ENGINEERING AND SCIENCE

JANUARY/1955

Radiation hazards . . . page 9

PUBLISHED AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY

John A. Bauscher, *Class of '43*
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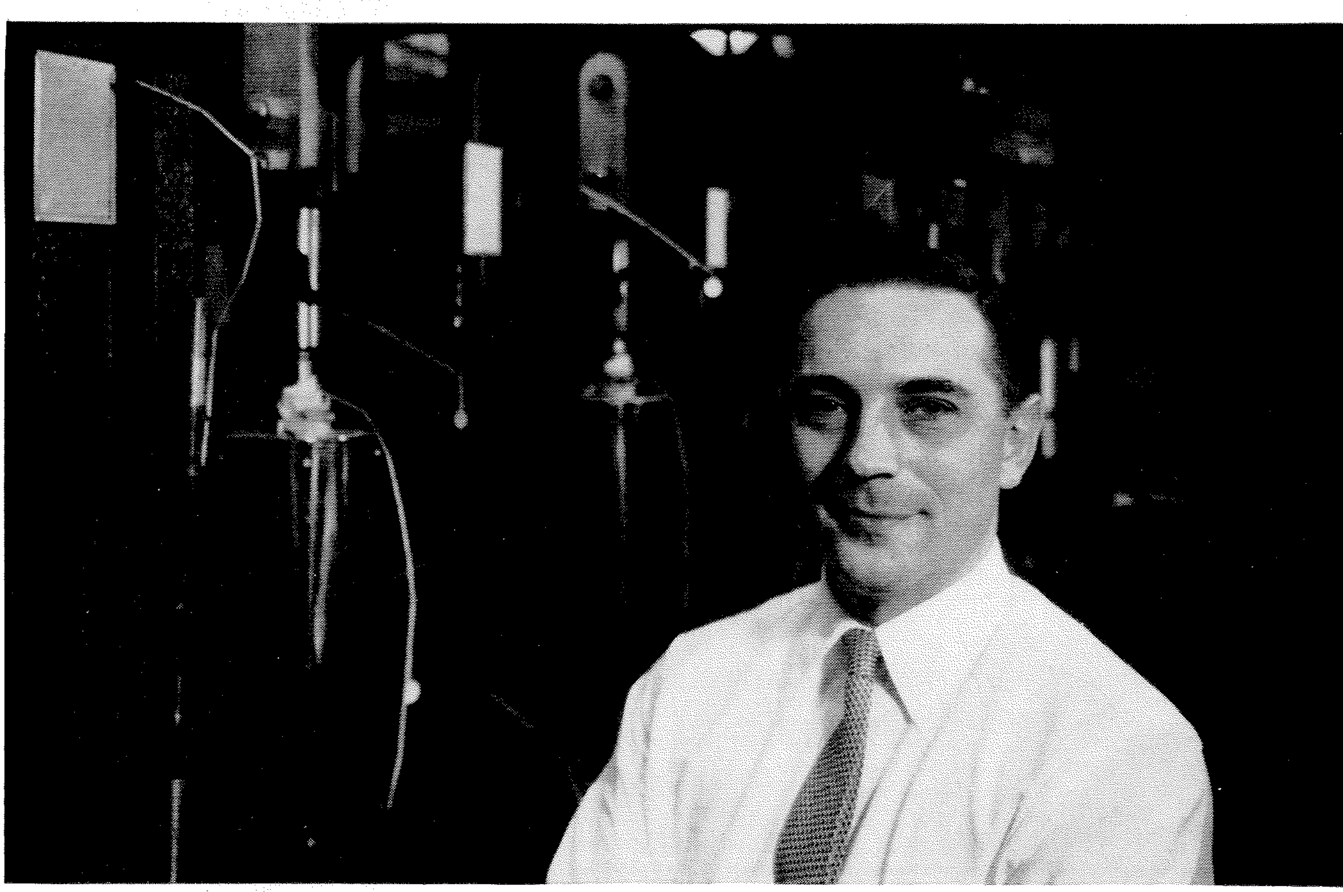

JOHN BAUSCHER graduated from college in 1943 with a B.S. degree in Metallurgy. After a stint in the Navy, he returned to college as a metallurgical research assistant. In 1949 he received his M.S. in Metallurgy and then came to work at the U.S. Steel Applied Research Laboratory. After just four and a half years, Mr. Bauscher had progressed to Division Chief for Sheet Products Development – responsible for the improvement of present sheet steel products and the development of new and improved types.

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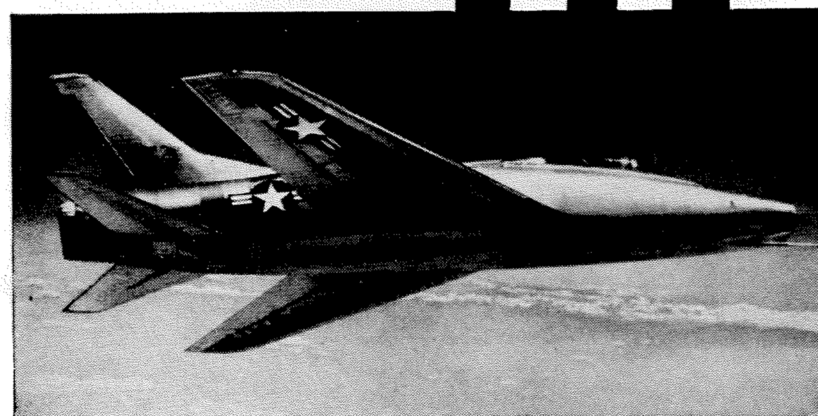

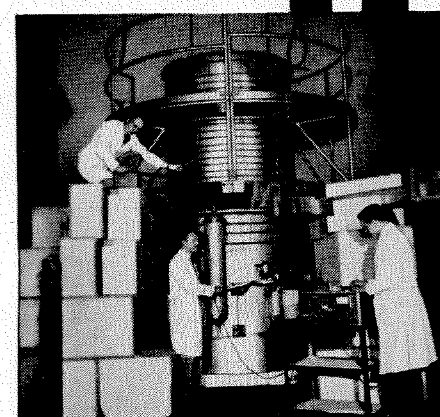

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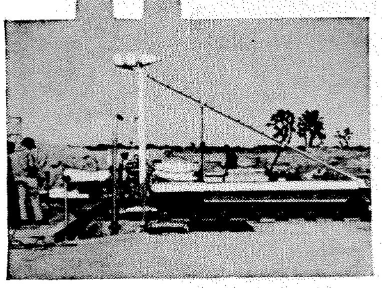

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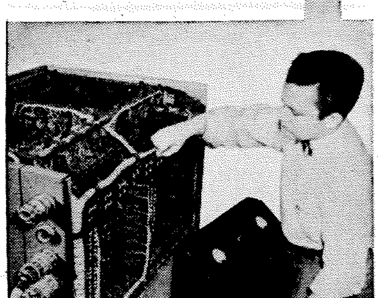

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ENGINEERING AND SCIENCE

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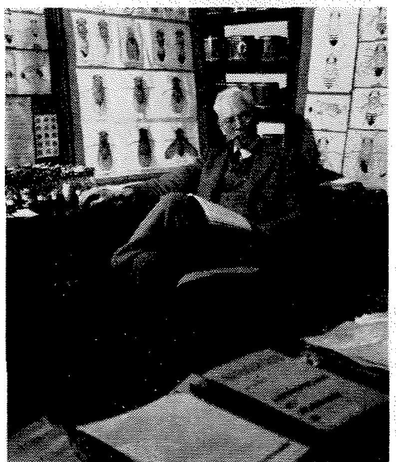

On the cover is a portrait of Dr. A. H. Sturtevant, Thomas Hunt Morgan Professor of Genetics at Caltech —and author of "The Genetic Effects of High-Energy Irradiation of Human Populations" on page 9 of this issue.

Last June, in an address before the Pacific Division of the American Association for the Advancement of Science (of which he was president in 1954) Dr. Sturtevant stated that, though the immediate or future benefits of atomic explosions might be great, it should be clearly understood that all of us have been subjected to irradiation from these sources—and this radiation should be considered as potentially dangerous to future generations.

Dr. Sturtevant's talk ("The Social Implications of the Genetics of Man") stirred up a certain amount of controversy and concern. Enough, in fact, to cause Dr. Sturtevant to set down the basic facts about the genetic effects of high-energy irradiation which you will find on page 9.

Dr. Arthur L. Klein, Caltech Professor of Aeronautics, and design consultant for the past 24 years for Douglas Aircraft, makes some predictions of what to expect in the way of aircraft 50 years from today—on page 20.

PICTURE CREDITS

Cover	Ross Madden, Black Star
pps. 13, 14	Wide-World Photos
p. 16	Ben Olender
p. 17	Byron Johnson, Jr., '56

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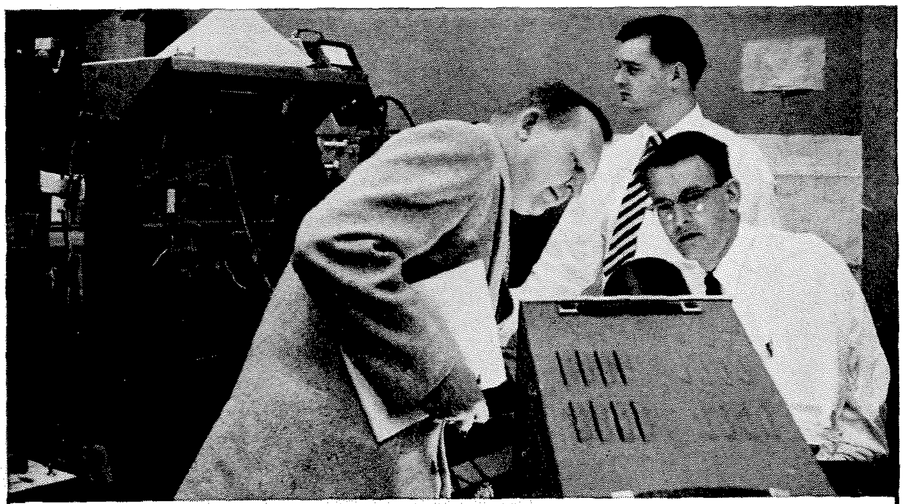


BOOKS

TABLES OF INTEGRAL TRANSFORMS, Vol. II

Edited by A. Erdélyi with the Bateman Project Staff
McGraw-Hill, 1954 $8.00

THIS IS THE SECOND of two volumes of tables of integrals involving higher transcendental functions, designed for the use of mathematicians, physicists and engineers. Based, in part, on notes left by the late Harry Bateman, Caltech Professor of Mathematics, Theoretical Physics, and Aeronautics, the material was compiled by the staff of the Bateman Manuscript Project.

This project was originally conceived by Dr. Bateman. After his death in 1946, Caltech, with the financial support of the Office of Naval Research, assumed responsibility for carrying out Bateman's plans. A. Erdélyi, Caltech Professor of Mathematics, supervised preparation and editing of the work. His staff consisted of Professor Wilhelm Magnus of New York University; Professor Fritz Oberhettingger of the American University in Washington; Professor Francesco G. Tricomi of the University of Turin, Italy; and several younger mathematicians.

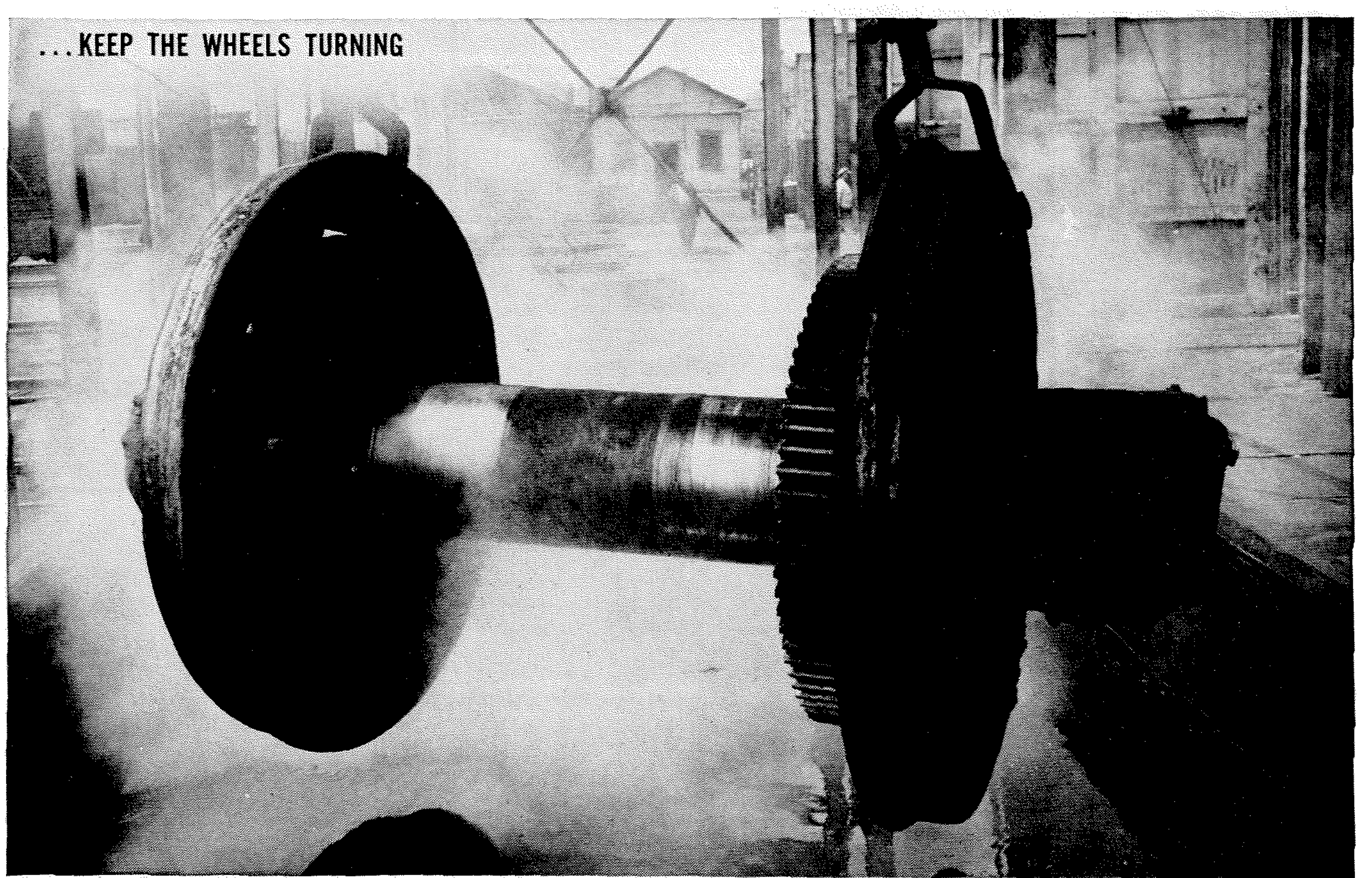
The project consists of five books: three volumes on *Higher Transcendental Functions,* and two supplementary volumes on *Tables of Integral Transforms.*

These books carry out Bateman's objective of compiling an encyclopedic reference work describing the properties and interrelations of special functions, bringing together for the first time information previously scattered through numerous journals and books.

ENGINEERING CYBERNETICS

by H. S. Tsien
McGraw-Hill, 1954 $6.50

DR. TSIEN IS Robert H. Goddard Professor of Jet Propulsion at Caltech's Daniel and Florence Guggenheim Jet Propulsion Center. In this text and reference work—developed for a course on Theory of Stability and Control—he aims to place the study of Engineering Cybernetics on an equal footing with other, older branches of engineering science such as Fluid Mechanics, Elasticity, and Theory of Vibration.



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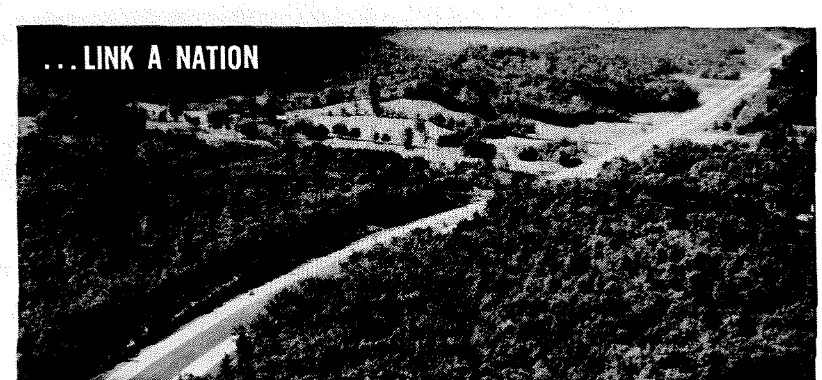

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THE GENETIC EFFECTS OF HIGH ENERGY IRRADIATION OF HUMAN POPULATIONS

by A. H. STURTEVANT

How much, of what, is happening to how many people? A consideration of the effects of radiation on exposed individuals —and their descendants.

HUMAN POPULATIONS are now being subjected to increases in high-energy radiation, through the explosion of A-bombs and H-bombs, and through the widespread medical use of X-rays.

The genetic effects of such exposures have recently been the subject of some public discussions. Since the matter is of public concern, and is also of considerable complexity, it seems desirable to elaborate somewhat on previous comments.

Two types of radiation hazard may be distinguished—those to the exposed individuals, and those to their descendants.

The present discussion is based on the latter class of effects—the genetic results, which will come to expression in the descendants of the exposed individuals.

It is not to be inferred that the direct effects on exposed individuals are negligible. In particular, there is evidence that irradiation does increase the incidence of leukemia and other malignant growths. These are difficult to estimate quantitatively, and there may perhaps be a dosage threshold, such that low doses of the sort here considered are ineffective. However, no such threshold has been demonstrated, and the safest course at present is to suppose that it does not exist—i.e., that even at very low doses there is a real, though small, hazard to the exposed individual.

The genetic effects of irradiation arise through effects *on the germ cells of exposed individuals. These germ* cells, like the other cells of the body, contain numerous separate hereditary elements, or *genes*, which are responsible for the inherited properties of individuals. The genes in any one individual are of many different kinds, but each particular kind is ordinarily transmitted unchanged from one generation to the next. On rare occasions, however, a gene may *mutate*—i.e., undergo a change to a new kind of gene, which is then transmitted to the following generations in the new, changed, form. The genetic interest in high-energy irradiation arises from the fact that it increases the frequency of such mutations.

As previously formulated, the basic facts here are:

(1) High-energy irradiation produces mutations.
(2) The frequency of induced mutations is directly proportional to the dosage of irradiation. There is almost certainly no threshold value below which irradiation is ineffective.
(3) The effects of successive exposures are cumulative.
(4) The effects are permanent in the descendants of the affected genes. There is no recovery.
(5) The overwhelming majority of these mutations is deleterious; that is, they seriously affect the efficiency of individuals in later generations in which they come to expression. These deleterious effects may lead to early death or to any of a wide variety of defects, often gross ones.
(6) There is a store of such undesirable genes already present in any population. What irradiation does is to add to this store.

A further elaboration of these facts falls naturally under two major headings. First, what are the quantitative relations between irradiation dosage and genetic damage? Second, to what dosages are people being exposed? Unfortunately, both of these questions are inherently difficult to answer, and only very rough approximations are possible. No scientist interested in exact quantitative results would touch the subject, were it not that its social significance leaves us no alternative. We must, like it or not, try to get some sort of idea as to how much, of what, is happening to how many people.

Irradiation and mutation

The quantitative determination of the relation between irradiation and mutation requires careful and elaborately controlled experiments, which must be carried out on a very large scale. It is quite impossible to get significant data directly concerning man, so we are forced to turn to other organisms, and it is also clear that our criteria for mutations in other organisms leave out of account some of the more important kinds that are to be expected in man—more especially those having to do with behavior. The most satisfactory data concern the small fly, Drosophila, and were collected by Spencer and Stern. Their data lead to the conclusion that 1 standard "Roentgen unit" of irradiation (written *1 r) will induce 1 lethal mutation per 10,000 treated germ-*cells of Drosophila (sperm cells, in this experiment).

It has recently been suggested that there is a much greater effect in mice, and presumably in people, but I cannot agree that this evidence is convincing. It would seem safest to assume—and it must be recognized that this *is* only an assumption—that the rate in man is roughly the same as that in Drosophila. In any case there appears to be no reason to suppose that man has a lower response to irradiation.

The above rate refers to lethal mutations. In general, according to the usual scheme, such a mutated gene has no effects on an individual that carries it—unless one of the same kind was received from each parent. (It may be estimated that, in man, something like 3 percent of the mutant genes will be expressed in males who received them only from their mothers; i.e., will be "sex-linked"). The result would be that an induced mutation of this type would not usually come to expression until numerous generations had passed. However, Stern et al have recently shown that, in Drosophila, even the individuals with only a single "dose" of a lethal mutation have, on the average, about a 4 percent impairment of efficiency, so the undesirable effects from these genes must be supposed to begin appearing in the generations immediately following irradiation.

Time and mutation

Some of the induced mutations will also be substantially the same as (in genetical terminology, will be allelic to) some of those already present in the population; these may come to expression before there is intermarriage among the descendants of a single exposed individual. This consideration does not lead to any change in the probable average amount of damage due to induced mutations, but it does lead to a decrease in the estimate of the probable average time interval between exposure to radiation and the expression of the effect of the induced mutations.

There are other, non-lethal, types of mutations that are induced by irradiation. The measurement of their frequencies is difficult, and it may be doubted whether *their frequency, relative to that of lethals, will be the* same in man as it is in Drosophila. In the latter organism the evidence is that non-lethal mutations leading to the production of clearly distinct changes in the structure of viable individuals are distinctly less frequent than lethals; mutations leading only to a somewhat lowered efficiency of the individual are roughly twice as frequent as lethals.

On the whole, then, it seems a reasonable guess that the rate of induction of lethals in Drosophila may be used as a very rough index of the probable rate of induction of undesirable mutations in man—an index that is more likely to be too low than too high. This rate—1 in 10,000 germ-cells per r unit—will be used here without attempting any corrections.

The physical measurement of radiation has been developed to a high degree of refinement. But the estimation of the effective doses received by man is a complex matter, and at best can yield only approximate values. We are all of us receiving radiation in small amounts all the time, from cosmic radiation and from naturally occurring radioactive elements in the ground, in the walls and floors of rooms, in the air, and in our bodies. Further, the amount of this radiation varies from time to time and from place to place. We can, at most, get an approximate average value for irradiation per unit time. Since altitude is an important variable in the cosmic ray component of this normal "background" radiation, I have given two values—one for approximately sea-level, and one for an elevation of 6000 feet.

Fall-out from bombs

It is especially difficult to arrive at a value for the increase in irradiation due to fall-out from the bombs, since this varies erratically from one place to another, since the activity from any one explosion rapidly decreases with time, and since the effectiveness of a radioactive element will be greater if it happens to become incorporated in the tissues of the body. It is for these reasons, rather than because of any policy of secrecy, that it is very difficult to obtain from the published accounts any very satisfactory figure for the average increase in background. The value I have taken from AEC reports appears to represent an estimate for an average locality in the United States in Sept. 1954.

In the following table I have included (from the summary by Plough, 1952, *Nucleonics* Vol. 10) some figures for dosages resulting from a few types of X-ray exposures to which people are sometimes exposed in medical practice. These again are averages, and there is much variation in the output of different machines. There is some scattering of radiation in any X-ray treatment, so that areas other than those intentionally treated will get some effect. The amount of such scattering is difficult to estimate. Accordingly I have included in the table only those treatments involving areas close to the ovaries or testes, and have not included the two exposures to which the largest numbers of people are subject—dental and chest examinations.

Irradiation, in r-units

Background, at sea level	— 0.1 per year	3.0 per generation
Background, at 6000 feet	— 0.15 per year	4.5 per generation
Increase in background due to bomb fall-out	— 0.0035 per year	0.1 per generation
X-ray examinations—		
lumbar, spine, anterior-posterior	— 1.5	per treatment
lumbar, spine, lateral	— 5.7	per treatment
pregnancy, anterior-posterior	— 3.6	per treatment
pregnancy, lateral	— 9.0	per treatment
gastro-intestinal fluoroscopy	— 10 to 20 per minute	
Irradiation of ovaries to induce fertility	— 200 or more	
Recommended maximum permissible for radiological workers	— 0.3 per week	15 per year
Average, Oak Ridge and Hanford workers, 1949	— 0.2 per year	

From a genetical point of view, what we are interested in is the product of the dosage received multiplied by the mutation rate per unit dose. In other words, what will be the frequency of deleterious mutations resulting from the various radiation sources to which people are subjected?

Considering first the natural background, 3.0 to 4.5 r per generation would yield from 3 to 4.5 mutations per 10,000 germ cells. This is probably less than the amount of mutation that would be present if it were possible to screen people from all irradiation of any kind. In Drosophila only a small fraction of the normal mutation rate is due to natural background irradiation; but the proportion due to that cause in man is presumably much larger because the length of a generation is hundreds of times greater, and the total background irradiation per generation is greater by the same factor, whereas the number of mutations not due to irradiation is probably proportional more nearly to the number of cell-generations than to time—and man and Drosophila do not differ greatly in this factor.

Incidentally, many discussions of irradiation and mutation emphasize the natural rate, and start with an attempt to determine the amount of irradiation necessary to double this rate. This seems to me a wrong approach, since the natural rate is not known and will not be easy to determine, and since the induced mutations are added to the natural ones and the two types do not have any fixed proportionality. The natural mutation rate is no more relevant than is the death rate from bacterial infection.

Natural background radiation

The natural background radiation is something that is always present, and discussion of whether it is a good thing or a bad one is pointless, since nothing can be done about it. The other sources here listed, however, are man-made, and it is legitimate to inquire what they may be expected to do to human populations.

If the increase due to bomb fall-out persists at current levels it may be expected to give about 1 deleterious mutation per 100,000 germ cells per generation—or, since each individual arises from two germ cells, 1 per 50,000 conceptions.

It may seem that this is a negligible proportion, and it should be emphasized that it is such a low number that no individual should be particularly disturbed about the probability that his immediate descendants will be affected.

But, according to the Population Division of the United Nations, there are something like 3,900,000 births per year in the United States, and about 90 million per year in the world. This means that, if the increase in irradiation due to fall-out continues at the estimated present rate, it will lead to the functioning of about 78 mutated germ cells every year in the United States; and, if the same level of irradiation occurs in the rest of the world, of about 1800 per year in the population of the world. These will go on arising at this rate, year after year, as long as the irradiation continues and the number of births stays in this same range.

Another calculation may be made that is of some interest. The Pacific tests of 1954 apparently gave an average total of about .0035 r for any one locality in the United States. It may be estimated that the people now living in the United States will produce, during their lifetimes, over 100 million offspring; i.e., over 200 million of their germ cells will ultimately function. The estimate then is that 70 of these offspring will carry deleterious genes induced by this one series of tests.

A conservative estimate

It may still seem that these numbers are too small to be seriously considered, but there are several points to be made. I have made every effort to be conservative; the numbers given should be considered minimal ones—the true value could possibly be 100 times greater. And there is a possibility that the irradiation of the germ-cells may sometimes be much greater than is here estimated, if there is a heavy fall-out, especially if some of the radioactive elements become incorporated in the tissues. Finally, from a humanitarian point of view, any increase at all in the number of individuals that are defective either mentally or physically is not to be lightly dismissed.

In any case, it is inexcusable to state, as has been done, that no hazard exists. One might agree that the hazard is slight when weighed against the possible benefits; and I would agree that the hazard to any one individual remote from the site of an explosion is so small as to be disregarded. But the fact remains that there *is* a hazard, and that it may become a significant one in terms of large populations.

The "maximum permissible" exposure has been set by the International Commission on Radiological Protection, evidently on the basis of probable effects on exposed individuals themselves, without regard to genetic effects. If one imagines a situation where an entire population should be exposed to this amount of irradiation continuously, the dose per generation would add up to about 450 r—corresponding to about 4.5 percent of all germ cells undergoing mutation—i.e., every year about one-third of a million infants would be born with newly-arisen deleterious mutations, in the United States alone.

This is an amount that some authorities believe might endanger the survival of the race if it were repeated in every generation, and even if the race survived its members would probably decrease in efficiency. It does not seem likely that any such general level of irradiation will be reached—unless possibly in the event of all-out atomic warfare—but to describe an exposure this large as "permissible" is misleading, to say the least, when one thinks in terms of populations.

The "maximum permissible" exposure will become a matter for careful consideration if nuclear reactors come to be widely used as power sources, since under those conditions also there will be an increase in the background radiation. The amount and character of such increases will depend in part on the type of reactors used, and on the details of their design and operation—and it is a matter of public concern that this factor, as well as economic ones, be taken into account in a program for the non-military development of atomic energy.

The figures for the medical uses of X-rays run higher than those we have been considering, and there can be no doubt that in much of the world this is a far more effective cause of mutation than is radioactive fall-out. The published dosage values are in some respects misleading, since many irradiations—especially among the more drastic therapeutic ones—are most often given to patients who are unlikely to have any further children. But in such cases as the pregnancy examinations here listed it must be remembered that not only the mother's ovaries but also the germ-cells of the child are being exposed. If all members of the population were to receive even 1 r-unit just before birth, as would be possible here, the expected result would be that about one in 5000 of the next generation would carry a new mutation due to the treatment. In the case of the irradiation of the ovaries of a sterile woman to induce fertility it may be calculated that the resulting child has at least 1 chance in 50 of carrying a new mutation due to the treatment.

Medical use of X-rays

In general, the conclusion seems warranted that the medical use of X-rays is dangerous, and should be applied with caution and with full realization of the genetic hazards involved. In any given case the potential gains should be weighed against the potential damage; and in order to do this intelligently it is necessary to get as good an estimate as possible for the weight to be assigned to each side of the balance.

The medical use and the fall-out danger are different not only in the amounts of irradiation involved, but also in some ethical respects. An individual does not usually have to submit to an X-ray examination, or treatment, and when he does so the irradiation is administered for his own personal advantage. But we are all of us submitted, willy-nilly, to fall-out, and while it may be argued that some of this is for our ultimate advantage, it must be recognized that we get fall-out from Russian bombs as well, and that the rest of the world gets it from Russian and American bombs alike.

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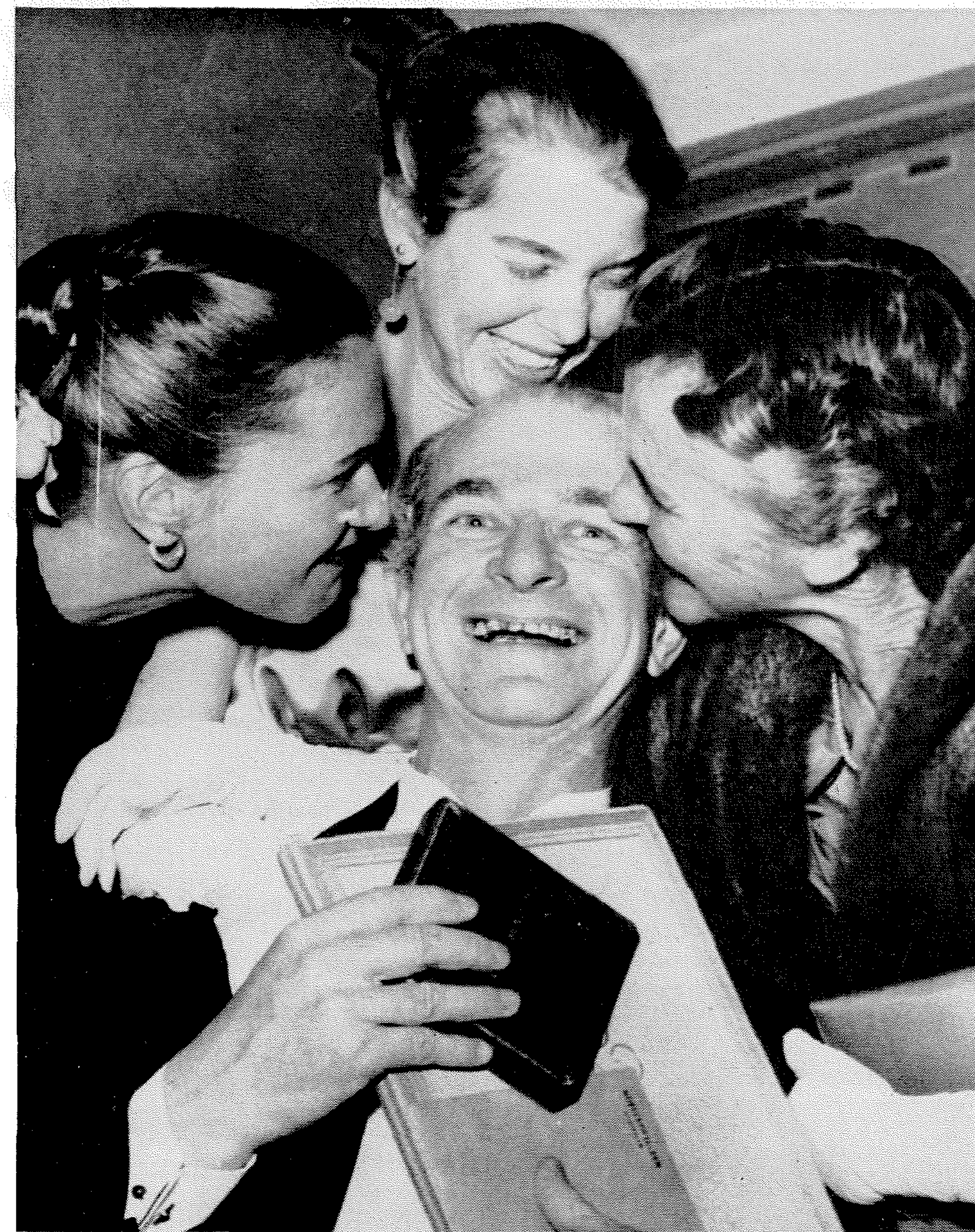


THE MONTH AT CALTECH

The Road to Stockholm

THE POPULAR gentleman pictured above is Dr. Linus Pauling, chairman of Caltech's Division of Chemistry and Chemical Engineering, just a few moments after receiving the Nobel Prize in Chemistry for 1954. He is being duly congratulated by his daughter-in-law Anita, his daughter Linda, and his wife Helen.

Dr. Pauling's award, which was presented to him by King Gustav Adolf VI in Stockholm on December 10, consists of a gold medal, a diploma, and a check for $35,000.

On the eve of his departure for Stockholm last month, Dr. Pauling was honored by the Caltech faculty, trustees and associates at a dinner in the Athenaeum on campus, followed by an entertainment in Culbertson Hall, fea-

Linus Pauling receives ovation after being presented with his Nobel Prize. Swedish royal family is at right.

Five of the seven 1954 Nobel Prizewinners—Dr. Thomas Weller, Dr. Max Born, Dr. Frederick C. Robbins, Dr. John F. Enders, and Dr. Linus Pauling. Weller, Robbins and Enders shared the prize in Medicine and Physiology for their work on polio; Born shared the Physics prize with Dr. Walter Bothe.

turing a hastily-organized Chemistry-Biology Stock Company in a rousing musical and dramatic production entitled "The Road to Stockholm."

Dr. Pauling's actual trip to Stockholm, via the polar flight from Los Angeles to Copenhagen, was the first leg of a three-month journey around the world, and the occasion for a Pauling family reunion. Dr. Pauling was accompanied from Pasadena by his wife, his 17-year-old son Crellin, his son Linus, Jr., 29, (now Resident in Psychiatry at Queens Hospital, Honolulu) and daughter-in-law Anita. In Copenhagen they were joined by the two other Pauling children—Peter, 23, and Linda, 22, who are students at Cambridge University in England.

After the award ceremonies in Stockholm last month Dr. and Mrs. Pauling set off on a tour which will take them to Norway, Israel, India, Thailand, Japan and Hawaii. Dr. Pauling is lecturing at a number of universities and research institutes during the trip. He expects to return home by the middle of March.

Achievement and Service

"ACHIEVEMENT and service have been the hallmarks of Dr. William B. Munro's long and brilliant career, which has been associated principally with Harvard University and the California Institute of Technology. One of the distinguished educators of Twentieth Century America, he is universally known and admired as administrator, scholar, author, and lecturer. He has long been a recognized authority on government, history, economics, and banking. Throughout his life he has been an intelligent and constructive influence in everything with which he has been associated."

With this tribute, Dr. Munro's colleagues saluted him this month on his retirement from the Board of Directors of the Security-First National Bank—which followed close on the heels of Dr. Munro's 80th birthday, on January 5.

Dr. Munro retired in 1945 as Edward S. Harkness Professor of History and Government at Caltech, and as a member of the Executive Council, to become Treasurer of the Institute and a member of the Board of Trustees—retiring, as Board Chairman James R. Page put it at the time, from a 40-hour-a-week job to take on a 180-hour one. In addition, Dr. Munro continues to serve as a director of the Southern California Edison Co., as a member of the Pasadena Advisory Board of the Security-First National Bank, as chairman of the Board of Trustees of the Huntington Library and Art Gallery in San Marino, and chairman of the Board of Trustees of the Huntington Memorial Hospital.

Born in Almonte, Ontario, William B. Munro got his BA, MA, and LLB degrees at Queens University, then went on to take MA and PhD degrees at Harvard. For three years he taught history and political science at Williams College, then joined the faculty at Harvard, where he remained for 24 years. In 1925 he was Jonathan Trumbull Professor of History and Government at

William B. Munro

Harvard, and chairman of the Department of History, Government and Economics when he came to spend a sabbatical year in Pasadena and, at the invitation of R. A. Millikan, agreed to divide his time between Harvard and Caltech.

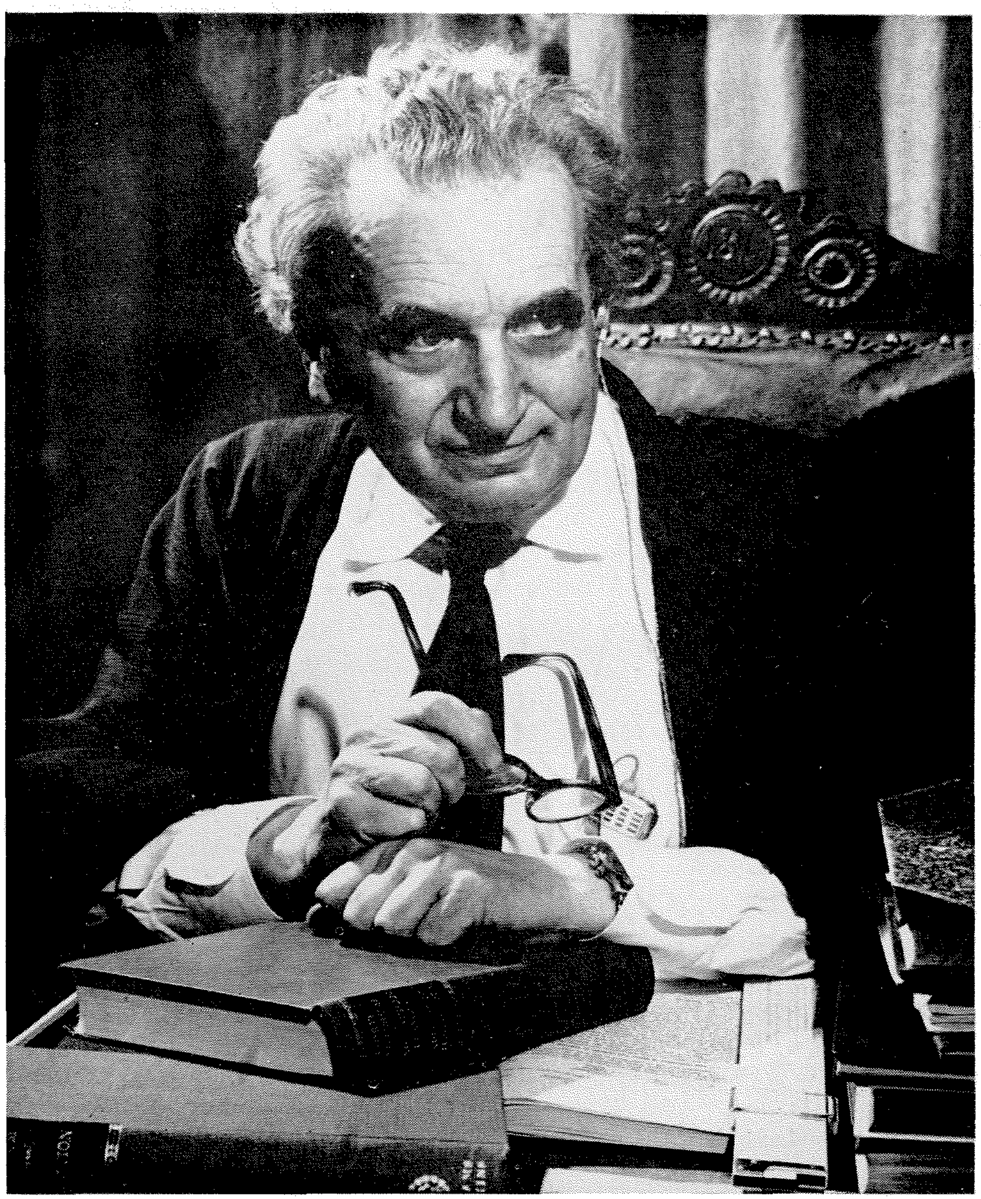
Dr. Munro's first big pioneering job at Caltech was the planning and promotion of a humanities building on the campus—Dabney Hall, built in 1928. In 1927 he became a member of the Institute's Executive Council, and in 1929 came to devote his full time to Caltech. In addition to teaching, he went on to make plans, let contracts, and supervise construction of most of the other buildings on campus.

As R. A. Millikan said of Dr. Munro in 1947, at the presentation of the portrait of him which hangs above the fireplace in Dabney Lounge—"As a teacher, scholar, writer, financier, businessman, promoter, wise counsellor, able administrator, and great humanitarian, William B. Munro rates as one of the most important builders of the California Institute of Technology."

American Universities Field Service

JAMES G. MADDOX, agricultural economist, visits Caltech from January 10 to 19 to report to the faculty and students on current conditions in Latin America. Willard A. Hanna, an expert on the Far East—and particularly Japan—will be on campus from January 24 to February 2. Richard H. Nolte, specialist on the Arab nations of the Middle East will be here from February 7 to 17. And Fred Warner Neal, a political scientist whose field is eastern Europe, including Yugoslavia, is scheduled to be here from February 21 to March 3.

All four men are representatives of the American



Dr. Theodore von Karman, winner of the Wright Brothers Memorial Trophy for significant public service in supersonic research.

Universities Field Staff, the organization set up in 1951 by Caltech and seven other educational institutions in this country to send qualified young men out as their correspondents in foreign areas. In addition to sending back regular reports to the sponsoring colleges and universities, each of these men returns home every two years to visit the campus of each of the sponsoring institutions to report in person on current conditions, problems, and personalities in the area he is studying.

Wright Trophy

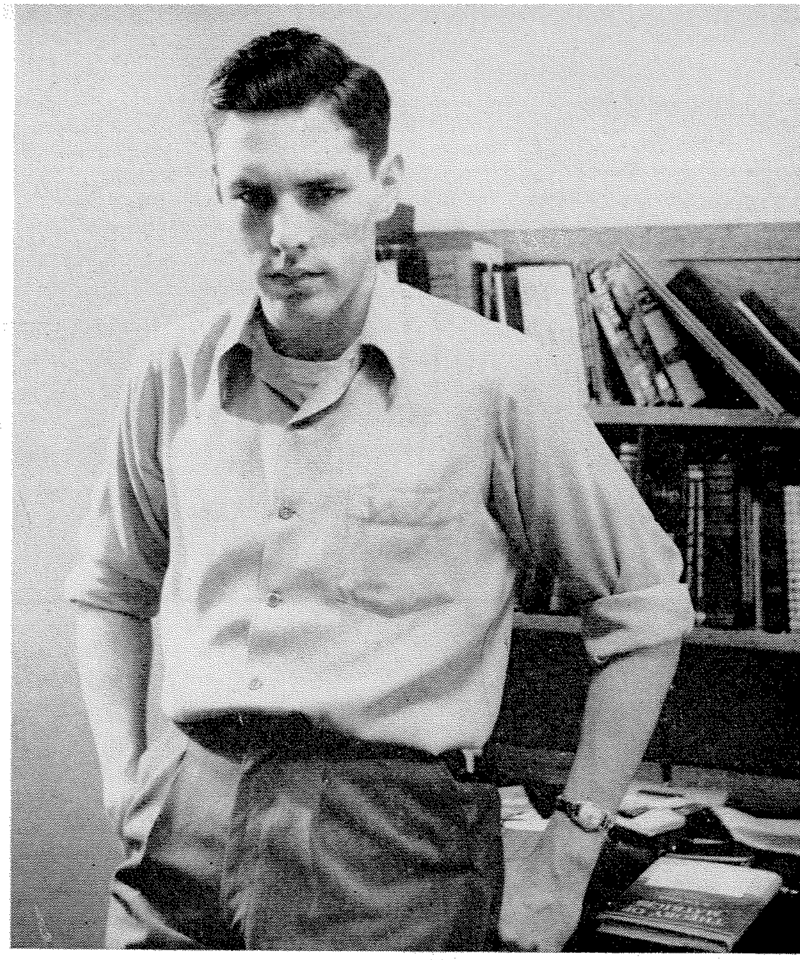
DR. THEODORE VON KARMAN, director of Caltech's Guggenheim Aeronautical Laboratory from 1928 to 1945 and now chairman of the Air Force Scientific Advisory Board, was presented with the Wright Brothers Memorial Trophy last month for his significant public service in supersonic research.

Described by the National Aeronautical Association as "dean of all aeronautical scientists of the world," Dr. von Karman received the trophy for such accomplishments as development of the theory of supersonic drag, for setting up the nation's first supersonic wind tunnel project, and for conceiving and developing jet-assisted takeoff for aeroplanes.

Dr. von Karman came to Caltech in 1928 as Professor of Aeronautics and retired in 1949—only to become even more active as NATO director of the group he originally founded during World War II, when the Air Force established its Scientific Advisory Board.

Scientific Monument

A MEMORAL PLAQUE honoring Dr. Chester Stock, Professor of Paleontology and chairman of the Division of the Geological Sciences at Caltech from 1947 until his death in 1951, was unveiled in Los Angeles' Hancock Park last month. The plaque, located at the site of the famous La Brea tar pits, which have furnished paleontologists with a wealth of fossil material, honors Dr. Stock as "a man who forwarded the development of Hancock Park as a scientific monument."



STATE OF MIND

SHUTTING THE DOOR to his room behind him and tugging at his clip-on bow tie, the sophomore looked sadly at his desk.

Damn, he thought, it'll be hard to get back to work. Two and a half weeks with the gang at home sure can do it to a guy when it comes to studying.

He hung up his house coat and sat down at the desk, his eyes scanning the row of books on the little bookcase in front of him. He pulled out the Theory of Matrices and flipped through it disconsolately. What am I doing, registering for this course? he asked himself. Better that than Physics 20, the answer came back.

What a hell of a way to die! More physics, more calculus, more history (how did that get squeezed in?), biology, and now Matrices and Quadratic Forms.

Suddenly he wasn't sure at all he wanted to be at Tech. When he had shown that exhibit at Students' Day last month he had felt sort of guilty. Look at all these guys, he thought, full to the gills with love of science (being a physicist, he never remembered to think of the engineers), bot to go to a school that's tough, so they could come away with that much better a technical education. Tough! They didn't know what tough was. And here *he* was, an A student all through high school, glad here to get a 2.3—here he was trying to give these innocent high-school seniors a sales talk for Caltech.

That's what *he* needed, the Sophomore thought, a good sales talk for Caltech. If he didn't get one pretty soon the dean's office just might not need to worry about him after this year. Now is the time to transfer out if I'm going to, he told himself. End of the sophomore year. I'm still passing!—and my record's clean, and lots of schools would be glad to have me now. Next year might be too late.

With a sudden inspiration he pulled out a large sheet of typing paper. Getting a pencil from his desk drawer, he drew a vertical line down the middle of the page the long way. Not a very straight one at that, he noticed.

Then at the top of the sheet, on the left-hand side, he put in bold letters the word "PRO"; on the right-hand side, "CON."

Always look at both sides of an argument, he said to himself. What's good about this place, and what isn't?

He started with the CON side; that'll be easy, he thought.

Academic load, he wrote: I *guess* that's a con, he said aloud, and was suddenly embarrassed. I may not have the Caltech Twitch yet, he smiled grimly, but already I'm talking to myself.

Academic Load. He underlined it twice. Sure, he thought, half the college kids in the country complain about their load, I guess—but it couldn't be like this. All my friends at other schools are taking four easy courses; but here I am, taking five tough ones—and against more competition.

He thought a while and then put down *Small Campus.* This won't be in order of importance, he thought with another smile, But dammit, I always thought of a college as being a great spacious park, almost like a forest preserve, with old gnarled trees and ivy-covered classroom buildings and couples in matched sweaters studying together on the great grassy lawns.

Iceplant! he snarled. Why don't they plant grass? A little voice inside him told him that grass was too expensive, that the guys would walk across it and ruin it. It was unconvincing.

He thought back to a 'Y' fireside at Dr. DuBridge's home the spring of his frosh year. The President had told the group of his plans to shoehorn a half-dozen more buildings into the pitiful little four blocks. He was even thinking of putting a library between Crellin and Bridge, where the only grove of trees on the campus held out against the tide of progress. Jizas! Once he had gotten a real thrill when he was walking back to school from the Caltech Barbers and had come around the corner of Mudd and seen the Institute spread out before him—the long portales and those funny little trees, and, 'way down at the end of the field of view, old Throop Hall overlooking the whole vista, with fluffy little clouds in the sky behind the dome. And he wants to spoil that! the Sophomore thought angrily.

Look what they did to Kerckhoff Jungle, he mused. Could have made that spot into the prettiest, shadiest, greenest spot in Pasadena. So they put up a new biochemistry building.

No girls, he wrote, changing the subject. Or maybe that's my fault, he reflected. Certainly are enough college girls in L.A. to satiate the Russian Navy, if I only would kick myself in the butt a few times to make a few dates. He remembered that when ASCIT threw a sock hop in December he had tried for a whole evening to get an Oxy girl on the phone and got nothing but busy signals—and what had he done? Given up and not gone at all. My fault, he sighed. Even when I was home for Christmas I wasn't moving very fast, even with the old gang, all the girls I knew in high school.

Dry subjects. He had been so hot to go when he came to Tech. Now every day's classes set his motivation back another notch. Was it because of the teachers—good scientists and poor educators? Maybe.

Cynical upperclassmen, he penciled with a grin. All he needed to completely destroy his interest in science and in Tech was a half-hour bull-session with any senior in the house. He heard that half a dozen seniors had quit science and were planning to go into medicine. Another gave up physics for law; another, for psychology. Must be dozens more I don't know about, he thought; and that doesn't even account for the flunk-outs who go into other fields. It struck him that Caltech ought to be investigated; every year it drives fifty top-notch scientists out of the field.

Good God, he said, I'd better start listing pro points or I'll be in UCLA in a month.

Good education. No getting around that, he smiled; even the seniors haven't talked me out of that yet.

Small school atmosphere. What hell it must be to go to MIT! All these headaches, and a huge student body besides! At Caltech he played baseball (at least he hoped he could make the varsity this spring), sang in the Glee Club, helped with the Big T. Coudn't do all that at UCLA, that's for sure. Baseball sometimes seemed like enough fun to make the whole business worthwhile.

Besides, it was nice to know most of the kids, to be able to eat dinner with his prof, or play football with the head of the geology department. He was sure he couldn't get that at any other good tech schools.

Student houses, he wrote; and, as an after-thought, *liberal administration*. He was really sold on the houses. After New Year's he could hardly wait to see the guys again, even if he had to come back to Pasadena to do it. And he liked the loose honor-system, give-a-guy-a-chance philosophy which stuck out all over the deans and the administration in general. He almost entered *student house food* on the other side of his sheet, but it struck him that you couldn't expect really too much for what you paid, and besides, all the seniors said the food was much better than it used to be, and the kitchen staff was open to suggestions.

Social program, he wrote, and underlined it. Girls or no girls, he thought, you can't beat it. He had heard from an SC girl while home for Thanksgiving that all the girls in her sorority talked about the fabulous Caltech parties—that is, if you could find a nice guy to go with, you know, 'cause so many of them are creeps.

It had been a pretty rude shock when a friend of his at Purdue had boastfully produced his frat's social calendar at a holiday party. Any house at Tech with a social program that bare would die of sexual starvation in a month. No, a guy at Tech with a steady girl could take her to the neatest round of parties on the Coast; he was convinced of that.

The Sophomore leaned back on the rear legs of his chair and looked over the list.

Wonder what I've left out, he thought. Couldn't have left out any cons, he smiled; I've heard that list from every senior in the house, and they wouldn't forget anything.

He pondered for a while, thinking how just a guy's frame of mind—so flexible—could make him love Tech or hate it. Maybe I can love it if I try, the Sophomore mused. Maybe that's a good resolution for 1955.

Flash! He suddenly remembered that he had forgotten his New Year's Resolutions this year.

He turned over the paper and was on the verge of starting a list when there was a knock on the door. It was a buddy; be wanted to take in a show. Classes for second term started in the morning.

The Sophomore knew without looking at his blue card that he had an eight o'clock the next day. He also knew full well that that didn't mean a thing to him. He was used to getting only half a night's sleep.

When he had his jacket on, he turned and looked again at his desk. Maybe I'll get around to those resolutions over spring vacation, he thought with a smile. Doubt it.

—*Martin Tangora* '57

Looking to the future—Convair's XFY-1 Navy fighter, the Pogo, takes off and lands vertically, is capable of high-speed horizontal flight.

THE FUTURE OF AIRCRAFT ENGINEERING

by A. L. KLEIN

POWERED FLIGHT will be one hundred and one years old on the one hundredeth anniversary of the Society of Automotive Engineers. Industries of this age are noted for their stodginess and lack of imagination. Let us hope that our industry will maintain its rate of progress and its freshness of approach.

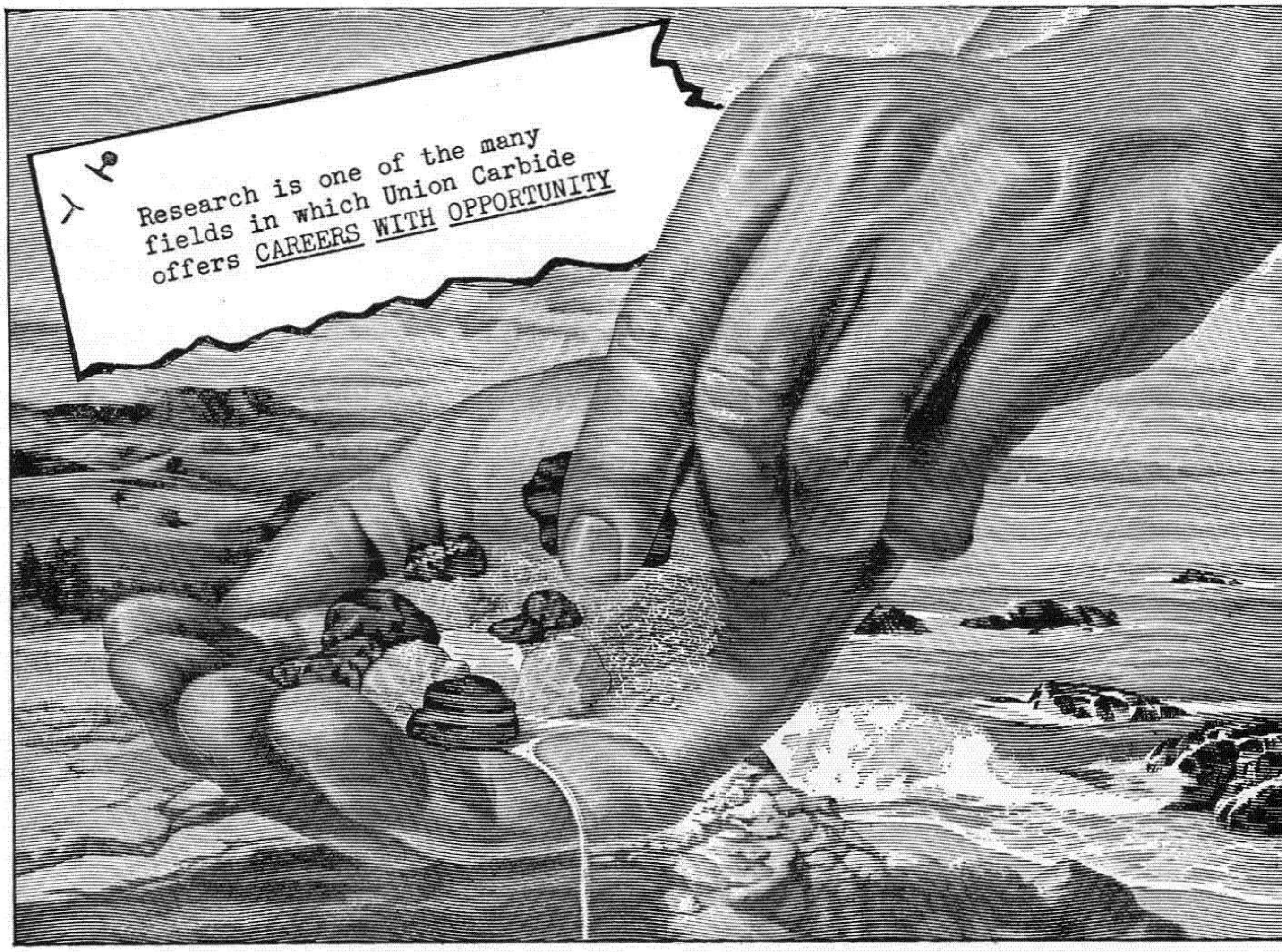
We hope that the present crop of juvenile imbeciles will not undo our work in building our industry to its present size and usefulness. We often are tempted to take the classical attitude that the new generation cannot amount to anything, forgetting that our generation was one of the most harebrained that ever came along. We actually believed that flying machines would work and be useful. We can therefore hope that with the aid of the psychologists and "human engineers" the new generation of aircraft engineers will make our future vehicles safer, more efficient and useful, and may, by means of some as yet unknown powerplants, enable us to escape into space.

We in this Activity are in all our efforts constrained by the requirements and needs of our customers and the output and opinions of the producers of powerplants. We are continually in the position of a chef who is asked to prepare filet mignon from round steak for a customer who can only pay for a hamburger. Fortunately for us, our fairy godmother, namely, the Armed Forces, has waved her magic wand and provided us with enough resources to make the above-mentioned miracle occur. Whether the international tensions that presently exist will continue for the next fifty years or whether a relaxed peaceful civilization or a war will replace the present turmoil is anyone's guess. I could, therefore, take the simple (and perhaps too simple-minded) course that the present international and internal conditions will continue. I hope that our industry and the communication industry will continue to do as they have in making world-wide access and knowledge available to everyone.

Our principal achievement, not without its disadvantages, is to provide cheap and rapid transportation for the world. We have now made it possible to get anywhere in our country in one day. Surely in fifty years the whole world will be reachable in the same time. This implies an average speed of at least 1000 miles per hour, which will be attained long before fifty years elapse. To be practical commercially such speeds must be economical.

The threshold of the supersonic era is on us and as the knowledge of the phenomena that exist at these speeds continues to accumulate there is an indication

"The Future of Aircraft Engineering" was originally presented at the Golden Anniversary Meeting of the Society of Automotive Engineers in Detroit on January 10, 1955.



Search is exciting!

Scientists are constantly probing deeper into the secrets of nature —bringing new and better things to you

AS THE PROSPECTOR thrills to the search for treasure, so does the scientist as he searches out the secrets of the earth, air, and water.

THE TREASURE that the scientist seeks is better understanding of nature, and ways to bring better living for all of us. To find them, he is constantly probing, taking the elements apart, putting them back together in different ways—always looking for something new and promising.

How important is such research? Today, more than one-third of the work of the people of Union Carbide is in providing products and processes that did not exist in commercial quantities 15 years ago. Each new product, each new process, was born of intensive search.

FROM CHEMICALS TO METALS—The results of these achievements are serving all of us today—chemicals for life-saving medicines and many other uses...a wide range of carbon and graphite products... oxygen for the sickroom and industry... a variety of wonderful new plastics... alloying metals for stainless and other fine steels.

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With airplanes the power needed for the desired (and economical) high speeds will automatically give a satisfactory takeoff. In the case of nuclear powerplants the landing problem becomes acute as the nuclear airplane is as heavy at landing as it is at takeoff and therefore the entire airframe, and in fact the entire proportions of the airplane, will be determined by the landing case. The nuclear aircraft will therefore have large and comparatively lightly loaded wings and will have its best performance at comparatively high altitudes.

Supersonic design

At the present time the major problems with supersonic aircraft are low speed and landing control. Maneuverable supersonic missiles of either the rocket type or the airplane type are not too difficult to design, but with them every landing is a crash. We have achieved a good deal of competency in supersonic design and are at last getting to have some feeling and intuition about this region. Up to now we have had to proceed either by inventorism, or by the elaborate procedure of calculation and testing to get a satisfactory vehicle.

Though difficulties have occurred, they have been superable and we are now at the point where supersonic design is becoming a matter of engineering judgment. The striking thing has been the small number of drawings that are made and the large number of calculations and discussions that are needed. Perhaps this is the way to the future.

Using true rockets (without wings and having thrust larger than their weight), the way to the future is less clear. The low speed control of these vehicles is difficult indeed and has only been solved by the science fiction writers. The true rocket, to be commercially useful, must achieve a landing reliability equal to that of other aircraft. If this is done by the use of reversed thrust we must also answer the problem of powerless landing.

As far as extra-terrestrial travel is concerned the vehicle designer is completely at the mercy of the powerplant industry. Financing for such an endeavor must be provided non-commercially as the only immediate uses are military and scientific.

The vehicle except for the landing problem mentioned above, is fairly straightforward, there being only two other important problems. One of these, the auxiliary power problem, is apparently going to be solved by either the solar energy converter, some models of which were displayed lately by some highly reputable organizations, or by means of the direct partial conversion of the energy of radioactivity into electricity. The atmospheric re-entry problem seems to be of an engineering type and needs a great deal of effort but its difficulties are not fundamental.

To reiterate, something is required to replace chemical fuels if extra-terrestrial flight is to be achieved; there are no other serious difficulties other than the financial one.

In the next fifty years the helicopter will come into its own. I have never been a believer in aircraft for everyone and am still less a believer in helicopters as a personal vehicle. If our colleagues in the other Activities of the SAE cannot solve the automobile accident problem, we in this Activity have no chance of solving the problem of safe personal aircraft.

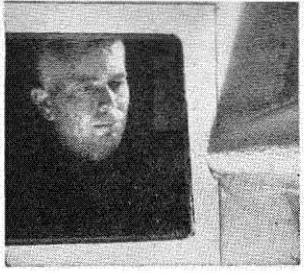
With helicopters the problem is even more aggravated as mere contact with another helicopter can be fatal. These infuriated windmills will destroy each other like creatures in a nightmare. Their present difficulties will be overcome when aircraft designers determine how to design high speed precision machinery. The convenience of the helicopter is so outstanding that its full utilization waits only on improvements in its reliability and safety with a consequent reduction in costs. Twenty years should see these problems solved.

Aircraft safety

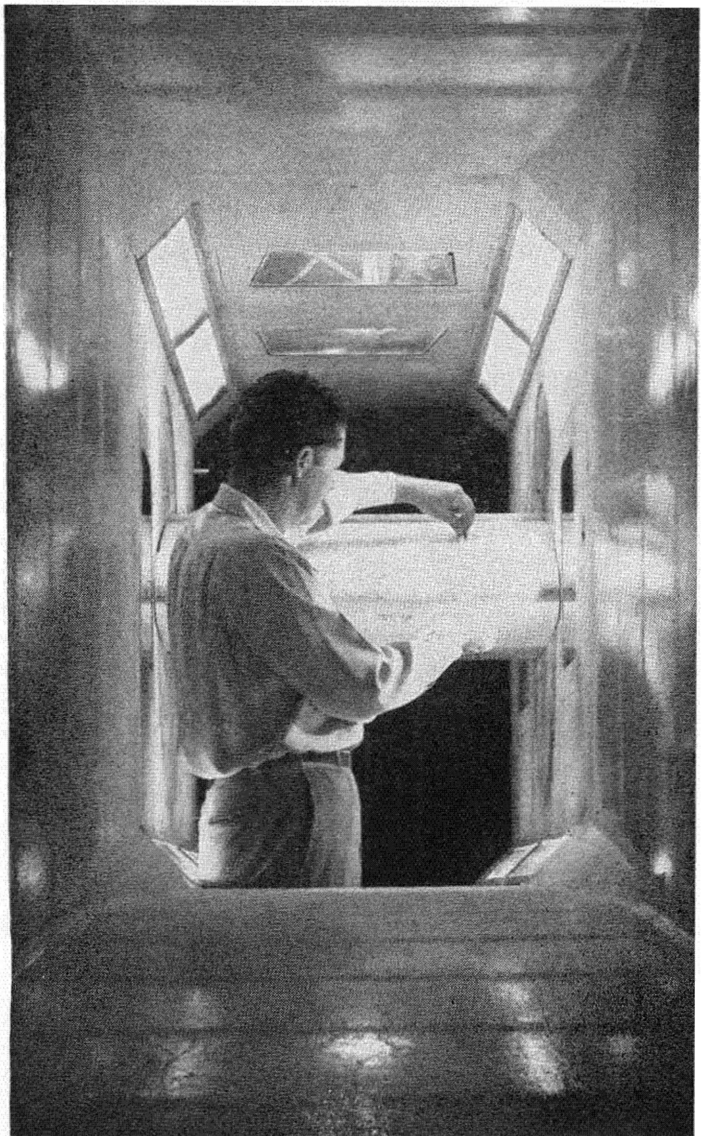
The problem of safety for aircraft is largely psychological. It is notable that "safe" small aircraft do not sell. People do not buy small aircraft because they are safe; they buy them to inflate their egos and therefore the more dangerous, the better. The psychological attitude is similar to that of mountain climbers and hot rodders, and if everyone were properly adjusted none of these would exist. There is something to be said for teaching every young man to fly, if it is possible to do it without terrific carnage. Unfortunately the accidents don't always involve only the pilots.

This Activity is also concerned with aircraft accessories. It is safe to say that within another fifty years most of these devices should work. Some of our present accessories, such as capacitance fuel gages, being based on unsound physical principles, will be replaced. Fifty years from now most of these gadgets will be about as reliable as telephones are now.

Our present instrument flying system must be replaced by something less confusing. Twenty years of trying to get a satisfactory instrument arrangement should prove to anyone that our present system is unsound psychologically and physiologically. The pilot must be given a 3D television type of presentation in the windshield so that he will have a natural view of the situation. Any-



Carl Vrooman, icing tunnel group head, studies hot-air cyclic de-icing test on wing section of C-130 transport. The tunnel has a temperature range of −40° F. to +150° F. and maximum air speed of more than 270 mph.

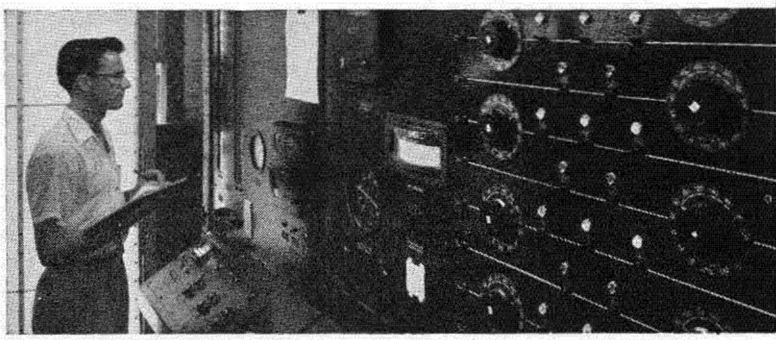


New icing tunnel speeds thermodynamics research at Lockheed

Designed to meet a constantly increasing volume of thermodynamics work, Lockheed's new icing research tunnel now provides year 'round testing in meteorological environments normally found only in flight. It is the first icing research tunnel in private industry.

Lockheed thermodynamics scientists were formerly limited to testing time available at installations such as Mt. Washington. Now they are able to study in greater detail problems such as: thermal anti-icing; cyclic de-icing; various methods of ice removal; distribution of ice; rate of temperature changes in aircraft components; thermodynamic correlation between laboratory and flight testing; and development and calibration of special instrumentation.

C. H. Fish, design engineer assigned to the tunnel, measures impingement limits of ice on C-130 wing section. The tunnel has refrigeration capacity of 100 tons, provides icing conditions of 0 to 4 grams per cubic meter, droplet sizes from 5 to 1000 microns.



Thermodynamicist Ed Dean monitors main control panel in picture at left. Temperature, air speed, water flow rate, air pressure and other variables can be regulated independently.

Career Opportunities at Lockheed

Increasing research and development work on nuclear energy, turboprop and jet transports, radar search planes, supersonic aircraft and a number of classified projects offers engineers outstanding opportunity for creative work.

This is true not only for men in thermodynamics but for Aerodynamicists and Aerodynamics Engineers, Structures Research Engineers, Airborne Antenna Designers, Flight Test Analysis Engineers, Physicists in fields of optics and acoustics, Mathematicians, and almost every other type of engineer.

You are invited to write for the brochure, "Your Future is Now" which describes life and work at Lockheed. Address E. W. Des Lauriers.

LOCKHEED AIRCRAFT CORPORATION

BURBANK **CALIFORNIA**

B. L. Messinger, department head, analyzes test results with Thermodynamics Engineer E. F. Versaw, right, and Thermodynamicist Tom Sedgwick, left. The report was in their hands *only two days* after it was decided to conduct the test.

thing less does violence to his instincts. In fifty years we can hope that the uniformity of design so typical of a mature industry will appear in these accessories and their functioning.

We can expect a great deal of progress in metallurgy. Duralumin as an alloy is not yet fifty years old. We can probably expect greater developments in this field than in many others since the metallurgists are just beginning to come out of the kitchen and to do their thinking at desks. Our structural alloys should be at least twice as strong as the ones we are now using; the non-metallic materials will also be improved in an even greater ratio. As a consequence of the improved materials, improved manufacturing, and assembly techniques, our aircraft fifty years from now will be as superior to our present best performance as today's aircraft are to those of the First War.

These aircraft may be made of metal or they may not. Some of the properties of long, fully saturated molecules are surprising. Who knows?—within fifty years perhaps someone will even come up with a non-destructive method for the measurement of incipient fatigue failure.

Engineering organization

We can expect engineering departments of the future to be differently organized. The problem of large engineering organizations operating on a small number of products is a new thing in human experience and as yet no standardization has developed. Let us consider the engineering organization of the future to be headed by a chief engineer and his immediate assistants: the sum of his detailed duties may be divided among several groups. A partial listing of these follows:

I. Internal Affairs
   1. Personnel
   3. Housekeeping
   3. Clerical services

II. External Affairs
   1. Customer contacts
   2. Project co-ordination
   3. Field service
   4. Licensing agency contacts

III. Engineering
   1. Intelligence
      a. Aerodynamics
      b. Structural
      c. Stress analysis
      d. Loads
      e. Weight
      f. Systems analysis
      g. Powerplants and thermodynamics
      h. Human engineering
         1. Acoustics
         2. Physiology
         3. Comfort and safety engineering
      i. Testing and Research
   2. Design
      a. General
      b. Specialists
         1. Structural
         2. Mechanical
         3. Electrical
         4. Thermodynamics
         5. Fluid Mechanics
         6. Controls
   3. Services
      a. Applied mathematics and computing
      b. Analog machines and simulation
      c. Metallurgical and Material services
      d. Production design
      e. Technical information
      f. Miscellaneous consultants

IV. Research and Testing
   Facilities
   1. Aerodynamics
   2. Structural
   3. Electronic
   4. Electrical
   5. Mechanical
      a. Hydraulic
      b. Pneumatic
      c. Power Plant
      d. Miscellaneous
   6. Simulation
   7. Flight Research

It will be noticed that all the information for the shop originates in Section III, 2—the only part of the entire department that makes drawings and transmits other information to the manufacturing organization. This group, which must weigh the information given to it by the other parts of the engineering department and must make the basic decisions which determine the general and specific nature of the product, is now inadequately educated, staffed and supported. In order for such a group to work at all, and for an organization to come up with sensible results, the members of this group must have an adequate training in evaluating the opinions of specialists. This means that this group requires a more complete, and broader education and training than that of the specialists groups.

Basically these people need the scientific background of a physicist with the practical approach of a mechanic. They need knowledge and skill capable of determining the optimum design in a multidimensional field. These men are frequently in the position of a family physician who can, according to the advice of specialists, have his patient's teeth pulled, operate on him for appendicitis, have him given psychiatric treatments, or put him on a special diet. The future education for these people will be discussed later.

Fifty years from now

Fifty years from now the designer will be much more of a mathematician than his present counterpart. He will be used to large calculating machines, and familiar with the characteristics and capabilities of analogs. He may work at his desk with a miniaturized multidimensional analog and solve some of his polydimensional and nonlinear problems directly.

It is difficult for us in the kindergarten epoch of the art to realize what fifty years will bring. The designer will think in terms of rates, not of magnitudes; problems will not be approached by sampling but will be optimized. Problems will be formulated in terms of physically independent variables and not in terms of meaningless parameters.* These aircraft design problems will contain from fifty to a hundred independent variables; the solution in terms of the desired operating characteristics, such as takeoff run, high speed, cost per ton mile, etc., will determine the values of wing thickness, sweep back angle, wing area, span, etc.

A further investigation will be made to determine the sensitivity of the results to variations in the excellence of manufacture and the quality of the detail design. A further study of the effects of powerplant growth and of changing economic conditions will permit an ade-

*The writer has come to the conclusion that a parameter is something that is used by a specialist to confuse his readers.

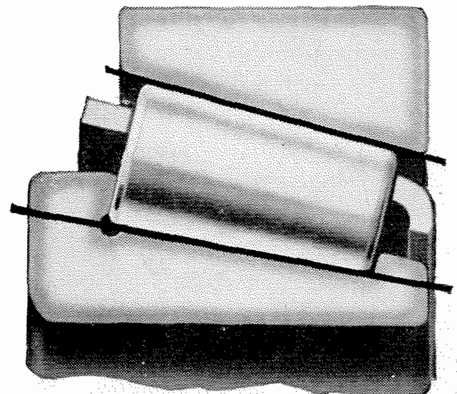
Another page for **YOUR BEARING NOTEBOOK**

How to beat shock loads in a big dragline

Imagine the shock loads put on this big dragline's intermediate swing shaft when the cab, the boom and an 8-yard load of dirt being swung through the air are suddenly stopped and the direction reversed! Engineers solved this problem by specifying Timken® tapered roller bearings. Timken bearings not only take radial and thrust loads in any combination, they also assure long, trouble-free operation.

Why TIMKEN® bearings have high load capacity

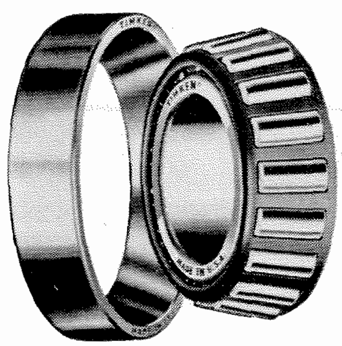
This cross section of a Timken tapered roller bearing illustrates one reason why Timken bearings do such a good job under heavy load conditions. Notice that there is full line contact between the rollers and races. It's this full line contact that distributes the load over a wider area, gives Timken bearings their extra load-carrying capacity.



TIMKEN

TRADE-MARK REG. U. S. PAT. OFF.

TAPERED ROLLER BEARINGS



Want to learn more about bearings or job opportunities?

Some of the engineering problems you'll face after graduation will involve bearing applications. For help in learning more about bearings, write for the 270-page General Information Manual on Timken bearings. And for information about the excellent job opportunities at the Timken Company, write for a copy of "This Is Timken". *The Timken Roller Bearing Company*, Canton 6, Ohio.

NOT JUST A BALL ○ NOT JUST A ROLLER ▭ THE TIMKEN TAPERED ROLLER ▭ BEARING TAKES RADIAL AND THRUST LOADS OR ANY COMBINATION

quate evaluation of the probable economic success or failure of the design. This method can be applied to any products, the characteristics of which can be expressed by mathematical relations. At the present time it can only be used where comparatively simple functional relations can be found. Let us give the mathematicians the next fifty years to produce better methods.

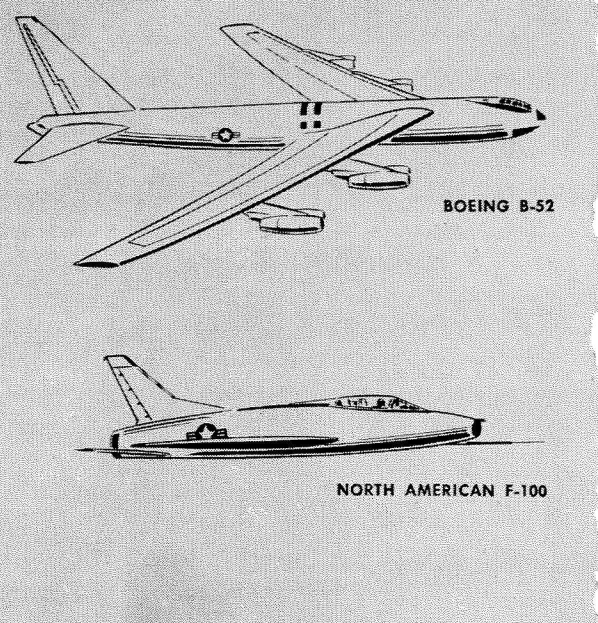
The engineer of the future will be much better educated than his present-day counterparts. He will have a solid foundation in the basic sciences, and will, in addition, be given a background in economics, industrial management, and psychology. He will be trained in the conveying of ideas, both upward and downward in his organization. He will know that the number of geniuses available in the industry is effectually zero.

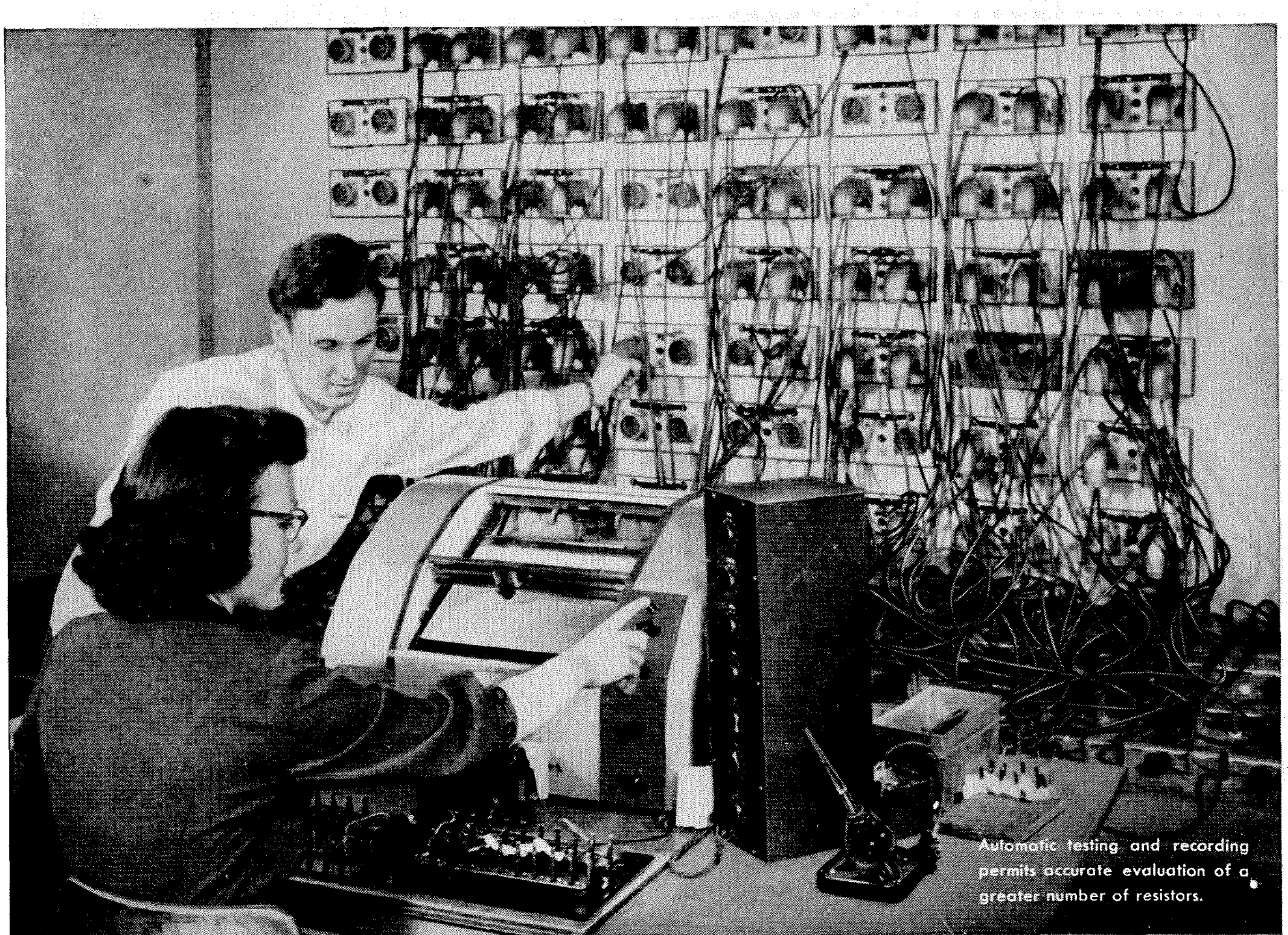
He will know that materials do not maintain fixed dimensions. He will know that neither mechanics nor pilots can be expected to give continuous and unfailing attention. He will know that all devices fail and what failure rate to expect from different kinds of equipment. He will be immune to false objectives such as "do it electrically."

He will recognize from his psychological studies when he, himself, is prejudiced and in important cases will accept good suggestions even if they come from disagreeable individuals. He will know the fields in which he is competent and will not hesitate to ask for help in others. He will be trained to recognize the cycles in human optimism and pessimism so that he can evaluate his performance properly. He will not be pressured into making impossible commitments, and he hopes that his customers will have reached the state where they do not need to be bolstered up by false expectations.

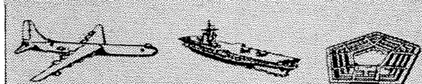
Education to prepare the designing engineer for his job will consist of an academic training roughly equivalent to that for a present-day PhD, plus an interneship under careful supervision.

The men who are to exercise judgment and to compromise the differences between the specialists must be carefully trained. They not only must understand the basic facts involved in each specialty but also must understand the personalities of the individuals concerned, and how far to believe them. In order to get the time to train these people a new synthesis of the scientific background will occur and the old breakdown into specialities will be avoided.


BOEING B-52
NORTH AMERICAN F-100



Automatic testing and recording permits accurate evaluation of a greater number of resistors.



BASIC REQUIREMENTS

JAN and MIL Specifications are basic guideposts for electronic advancement, whether used as engineering reference points or as procurement standards. IRC's dual emphasis on mass production and exacting testing assures highest performance standards at lowest possible cost.

SPECIFIC EXAMPLES

Type BT Insulated Composition Resistors
MIL-R-11A Specification

IRC Power Wire Wound Resistors
MIL-R-26B Specification

Type BW Low Wattage Wire Wounds
JAN-R-184 Specification

Sealed Precision Voltmeter Multipliers
JAN-R-29 Specification

ONLY IRC MAKES SO MANY JAN AND MIL TYPE RESISTORS

. . . another reason why engineers prefer IRC Resistors

56 different IRC resistors is today's figure—all equivalent to JAN or MIL specifications. Manufacturers of military equipment who must meet these specifications depend on IRC for all their resistor requirements. Offering the widest line of resistors in the industry—138 different types in all—IRC is the logical source of JAN and MIL type units.

IRC

Wherever the Circuit Says -ww-

INTERNATIONAL RESISTANCE CO.

401 N. Broad St., Phila. 8, Pa.

In Canada: International Resistance Co., Toronto, Licensee

PERSONALS

1926

Ted C. Coleman with two associates started the Coleman Engineering Company in 1950, to engage in research and development in the guided missile and related fields. Since then, the Coleman Engineering Company has been incorporated and has 110 employees working in the engineering offices and plant in Los Angeles. Ted's company was recently selected by the Air Force as the chief contractor in the design and construction of Project SMART—a supersonic research track to be built early in 1955 on top of a mesa near Zion National Park. It will be 2½ miles in length and accommodate rocket-propelled vehicles at supersonic speed. The Colemans have two children, a daughter in college and son in junior high.

1927

Robert Creveling is now a grandfather—and he proudly reports that his daughter named the first grandchild after him. Bob has been with the Sandia Corporation in Albuquerque since 1951.

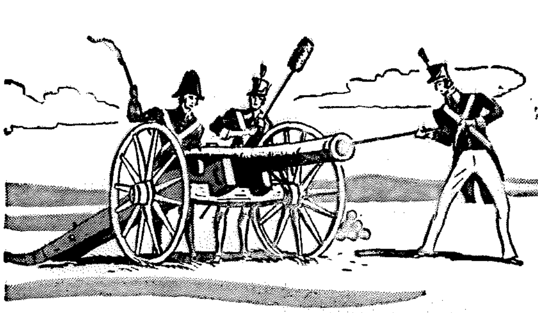
1928

W. Morton Jacobs was recently appointed vice president and assistant general manager of the Southern California Gas Company, and another Caltech man, *Frank M. Foster*, '25, has been named to fill Morton's former position, that of vice president in charge of sales and customers functions within the company. Both men have been with the gas company a long time—Morton joined the company in 1930 and has been a vice president since 1949, a director since 1950. Frank, who has been general sales manager since 1949, first joined the company in 1936.

Edwin M. McMillan, MS '29, has been appointed to the General Advisory Committee of the Atomic Energy Commission by President Eisenhower. As a member of the Committee, Ed will attend monthly meetings in Washington, D.C., where he and other members will advise with the Commission. This appointment will expire on August 1, 1960. Ed has been a faculty member of the University of California since 1932, except for the war period when he worked on atomic energy projects and was one of the Los Alamos project founders. In 1951 he was co-recipient of the 1951 Nobel Prize in physics for his work on new elements beyond uranium.

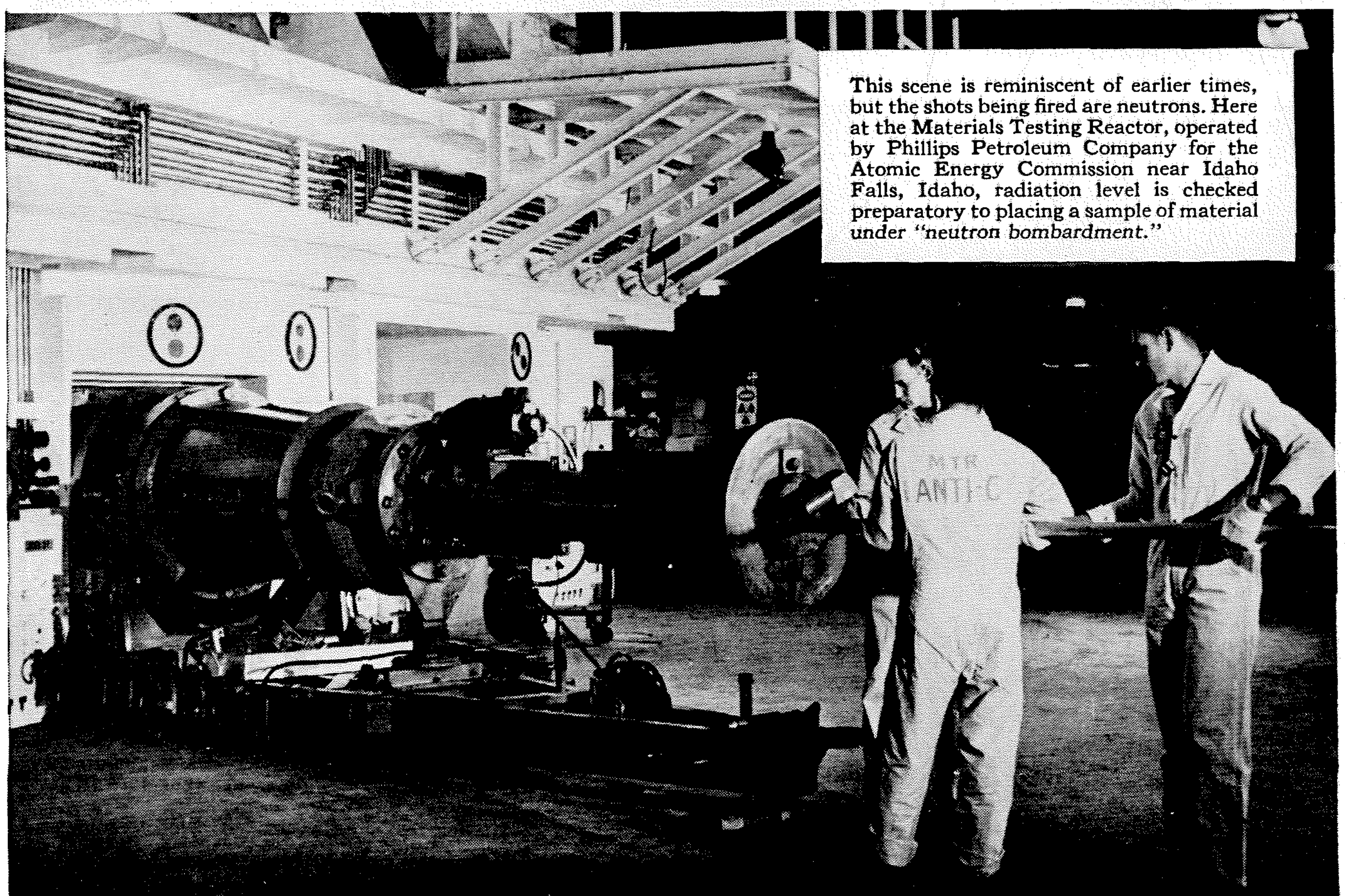
1929

Howard G. Dodge died on November 21 from a heart attack. This information was sent in by *Henry P. Henderson*, '26, who says: "For a number of years Howard had been senior engineer in the San Francisco office of the Underwriters Laboratories, Inc. and recently had been spending a great deal of time in getting their new Santa Clara plant ready for opera-



Muzzle Loader—

1955 STYLE



This scene is reminiscent of earlier times, but the shots being fired are neutrons. Here at the Materials Testing Reactor, operated by Phillips Petroleum Company for the Atomic Energy Commission near Idaho Falls, Idaho, radiation level is checked preparatory to placing a sample of material under *"neutron bombardment."*

Broad assignments in atomic energy represent just one phase of the widely diversified interests of Phillips Petroleum Company.

Whatever your specialty in engineering or the sciences, you may be sure that we are interested in your abilities and your achievements. Already, well over 2,800 technical graduates are found among our 23,000 employees.

Some of these scientists and engineers work to produce and improve our automotive fuels and lubricants. Others develop and manufacture such products as carbon black, synthetic rubbers, chemical fertilizers, sulfur compounds, and chemicals used in synthetic fibers.

If you're looking for a career with a future we invite you to write to our Employee Relations Department for further information about opportunities with Phillips Petroleum Company and its subsidiaries.

Phillips 66

PHILLIPS PETROLEUM COMPANY, Bartlesville, Oklahoma tion sometime in the early part of 1955.

"You will recall that he was a very active member of the Tech tennis team . . . in connection with his tennis activities, it might be interesting to note that he carried this through until very recently, and, because of his very active participation in the Junior Tennis Tournament every year on the San Francisco Bay Peninsula, received the Valuable Citizen award from the Chamber of Commerce in Burlingame several times.

"Those of us who knew Howard will miss his jolly laughter at our get-togethers as well as his valuable help and advice. He leaves a son, Howard, who is in the Armed Forces, and his wife Gwen, who resides at the family home, 444 Bloomfield Road, Burlingame."

William G. Young, PhD, has been re-elected to a three year term on the board of directors of the American Chemical Society. Bill will be regional director for the Society's Sixth District, which consists of eighteen Western states, Alaska and Hawaii. Since 1930 he has been a member of the UCLA faculty, and in 1946 was named dean of the physical sciences.

1930

John L. Hall is the general staff supervisor, new business sales, of the Southern California Gas Company, and for more than 20 years has been giving the "gas pitch" to Los Angeles building industries. John started with the gas company right after graduation, and since 1944 has been supervising, in one capacity or another, the company's dealings with the construction industries.

1933

John E. Meskell has been elected president of the Building Contractors Association of California for the year 1955. John served as director of the association during 1954 and was largely responsible for negotiations with UCLA which led towards the establishment of a full four-year course in general contracting in the School of Business. John is a partner in the firm of Thiesen Company, which specializes in commercial construction.

1935

Robert C. Warner is now Associate Professor of the Department of Biochemistry at New York University College of Medicine. Bob, a member of the staff of New York University College since 1946, has been doing extensive research on the chemistry of proteins, and is presently a member of the Panel on Plasma, Division of Medical Sciences, National Research Council.

1936

Richard Wallman, MS, is now president of the Leonard Melton Company of Nashville, Tennessee, a wholesale sporting goods firm. Dick has two children, a girl and a boy.

1939

J. Scott Gassaway, who is leading an active life trying to keep up with his four boys, writes: "We (wife Marilyn and I) are still owners of the engineering company in Los Angeles which bears my name. We have four boys and I am a neighborhood commissioner with the Boy Scouts, and a vice-president of a Lion's Club. We have an interest in the nationally known Bank Coin machines, which are sold under the M.P. trademark. (I designed them). We love the outdoors and are ardent trailer campers—about 10 trips a year."

1941

Roy M. Acker is a member of the technical staff of the Guided Missiles Division for the Ramo-Wooldridge Corporation in Los Angeles. Roy was formerly with Hughes Aircraft in Culver City. He and his wife Hazel have two daughters, Cheryl, age 4, and Janet, one year.

Richard M. Vaughn was married on December 18 to Constance Ellis of Los Angeles, and they are now living in Beverly Hills. Dick is president of the Town and Country Builders of Beverly Hills.

Claud S. Rupert, who received his PhD in physics from Johns Hopkins in 1951, has been appointed assistant professor of biophysics at Johns Hopkins. Claud joined the Biophysics Department in 1952 as an American Cancer Society Postdoctoral Fellow in cancer research. He was married to Clara M. Sorensen of Baltimore last July.

Roger Wallace is now employed in the health physics division of the Radiation Laboratory, of the University of California at Berkeley. Roger received his PhD in physics from UC in '53. The Wallace family now numbers three; their first child, Elizabeth, was born last April.

1943

Jack L. Mataya, MS, is in the geophysical office of the Stanolind Oil and Gas Company at Tyler, Texas.

Leonard S. Alpert was transferred by the Shell Chemical Corporation to their Ventura Ammonia Plant, where he is senior engineer. Leonard and his wife live in Ojai, California, and with the recent addition of Evelyn Ann, now boast three beautiful daughters.

Richard J. Conway, Lehigh '51, selects Manufacturing Engineering at Worthington

RICHARD CONWAY checks cutting tool with machinist before milling a pump casing.

After completing his general training which brought him in contact with all departments, Richard J. Conway decided that manufacturing engineering was his field. He says, "I chose the Manufacturing Engineering Department after completing my general training at Worthington because as a graduate in Industrial Engineering I can learn the practical aspects of my field while applying theory I learned in college.

"The personnel of this department work together as a team toward the solution of the numerous problems which arise daily. We have the cooperation of all other departments in the corporation in getting the necessary facts pertinent to the solution of these problems. In the course of our day it may be necessary for us to meet the Plant Manager, Chief Engineer, Comptroller, several department heads, clerks, foremen, machinists and many others throughout the company.

"I have contributed to the solution of many problems handled by this department including metal spraying, machining procedures, purchasing new equipment and designating proper dimensions to obtain desired fits between mating parts.

"I enjoy my work because I'm doing the work I want and my formal education is being supplemented with practical knowledge gained from the tremendous wealth of knowledge available to me at Worthington. I know from personal contact with many other departments in the Corporation that Worthington can and will find their young engineers a spot which will give them the same opportunities as have been afforded me."

When you're thinking of a good job, think *high*—think *Worthington.*

FOR ADDITIONAL INFORMATION, see your College Placement Bureau or write to the Personnel and Training Department, Worthington Corporation, Harrison, N. J.

WORTHINGTON

The Sign of Value Around the World

PERSONALS . . . CONTINUED

1944

Eric Weiss is now a member of the technical staff, Research and Development, at Hughes Aircraft in Culver City. Before joining Hughes, Eric was employed as project engineer for the J. B. Rea Company of Los Angeles.

1946

John P. Calligeros has been acting as senior development engineer for the Arabian-American Oil Company, and is located at the company's general offices in Dhahran, Saudi Arabia. Last summer he and his wife Jae made a tour through most of Europe in their little Fiat, and during this vacation did some skiing in the Swiss and Austrian Alps.

Eberhardt Rechtin, PhD '50, is the new section chief of electronics research at Caltech's Jet Propulsion Laboratory. He succeeds *Frank Lehan*, '44, who has joined the Ramo-Wooldridge Corporation.

1947

Col. John A. Graf, MS, is now in command of the San Francisco district, Corps of Army Engineers. John, who graduated from West Point in 1940, will direct a 20 million dollar construction program during the next six months. Included in this program is the completion of NIKE guided missile launching sites, and the building of a hydraulic model of San Francisco Bay. Before this assignment John was executive officer of the Portland, Oregon, district office. The Grafs have two children.

1948

Kurt Barnett, MS, writes from Montreal, Canada: "Here's some news. I was married on November 25th to Charlotte Hojtasova, honeymooned in New York. Working with a firm of consulting engineers in Montreal on the design of industrial electrical installations. Did quite a lot of cross-country skiing up here last year. Miss folk dancing. Always happy to hear of visitors here from Caltech."

Richard A. Spellman joined the California Research Corporation in Richmond last spring. Formerly he had been with the Lago Oil & Transport Company.

Robert C. Hopkins, MS, is now a member of the technical staff of the Field Engineering Department at the Hughes Research and Development Laboratories in Culver City. He was formerly employed by the Digital Computor Laboratory.

1949

Lloyd P. Geldart is the chief geophysicist for Dominion Oil Ltd., (a subsidiary of Standard Oil Company of California), and is located at Port-of-Spain, Trinidad. Lloyd reports that after two years of exploration the company has "spudded" in their first wildcat well.

Jack L. White sent in the following report of his recent activities: "We're returning to the States after 1½ years of research at the Imperial College in London. Managed to cap off our time in Europe with a two-month, 10-country tour through Scandinavia and the Continent by automobile—6,600 miles in all. Looking forward to spending some time in the States now, though the exact location and position are not known."

1950

John P. Francis left the National Bureau of Standards nearly a year ago to become a member of the Magnavox Company Research Laboratories in West Los Angeles. John is working on the design of digital data, handling systems, and the research and development of components. He was married last June to Jean Howard in Westwood, California.

Edmund A. Milne, MS, PhD '53, is assistant professor at the Naval Postgraduate School in Monterey, California. Before this, Ed held a resident fellowship here at Caltech.

1951

Richard B. Campbell, MS, has moved from Vancouver, British Columbia, where he was in the B. C. office of the Geological Survey of Canada, to Whitehorse, Alaska. Right now Dick is in the process of opening and organizing a new survey office for the Yukon.

Gunnar Bergman, PhD, and wife Judy announce the birth of Charles Kimball, their first child, on November 11. Gunnar is Assistant Professor of Chemistry and Mechanical Engineering at Caltech.

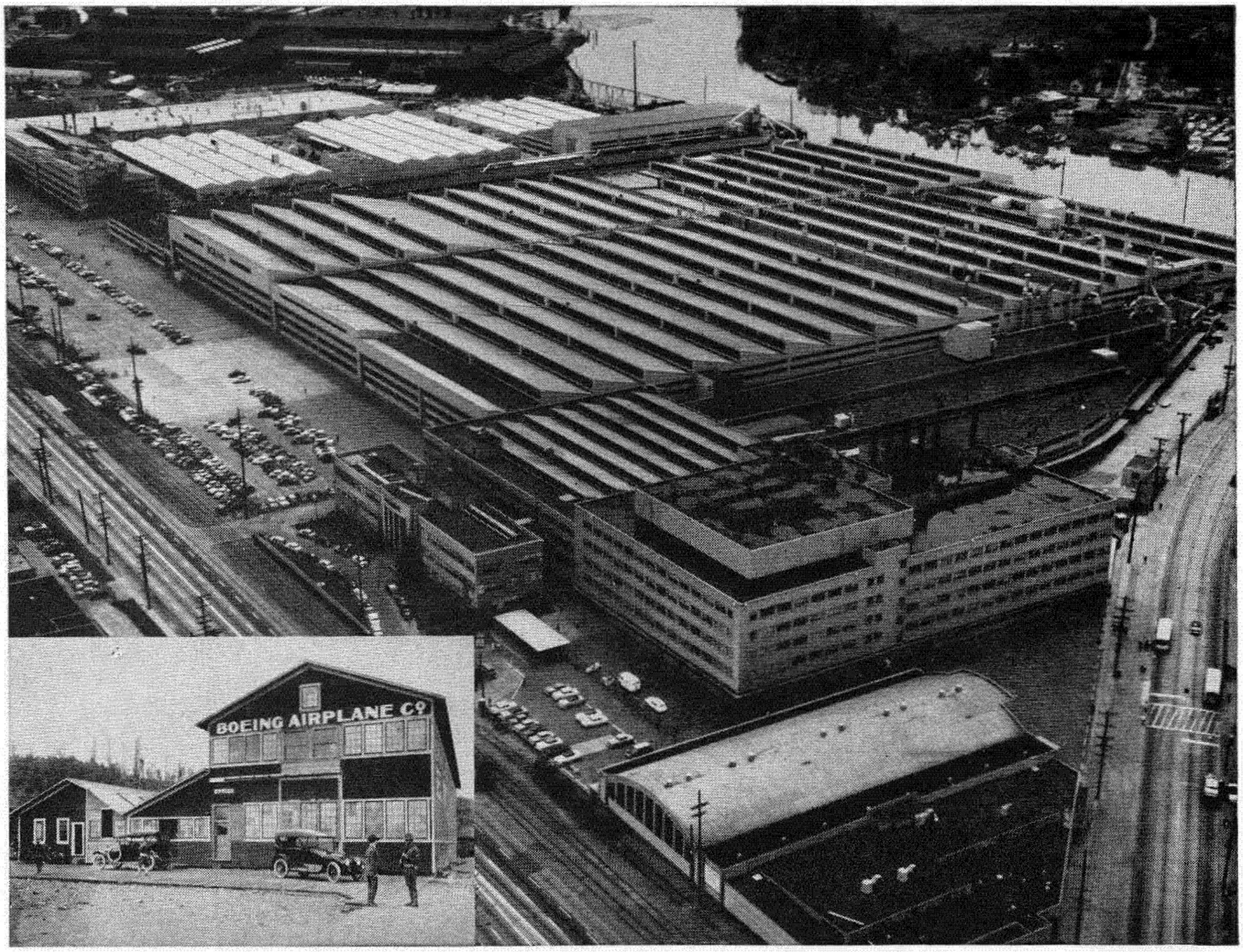
1952

Richard Von Herzen, a Corporal in the Army, is due for a discharge at the end of this month, and he plans to enroll immediately in the Harvard University Graduate School to study geophysics. Dick hopes to make the U. S. Pan-American games swimming team, and for the past month has been training with other Armed Forces swimmers at the Treasure Island Naval Base. After his discharge he will continue his training at Harvard right up to the time of the preliminary trials at Yale in February. Dick never swam competitively until he entered Caltech—but in spite of the late start, he won blue ribbons at the California Conference meets in 1951 and 1952.

Clinton Lew has been in the Guided Missile Division of the Hughes Research and Development Laboratories since leaving Caltech. Last January he received his MS in physics from UCLA. Clinton's due to marry Hawn Young of Buena Park, California, next February.

1953

Robert L. Smith was married on December 18 to Susan Zugsmith of Brentwood, California. Bob is doing graduate work at Caltech.

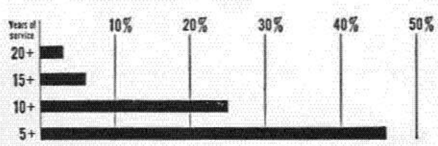


1916—The first Boeing plant, Seattle

1954—Boeing's Seattle plant as it appears today. New Engineering Building is shown in foreground.

Is career stability important to you?

Then the chart below will be of interest. It shows that 46% of Boeing's engineers have been with this company for five or more years; 25% have been here 10 or more years, and 6% for 15 years.



One reason for this stability is that Boeing has grown steadily for 38 years, providing plenty of room for advancement. Another reason is the highly interesting type of work at Boeing, such as designing and building America's first jet transport and the revolutionary B-47 and B-52 jet bombers, as well as work on pilotless aircraft, supersonic flight and research in nuclear-powered aircraft.

Still another reason is this: Boeing always has put dominant emphasis on engineering development. Pioneering in this field has meant that Boeing constantly has increased its engineering staff in relation to total employees. Fifteen years ago, one out of 16 employees was in engineering. Five years ago the proportion of engineers had been raised to one in ten and today it has climbed to one in seven.

Boeing has rewarding openings for engineers of EVERY category—electrical, civil, mechanical, aeronautical and related fields, as well as for applied physicists and mathematicians with advanced degrees.

Careers at Boeing afford a wide variety of experience in research, design and production, as well as work with new materials and techniques, and contacts with a cross section of industry through Boeing's vast subcontracting program.

Boeing promotes from within and holds regular merit reviews to assure individual recognition. Engineers are encouraged to take graduate studies while working and are reimbursed for all tuition expense.

For further Boeing career information consult your PLACEMENT OFFICE, or write

JOHN C. SANDERS, Staff Engineer — Personnel
Boeing Airplane Company, Seattle 14, Wash.

BOEING

SEATTLE, WASHINGTON   WICHITA, KANSAS

ALUMNI NEWS

Class News Letter

THE CLASS OF 1950 is hoping to get out a brief news letter concerning as many members of the class as possible in order to have it available for the fifth reunion of the class in June. Anyone having any information or personal news items concerning members of the class of '50 is requested to pass them along to Ralph Stone, P. O. Box 3546, Phoenix, Arizona.

Seminar Day

THE ANNUAL Alumni Seminar Day falls this year on April 16, the Saturday following Easter. The committee promises an outstanding program of interest to everyone, to be climaxed by dinner at the Elks Club.

Here is your opportunity to meet old friends, spend an enjoyable day on campus, entertain your wife and guests, and thoroughly enjoy yourself. You will probably want to inspect the new Alumni Swimming Pool, Scott Brown Gymnasium, and athletic offices.

A copy of the program and reservation forms will be mailed to all alumni in southern California in March. Any alumnus not living here, but who will be in this area on Seminar Day, should send a card to the alumni office for information.

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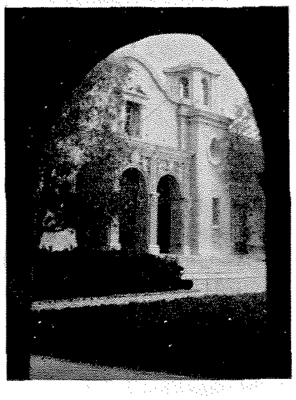

CALTECH CALENDAR

January, 1955

FRIDAY DEMONSTRATION LECTURES

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

Jan. 14—
The Earth's Atmosphere—
Dr. Oliver Wulf

Jan. 21—
Pistons or Pinwheels?—
Dr. Peter Kyropoulos

Jan. 28—
The Size of the Universe—
Dr. William Baum

Feb. 4—
A Demonstration of Some Critical Phenomena—
Dr. Bruce Sage

YMCA LUNCHEON FORUMS

Athenaeum, 12 Noon

Jan. 26—
Problems Arising out of American Military Bases in Japan—Willard A. Hanna

Feb. 2—
Planned Parenthood and Human Relations—
Dr. Ofelia Mendoza, M.D.

Feb. 9—
United Nations War Relief and the Palestine Refugee —Richard H. Nolte

Feb. 16—
Modern Drama and the Human Predicament—
Dr. William Hawley

ATHLETIC SCHEDULE

Varsity Basketball

Jan. 18—Pomona at Caltech

Jan. 21—Whittier at Caltech

Jan. 25—Nazarenes at Caltech

Jan. 28—Caltech at L. A. State

Feb. 5—Caltech at Redlands

Feb. 8—Chapman at Caltech

Feb. 11—Caltech at Whittier

Feb. 15—LaVerne at Caltech

Feb. 19—Caltech at Nazarene

Feb. 19—Caltetch at L. B. State

ALUMNI CALENDAR

Jan. 12	Dinner Meeting
Feb. 5	Dinner Dance
April 16	Seminar Day
June 8	Annual Picnic

Westbound Rio Grande freight in Ruby Canyon of Colorado River.

The freight rolls away an hour sooner

because photography cuts yard bookkeeping

The Denver and Rio Grande Western Railroad microfilms its waybills in minutes, cuts running schedules, saves costs in train idling time.

You don't find a Rio Grande freight idling at the terminal while waybills are copied by hand. Instead, Recordak Microfilming copies them. Then they're put aboard and the train is off in just about one-fifth the time it used to take, thus saving hours of valuable crew and train time. Then the wheel reports are made up from the films and teletyped ahead.

Railroading is but one of over a hundred types of businesses now saving money, time and space with microfilming. It is one of the fast growing and widely used ways photography works for industry.

Small businesses and large are finding that photography helps in simplifying routine procedures, in product design, in personnel relations. It improves production, saves time and cuts costs.

Graduates in the physical sciences and in engineering find photography an increasingly valuable tool in their new occupations. Its expanding use has also created many challenging opportunities at Kodak, especially in the development of large-scale chemical processes and the design of complex precision mechanical-electronic equipment. Whether you are a recent graduate or a qualified returning service man, if you are interested in these opportunities, write to Business & Technical Personnel Dept., Eastman Kodak Company, Rochester 4, N.Y.

Eastman Kodak Company, Rochester 4, N.Y.

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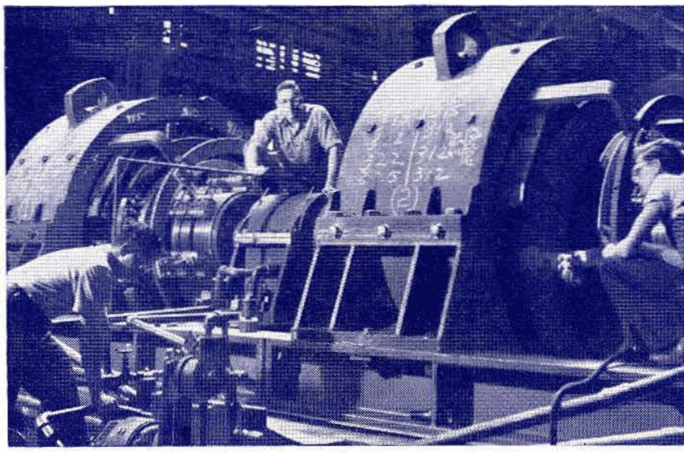
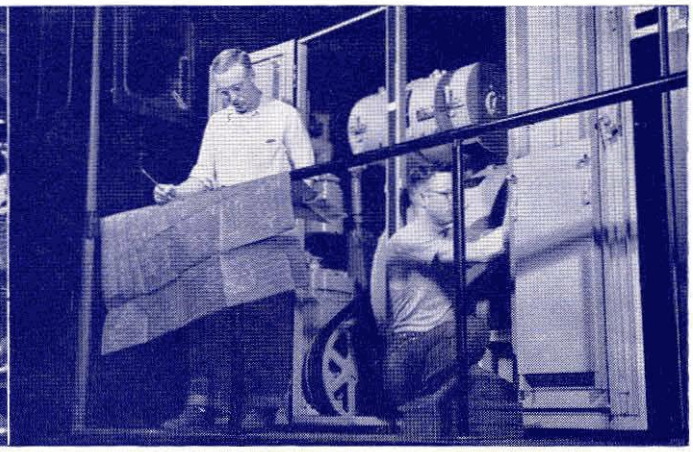
Engineering & Science
Calif. Inst. of Technology
Pasadena, Calif.



CHARLES SNYDER, R.P.I., (center) adjusting 5250 triple-unit d-c mill motor for use in a steel mill.



Engineers RICHARD RENK, IOWA STATE, (left) and ALLEN FRINK, CATHOLIC UNIV., make last-minute check on 1600-hp diesel-electric switcher before it is moved to test track.

THEY'RE "GOING PLACES" AT GENERAL ELECTRIC

Like these young men pictured here, hundreds of scientists, engineers, chemists, physicists and other college graduates are "getting ahead" fast at General Electric . . . . and they are working on projects with the assurance that their contributions are meaningful and important.

They are moving up rapidly because at General Electric a world of opportunity awaits the college man of today—a world limited only by his own ability and interest. The variety of General Electric products and the diversity of the Company's operations provide virtually unlimited fields of opportunity and corresponding rewards, both materially and in terms of personal satisfaction to young men who begin a G-E career.

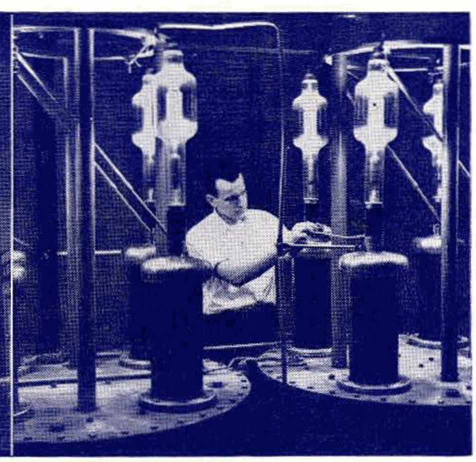
New developments—in silicones, electronics, semi-conductors, gas turbines, atomic power, and others—springing from G-E research and engineering, are creating exciting new opportunities, and are giving college graduates the chance of finding satisfying, rewarding work.

And by placing prime importance on the development of talent and skill, developed through G-E training programs and broadened through rotational job programs, and by providing incentives for creative minds, General Electric is hurrying young men into success in an industry that is devoted to serving all men through the ever-increasing and ever-widening uses for electricity, man's greatest servant.

If you are interested in building a career with General Electric see your college placement director for the date of the next visit of the General Electric representative on your campus. Meanwhile, for further information on opportunities with General Electric write to College Editor, Dept. 2-123, General Electric Company, Schenectady 5, New York.

Test engineers E. K. VON FANGE, U. OF NEB., (left) and R. E. LOVE, U. OF TEXAS, work on stacker and stapler built by them for homework project.

Physicist ROGER DEWES, BROOKLYN POLY., working with scintillation counter in G.E.'s Engineering Laboratory.



ANTHONY TERZANO, PRATT INSTITUTE, checks connections on direct-current rectifier which charges 7,500,000-volt impulse generator in G.E.'s new High-voltage Laboratory.

GENERAL ELECTRIC