Ralph S.
Clancy, Albert H., Jr.
Clendening, Herbert C.
Craighead, Emery M.
Denton, Jesse C.
Foster, Francis C.
Hrebec, George W.
Krasin, Fred E.
Kuchar, Charles E.
Lowrey, Richard O.
MacKinnon, Neil A.
Matteson, Robert C.
McElligott, Richard H.
Pace, Stanley C.
Petty, Charles C.
Pons, Robert L.
Ringness, William M.
Rudin, Marvin B.
Smith, Vernon L.
Weiss, Mitchell
Yu, Sien-Chiue

1950

Bryan, William C.
Hottenroth, James H.
Li, Chung Hsien
McDaniel, Edward F.
McLaughlin, Jack E.
McMillan, Robert
Monroe, Alfred J.
Nelson, Robert C.
Oakes, Gibson
Pao, Wen Kwe
Roberts, Morton S.
Roddick, James A.
Scherer, Lee R., Jr.
Schmidt, Howard R.
Schneider, William P.
Shen, San Chiun
Spevak, Ezra
Sullivan, John H.
Vivian, James A.
Ycas, Martynas F.

1951

Arosemena, Ricardo M.
Brewer, Richard G.
Carter, Cecil V.
Dankworth, E. G., Jr.
Davison, Walter F.
Denton, James Q.
Lafdjian, Jacob P.
Li, Cheng-Wu
McConnell, Harden M.
Norris, James C., Jr.
O'Connell, Robert F.
Ostrander, Max H.
Price, Peter
Ragon, Rex B.
Reynolds, H. Kendall
Struble, Arthur D., Jr.
Summers, Allan J.
Yoler, Yusuf A.

1952

Abbott, John R.
Arcoulis, Elias G.
Beyer, David D.
Bucy, Smith V.
Guess, Arnold W.
Loftus, Joseph F.
Long, Ralph F.
Lunday, Adrian C.
Moore, Randolph
Munson, Henry G.
O'Brien, Joseph
Price, Edgar P.
Pruett, Jeter A.
Schaufele, Roger D.
Shelly, Thomas L.
Verdier, Peter
Wiberg, Edgar

1953

Clark, David J.
Fazio, Patrick J.
Mishaan, Alberto
Morishita, Naoji
Rankin, Fred W., Jr.
Slodowski, Thomas R.
Vidal, Jean L.
Wood, Robert H.

1954

Gutierrez, Reinaldo V.
McGregor, James L.
Morgan, Bruce H.
Quiel, Norwald R.
Sato, Takeshi

1955

Barrios, Alfred A.
Hsieh, Hsung-Cheng
Johnson, Walter A.
Orr, Jerry A.
Paul, Roy W.
Shumate, Paul (Farley)

1956

Lansingh, John K.

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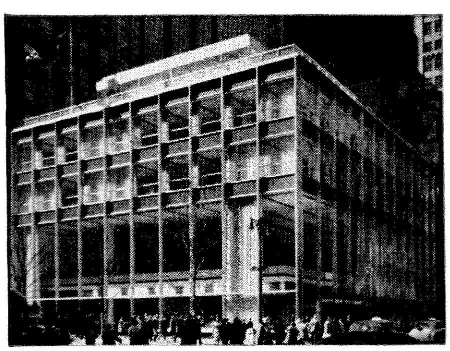

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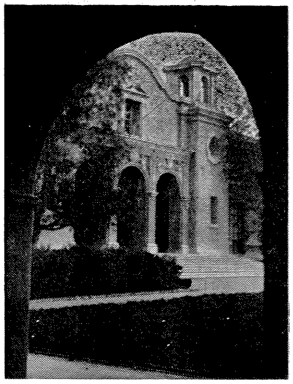

CALTECH CALENDAR

ALUMNI EVENTS

January 17	Winter Dinner Meeting
February 9	Dinner Dance
April 6	Alumni Seminar
June 5	Annual Meeting
June 29	Annual Picnic

ATHLETIC SCHEDULE

Basketball

January 5	Caltech at Cal Poly (SD)
January 11	Chapman at Caltech
January 15	Caltech at Occidental
January 8	Caltech at Pomona

FRIDAY EVENING DEMONSTRATION LECTURES

December 14
Coral Reefs: Present and Ancient — by Dr. Heinz Lowenstam

January 4
The Shakespeare Problem — by Dr. Hallett D. Smith

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State Division of Highways, Design Department,
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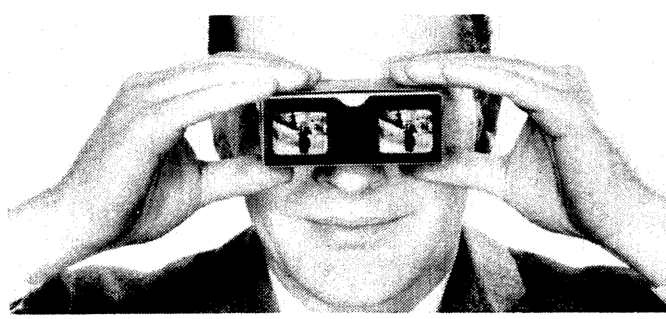

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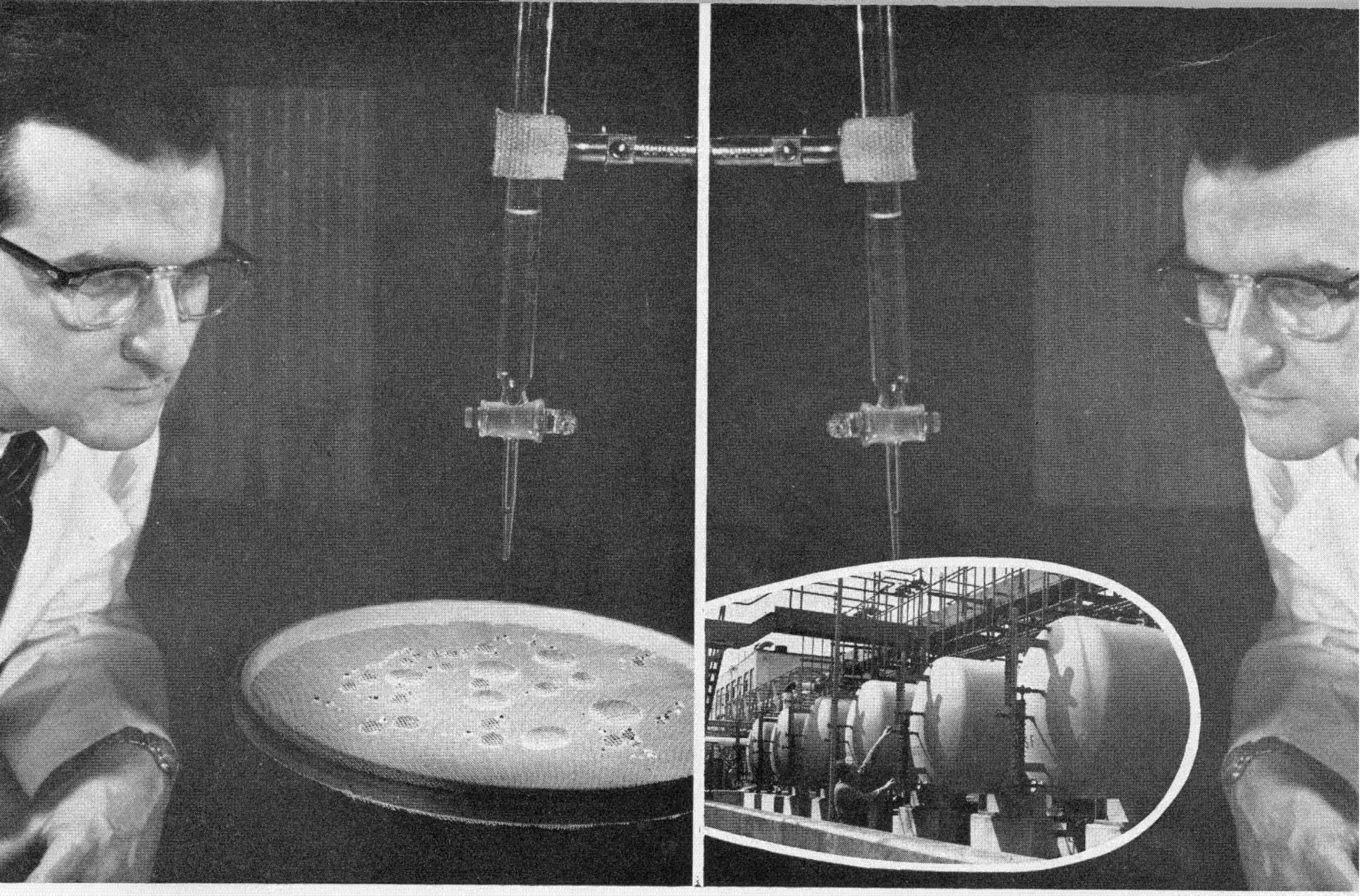

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