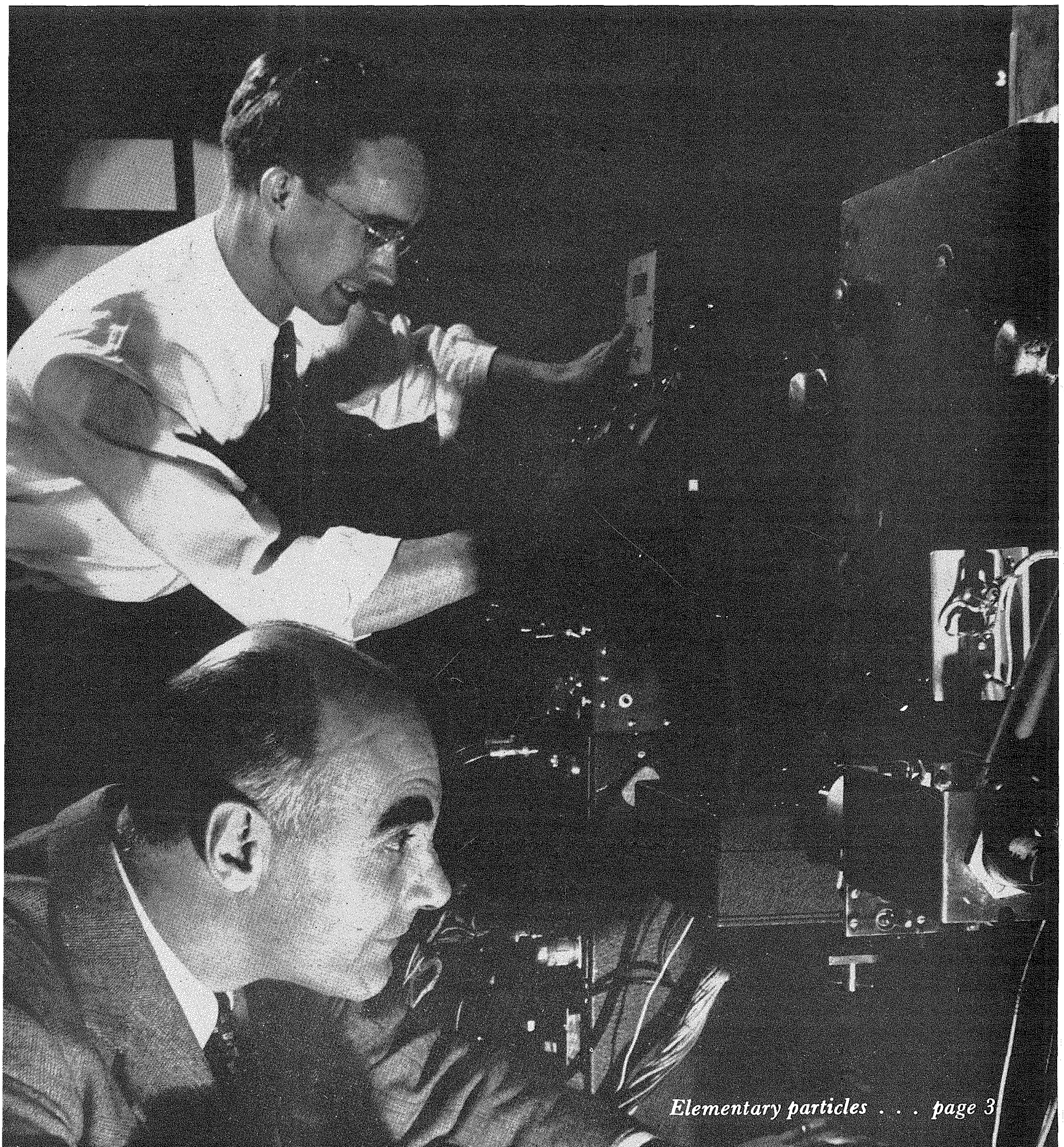
April, 1949

ENGINEERING AND SCIENCE



PUBLISHED BY THE CALIFORNIA INSTITUTE OF TECHNOLOGY ALUMNI ASSOCIATION

The Main Line

APRIL, 1949

This is the time of year when the fancy of Lorenzo—our demon statistician and expert on How To Get the Most from Every Shining Hour—lightly turns to thoughts vacational. And this year he has come up with a check list of "Over-length Two-Week Vacations in 1949."

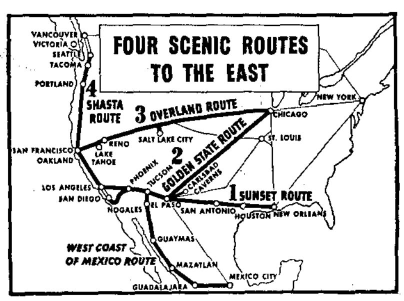
Here they are:

May 16-May 28. (You get Monday, May 30—Memorial Day—as a bonus.)

June 19-July 2. (Plus the Fourth of July week end for good measure.)

August 21-September 3. (And add on the following Monday, Labor Day, September 5.)

According to our calculations—painstakingly arrived at by counting on fingers and toes—a person who doesn't have to do any daily grinding on Saturdays can have a two-week vacation of 17 days by taking one of the above-listed helpings of holiday.



So, a suggestion: now is the time to pre-empt one of these time segments on the office vacation list for yourself—and to start making plans and getting travel and resort reservations lined up.

★ ★ ★

How to go? That's a question on which we have a very definite opinion, and we give it loud and clear—namely:

Next Time—Try the Train!

Why spend your vacation shackled to a road map? Go by train... relax in safety while the engineer drives you... enjoy the country en route... and have plenty of vim and vigor stored up to enjoy the place of places you visit.

★ ★ ★

Where to go? Well, every man to his own taste—as the saying goes. But for that first segment—May—we'd head South—down along our Southern Pacific Los Angeles-New Orleans *Sunset Route.* Down Louisiana-way, the azaleas will still be blooming . . . the bayous quiet and dreamy... and the streets of New Orleans' delightful Vieux Carre most pleasant to explore.

And this side of the bayouland there's Texas... the Gulf Coast, Houston, San Antonio and the Alamo, and El Paso—with the Carlsbad Caverns near by for a side trip, and Juarez in Old Mexico just across the river.

Yes, there's lots to see all along the *Sunset Route*—and two daily S.P. trains to take you there: the *Sunset Limited,* fastest Los Angeles-New Orleans rail service there is (and at no extra fare, either); and the economy *Argonaut,* if you prefer a night departure train.

However — and we repeat it hastily, ere some irate advocate of another sector of S.P.-land lowers the boom on us—that's only one vacation suggestion.

★ ★ ★

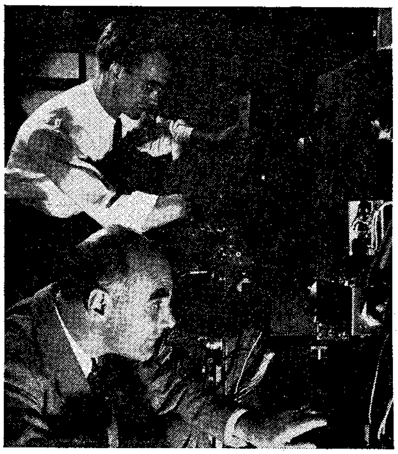
Tell you what you ought to do: see your near-by S.P. Agent and talk vacation with him. He has plenty of notions —about vacationing on S.P., that is.

You have plenty of choice when you go via S.P. Southern Pacific is the only railroad with *four* routes from the Pacific Coast: the only railroad on which you can go one route, return another—see twice as much of America en route.

(Yes, *four* routes. Count 'em on the little map: *Sunset Route,* Los Angeles-New Orleans; *Golden State Route,* the celebrated low-altitude route between Los Angeles and Chicago; *Overland Route,* from San Francisco over the High Sierra to Chicago; *Shasta Route,* via the Evergreen Pacific Northwest.)

S•P the friendly Southern Pacific

In this issue



On the cover

Carl Anderson, author of "The Elementary Particles of Matter" on page 3 is shown on this month's cover (he's the low man) with Ray Adams, Research Fellow in Physics, at the controls of the magnet cloud chamber—built in 1930—in which the positron and mesotron were discovered.

Cosmic ray research in general has added immeasurably to our knowledge of the ultimate nature of matter. Cosmic ray research at Caltech in particular has had a full share in this work. Robert A. Millikan started the cosmic ray program here more than 30 years ago, and his pioneer work called the world's attention to the importance of cosmic ray investigation. As an outgrowth of the program which has been carried on here—under Dr. Millikan's direction—ever since, Research Fellows Robert B. Leighton and Raymond V. Adams have recently made important contributions to the work being done on the properties of mesotrons. And Carl Anderson himself has been credited with the discovery of the positron in 1932—for which he received the Nobel Prize—and (with Seth H. Neddermeyer) of the mesotron in 1936.

Characteristically, Dr. Anderson has neglected to mention these facts in his article, which is otherwise one of the best we've ever seen on this subject.

Titanium

Pol Duwez, author of "Titanium" on page 8, is a native of Mons, Belgium. He was graduated in 1932 as a Metallurgical Engineer from the School of Mines there, and he received his D.Sc. from the University of Bruxelles in 1933. He has been on the staff of the Jet Propulsion Laboratory since 1945, and since 1947 he has been Associate Professor of Mechanical Engineering at Caltech.

ENGINEERING AND SCIENCE MONTHLY

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LETTERS

Oops!

Sirs:

In your advertisement for the Alumni Seminar on the back cover of the March E & S you printed a fine old-fashioned picture with the caption, "Times have changed, son . . . the ME lab doesn't look like this any more." You're right there—it doesn't. But what's more, it never did. Probably because that's the EE lab in your picture.

Chet Ashton '26
Los Angeles

Duel in the Rain

Sirs:

In his article, "What's New About the New Cars" (E & S, March), Peter Kyropoulos says he'd like to try changing a front tire on the Nash 'Airflyte'—"preferably on a side road with plenty of camber, in the rain, at midnight, and in evening clothes."

I'll be glad to arrange this for Kyropoulos, with a photographer on hand to record the event. He can pick the night, the side road, and we'll use a garden hose for 'rain' if the natural stuff isn't available on the date selected. If he needs a rest before rolling the tire into position, he can take a nap on one of the car's convertible beds.

W. G. Haworth,
Associate Director of
Public Relations,
Nash Motors
Detroit

¶ E & S hereby disclaims any further responsibility in this matter; from here on, it's an affair of honor between Haworth and Kyropoulos.

Short Cheer

Sirs:

Congratulations on producing an alumni magazine worth reading.

It is, at least, stimulating to believe that your alumni are interested in articles which depict scientific progress. One becomes a little weary of the customary rah! rah! stuff, personals, and pleas for money as an exclusive diet.

Raleigh Bishop,
Manhasset High School
Manhasset, New York

CONTINUED ON PAGE 23

PICTURE CREDITS

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p. 14—Los Angeles Times
p. 15—Hugh Stoddart
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A report on what man already knows — and what he is finding out — about the ultimate nature of matter

The Elementary Particles of Matter

by CARL D. ANDERSON

THE IDEA of elementary particles of matter, of small, discrete, indivisible particles out of which all matter in the universe is constituted, is as old as recorded history. The Greeks in their philosophical speculations discussed at length the question of the ultimate nature of matter. They realized that there were only two possible choices open to them; either matter must be thought capable of being divided into smaller and smaller units without end, or else it must consist of small units which are themselves wholly indivisible.

Many of the Greek philosophers experienced a philosophical difficulty in trying to conceive of infinite divisibility, whereas others found it equally difficult to think of a particle as being truly indivisible. The difficulty is closely akin to that which one experiences when contemplating the limits of the universe, and trying to decide in his own mind whether it pleases him more to think of the universe as unbounded and extending to infinity, or to imagine a finite universe with definite bounds, beyond which there is nothing—not even space.

The idea of the existence of indivisible material particles, however, seems to have had the most appeal to the Greeks, and the atomic hypothesis was expounded and developed in the fifth century B.C., chiefly by Thales, Leucippus, and his distinguished pupil Democritus, until in many respects it resembled the views which are held today.

The views of Democritus were prominent for 500 years but began to wane after the beginning of the Christian Era and by about 200 A.D. had almost wholly disappeared from European philosophical thought. The idea of material atoms did not really appear again in Europe until about the middle of the seventeenth century, a time marking the beginning of the great era of scientific experimentation which has continued with an ever increasing tempo up to the present.

During this period, through scientific research based on experimentation, the atomic theory of matter slowly developed. By the beginning of the twentieth century, the concept of the chemical atom had received general acceptance as a theory based on scientific experimentation. The idea of atoms had thus been removed from the realm of philosophical speculation and had become a proved scientific fact. According to this picture all matter, depending upon its nature, consists of a mixture of varying numbers of the 90-odd different chemical atoms. The size, mass, and other properties of most of the chemical atoms had been determined, although not with great precision.

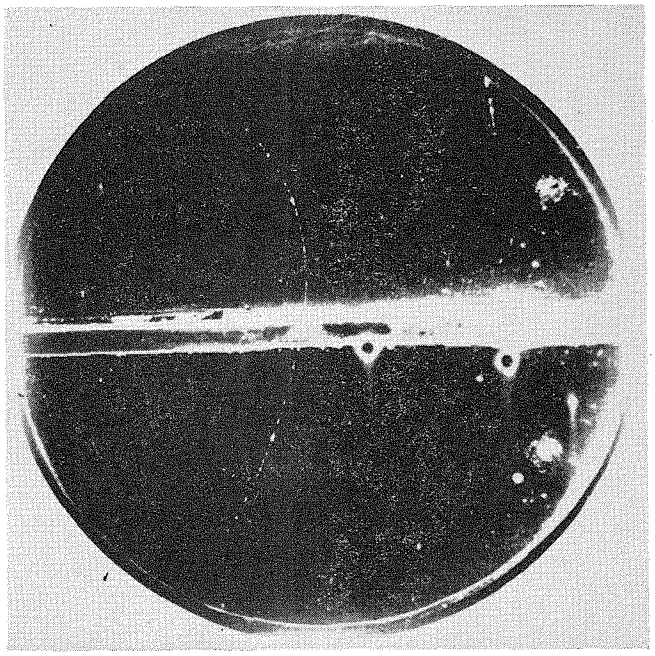
Discovery of first elementary particles

During the time when the chemical atom was being firmly established as a scientific fact, other scientific investigations were succeeding in proving the existence of at least one particle of matter which was more elementary in character than the chemical atoms. In the decade from 1890 to 1900 the discovery of x-rays and radioactivity, and studies of the phenomena associated with the discharge of electricity through gases, soon proved the existence of the *electron,* and showed that the atoms of chemistry must all be considered as complex structures—structures which are themselves built up of particles of a more elementary character.

The electron was distinguished from the other particles previously studied by physicists and chemists in one very important respect. It was established as a unique particle in the sense that all electrons were identical, no matter from what form of matter they were derived. For the first time, then, the presence of a truly elementary particle was revealed to science. It was found always to carry a negative electric charge, and to have a mass about 2,000 times less than the hydrogen atom, the simplest and least massive of all the chemical atoms. The electron immediately took its place as one of the elementary particles common to all forms of matter.

The following thirty years, from 1900 to 1930, were extremely fruitful in furthering our knowledge of the properties of the chemical atoms. The work of Moseley showed that chemical atoms were members of a family, all of them being related to one another in a perfectly definite and simple way. In 1911 the experimental genius of Rutherford in Cambridge, England, proved the existence of the atomic nucleus, and in 1919 he succeeded for the first time in producing an atom of oxygen from the disruption of the nucleus of an atom

This article is adapted from the Sigma Xi Lecture delivered by Dr. Anderson at the centennial meeting of the American Association for the Advancement of Science in Washington, D.C. It also appears in the spring issue of the American Scientist.



Positron, or positive electron (above), was accidentally discovered in 1932 while cloud-chamber photographs were being made for measurements of cosmic rays.

of nitrogen. Thus in 1919 the will of man for the first time was able to cause the disintegration of an ordinarily stable element, with the accompanying release of nuclear energy. These and other investigations all combined to prove that the *proton*—the nucleus of the hydrogen atom—is a constituent of all other chemical atoms, and hence is in fact one of the elementary particles of matter.

In 1930, then, the physicist had at his disposal two elementary material particles, the electron and the proton, in terms of which to try to understand the structure of all matter. In general he was successful in understanding phenomena which we may classify, for want of a better term, as extra-nuclear phenomena. He was unsuccessful in understanding nuclear phenomena. Extra-nuclear phenomena are those processes in which the electrons which form the outer shells of the atom are the active participating agents. The central core of the atom or the nucleus is present, but remains undisturbed and does not participate actively in the phenomenon. In extra-nuclear phenomena the electron is the active participant; in nuclear phenomena the nucleus is the active participant.

These phenomena have a great many distinguishing characteristics. One of the most interesting and important is concerned with the level of energies involved. Extra-nuclear phenomena involve very low energies as compared with nuclear phenomena. The physicist uses the term electron-volt as a measure of energy. The energies of extra-nuclear phenomena are usually found to range from a fraction of one electron volt to several electron-volts, whereas nuclear phenomena are usually found to correspond to several millions of electron-volts.

In our environment, almost every phenomenon in nature represents an extra-nuclear phenomenon; the burning of coal, the growth of plants, the generation of electric power by conventional means, the fermentation of wine, the explosion of dynamite, and others in uncountable numbers. Nuclear phenomena are not so commonplace, but a few examples are the generation of the sun's heat, the decay of radium, the manufacture of plutonium, the absorption of cosmic rays in the earth's atmosphere, and the explosion of an atom bomb.

The concept of energy has been introduced here because of the great importance that this concept has in the discussion of any physical phenomenon. I have stated that extra-nuclear phenomena represent low energy phenomena and nuclear phenomena represent high energy phenomena. To be more accurate I should have said that in extra-nuclear phenomena we find low *concentration* of energy; that is, the energy changes that one associates with a single elementary particle are low in extra-nuclear phenomena and high in the case of nuclear phenomena. Moreover, physicists for the past several years have been studying certain phenomena which represent energy concentrations many thousands of times greater than those represented even by nuclear phenomena. This has been called the range of *ludicrously* high energies. So far the only opportunity the physicist has had to study phenomena in the range of ludicrously high energies is in connection with observations associated with cosmic rays, but important knowledge of the elementary particles of matter has come from these studies.

By 1930 two elementary particles of matter were known to the physicist. Then suddenly in 1932 two new elementary particles were discovered—the *neutron* and the positive electron, or *positron*. The known elementary particles were therefore doubled in number, increasing from two to four.

The discovery of the neutron, which came as a result of experiments performed in Germany, in France, and in England, was immediately welcomed, for now neutrons together with protons could serve as the building stones for the various types of atomic nuclei. Now it was no longer necessary to assume the existence of electrons *inside* the nucleus, a concept which always had been accompanied by very serious theoretical difficulties.

The discovery of the positive electron, or positron, came during a series of experiments being performed for the purpose of measuring the energies of the particles produced by cosmic rays. It was an unexpected discovery. This statement is true, although about two years before, a British physicist, Dirac, had announced a new theory which actually predicted the existence of positrons. This feature of the theory was not welcomed by physicists, however; on the contrary, it was considered to be an unfortunate defect in the theory and many attempts, by Dirac himself and others, were made to remove it, although all were unsuccessful. If even one physicist had taken the theory seriously, he would have had an admirable guide leading directly to the discovery of the positron. Had this happened, the positron would almost certainly have been discovered by 1930 rather than in 1932. However, after the positron was shown actually to exist, then it was a very short time indeed until many of its properties were understood in terms of the Dirac theory.

The discovery of the positron represented the first instance in which it was recognized that an elementary particle of matter may have only a transitory existence. In ordinary matter, for example, the average life-span of a positron is only a few billionths of a second, for when a positron and a negative electron come close to each other they mutually annihilate each other. The two particles disappear and in their place one finds only radiation; the whole of the material substance constituting the particles is spontaneously transformed into radiant energy. Measurements show that this process is quantitatively in accord with the now famous Einstein equation $E = mc^2$, which relates mass and energy. The process which is the inverse of the annihilation of material particles also occurs—namely, the production of particles out of radiation. If radiation of sufficiently high energy is passed through matter, electrons and positrons are generated. In this process the material substance of the two particles is actually created out of the energy represented by the radiation, and again in conformity with the Einstein equation $E = mc^2$.

In the light of these happenings one must change his concept basically of the elementary particles of matter. These particles are no longer to be thought of as permanent objects which always preserve their identity, and which serve only as building blocks of matter by joining together in groups to form the more complex chemical atoms. One must recognize instead the possibility of the creation of material particles out of radiation, and the annihilation of material particles through the production of radiation. Such a possibility, of course, was completely inconceivable to the Greeks in their long philosophical discussions on the indivisibility versus the divisibility of matter.

The mesotron

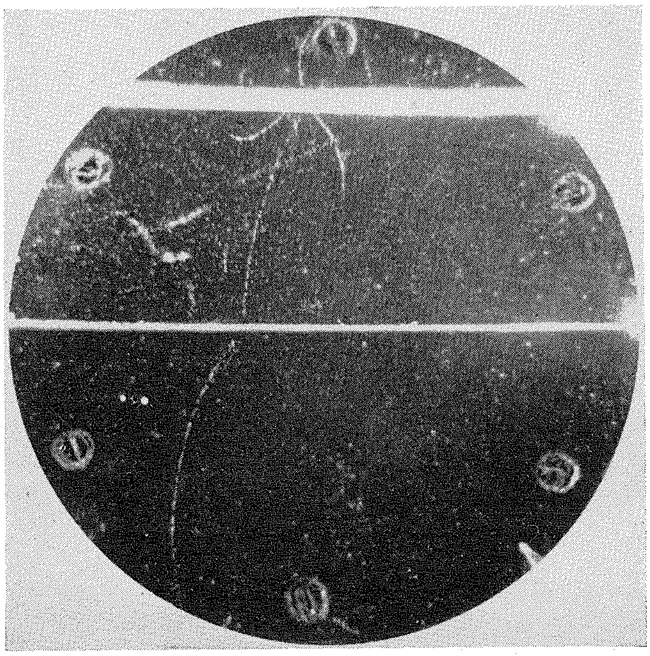
A further step toward a realization of the great complexity inherent in the relationships among the elementary particles of matter came in 1935 with the discovery of the *positive* and *negative mesotrons* or *mesons*, as they are often called. This discovery was also made in investigations of the high energy phenomena occurring when cosmic rays are absorbed in their passage through matter.

The mesotron is a particle some two hundred times as massive as an electron, and therefore about one-tenth as massive as either a proton or a neutron. It occurs with both positive and negative electric charge. The discovery of the mesotron did not come quickly and accidentally, as was the case with the positron and the neutron. It came only after the completion of a sustained series of observations covering a period of four years, which were designed to remove certain inconsistencies always present when we attempted to understand certain cosmic ray phenomena in terms of the elementary particles then known. These inconsistencies were removed in terms of the existence of the mesotron, whose discovery was publicly announced in 1936.

Unlike the neutron, the mesotron was not a particle to be immediately welcomed by the physicist. The physicist makes his advances by simplifying his understanding of nature; hence a physical world which could be explained in terms of only one or two distinct elementary particles would be most to his liking. The discovery of the mesotron did not introduce a simplification; rather, it complicated the situation, for it increased the number of material elementary particles from four to six. Apparently the Creator does not favor a world of too great simplicity.

Before the discovery of the mesotron a Japanese physicist, Yukawa, had postulated, on theoretical grounds, the possible existence of particles of a mass intermediate between a proton and an electron. His theory, however, was not generally known to physicists at that time, and did not have any part at all in the discovery of the mesotron. Had this theory been generally known, it is still doubtful if it would have affected the course of cosmic-ray research. Unlike the Dirac theory of the positron, it would not have served as so useful a guide for the research to follow.

Like the positron, the mesotron has a very short life-expectancy. In free space, both positive and negative mesotrons have a normal life-span of just over two millionths of a second, after which time they spontaneously disintegrate. Very recent observations have shown

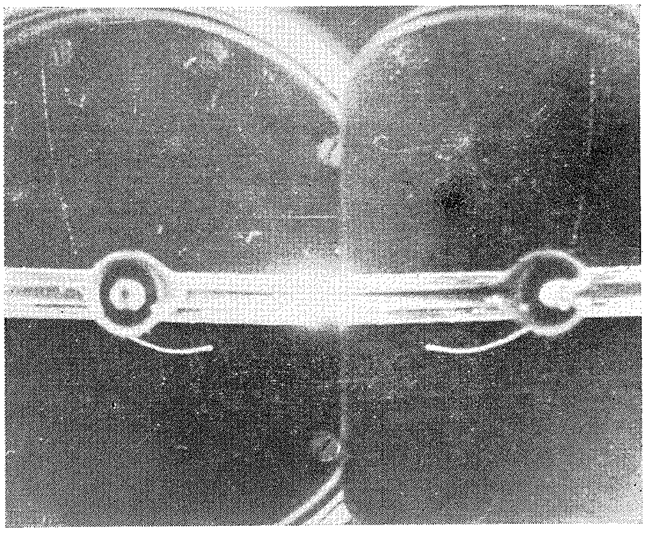


Positron above was produced by ordinary gamma rays from radioactive substances. Picture marks first time positron was found in other than the cosmic rays.

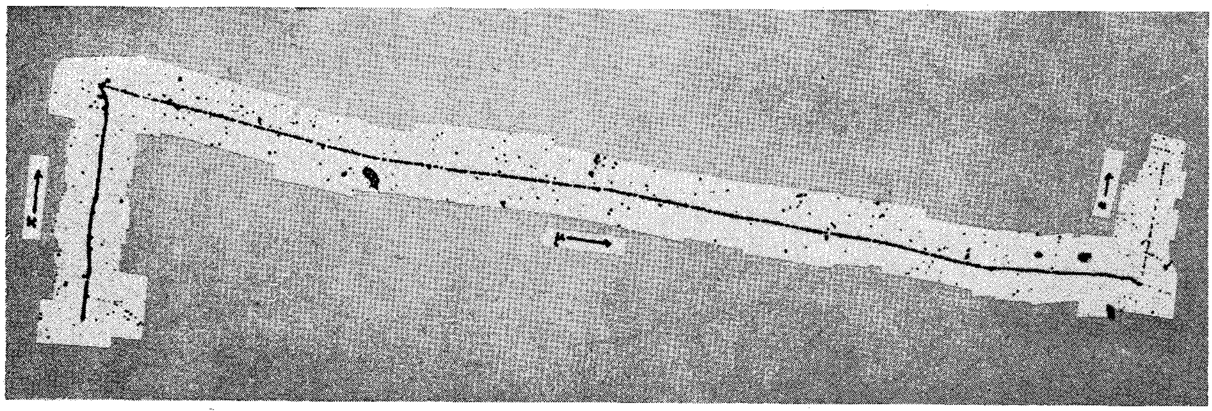
that in all probability the spontaneous disintegration of a mesotron results in the simultaneous production of an electron and two *neutrinos*. Neutrinos are the interesting elementary particles which had previously been invented in order to balance energy and momentum in the process in which an electron is produced when a radioactive nucleus decays. A similar situation exists in the case of the decay of a mesotron, except that here, because the mesotron disappears entirely, it is necessary to postulate the emission of *two* neutrinos in order to balance energy and momentum.

In free space, mesotrons spontaneously decay after about two millionths of a second. In the presence of matter, a mesotron of negative charge may terminate its existence in an even shorter time. It does this by entering an atomic nucleus or, in the language of the physicist, by undergoing nuclear capture.

The mesotrons observed in cosmic rays are produced



Mesotron was no accidental discovery; it was found after an exhaustive four-year effort to track down the countless clues to the existence of such a particle.



In Bristol, England, C. F. Powell is now analyzing tracks produced by mesotrons in emulsions of photographic plates. The track above shows how the decay of a pi mesotron (left) produces a mu mesotron (long horizontal line), which decays in turn to produce the electron whose track is shown at the right.

by the very high energy particles of the primary cosmic ray beam as it comes into the earth from outer space and plunges through the earth's atmosphere. In a manner somewhat analogous to the creation of positrons and electrons, the mesotrons are born out of the tremendous energies carried by the primary beam.

There are many interesting phenomena involved in the birth and death of mesotrons and in the violent nuclear processes which accompany these phenomena. Though it will not be possible to discuss them here I should like to mention in this connection two important advances which have been made in the last two years.

A new type of mesotron

One of these is the work under way in Bristol, England, by Powell and his co-workers, which has consisted of a detailed analysis of the tracks produced by mesotrons in the emulsions of photographic plates. These investigators have discovered a mesotron of a new type which is heavier than the ordinary mesotron. It is about 285 times as massive as an electron, whereas the ordinary mesotron is about 215 times as heavy. The heavy mesotron has a very short life; it lives only about one-one hundredth as long as the light mesotron, after which time it disintegrates and produces a light weight mesotron and another particle, which is probably a neutrino. The negatively charged heavy weight mesotron may also directly enter an atomic nucleus and give rise to a violent nuclear disruption.

Although both the newly discovered heavy mesotrons and the light mesotrons discovered in 1936 have some properties in common—both types of particles occur with positive and negative charges, both have short lives, and both are found in cosmic rays—nevertheless in some very fundamental respects they are entirely different types of elementary particles. The heavy mesotron interacts very strongly with atomic nuclei, but the light mesotron interacts only very weakly with atomic nuclei. Another difference lies in the respective values of that important property known as the spin or angular momentum; recent researches indicate that the heavy mesotron has an integral spin while the light mesotron has a half-integral spin.

In all probability it is the heavy mesotron and not the light mesotron which is to be identified with the particle first postulated on theoretical grounds by Yukawa in 1934. The theory of Yukawa, even in its present state, is very primitive. However, it still provides the best basic concept in terms of which to understand processes involving mesotrons, and after further development, the theory may provide an understanding in terms of mesotron exchange forces of that all-important problem as to the nature of the forces acting between the particles inside a nucleus. So far no satisfactory theory has been developed in terms of which to understand many of even the simplest phenomena involving the nucleus. To acquire a quantitative understanding of the interactions of elementary particles of matter and of fundamental nuclear processes is one of the great tasks of theoretical physics today.

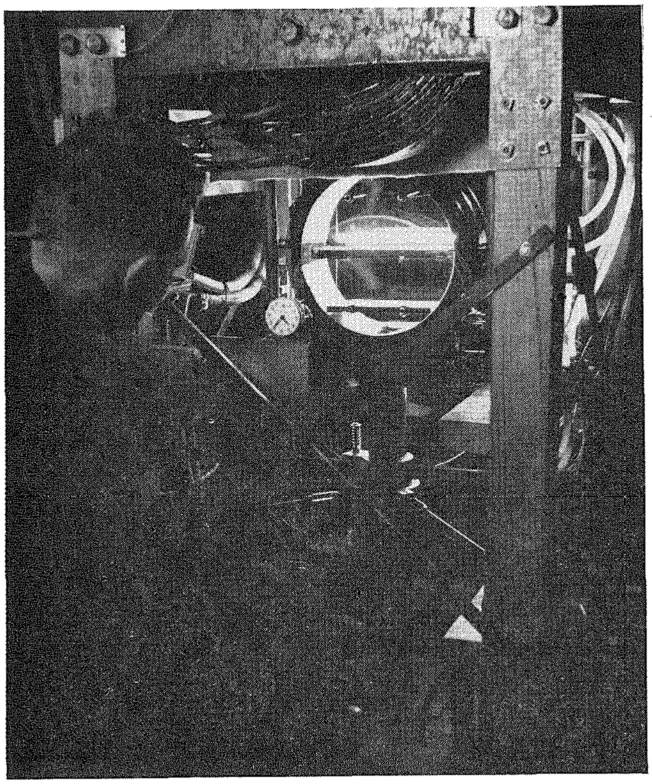
To complete our list of elementary particles we should perhaps include also the *photon*. This particle and the neutrino are, however, in a somewhat different category from the other types of particles. The photon is not a *material* particle in the sense that it cannot be identified with any particle which can exist at rest, and have associated with it a finite amount of ponderable material substance. Photons are to be identified only with radiation or radiant energy. The neutrino must also be placed in a special category, since it cannot have associated with it an appreciable amount of ponderable material substance—if any at all—and since it has never been directly observed.

In all, then, the physicist at the present time recognizes at least ten distinct elementary particles of matter. Whether this list is complete or not no one can say with certainty. The indications are that it is not, for evidence seems to be rapidly accumulating for the existence of at least one additional elementary particle. This particle is found in cosmic rays and appears to have a mass some one thousand times the mass of the electron. But what its properties are, and how it is related to the light and heavy mesotrons, and to the other elementary particles of matter, is a subject which must await the results of further observations.

The thought of probable further additions to the list of elementary particles of matter suggests a question which is quite apart from physics, and has to do simply with the naming of new particles. We have here, actually, an interesting example of the great difficulties that physicists sometimes have merely in assigning labels or names to the various concepts which their experiments or theories may bring forth. It is usually necessary to choose some sort of name for these concepts (whether they be elementary particles of matter or something else) before all the facts regarding them are known. In 1937 the term mesotron was suggested to designate the new particle of intermediate mass discovered in the cosmic rays in 1936. Since then this term has often been contracted to meson and has been so employed. Since the discovery of the new particle whose mass is greater than the mass of the original cosmic ray mesotron, the term mesotron or meson has been employed to designate both types of particles and the Greek letter prefixes *pi* and *mu* used to differentiate between them. Thus the term *pi* mesotron or *pi* meson designates the heavier particle and *mu* mesotron or *mu* meson designates the lighter particle. This nomenclature, in spite of the inconveniences resulting from the use of Greek letter prefixes, seemed satisfactory until continued experimentation began to show more and more clearly the important basic differences between the two types of particles.

It is beginning to be quite apparent now that the properties of these two types of particles are such that they will not naturally fall into the same classification. Thus the use of a common generic term such as mesotron or meson to designate both these types of particles may in the future prove to be inconvenient and illogical. Just what should be done with respect to nomenclature at this time is not clear, but it is a matter which should receive serious consideration, especially in view of the apparent entry of still another new elementry particle into the fold. Perhaps a committee of very wise souls should be assembled to make recommendation, and set a day for a great christening party to be attended by all the physicists in the world.

Another important advance that I want to mention is the recent success in producing mesotrons in the large cyclotron on the University of California campus at Berkeley. This represents the first time that it has been possible by artificial or laboratory means to imbue a single particle of matter with an energy sufficiently high to make possible the creation of mesotrons. This they have succeeded in doing in Berkeley with their beam of alpha-particles or helium nuclei which have been accelerated to an energy of 400 million electron volts. They observe the production of both the heavy and light mesotrons, and all indications are that the mesotrons they produce are identical with those previously observed among the particles produced by cosmic rays.



Robert B. Leighton, Research Fellow, looks into cloud chamber which first revealed that the mu mesotron decays into an electron and two neutrinos.

Now in the design stage are other particle-accelerating machines which will yield particle energies several times the 400 million electron volts so far achieved in the Berkeley cyclotron. When these machines are in operation, working at energies up to six or seven billion electron volts, we can expect to learn much more about mesotrons and the other elementary particles.

Moreover, we must expect that a continuation of research in cosmic rays will also extend our knowledge in this field, since in the cosmic rays, particles are available for study whose energies are even ten to a hundred thousand times greater than those to be expected from any of the accelerators being planned.

In this discussion I have classified physical phenomena according to the energy associated with them, into three categories: (1) low energy or extra-nuclear phenomena, (2) high energy or nuclear phenomena, and (3) extremely high energy or what we might call, for want of a better name, elementary particle phenomena. Knowledge of the first of these, low energy or extra-nuclear phenomena, has already profoundly affected the life of nearly every human being on earth. The Industrial Revolution, our mechanized civilization, the shrinking of the world through advances in communication and transportation have all come as a direct application of our knowledge of low energy or extra-nuclear phenomena. Indirectly it has been responsible for the political and economic organization of the whole world. Our present age might well be classified as an extra-nuclear age.

Since the explosion of the atomic bomb, and the achievement of the release of nuclear energy on a large scale, it seems rather clear that we are now entering a new period in which nuclear phenomena are destined to have an important part in shaping the world, politically if not economically, in the very near future.

It is only fifty years since our direct knowledge of the electron was not much more than a faint green glow in a glass tube—and now no one would deny that our knowledge of the properties of the electron has had an effect of profound importance in shaping our civilization. It is also only about fifty years since the world's knowledge of nuclear phenomena consisted of nothing more than the thoughts passing through the mind of Becquerel as he pondered a darkened arc on a photographic plate. At present our knowledge of all these fields is incomplete, but particularly is this true of nuclear phenomena, and most particularly true of high energy phenomena—elementary particle phenomena.

So far, the world's knowledge of the phenomena of high energies or the interactions between the elementary particles is represented by nothing more than a few printed pages in the scientific journals, by discussions among physicists, or perhaps by an occasional lecture. But we can look forward with anticipation and even excitement to the new discoveries which are surely to come as studies are carried forward of elementary particles and very high energy processes. New phenomena of great beauty, extreme complexity and novelty are certain to be revealed and finally understood.

Whether our knowledge of these new phenomena will then exert a great or a small influence on the world as a whole no one can say. I believe it would be most unwise, however, in the light of the history of scientific development, to expect this influence to be small.

Ilmenite ore, main source of titanium, is plentiful. The National Lead Co. takes ore out of huge "benches" like these in New York's Adirondack Mountains.

TITANIUM

It's an old metal, but now that it's been discovered by the engineers its future looks bright

by POL DUWEZ

LAST SEPTEMBER, headlines in a Paris newspaper proclaimed that "a new metal has just been discovered in the United States; it is lighter than aluminum and stronger than steel." This enthusiastic misstatement is typical of the general public relations approach to titanium. As a matter of plain fact titanium is not a new metal; it was not recently "discovered" in the United States; it is not lighter than aluminum; and it is not stronger than steel.

For the record, titanium was first recognized in 1791, and the pure metal isolated in 1911. It is heavier than aluminum, though not as heavy as iron. It has a specific gravity of 4.4 It is strong, but not as strong as steel. Pure titanium has a tensile strength of 80,000 lb/sq in.—and many alloy steels may be heat-treated to much higher tensile strength.

But in spite of the fact that titanium is an old metal for chemists and physicists, it has just been discovered by the engineers. It combines a number of physical properties of special interest to the engineer. It has a great resistance to heat; in spite of its rather low specific gravity, it has a melting point of about 3300 F.—higher than that of iron, nickel, or cobalt. It also has a remarkable resistance to corrosion—better than that of stainless steel. Pure titanium is ductile and can be rolled and forged. On a strength per weight basis, it compares favorably with the two older classes of aluminum and iron base alloys. Titanium is abundant, being the ninth most plentiful element in the chemical composition of the earth, and the fifth most common metal.

With this combination of properties, titanium has a wide field of applications in engineering. It may be substituted for stainless steel in aircraft construction with a substantial saving in weight. Its remarkable resistance to corrosion by sea water makes it an ideal material for ship building. Replacing steel, titanium base alloys can appreciably decrease the weight of engines. But perhaps the most important application, and one for which titanium may be found to be the only successful metal, is in the field of supersonic aircraft. At supersonic speeds, aerodynamic heating of the structure is inevitable, and aluminum alloys may become useless because of their poor mechanical properties at temperatures above 300 or 400°F. Today, steel seems to be the only solution to the problem, but the development of titanium alloys may change the picture radically.

What's holding things up?

Considering all the possibilities of titanium, it is surprising that such a metal has not been more extensively studied in the past. But the preparation of pure titanium is a difficult problem of extractive metallurgy. The ordinary method of thermal reduction of an oxide by carbon does not apply to titanium. At high temperature titanium oxide in the presence of carbon is transformed into a very stable carbide. And this tendency of titanium to form interstitial compounds at high temperature is not limited to the case of carbon, but exists for other elements such as nitrogen, oxygen, and hydrogen. Even minute quantities of these elements exert considerable effect on the mechanical properties of titanium, especially on its ductility. As little as a few hundredths of a per cent of nitrogen renders titanium brittle at room temperatures. Consequently, the various metallurgical operations must be performed in high vacuum or in an atmosphere of purified inert gas, such as helium or argon.

Titanium is now being produced, but in small quantities—and, at $5.00 a pound, its cost is still very high. This is no reason for pessimism. In 1885 aluminum also cost about $5.00 a pound. Only a few years later, after the simultaneous discovery of the electrolytic process by Hall in the United States and Heroult in France, aluminum was produced in large quantity and the price dropped to as low as $0.25 a pound.

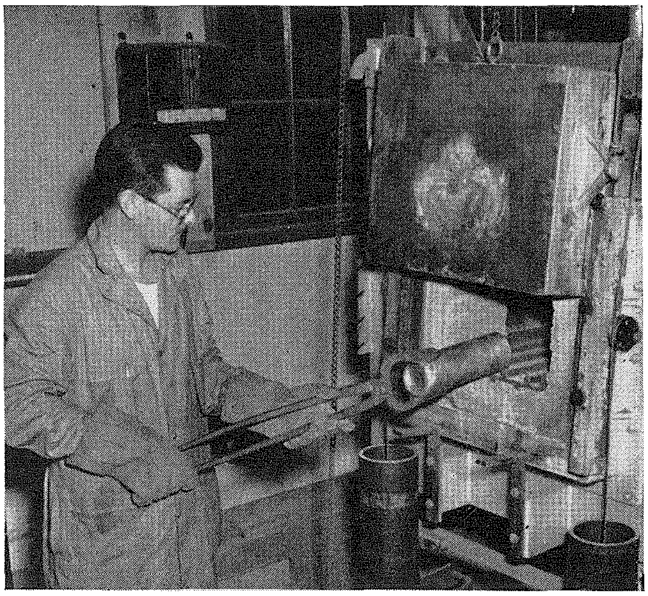
Metallurgy of titanium

Today only two methods are known for the production of titanium. The first consists of reducing titanium tetrachloride by molten magnesium in vacuum or in an inert atmosphere. In the second, titanium iodide is decomposed by heating in vacuum, and pure metallic titanium is deposited from the vapor phase on a heated filament.

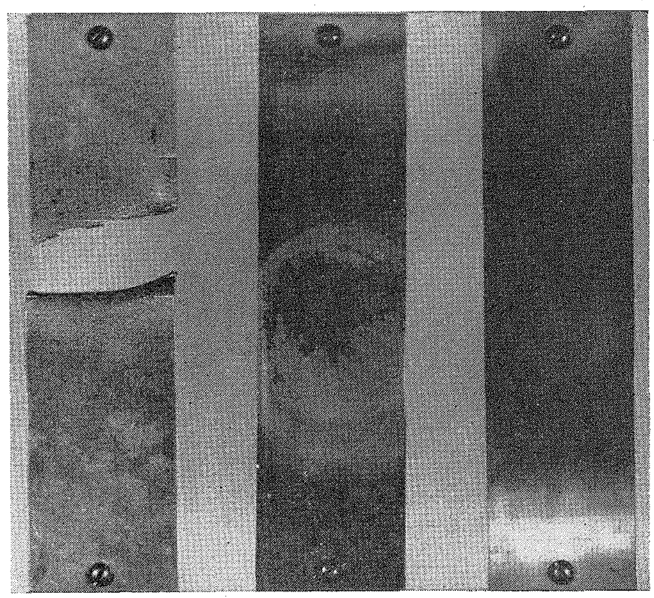
The principle of the first method was discovered in 1910 by Hunter, when he isolated titanium for the first time. His experiment consisted of heating titanium tetrachloride in the presence of sodium in a sealed bomb. Kroll later proposed the substitution of magnesium for sodium and built "production" units capable of treating several pounds of titanium per batch. The Kroll method is the starting point of the U. S. Bureau of Mines development work on the metallurgy of titanium.

In this process, magnesium is melted in a cast-iron reaction chamber heated electrically to a temperature of about 1400°F. The chamber is filled with an atmosphere of carefully purified dry helium. Liquid titanium tetrachloride is slowly added to the melt and immediately reacts to form titanium and magnesium chloride. The reaction being exothermic, the temperature increases slowly during the operation and may reach 1650°F. After the reaction chamber has cooled down, the spongy mass of titanium mixed with magnesium chloride is extracted. A leaching treatment with a dilute solution of hydrochloric acid eliminates the magnesium chloride and pure sponge titanium is separated. The solubility of magnesium in titanium being very limited, the metal produced by this process retains a negligible amount of magnesium, which does not seem to be an objectionable impurity. As a result of the acid treatment, however, some hydrogen is absorbed by titanium; hence the sponge metal is rather brittle. Fortunately, hydrogen can be removed by subsequent heat treatment in high vacuum, and the metal is not permanently contaminated, as it would be in the case of nitrogen or carbon impurities. At the Bureau of Mines, experimental units are operating at present with a capacity of about 100 pounds of titanium per batch. The efficiency of the process may be measured by the weight of titanium produced per pound of magnesium. It is approximately 0.68, and might be increased to about 0.8.

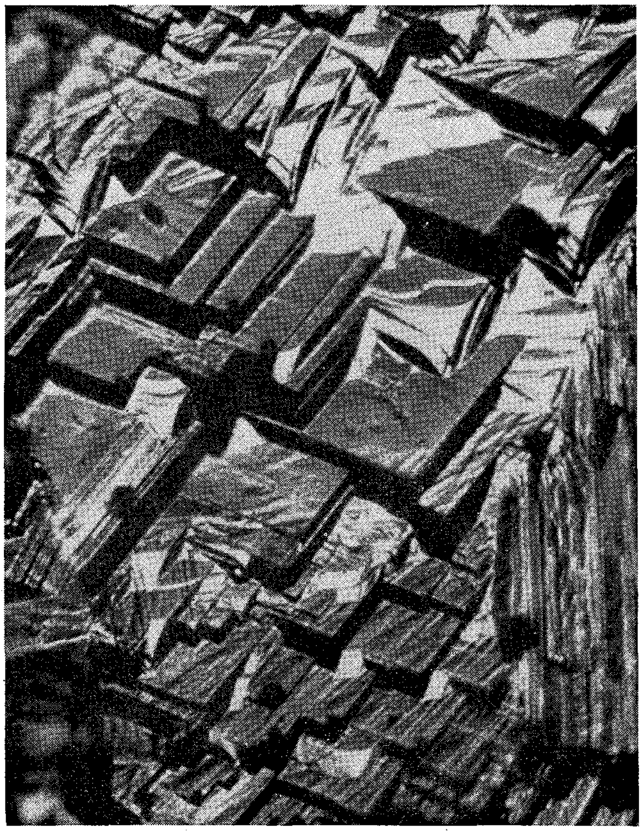
The second method by which titanium may be obtained in the pure ductile state is based on the original work of the Dutch physicist van Arkel, published in 1925. In this process, impure titanium powder is first mixed with a certain quantity of iodine and placed in an evacuated and sealed glass container. When the mixture is heated to about 800°F, titanium iodide forms and vaporizes. On contact with a tungsten filament heated to about 2000°F, the iodine liberated reacts with the impure titanium and the process is cyclic. The metal produced by this method is in the form of a rod about one foot long and about 3/8 inch in diameter. It is made of very large crystals, as much as 1/4 inch across. This titanium has a degree of purity not attainable by any other method. Unfortunately, the vapor deposition



Scores of companies like Remington Arms, Du Pont subsidiary, are now conducting research on melting, alloying, and (above) fabricating titanium metal.



Remington Arms test shows effect of 30-minute exposure to 2,200-degree F. flame of aluminum alloy (left), stainless steel (center), and titanium (right).



This photomicrograph reveals the crystal formation which is obtained in a titanium-molybdenum alloy by cooling through the allotropic transformation.

process in its present form produces only small quantities of metal. It is too early to state whether or not future engineering developments will bring this process into the field of large-scale production.

Obviously, the metallurgy of titanium is based on principles entirely different from those encountered in the production of the more usual metals. A striking feature of the metallurgy of titanium is the fact that the metal does not appear in the liquid state at any time during the process. In the Kroll method, the titanium tetrachloride is reduced to solid titanium, which remains solid at the temperature of liquid magnesium. In the van Arkel process, the vapor of titanium iodide decomposes into the solid metal at a temperature much below the melting point.

Preparation of titanium ingots

Transforming either the sponge metal or the van Arkel rods into ingots and then into structural shapes is the next difficult step in the metallurgy of titanium. The obvious reaction of any metallurgist confronted with the problem would be to try to melt the metal in vacuum or purified inert atmosphere. Here again titanium proves to have unusual properties. In the molten state it is chemically so active that it "alloys" with any presently known crucible material. Graphite is readily dissolved and contaminates the melt. Pure oxides of high melting points, such as alumina, beryllia, and thoria, are reduced by molten titanium and the amount of oxygen picked up by the metal is sufficient to promote brittleness. An additional difficulty comes from the extreme wetting power of the molten metal, which penetrates into the most minute pores of the crucible and creeps up along the walls. The crucible may empty itself, even against the force of gravity.

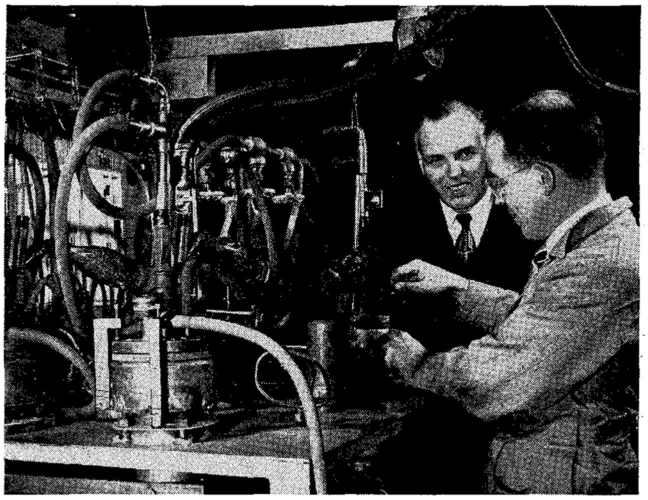
The problem of melting titanium, however, is not a hopeless one. Recently a technique previously used for melting molybdenum has been successfully applied to titanium. It consists of striking an arc between an electrode of the metal and a water-cooled copper crucible in an evacuated chamber. The liquid metal from the electrode flows into the crucible, where it is immediately solidified so that reaction with copper is prevented. The resulting ingot has a normal coarse-grained cast structure, and can be subsequently rolled or forged. This method will probably play an important role in the metallurgy of titanium.

When confronted with a problem hard to solve, it is sometimes possible to find a way out by avoiding the problem altogether. This principle finds an application in the case of titanium. It is indeed quite possible to process the metal entirely by powder metallurgy methods, thus avoiding the inherent difficulties of the melting process. The sponge metal obtained by the Kroll process is first ground into a fine powder. This grinding is relatively easy, because the sponge titanium is rather brittle as a result of the hydrogen absorbed during leaching. The powder is then compacted into dies at pressures from 20 to 40 tons/sq in. The compacts are sintered at high temperature (generally above 2000°F) in a vacuum of at least 10^{-4}mm of mercury, during which treatment most of the hydrogen is removed. The sintering could also be carried on in a purified inert gas, instead of a vacuum, if the metal powder could be obtained free of hydrogen. Except for the necessity of sintering in a high vacuum, the powder metallurgy of titanium offers no difficulties. The powder can be considered as a soft powder (like copper or pure iron) and is easily pressed into strong compacts. During sintering, shrinkage proceeds without producing appreciable distortion, and relatively high densities may be obtained with temperatures of the order of 2000°F. The size of ingots produced by powder metallurgy methods depends on the capacity of the hydraulic presses required for compacting the powder.

Processing titanium

Pure ductile titanium obtained by one of the methods described above can be cold-rolled. Intermediate annealing treatments are, of course, necessary to prevent brittleness due to excessive cold working. Annealing can be achieved at a relatively low temperature (1500°F), but it is imperative to perform the heat treatment either in high vacuum or in an atmosphere of purified inert gas. It must be remembered that titanium at high temperature has a great tendency to dissolve ntirogen, oxygen, or hydrogen, with consequent loss of ductility. Although hydrogen can be extracted by subsequent treatment in high vacuum, nitrogen and oxygen are permanently retained. In this connection it should be pointed out that the safe temperature at which titanium can be heated in air may not be higher than about 1000°F. Unless alloys of titanium are developed that are less sensitive to the action of gases at high temperature, titanium will not be the outstanding high-temperature metal which over-enthusiastic promoters have suggested.

Small ingots of titanium alloys are melted and cast in these improvised arc furnaces at Battelle Institute. Coca-Cola bottles are containers for charging materials.



The hot-rolling of titanium brings up the same problem of protecting the metal from atmosphere. A solution to this problem which has proved to be successful on an experimental scale consists of "canning" the piece to be rolled in a sealed iron box. Heating and rolling can then be performed in air and the iron container is removed after cooling.

Alloys of titanium

As with aluminum and iron, it is quite certain that the alloys of titanium will have a much wider use than the pure metal. Iron is perhaps the best example of a metal whose physical properties are improved by alloying. Pure iron has very limited use compared with the ever-increasing applications of carbon and alloyed steels. The extraordinary versatility of alloys of iron is due to the fact that iron is a transition element, and that it has an allotropic transformation. As a transition element, iron forms extended solid solutions with a great number of metals. Having a transformation point, it lends itself to heat treatments by which non-equilibrium structures of infinite varieties can be produced.

These two remarkable features are also found in titanium, and their existence may be the most convincing argument in favor of the future importance of titanium alloys. The field is wide open for the development of alloys that might duplicate in number and versatility the older iron base alloys, with the added advantage of less weight.

Need for fundamental research

The present knowledge of titanium alloys is fragramentary. Only a few phase diagrams involving titanium have been studied. Titanium has generally been considered as a minor alloying element and only the portion of the phase diagrams in which the concentration of titanium is relatively small has been investigated. Furthermore, the few alloy systems for which these portions of phase diagrams exist do not include the most promising ones. On the basis of the modern theory of alloys, it is quite probable that the alloys of titanium with molybdenum, tungsten, vanadium, columbium, and tantalum will be among the most outstanding. At present, only sketchy information is available on these important systems. Additional research work on the phase diagrams of titanium with carbon, oxygen, and hydrogen remains of primary importance, in view of the very marked effect these three elements have on the mechanical properties of titanium.

The need for basic research on alloy systems containing titanium may not be obvious to the practical-minded metallurgist, who may object that many of our present-day alloys were developed and used long before the theoretical metallurgist was able to explain their properties. But the same practical metallurgist is using iron-carbon phase diagrams and data on rates of transformation of austenite in alloy steels without perhaps realizing that they are the result of the type of research he proposes to by-pass in his impatience to obtain new alloys of titanium. Without fundamental research the choice of alloying elements and the conditions of processing will have to be established on a semi-empirical basis—a method frequently costly in effort, time, and money.

In connection with the study of alloy structure, it is interesting to point out that in the past most of the basic work on the phase diagrams of metals has been done in Germany and in England. Even during the war these basic studies seem to have been carried through in spite of more urgent practical problems. In an article entitled "The Designation of Phase Alloy Systems" (*Metal Progress*, January 1949), Tylor Lyman draws attention to the very small contribution by workers in the United States to the origin of phase diagrams. He finds that the United States has originated only about eight per cent of the phase diagrams, while Germany has contributed 45 per cent, and England about 17 per cent. Lyman puts the question, "Who will do this fundamental research now that German science is so largely impoverished?"

This question deserves careful attention. At present, titanium research is oriented toward the rapid development of alloys for immediate use. These efforts will doubtless yield much new information quickly, but they can scarcely provide a sound understanding of the alloy systems. It will take a logically balanced program of scientific research and engineering development to realize the full possibilities of this most promising metal.

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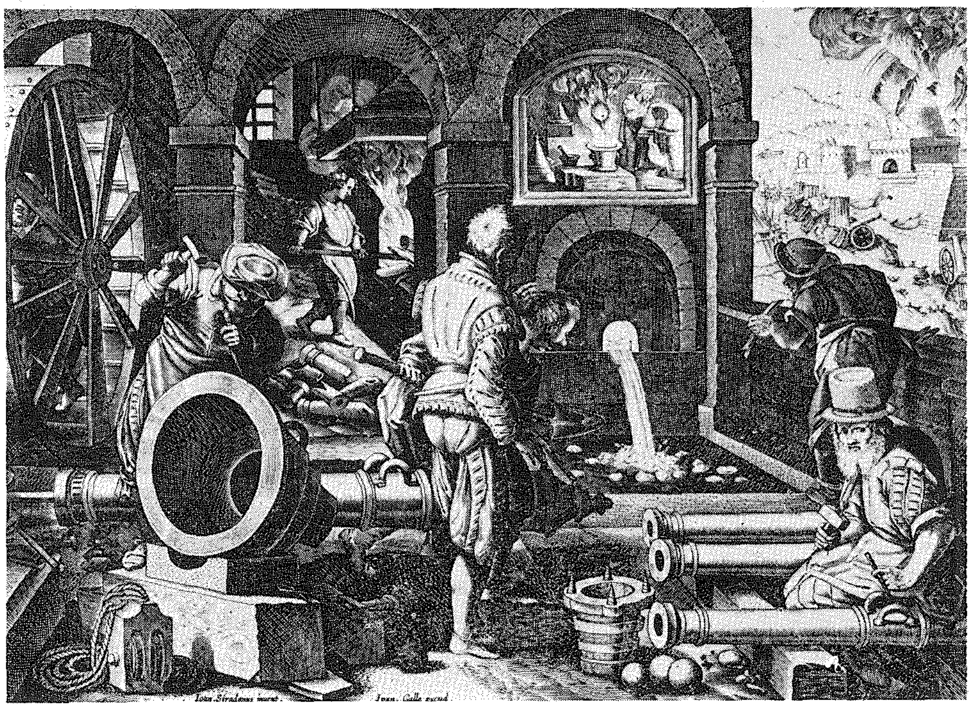


GUNPOWDER: According to the legend on the original engraving, "Thunder and lightning shaken with the hand seem to have been granted by the jealous underworld powers."

New Discoveries of the Middle Ages

by E. C. WATSON

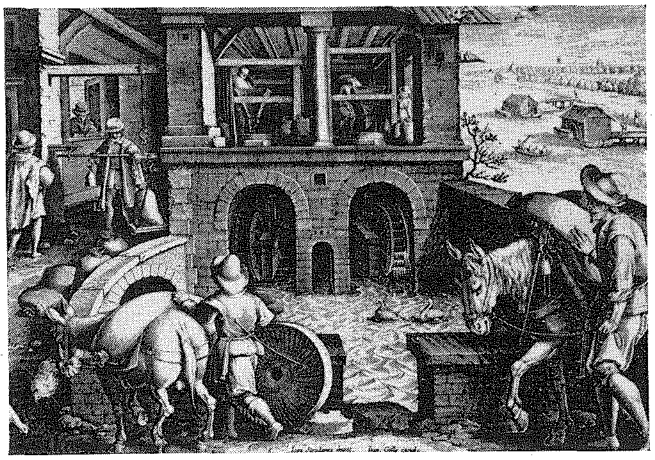
SOMETIME during the last decade of the sixteenth century (the exact date is uncertain) a set of twenty beautifully engraved plates, entitled *Nova Reperta (New Discoveries)* and illustrating the most important discoveries and inventions of the Middle Ages, was executed at Antwerp by Philipp Galle from designs painted or sketched by Joannes Stradanus. These delightful engravings represent one of the early attempts to popularize new scientific discoveries—attempts which have multiplied since that time almost as rapidly as have the new inventions themselves. And it is a peculiarly interesting attempt because it appeared at the beginning of our modern scientific period. Consequently it portrays the state of science and invention—as well as of various trades and handicrafts—as they were before the "experimental method" was consciously and systematically used in either science or industry, and before the rapid acceleration in the rate of scientific invention (brought about by that method) had begun.

The discoveries and inventions portrayed in the *Nova Reperta* are: The Continent of America, The Magnetic Compass, Gunpowder, Printing, Clocks and Watches, Guaiacum Wood as a Remedy for Syphilis, Distillation, Silk from Silk Worms, Stirrups (it is interesting that this is rated as a discovery of equal importance to that of printing or gunpowder), Water Mills, Wind Mills, Olive Oil, Sugar, Oil Pigments for Artists, Spectacles, The Determination of Longitude from the Declination of the Magnetic Compass (this suggestion, which is credited to Peter Plancius, has turned out to be erroneous), Armor Plate, the Astrolabe, and Copper-Plate Engraving.

Each plate shows with considerable accuracy and detail the various tools and implements used and the processes followed. (Thus printing, copper-plate engraving, oil-painting, distillation, the manufacture of cannon, of clocks and watches, of sugar, and of olive oil, and the cultivation of the silk worm are shown very clearly as they were practiced in the sixteenth century.) The shop of a spectacle-maker, with his stock of spectacles of different types, and their use by various people, makes a most interesting picture. Quite different, but no less interesting, is the plate showing a man suffering from venereal disease and the preparation of the remedy—a decoction of guaiacum wood or lignum vitae, which, from 1508 until about 1800, was considered a certain specific for syphilis. A map of the American continent is given on the title plate and the discovery of America is correctly attributed to Columbus, with Americus Vespuccius as explorer and namer.

"The Magnetic Compass" (opposite page) shows the floating loadstone of the Middle Ages, with a navigator studying its uses, surrounded by the various instruments of his profession. The legend under this plate assigns the discovery of the magnetic compass to Flavius of Amalfi, Italy. As pointed out by Silvanus P. Thompson in his article on the compass in the *Encyclopaedia Britannica*, this was a belief which took shape early in the seventeenth century and probably arose as follows:

The historian, Flavius Blondus, in his *Italia Illustrata*, written about 1450, stated that the floating magnet (which was commonly used by Italian sailors at least as early as the twelfth century) was introduced by traders belonging to the port of Amalfi, but added that its origin was uncertain. In 1511, Battista Pio, in his *Commentaries*, repeated this statement as the first use of the magnet and quoted Flavius as his authority. Gyraldus, while writing his *Libellus de re nautica* in 1540, apparently misunderstood this reference and stated



WATER MILL: "Whoever thinks that water mills were discovered anciently is totally mistaken."

DISTILLATION: "In fire the juice of all bodies, by means of art, becomes a vigorous liquid."

that the pole-seeking property of the loadstone had been handed down as the discovery of "a certain Flavius". As time went on this statement grew into the story "that the compass was invented in the year 1302 by a person to whom was given the fictitious name of Flavio Gioja, of Amalfi."

This is a good illustration of the way in which many popular beliefs have arisen. The real inventor of the magnetic compass remains unknown; in fact it is peculiarly characteristic of the so-called discoveries of the Middle Ages that when first mentioned by historians they are already in general use.

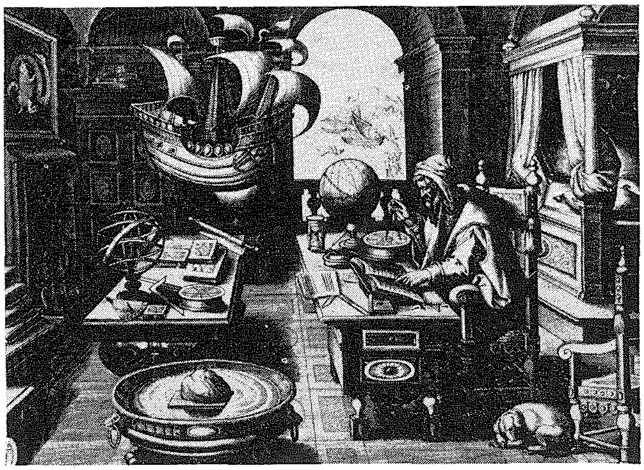
The picture, "Spectacles", not only makes it clear that spectacles were in general use in Europe before 1600 (actually they came into use in Italy near the end of the thirteenth century), but it is of special interest because of the place (Antwerp) and the time (c. 1600) at which it was executed. For it was in Middleburg, less than 50 miles from Antwerp, in just such a spectacle-maker's shop, in 1590 or thereabouts, that a lens-grinder by the name of Zacharias Jansen combined two spectacle lenses to form the first compound microscope. And it was in a neighboring shop in the same town, in 1608, that another spectacle-maker, Hans Lippersley by name, combined two other lenses to produce the first practical telescope.

This legacy from Stradanus and Galle enables us to understand at a glance how the practical discovery of both the compound microscope and the telescope came to be made. Indeed, we do not need to be told, as we have been, that Lippersley, while holding two lenses, one in each hand, happened to direct them towards the steeple of a neighboring church and was astonished, on looking through the nearer lens, to find that the weathercock appeared closer and more distinct—and that he subsequently fitted the lenses into a tube in order to adjust and preserve their relative distances. Nor is it surprising that, once a telescope of this kind was made, the discovery was claimed for many people. The surprise is rather that it was not made in clean-cut fashion much earlier.

Several of the plates have an added interest because of the care and detail with which many of the tools and instruments of the period are delineated. Thus, the picture entitled "The Water Mill", shows two steelyards in some detail. They are modern in type, with fixed pin pivots, and each instrument has two fulcrums—one for light, the other for heavy loads. The stop adopted to limit the movement is similar to that used in Roman times. Apparently, in the sixteenth century, farmers in the Netherlands carried their own steelyards with them when they took sacks of grain to the mill.

Taken as a whole these twenty plates, five of which are reproduced here, give a beautiful as well as a fairly accurate picture of the state of science and invention at the very beginning of the modern period.

SPECTACLES: "Spectacles are invented which clear the obscure mists of the eyes."



MAGNETIC COMPASS: "That stone has disclosed to Flavius its own hidden love of the pole."

The month at Caltech

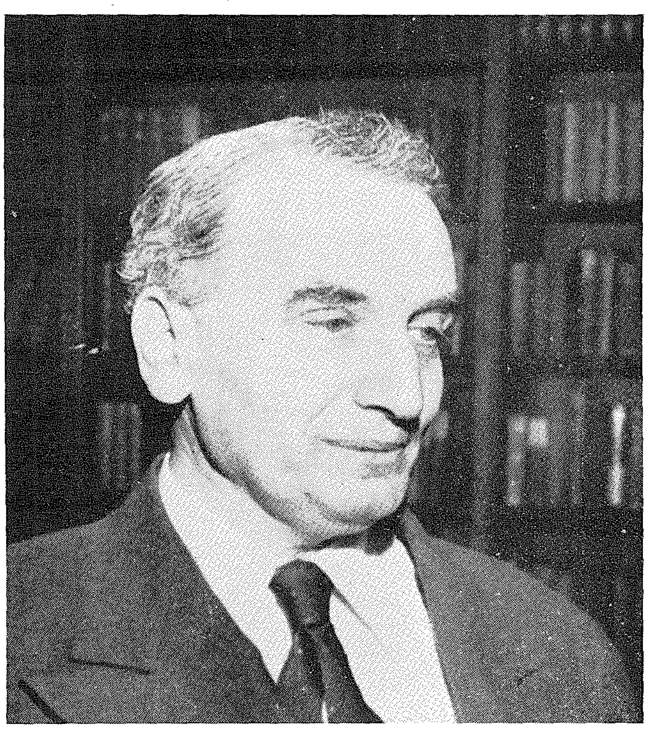
"The State, Industry, and University"

President DuBridge this month journeyed to Cambridge to attend the Mid-Century Convocation at the Massachusetts Institute of Technology and the inauguration of President James R. Killian, Jr. In a three-day program which included Winston Churchill's speech, Dr. DuBridge participated in one of six panel discussions among a distinguished group of educators, scientists and statesmen.

Speaking on "The State, Industry, and University," Dr. DuBridge emphasized the role of the government in supporting institutions of learning, and warned of the dangers of direct subsidy by Federal grants.

"Anything which a government agency supports financially, it must of necessity also control," he said. "The right of the government to control that which it pays for has, of course, long been established, but I think it can also be held that the government has a *duty* to control that for which taxpayers' money is being spent. . . . .

" 'Federal support without Federal control' is not only a meaningless and unrealistic, but is essentially an immoral motto whose only result is to mislead and confuse.



Theodore von Karman turns over job to Clark Millikan.

"Now it is hardly necessary on this occasion to present the arguments why Federal control of our private universities is undesirable. Intellectual inquiry must be free to go in all directions. It may, and frequently does, run counter to existing theories, vested interests, long-established prejudice. Truth, in the long run, is always revolutionary for it broadens men's horizons and this usually suggests new and better ways of doing things. . . .

"Academic freedom is not something which is destroyed only by concentration camps and firing lines. It can be withered to a shadow merely by a threat of economic insecurity, of unearned disgrace, of unsupported public attacks.

"Scholarship is a delicate flower. Though its hardy roots have survived a thousand years of persecution, its blossoms have come to full glory only in a few places and at few times in human history. Here in America today it is thriving as in no other place at no other time. And even here it thrives best only in those places where its freedom is most nearly unrestricted. We shall not want to run even the remotest danger of destroying this flower. Rather we need to redouble our efforts to insure the flourishing of scholarship of the highest order.

"I think no one can argue that the positive way to insure this development is to throw our private universities into the lap of the Federal government. Much as we may welcome the government as a purchaser of some of the services rendered by our universities we do not welcome it as an owner of the business. Freedom and progress for education and research do not lie in that direction."

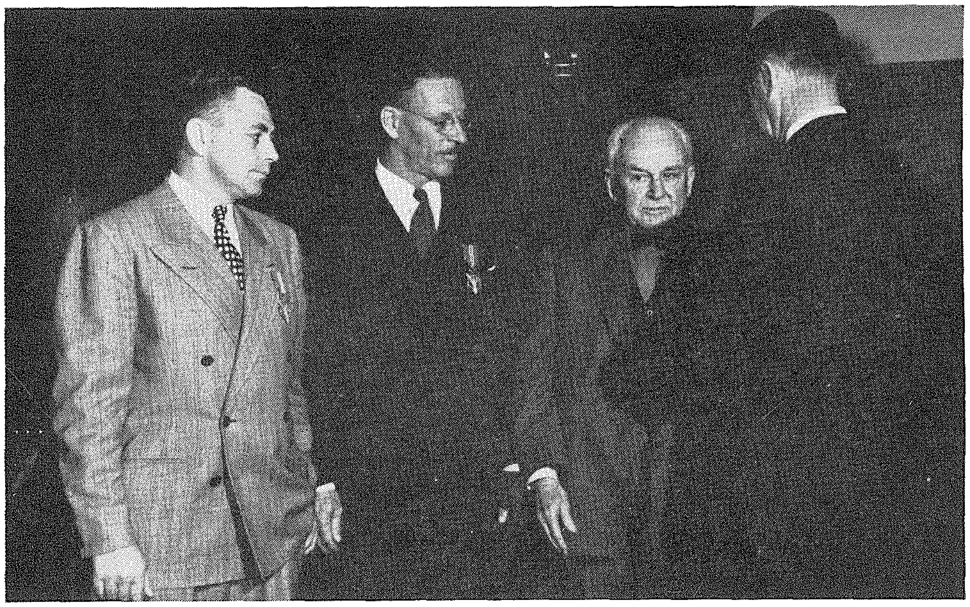
Four days earlier, on March 29, Dr. DuBridge delivered the principal address at the dedication of the University of Rochester's new 250,000,000-volt cyclotron. As chairman of the university's physics department before coming to Caltech in 1946, Dr. DuBridge was largely responsible for inducing the U. S. Office of Naval Research to sponsor the 130-inch atom smasher at Rochester. At present the instrument is second in size only to the one at the University of California's Berkeley Radiation Laboratory.

von Karman's Travels

Theodore von Karman, Ph.D., Dr. Ing., Sc.D., LL.D., and Eng.D., carries more degrees after his name than any other man in the Caltech catalogue. He also bears a formidable list of titles: Professor of Aeronautics, Director of the Daniel Guggenheim Laboratory, and Chairman of the Jet Propulsion Laboratory Executive Board.

Last month he officially relinquished his posts at the Guggenheim Lab and JPL to Dr. Clark B. Millikan (see page 15), who has held them in an acting capacity since 1944, when Dr. von Karman was called by General H. H. Arnold to help plan the long-range research program of the Air Force. Dr. von Karman intends now to devote most of his time to his work for the Air Force, to his own theoretical research, and as chief technical consultant to the Aerojet Engineering Corp., which he helped found.

For the immediate future, he has a heavy schedule mapped out: leaving Pasadena April 5, he goes to Washington, D. C. for a meeting of the Scientfic Advisory Board of the Air Force, of which he is Chairman. Next he goes to Princeton University for a meeting on rocket research and planning of scientific publications in the field of high-speed aerodynamics and jet propulsion. From there, he heads for Madrid, where he will represent the National Academy of Sciences at the



Louis Dunn, Clark Millikan, and Robert Millikan receive Medals for Merit from Air Secretary Stuart Symington.

centenary meeting of the Spanish Academy of Sciences. Paris is his next stop. There he will deliver an address at the International Aeronautics Exposition in May, and will attend a meeting of the International Scientific Union, in connection with projects of the International Scientific Research Institutes of the United Nations. From Paris he goes to Oslo, Norway, to attend a conference on Aerodynamics Problems in Astronomy. To date, Oslo is the last city on the itinerary.

By now Dr. von Karman should be well acquainted with European timetables. In 1945 he made a survey of technical developments in Germany and several other European countries, including Russia. Last year he spent most of his time abroad, representing the Air Force and scientific organizations, and lecturing at the Sorbonne in Paris and the Aeronautical Institute of Madrid. For all these activities, as well as for his scientific contributions, Dr. von Karman has been awarded honors by most of the scientific and aeronautical societies in Europe. In the U. S. he has received the 1947 John Fritz medal, highest engineering honor awarded in this country; the 1948 Franklin Gold Medal, highest honor of the Franklin Institute of Pennsylvania, and the Presidential Medal for Merit, highest civilian award for outstanding contributions to the war effort.

Dr. von Karman will maintain his connection with Caltech as Professor of Aeronautics and advisor to the staffs of the Guggenheim and Jet Propulsion Laboratories.

Medals for Merit

The Presidential Medal for Merit, highest decoration given by the government for civilian wartime service, was awarded last month to three Caltech men: Drs. Robert A. Millikan, Clark B. Millikan, and Louis G. Dunn. Secretary of the Air Force W. Stuart Symington flew from Washington to make the presentations.

The citations were authorized by President Truman in recognition of "exceptionally outstanding conduct" in the development of rockets and jet propulsion during World War II. Specifically, Dr. Dunn, as Director of the Jet Propulsion Laboratory, was credited with important advances in underwater missiles, and was directly responsible for the training of some 800 naval officers. Dr. Clark Millikan was cited for supervision of the design and construction of the Cooperative Wind Tunnel. Dr. Robert Millikan, in addition to his supervisory role as Chairman of the Institute's Executive Council, served throughout the war as a member of the important Missiles Committee of the Bureau of Ordnance.

Some 200 faculty members and guests attended the ceremony, which took place on March 21 — ten days after Clark Millikan's appointment as Director of the Daniel Guggenheim Laboratory of Aeronautics, and Chairman of the Jet Propulsion Laboratory; one day before Robert A. Millikan's eighty-first birthday.

Count Rumford Medal

Dr. Ira S. Bowen, director of the Palomar and Mt. Wilson Observatories, has been named 1949 winner of the Count Rumford Medal of the American Academy of Arts and Sciences for his "important discoveries in the fields of heat and light."

CONT'D ON NEXT PAGE

Ira S. Bowen, 1949 winner of the Count Rumford Medal.

Specifically, the award went to Dr. Bowen for his explanation of "nebulium," which has puzzled astronomers for years. Because a number of lines in the spectra of bodies in the Milky Way did not match those of any known elements, scientists have theorized that the bodies were of a new element which they referred to as "nebulium." It was Dr. Bowen who suggested that the spectral lines were merely those of oxygen and nitrogen, which differed from "normal" spectral lines because of the near-voids in which the nebulae exist.

Digital Computer

Dr. Stanley P. Frankel has joined the department of Applied Mechanics, as Assistant Professor, to head up a new group to conduct basic research on the application of digital computing methods, and function as a service group for Institute research problems.

As a complement to the electric analog computer (see page 17) a digital computer will be established in the Analysis Laboratory to extend machine computation into such fields as statistical analysis and very high accuracy computation. It will be Dr. Frankel's job to translate physical problems into machine terms and explore new computing techniques.

Dr. Frankel, who attended Caltech from 1935 to 1937, received his B.S. in physics in 1938 and his Ph.D. in 1942 from the University of California at Berkeley. In 1942 he went to work for the Manhattan District, and set up the Los Alamos computing group, as well as the I.B.M. group—which he helped direct. In 1946 he became an assistant professor at the University of Chicago's Institute of Nuclear Studies. Since 1947 he has been a partner in the Frankel-Nelson Consulting Service in Los Angeles.

Degree for Hubble

Dr. Edwin Powell Hubble, research associate in astronomy and staff member of the Mt. Wilson and Palomar Observatories, has received an honorary doctor of laws degree from the University of California at Berkeley.

Service League

On Thursday evening, April 22, the Caltech Service League will hold its third meeting of the year. Speakers will be President DuBridge, who will discuss the Institute's educational philosophy; Dr. F. E. Lindvall, Chairman of the Division of Engineering, who will speak on educational trends; and Dr. Donald S. Clark, Associate Professor of Engineering and Director of the Alumni and Placement offices. In his talk on "Educational Dividends," Dr. Clark will describe the fields open to Caltech graduates.

The meeting will mark the completion of the League's second year of operation. Organized in 1947 by a group composed of parents of students, members of faculty families and other friends of the Institute, the League now has over 500 members, living in many parts of this country and abroad.

The League's purpose is twofold: to keep friends of the Institute in touch with Caltech activities, and to serve the needs of the students in any way possible. It keeps friends of Caltech up to date on student activities by sending out regular newsletters to parents, and by planning meetings around various aspects of Institute activities.

At the first Service League meeting this year, the subject of the program was "How to Keep House on $7,416,832 a year." Charles Newton, Assistant to the President, George Green, Business Manager, and George Hall, Director of Public Relations, described the organization of the Institute, and the operation of the student houses, the cafeteria, bookstore, etc. At the next meeting, in January, Dr. W. S. Gervurtz, Director of Student Health, outlined plans for the operation of the Caltech Health Center, its need for more and better equipment, and for the addition of dental and psychiatric services.

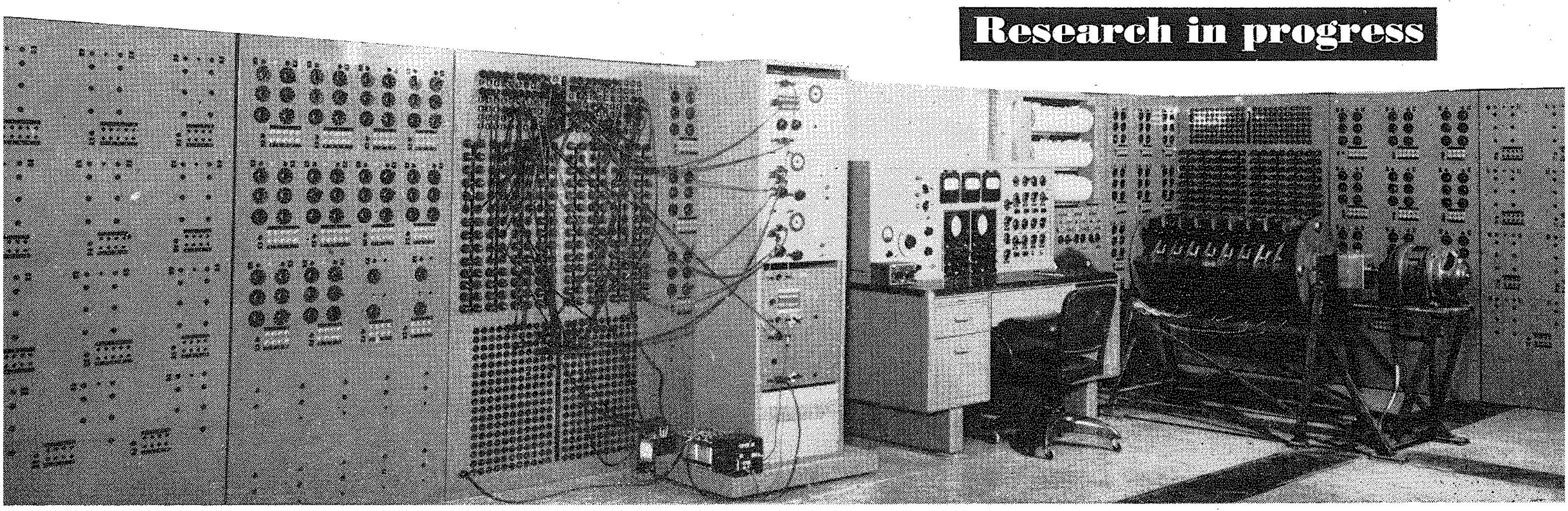
In 1947, when the Service League was organized, the Institute was badly in need of a Health Center. With the League's help, the Center was established, and housed in a temporary wooden building on the campus. Under the direction of Dr. W. S. Gervutz, the Center operates a small infirmary, and there—and in the outpatient department—cares for over a thousand patients each month. Most patients are students, but the Center also cares for faculty members, members of the families of married students, and Caltech employees.

The League has met the needs of students in a number of other ways. It maintains a Well Baby Conference which meets several times each month with Dr. Lucy Gale McMurray, a Pasadena pediatrician. Its Furniture Pool now has several hundred pieces of furniture—cribs, playpens, etc.—out on loan to families of married students and graduate students. In addition to making the Health Center attractive and keeping it stocked with books and magazines, the League has helped to furnish a clubroom for the Internations Association, and the Snow Valley Ski Hut for the Caltech Ski Club. It plans to help with student dances, and has helped with the operation of the housing project for married students and graduate students in Arcadia. And whenever the need has arisen, it has helped students, through its Welfare Chairmen, to become familiar with community agencies like the Council of Social Agencies, the Pasadena hospitals, and the Caltech "Y." The effectiveness of the League's work has been especially implemented by the fine cooperation of the Red Cross, and the National Foundation for Infantile Paralysis.

Tiselius Visit

Dr. Arne Tiselius, winner of the 1948 Nobel Prize in chemistry, made a two-day visit to Caltech this month. Professor of Biochemistry at the University of Upsala in Sweden, Dr. Tiselius had come to this country to address the annual convention of the American Chemical Society. At the invitation of Dr. Linus Pauling, he made a quick trip to Caltech, addressed a biology seminar on "Some Physical and Chemical Properties of Bacterial Flagella," a chemistry seminar on "Some Attempts to Apply Chromatography for the Fractionation and Identification of Large Molecular Weight Substances"—and was profoundly impressed with the cooperation existing between the biology and chemistry divisions.

Dr. Tiselius won the Nobel Prize for the development of electrophoresis—a technique for analyzing complex mixtures of proteins and other giant molecules, based on the varying responses of minute particles to electric current. His work has already made possible the development of techniques to separate the protein components in blood, and it resulted in improved processing of blood plasma during the war. Eventually, electrophoresis may prove to be of value in isolating the virus, and the basis of heredity, the gene.



This is one of two control panels for the Electric Analog Computer located in Caltech's Analysis Laboratory.

The Electric Analog Computer

SMOOTHER riding trains, stronger buildings and machinery, better jet engines—these are just a few of the things that may come as a result of work now in progress on Caltech's electric analog computer.

This 33,000-pound machine is the first of its kind to be put into service. Under the supervision of the men who feed it mathematical problems, the computer takes just a few days to solve problems that once would have kept three or four mathematicians busy for years.

The product of several years of research itself, the computer has been in limited operation for over a year, and in full operation for the last few months in the Institute's Analysis Laboratory. This laboratory, with Dr. G. D. McCann, developer of the computer, as director, has been set up to study and develop a number of different types of "thinking machines." And the facilities of the laboratory are available not only to research groups at the Institute, but to industrial and engineering organizations everywhere.

The Analysis Laboratory was established late in 1946. Its first objective was the development and construction of the analog computer—chosen as the first unit in the laboratory because of its usefulness in such a wide variety of industrial problems. Under the supervision of Dr. C. H. Wilts, the computer has been enlarged recently so that it can handle linear partial differential equations with up to three independent variables, and non-linear partial differential equations with two independent variables.

In most engineering fields the mathematical problems of greatest complexity—and greatest importance—have to do with equations of this type. In the past engineers have not had adequate facilities for solving these problems fast enough. Manufacturers have had to put equipment into use through the expensive process of building and testing models, or through the even more expensive process of building equipment, trying it out, and eliminating defects in a later model. Now, however, manufacturers can send problems to the Analysis Laboratory where they can be speedily solved.

A case in which the computer's speed was of great importance occurred during the war. At that time the computer's pilot model, developed by Dr. McCann and Dr. H. E. Criner at the Westinghouse Research Laboratories, was given the job of finding out just how electron tubes for vital radar sets should be packaged for overseas shipment so that they could not be harmed by vibration.

Ordinarily a vibration analysis of this sort would have taken two mathematicians about three years to complete. The machine did it in a little over a week and turned the results over to the Bell Telephone Laboratories, where they were needed.

The scope of the computer has been greatly expanded since the days of the pilot model. The machine has already solved a number of problems for leading aircraft companies, and done a vibration analysis for the Pullman Standard Car Company. In addition it is serving as a teaching aid to course work in applied mathematics, electrical engineering and mechanics, and as a research tool for the Institute and its Jet Propulsion Laboratory.

A recent publication by Dr. McCann lists 92 fields in which the computer can be useful to industry. These range all the way from the analysis of electrical circuits for utilities companies to problems of applied mechanics, such as the study of gas and Diesel engines, or the shock problems created by the firing of big guns. The list includes problems in temperature distribution in jet engines and gas turbines, aircraft vibration analysis, wing flutter and landing shock, general aerodynamic stability and the stability of autopilots for guided missiles. Along more fundamental lines, the computer can be of great help to the researchers who must analyze electromagnetic radiation in the course of their investigation of the ultimate particles of matter.

Many of these problems have no simple answer. Some of them require as many as 10,000 answers for a full solution. Often in the past these answers had to be found many times over by mathematicians working in different parts of the country. But the analog computer tabulates its answers once and for all, so that they can be distributed wherever and whenever they are needed. The machine's efficiency is further increased by its being able to handle two separate problems at one time.

Digital vs. analog

There are, in general, two types of computers. "Digital" computers operate in a step-by-step fashion, while "analog" computers operate continuously. Your hand is a digital computer; it can count, finer-by-finger, up to five, and if the thumb "remembers" five, it can count up to nine. The abacus is a more efficient digital computer, and most modern office machinery is based on the digital principle.

Recently digital computers have been developed to work on more complex mathematical problems. They can do arithmetical calculation, store numbers, look up functions, control the sequence of computation, feed data into the computer and record the solutions of advanced problems in algebra and calculus. There are successful machines of this type in operation at many centers: the Automatic Sequence Analyzer built by the International Business Machines Company for Harvard University, for instance, and the ENIAC developed at the University of Pennsylvania. Recently the facilities of the Analysis Laboratory at Caltech have been extended by the addition of a digital computing group which has been set up under the direction of Dr. Stanley P. Frankel (see page 16).

Analog computers operate by means of a system that is an analog or replica of the physical system to be studied. A slide rule is a simple analog computer; it finds its answers in terms of logarithms. The first successful large-scale analog computer for the solution of complex problems was the differential analyzer developed at the Massachusetts Institute of Technology. This machine, and newer ones based on the same principle, operate by means of a mechanical system set up to represent the conditions of a problem.

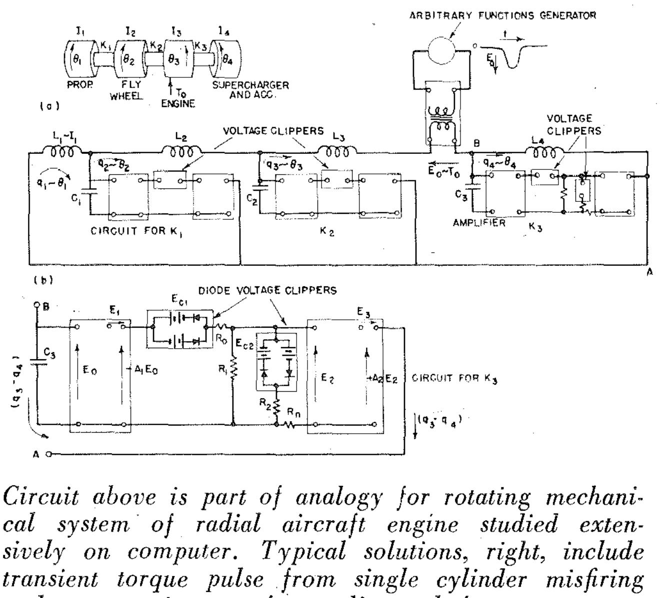
In the Caltech computer, however, the analogous system is an electric curcuit. The computer is the result of a program, begun jointly in 1946 by Westinghouse and the Institute, for the development of two identical large-scale, general-purpose computers. The Westinghouse unit, known as the Anacom, is located at the Research Laboratories in East Pittsburgh; the Caltech computer is in the Norman Bridge Laboratories on the Caltech campus.

It was decided to limit the accuracy of these two machines to one percent—a figure which makes the computers adaptable to the vast majority of problems in the general field of engineering analysis. Development of the computer has reached the point where analogous electrical circuits can be devised for almost any physical system for which differential equations can be written. Electric circuits can readily simulate addition, subtraction, multiplication by constants, integrating or differentiating and the formation of equations. Special electronic multipliers have been developed to make the computer adaptable to non-linear equations, also.

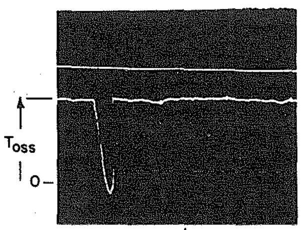
The computer has three main elements: the "forcing function"—to generate electrical voltages equivalent to the forces applied to the actual physical system; the electric counterpart of the system being studied—110 sets of special precision capacitors, inductors and resistors and 25 sets of special transformers; and the measuring equipment, where the machine delivers its answers. While the type of measurement varies with each analysis, in general answers are read in terms of currents and voltages on meters and oscilloscopes.

Actually the Institute's machine offers far more than a mere computation service. It offers a complete engineering service as well. This is partly because of the close association between the Laboratory's staff and the rest of the Institute's faculty and partly because of the nature of the electric analog principle of operation. Because answers are read from a continuous record which can be photographed and then analyzed, the effect of changing one design requirement in a system can be studied for the entire system.

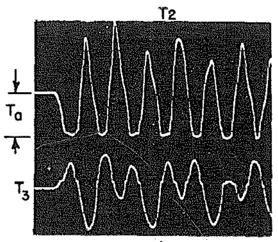
The development of large-scale computers has greatly speeded up technological progress in recent years, and has brought forth predictions about "thinking" machines that will rival the human brain in their ability to remember and handle data. While Institute researchers make no predictions about machines that can think, they do predict that the Institute computers will continue to be invaluable in research and in the service they offer to industry.



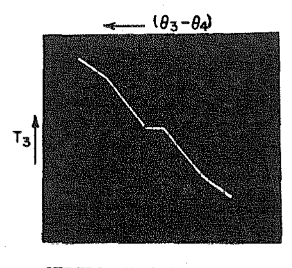
Circuit above is part of analogy for rotating mechanical system of radial aircraft engine studied extensively on computer. Typical solutions, right, include transient torque pulse from single cylinder misfiring and stress-strain curve for nonlinear shaft.



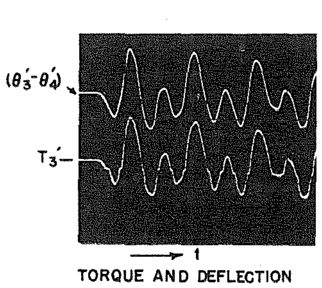
ENGINE MISSFIRE TORQUE PULSE



SHAFT TORQUES



STRESS-STRAIN CURVE FOR SHAFT NO. 3



TORQUE AND DEFLECTION FOR SHAFT NO. 3

BOOKS

ENGINEERING THE NEW AGE

by John J. O'Neill
Ives Washburn, Inc., New York 320 pp. $3.50

Reviewed by R. R. Martel
Professor of Structural Engineering

IN *Engineering the New Age,* John J. O'Neill sets out to "survey man's past efforts to set up civilizations and ascertain what happened to them and, if possible, why—to examine, with a constructively critical eye, the existing situation, to draw up a statement of assets and liabilities and ascertain what we may salvage for the new construction."

That's a large order for anybody, and though Mr. O'Neill tackles it with plenty of gusto, he is hardly able to do it justice.

It is Mr. O'Neill's firm belief that, since engineering has contributed so much to human welfare in material ways in the past, the same scientific method can now be successfully applied to the problems of human relations. "Science and engineering," he says, "are the twin giant forces in the world today. Both of them, in their organized aspects, are lacking a social consciousness. Development in them of a social consciousness is the next major step in cultural progress."

As the man who "carries the burden of applying knowledge to the solution of human problems," the engineer is the one who is expected to develop this social consciousness which will permit him to "evaluate impartially and efficiently, the desirable direction of human energy in the same way as he now does with mechanical energy."

This assumes that the engineer of the future will know which are the best targets for human endeavor. It also assumes that human affairs are subject to rational treatment, and that the engineer will be able to evaluate the long-range effect of present-day actions. This is highly flattering to the engineering profession—though it might be noted here that Mr. O'Neill's definition of "engineer" is extremely broad; he includes "not only those now designated by that term, but economists, sociologists, anthropologists, business executives, bankers and a host of members of other professions." Even in this broad definition, Mr. O'Neill's engineer of the future sounds more Superman than ordinary mortal.

In general, *Engineering the New Age* consists of a series of sketches, covering a broad field, of the impressive advances of applied science and engineering. As would be expected from his two-score years as a newspaper science editor (for the Brooklyn *Daily Eagle*, and the New York *Herald Tribune*,) the author shows a wide general knowledge of many facets of science and engineering, and avoids highly technical terms. Engineers—even in Mr. O'Neill's expansive definition—ought to find the book provocative, if rambling, and pleasingly complimentary.

Six-man crew of the schooner California, now on its way around the world, includes Hal McCann, '46 (checked shirt), Ward Vickers, Art Teets, '45 (right).

ALUMNI NEWS

Two Years Before the Mast

The only people we happen to know about who are doing precisely what they want to right now are three Caltech alumni: Hal McCann, '46, Art Teets, '45, and Ward Vickers, V-12 student during the war. With three others they're on their way around the world in a 72-foot three-masted schooner.

Their ship, the *California*, was built in 1936 and participated in the Hawaii sailing race of that year. It is refitted with a 100-horsepower Diesel auxiliary engine, a radio, and new bunks— including an out-sized one for six-foot-six McCann. Stowed in the hold are 200 gallons of fresh water and some eight tons of canned goods, which they expect to last them about 400 days. Thoughtful friends also contributed cook-books.

All told, the six crew members have invested about $16,000 in the trip. They expect to pay their way, and perhaps get back some of their investment, by supplying articles and photographs (already contracted for) to travel and yachting magazines, and by doing odd jobs in various ports-of-call. Four of the crew are fliers, and they hope to get jobs as bush pilots for small airlines during a two-month stop-over in France.

Their itinerary includes Acapulco, Costa Rico, through the Panama Canal to Jamaica, Haiti and Bermuda. Then across the Atlantic to the Azores, Lisbon, and around Gibraltar to the French Riviera. After a two-month-or-more lay-over, they plan to cross the Mediterranean to the Suez Canal, the Red Sea, the Indian Ocean and Singapore. From there they will sail to Australia, over to Fiji and South America, and up the Pacific Coast to California.

The boys have no timetable, and they're in no hurry. About two years ought to do it, they say.

Battling Boyd

After a two-year fight, James Boyd, '27, has finally been confirmed by the United States Senate as Director of the Bureau of Mines. John L. Lewis, president of the United Mines Workers, who has done his best to block Boyd's confirmation since 1947, went so far as to call a two-week coal mining stoppage this spring in protest against the appointment. Boyd's appointment was promptly approved by a Senate vote of 50 to 11.

Lewis's chief objection has been that Boyd never worked as a coal miner. As Director of the Bureau of Mines, however, Boyd's job includes a good deal more than making mines. He is not only responsible for mine safety, but for scientific research in the problems of mineral conservation and utilization.

For the record, Boyd received his B.S. from Caltech in engineering and economics, then went to the Colorado School of Mines, where he received his M.S. in geophysics in 1932, and his Sc.D. in geology in 1934. He taught at the school until the war, when he entered the Army as a captain in 1941. He was discharged as a Colonel in 1946, and served as dean of the Colorado School of

Mines until his appointment to the Bureau of Mines post in 1947.

Boyd took over as Director of the Bureau in August, 1947. He received pay for about four months, but this stopped when a short session of Congress adjourned without confirming him. His nomination was sent to the Capitol in 1948 and again this year before it was finally confirmed. This month he will be getting his first paycheck since December, 1947.

Placement Year

The Discussion Series on Placement Opportunities, cooperative venture of the Placement Committee of the Alumni Association, the Student Relations Committee of the Alumni Association and the Institute Director of Placement, recently concluded its first annual program.

The purpose of the series was to offer Caltech students an opportunity to find out what fields are actually open to trained engineers and scientists. Starting last October 20, discussions were held weekly—when school was in session—through February 23. Specific fields covered in the series included the petroleum industry, construction, aeronautics, industrial research, business management, sales, teaching and academic research, design engineering, and production and manufacturing. More general discussions covered opportunities in large and small industries, non-technical requirements for success, the problem of looking for a job, and summer jobs.

Speakers included T. A. Atkinson of the General Petroleum Corp., Edgar Layton of the Holman and Powell Paving Co., Milton U. Clauser of Douglas Aircraft, Norris Johnston of Oil Properties Consultants, Charles B. Thornton of Hughes Aircraft, R. E. Johnson of General Electric, Dr. Joseph F. Manildi of the Department of Engineering at U.C.L.A., Arthur M. Whistler of the Fluor Corp., O. N. Anderson of Procter & Gamble, T. W. Johnson of the Security First National Bank of Los Angeles, William V. Roberts, M. M. Boring of General Electric, and Hugh Colvin of the Consolidated Engineering Corp.

Success of the series was chiefly due to the herculean efforts of W. D. Sellers, '25, chairman of the Alumni Placement Committee, and Ruben F. Mettler, B.S. '44, MS. '47, head of the Student Relations Committee—with the assistance of Dick Shuster, Dan King, and Dick King, all '49. The various sponsoring committees are now considering following through with a second series of placement talks next year.

Meanwhile, the Placement Consultant Service established this year by the Alumni Placement Committee continues to operate in high gear. Some 100 alumni in this area have now agreed to act in an advisory capacity—to counsel Caltech students on courses of study or employment requirements and opportunities in various fields. All deans, department heads, and placement representatives at Caltech have lists of these consultants, who are available at all times.

Alumni Dance

The Alumni Association held its "lucky" thirteenth annual dinner and dance at the Oakmont Country Club on March 4. With John Farneman, '38, in charge, the evening went off smoothly and highly successfully. There were 330 at the party—174 for dinner, and 156 who came later on to dance to Hal Lomen's music.

The next dance, for both alumni and undergraduates, is scheduled for May 21, at the Altadena Country Club. Jack Osborn, '39, is alumni chairman for the event; Bill Freed, '50, is student chairman.

Chapter Notes

The San Francisco Chapter gave a Pot Luck Supper at the Twentieth Century Club on February 18. After supper there was a brisk business meeting, followed by a showing of the popular Palomar film. On hand, with wives or girls, were: K. B. Andersen '24, Bob Bowman '26, Manly Edwards '26, H. P. Henderson '26, Maurice Jones '26, Marshall Baldwin '27, Hilmer Larson '27, Bob Vaile '27, Alex Hazzard '30, Bob Stirton '30, Chuck Lewis '31, Charles Gibbs '35, Jim Halloran '35, Bob Jones '35, Virgil Erickson '37, George Horne '37, Bob Jones '37, Walton Wickett '37, Al Jurs '38, Jerry Kohl '40, Dick Walker '40, Harrison Price '42, Leonard Alpert '43, Andy Benson '43, John Otvos '43, Shelton Steinle '43, Charles Wagner '43, Jim Hadley '45, and Joe Rosener '47.

The New York Chapter held a dinner meeting at the Hotel Holley on March 30, took time to nominate a nominating committee to nominate nominees for next year's officers, then heard a talk by Caltech's Professor of Business Economics, Horace N. Gilbert, on "How's Business—East and West."

ANNUAL MEETING AND BANQUET

of the

ALUMNI ASSOCIATION

and the installation of new officers

will take place

WEDNESDAY EVENING, JUNE 8

COMMENCEMENT WEEK REUNIONS, JUNE 8

for the classes of 1944, '39, '34, '29, '24, '19

PERSONALS

1920

Mark A. Sawyer has been made Plant Engineer for the southern California area of Pacific Tel. & Tel. He was previously Protection Engineer.

1921

Paul Perkins, Ex-'21, died January 19 in Grants Pass, Oregon. He had retired to a farm, and was living in Murphy, Oregon. He is survived by his wife, Isabella, and three sons, Leland, David, and Robert.

1927

Robert Creveling is now at the New Mexico School of Mines in Albuquerque. A member of the school's Research and Development Division, he is in charge of the proximity fuze program being conducted at the New Mexico Experimental Range.

1928

Frederick C. Lindvall, Ph.D., Chairman of the Division of Civil and Mechanical Engineering and Aeronautics at Caltech, has been elected to the Board of Directors of the Stanford Research Institute.

1929

Thomas H. Evans, M.S., '30 is the new Dean of Engineering at Colorado State College in Ft. Collins, succeeding **Nephi Christensen,** M.S. '34, Ph.D. '39, who left last fall to become Director of the School of Engineering at Cornell University.

Evans had previously served as Instructor and Assistant Professor at Yale, and as Associate Professor at the University of Virginia. During the war he was a Lt. Colonel in the Army Corps of Engineers. He comes to his new post from the Georgia Institute of Technology, where he was head of the Department of Civil Engineering.

1931

Lawrence L. Ferguson must be one of the busiest men in the General Electric Company these days. Besides his duties as Administrative Assistant in the Knolls Atomic Power Laboratory, operated by GE for the Atomic Energy Commission, he has just been made Assistant Executive Engineer of the General Electric Research Laboratory.

Ferguson has been with GE since 1934. Until 1941 he was engaged in statistical work. The next two years were spent on a special assignment to the New York office of the company's president. In 1942 he entered the Navy, leaving in 1946 with the rank of Lt. Commander.

On his return to General Electric he spent a year in the Investments Department in New York City. He was assigned to the Knolls Atomic Power Laboratory in 1947.

1932

Randal Maas has been promoted by the General Petroleum Company from Process Engineer to Assistant Manager of the Torrance Refinery.

1933

Daniel D. Taylor, Ph.D., a consulting physicist living in Altadena, recently broke into the news in the role of father. His 17-year-old son, Dwight, was top award winner in this year's annual science talent search, sponsored by the Westinghouse Educational Foundation. A collection of 120 different species of mollusks from the New England coast—more species than have previously been seen from this region—earned Dwight first place among some 16,000 teen-age contestants, and a scholarship.

1934

Charles L. Schneider is now Resident Physician in Obstetrics and Gynecology at Herman Keefer Hospital, Detroit. He got his M.A. and Ph.D. from Harvard, and his M.D. from Stanford in 1945. Since then—except for a two-year interval with the Army Medical Corps in Japan—he has been at the Henry Ford Hospital and the Woman's Hospital in Detroit.

On February 25 he married Ruby Maria Engstrom. Mrs. Schneider holds a B.S. from Northwestern University and an M.D. from the University of Minnesota Medical School. She is interning at Wayne County General Hospital in Eloise, Michigan.

1935

John B. Higley writes that since his discharge from the Army Air Forces in 1946 he has been working for Transducer Corp. in Boston, as project engineer on the development of "an electronic-mechanical device" for the Army. He is married (to Alice Sanderson of Marblehead, Mass.) and has two children (Joanna, 2½, and Paul, 8 months).

1936

Curtis G. Cortelyou, who has held various positions with General Petroleum since 1939, has recently been promoted to Project Engineer.

1937

Roland A. Budenholzer, Ph.D. '39, Professor of Mechanical Engineering at the Illinois Institute of Technology, is directing the Institute's 11th annual Midwest Power Conference, which will be held at the Sherman Hotel in Chicago from April 18 to 20.

Holloway H. Frost has moved from the Socony-Vacuum Oil Co. to its subsidiary, the Magnolia Petroleum Co. He will be party chief on an experimental seismic party, working in conjunction with Magnolia's Field Research Laboratory in Dallas, Texas.

1938

John J. Lentz, M.S. '39, is on the staff of the Watson Scientific Computing Laboratory at Columbia University, working on electronic calculators. **Byron L. Havens,** M.S. '39, is also in the lab; he spent the war years at the Radiation Laboratory, M.I.T.

Lupton A. Wilkinson writes: "In June, 1947, I left Lockheed Aircraft Corp., where I was a Supervisor of Manufacturing Engineering, to work at the Stanford Research Institute at Palo Alto on a study of the aircraft industry for the Air Force and Navy. The purpose of the investigation was to determine the expansibility of the industry, in terms of monthly production of specific models, in case of a surprise attack on the U.S. Upon completion of the project, I went to work in June, 1948, for McDonell Aircraft Corp. in St. Louis, as Chief of Schedules and Production Control. We are building the Banshee Navy Fighter, and experimental models in which we have high confidence. Incidentally, our production *is* on schedule—naturally."

1939

Richard H. Hopper, Ph.D., is a geologist with the Nederlandsche Pacific Petroleum Maatschappij in Batavia, working in Java and Sumatra. Married in 1944, he now has a four-year-old son and an almost-one-year-old daughter.

1940

William R. V. Marriott, M.S. '42, is a Captain in the U. S. Air Medical Group. He is stationed in Wiesbaden, but appears to cover a good deal of Europe. Marriott left the U. S. about ten months ago, after a year spent in Texas doing research and laboratory work for the Army. He expects to remain in Germany at least another year.

Miller Quarles, Jr., B.S. and M.S., is a geophysical supervisor for the United Geophysical Co. He lives in Dallas, and works primarily in Texas. In the line of duty he owns and flies a Beechcraft Bonanza plane, and reports a recent visit with Raymond Peterson (B.S. '31, Ph.D. '35), v.p. of the United Geophysical Co., during which he gave Peterson piloting instructions en route from Laredo to Houston and Dallas.

1941

Joseph F. Rominger married Betty Suor, of Pittsburgh, Penna., last December. They're now living in Tulsa, Okla., where he is Research Geologist in the laboratory of the Carter Oil Co.

1944

Joseph R. Bruman, B.S. & M.S., has been working on the construction of a wind tunnel at North American's Los Angeles Airport factory. Recently completed, it is the largest supersonic tunnel operated by an aircraft factory, with speeds of over 4,000 mph. It is designed primarily for study of pilotless guided missiles.

Keith W. Miller, M.S., was graduated last June from the Yale Law School, and is now working in Los Angeles for the Bank of America. He will be married this spring to Ruth Elizabeth Adams of Schenectady, N. Y. Miss Adams is a graduate of Vassar College, and a student at the Yale School of Nursing.

1945

Ralph S. White received his master's degree in Business Administration from the Stanford Graduate School of Business last June, and is now settled in Glendale, where he is Production Assistant for the Drewry Photocolor Corp.

Two recently announced engagements are those of **Bradley G. Morison,** to Barbara West Bissell of Minneapolis, and **Melvin N. Wilson, Jr.,** to Adina M. Wagner, of Coram, N.Y.

1947

G. S. Ramaswamy, M.S., is now Instructor in Civil Engineering at Kakinada Engineering College, Madras Province, India.

1948

Harry Lass, Ph.D., is in the Mathematics Department of the University of California at Santa Barbara. His engagement to Dorothy Helen Goedhart, of Pasadena, was recently announced.

Letters CONTINUED FROM P. 2

Ten Year Talley

Sirs:

This spring brings with it a ten year milestone for the Class of 1939. The completion of ten years, if they are all as tough as the last ten, is an accomplishment in itself and probably an occasion well worth some special recognition.

Certainly many interesting stories could be developed from the experiences of the members of the Class of 1939. Enough, I believe, to make them the theme of an edition of *Engineering and Science* sometime this year.

Those of us who have left California especially have a longing to hear about old friends at school: how and where they are and what they are doing. A real get-together with the class through the pages of *Engineering and Science* would be long appreciated by us.

From the sound of the Alumni directory, it appears that Bill Norton is selling automobiles. What is the real story?

Cary Paul started with Caterpillar Tractor. Is he still there and doing what?

I have seen John Black a few times. He is Howard Hughes' righthand man. He can tell many a story.

So can Tyler Matthew, who is an officer in the Navy.

Is Chuck Carstarphen still selling soap for Procter & Gamble? And how about Scott and Lee and Ritchey and Deverian, and the others?

Why not ask every member to send in something about his ten years for inclusion into an article. Better yet, since people are often shy or reticent, why not assign volunteers to contact and send in writeups about others near them. I am certain there are many others like myself who would volunteer to do that.

Richard K. Pond
East Orange, New Jersey

¶ E & S has already snapped up Dick Pond's offer; he's been assigned to collect biographical material from men in the class of '39 now in the New York area.

Are there other volunteers?

With their help, E & S can present, early in the fall, a 1949 report on the class of '39—a composite picture of the Caltech graduate ten years later, as well as individual reports on as many '39 men as we can reach.

Better Late . . .

Sirs:

In the October '47 issue you published a plea for criticism of the articles in E & S. I sat right down and started this letter. It has taken a couple of New Year's resolutions before I have been able, finally, to finish it. The following are my personal comments—why not send out a poll to find out what other alumni think? This business of writing letters sounds easy, but it takes a lot more time than filling out a questionnaire.

I think changes in the courses and educational standards at CIT should be *discussed* at some length in E & S, if and when they occur. Also, of course, changes in the plant.

I suggest that a tabulation of the publications originating at CIT be included—so alumni can keep up with science—or at least keep it in sight a little longer. It would be still better to have a short paragraph describing the significance, if any, of each publication.

I commend you on the "In This Issue" column—it's not stuffy like most of the rest of the departments tend to be. However I thought "With The Editor" a more appropriate heading.

Years ago the *Alumni Review* published, I believe, a column devoted to puzzles (mathematical etc.) submitted by the readers. This sort of thing I think is fun. In case you are interested here is a choice one:

"Given twelve balls identical in appearance, eleven of which are identical in weight. To find which of the twelve is the odd ball, *and* whether it is heavier or lighter, in three weighings on a pan balance."

You need an annual index, badly.

Unquestionably, and as you have noted (With The Ed. 5-48), your issues devoted to departments or divisions at Tech—Wind Tunnel, 7-45; Jet Propulsion, 7-46; Biology, 5-47; Geology 2-48 and Mt. Palomar 6-48—have been outstanding. Let's have some on Physics, Mathematics, Chemistry, E.E., Ch.E., and ME too. Actually these major departments, I think, would be of even more interest, to more alumni, than some of those you have presented.

As a generality, I shall dare to venture the opinion that articles by members of the CIT staff—or students—will appeal to a wider audience among the alumni than articles by the alumni themselves. This is because of the necessary narrowing down that alumni undergo after leaving school. To take the December issue of E & S for example, I thought Borsook's article most interesting and timely: the thing on comets quite good and of just about the right length for the type of presentation it is; Millikan's speech enjoyable (one of the few speeches I have actually read through for a long time). In other words, I consider this issue, originating essentially within the Institute, a very successful one. Of course, a good way to find out whether anyone else holds with these viewpoints is to poll the readers, as I suggested above.

And this brings up a suggestion rather unrelated to the foregoing. I would like to propose that the Alumni Association undertake an economic status survey of the Alumni. This was done back around '41, I believe. Correlations between income and major in school, year graduated, type of employment (what industry, etc.), profession, number of positions that have been held, and years in present job—etc., might be included. Such data are definitely of value—to the school, to students, and to alumni.

Los Angeles

¶Before taking a poll of the rest of our readers, E & S might better take a stand on *this* reader's pertinent—and welcome—criticisms and suggestions. He didn't want his name used because he thought he was being too rough on us. But this is the kind of letter we relish—especially when we think we have most of the answers to it.

1. We plan to discuss changes in courses and educational standards

regularly: Winchester Jones, Registrar and Dean of Admissions, is now preparing an article on Caltech's admissions policy. As to plant changes —E & S for February reported on the new biology annex, in June or July will cover the even-newer Earhart Greenhouse.

2. Publications originating at Caltech now appear in an annual Institute bulletin, *Publications of the Staff*. Space prevents our running these each month in the magazine.

3. We'll consider that switch to *With the Editor,* but when you call "the rest of" our departments stuffy —smile.

4. If enough readers will send in enough puzzles, we'll run a column. Meanwhile, will somebody give us the answer to this one?

5. E & S will have an annual index for 1949—and thereafter.

6. Coming up—special issues on Chemistry and Engineering. Eventually we'll cover all Divisions.

7. At least 65% of the material in E & S now originates within the Institute. Any complaints?

8. An economic status survey of Caltech alumni would, of course, be invaluable. But, like Dick Pond's suggestion above, it would take a lot of man-hours. Are there enough men who are men enough to help launch it?

POSTMASTER: Return
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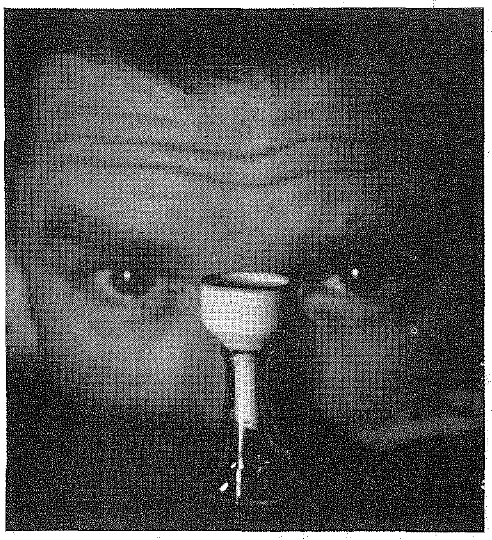
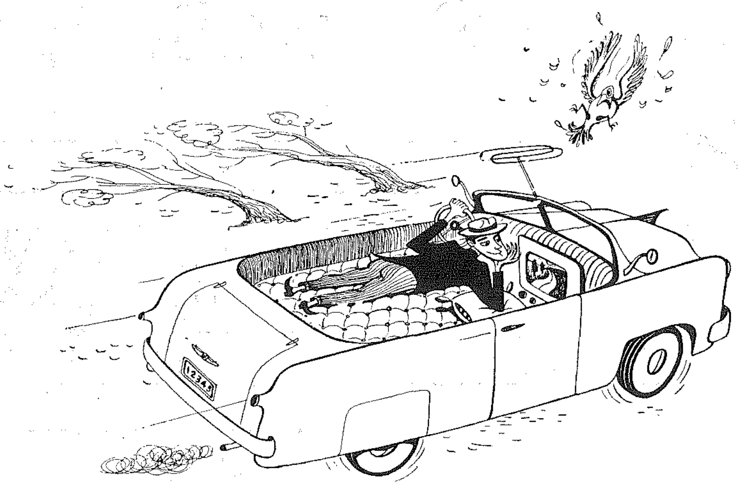
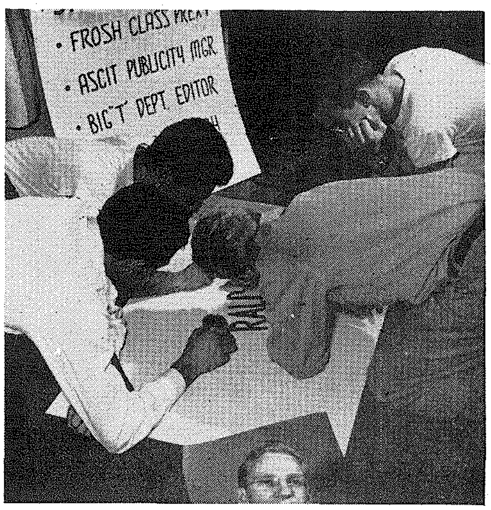
What's going on here

There's plenty going on. And each month Caltech faculty, alumni and students join in telling you all about it in "Engineering and Science," the magazine published by Caltech's Alumni Association.





Here's a sample: in February a biochemist described the flavor analyses that are winning him national renown. In March, an engineer had his say on the subject of the new cars. And "E&S" reports on student activities, too; at election time "E&S" was there with a camera.



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