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ENGINEERING AND SCIENCE

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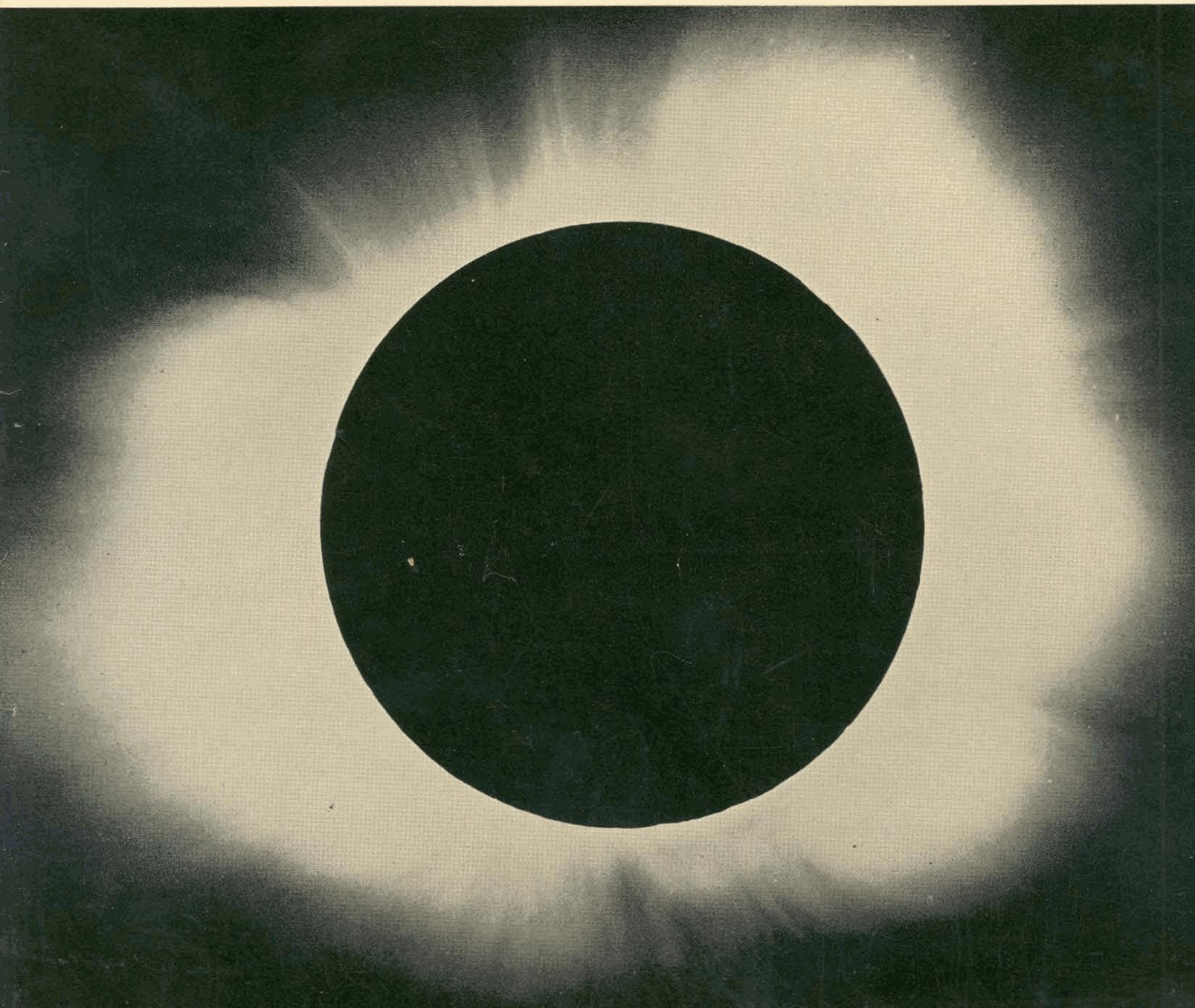

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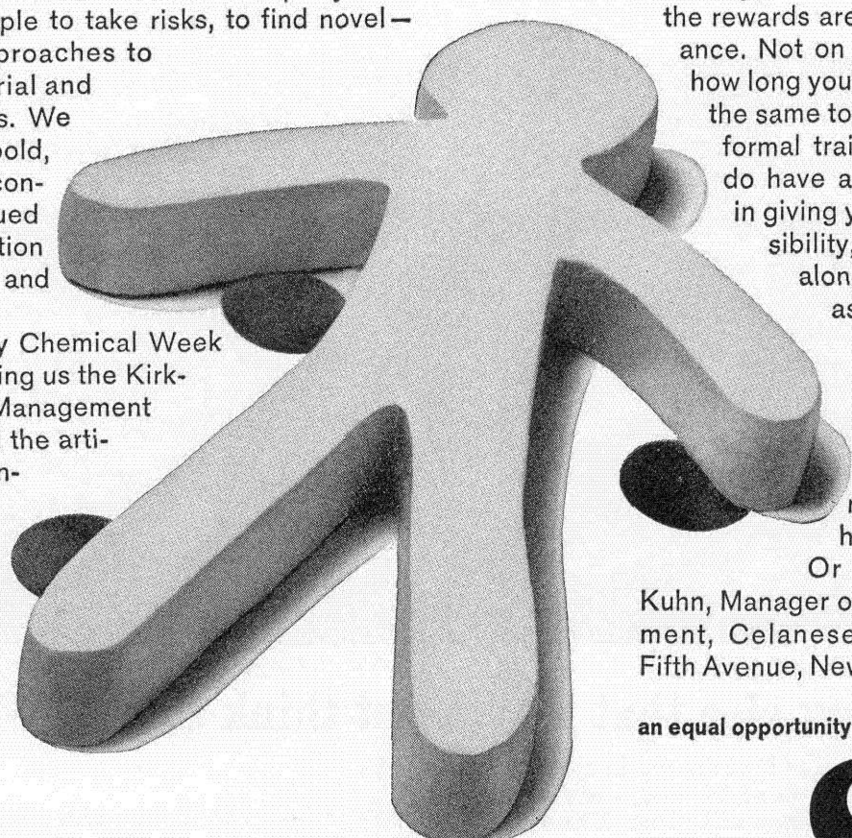

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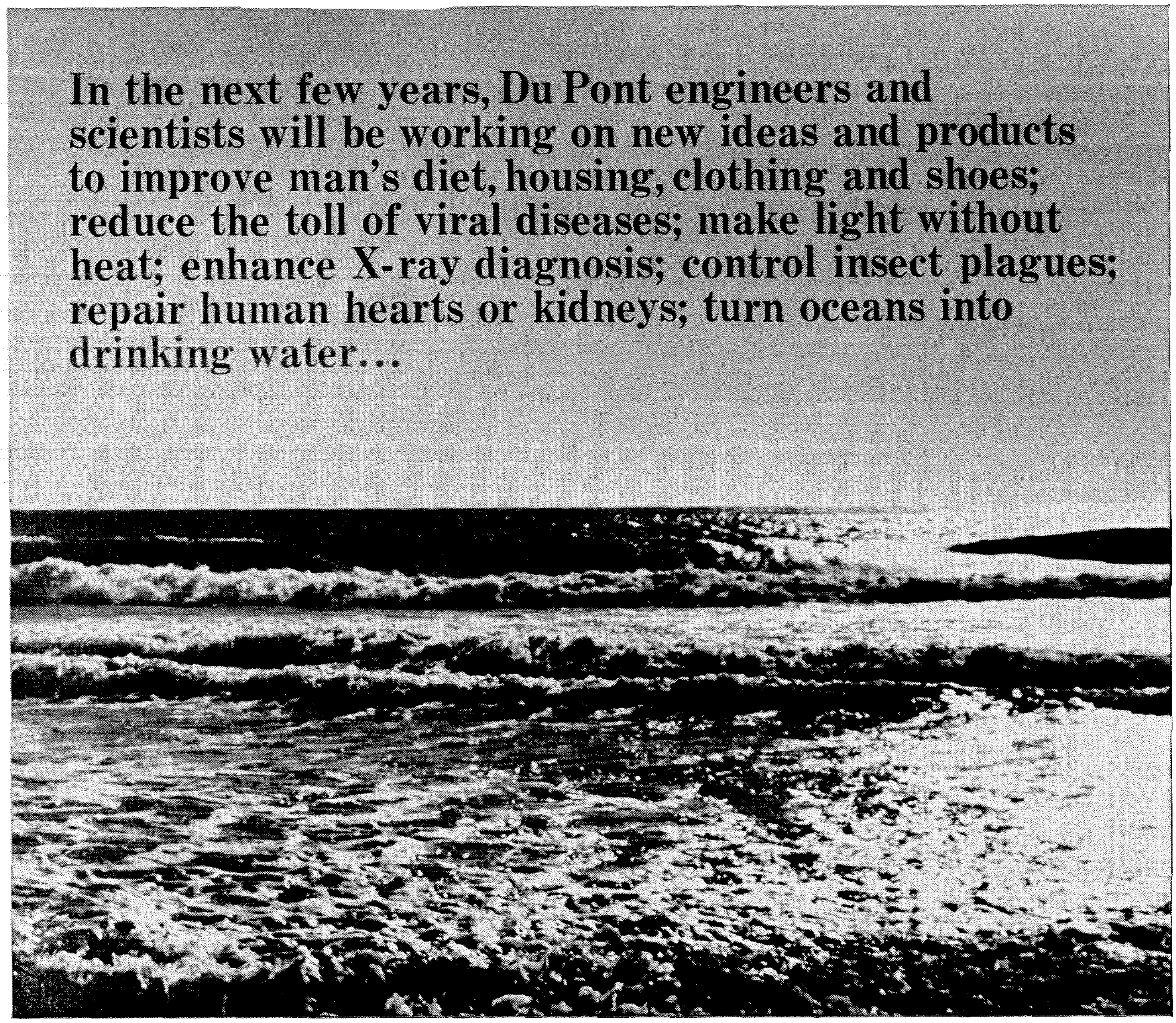

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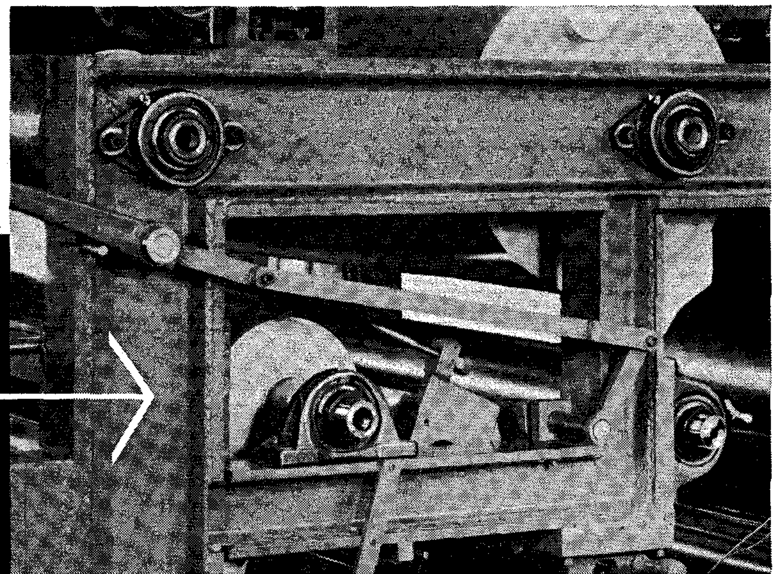

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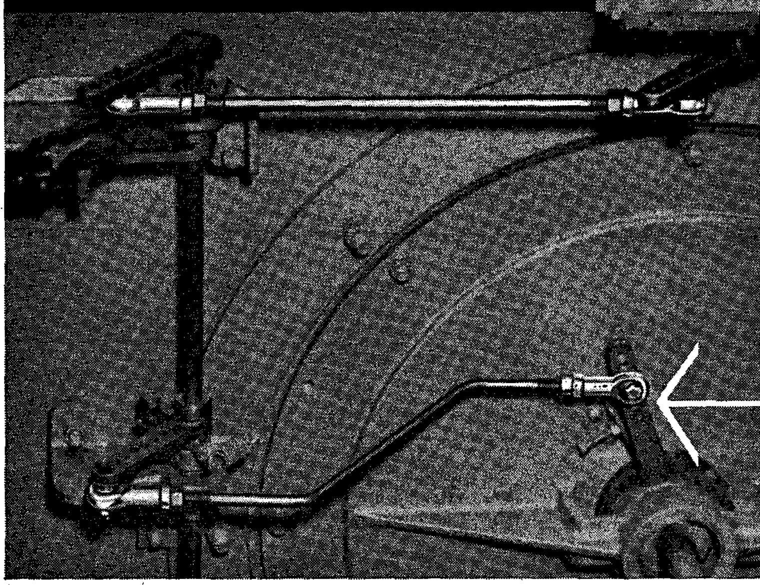

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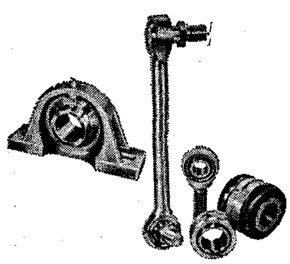

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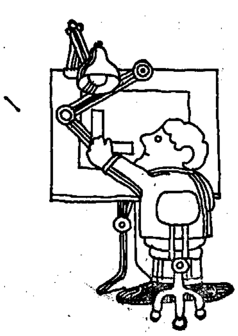

The Next Ninety Years
Proceedings of a Conference Sponsored by the Office for Industrial Associates at the California Institute of Technology

California Institute of Technology

*Reviewed by Irving S. Bengelsdorf, science editor, The Los Angeles Times**

From the oracle of Apollo at Delphi in ancient Greece, through astrologers and crystal-ball gazers, to modern-day electronic computers, man always has been interested in techniques to foretell the future.

Ten years ago, in a nationwide series of lectures presented before American industrial leaders, three faculty members of the California Institute of Technology, Pasadena, presented their evaluation of the future of man—"an effort to forecast the future of our scientific-technological-industrial civilization."

The 1957 talks, delivered by Drs. Harrison Brown, professor of geochemistry; James Bonner, professor of biology; and John Weir, associate professor of psychology, were collected and published as a book entitled *The Next Hundred Years.*

In March 1967, the three Caltech professors met again to discuss the future and to evaluate the predictions they had made 10 years earlier.

At this second conference on mankind's future, sponsored by Caltech's Office for Industrial Associates, Brown, Bonner, and Weir were joined by two additional Caltech faculty members—Drs. Norman H. Brooks, professor of civil engineering, and Thayer Scudder, associate professor of anthropology.

With funds made available by the Camille and Henry Dreyfus Foundation, Inc., Caltech now has published the stimulating and provocative proceedings of this "10 years after" conference as a book entitled *The Next Ninety Years.*

This second book, now available from Caltech, not only presents the five talks given by the Caltech professors but also contains the lively round-table discussions that followed each presentation.

Additional speeches were given by two non-Caltech guest speakers—Drs. Athelstan Spilhaus, dean of the Institute of Technology, University of Minnesota, and J. George Harrar, president of the Rockefeller Foundation—also are included.

Unfortunately, an excellent and witty talk dealing with the funding of scientific and technological research projects in America, presented at the conference luncheon by Dr. Arnold O. Beckman, chairman of Caltech's board of trustees, was omitted.

How is the world of today significantly different from the one predicted a decade ago?

Dr. Brown notes two major surprises. One surprise is the fantastically rapid growth of world population. He summarizes the situation: "We now are experiencing rates of population growth which greatly exceed those which were imagined even by the gloomiest pessimists 10 years ago."

Another important surprise has been the onrushing acceptance of nuclear energy to generate electricity. Brown continues, "It is a major revolution in the world energy picture, brought about largely by rapidly decreasing costs of nuclear power."

And there have been two major disappointments. One involves agriculture and the worldwide food problem. Brown adds, "Agricultural production has increased far less rapidly than we had hoped, with the result that hunger is far more widespread in the world today than it was 10 years ago."

What is even more disturbing is the ever increasing economic gap among nations. Brown explains, "Although we in the more technologically developed West are getting richer even more rapidly than we thought possible 10 years ago, the poorer nations of the world are not sharing significantly in this bounty."

In an evening banquet speech, Dr. Harrar again focused on the overwhelming problem of overpopulation. He warned, "While the debate (on population) rages, wave after wave of new citizens join our ranks at the current rate of 65 million per year.

"Although millions upon millions of these individuals are unwanted and unplanned for and cannot be properly fed, clothed, housed, or provided with educational and other opportunities, we have thus far been unable to stem the tide. Unless we do succeed, however, survival may well become our chief concern, with attendant degradation of the human condition.

"It would be a melancholy paradox if all of the extraordinary social and technological advances that have been made by man were to bring us to the point where society's sole preoccupation becomes survival rather than fulfillment."

The Next Ninety Years should be required reading for high school, college, university, and adult education classes. Only if we are aware of the problems facing us in 1967, may we be able to do something about the world of 1977.

Basic Principles of Chemistry
by Harry B. Gray and
Gilbert R. Haight, Jr.

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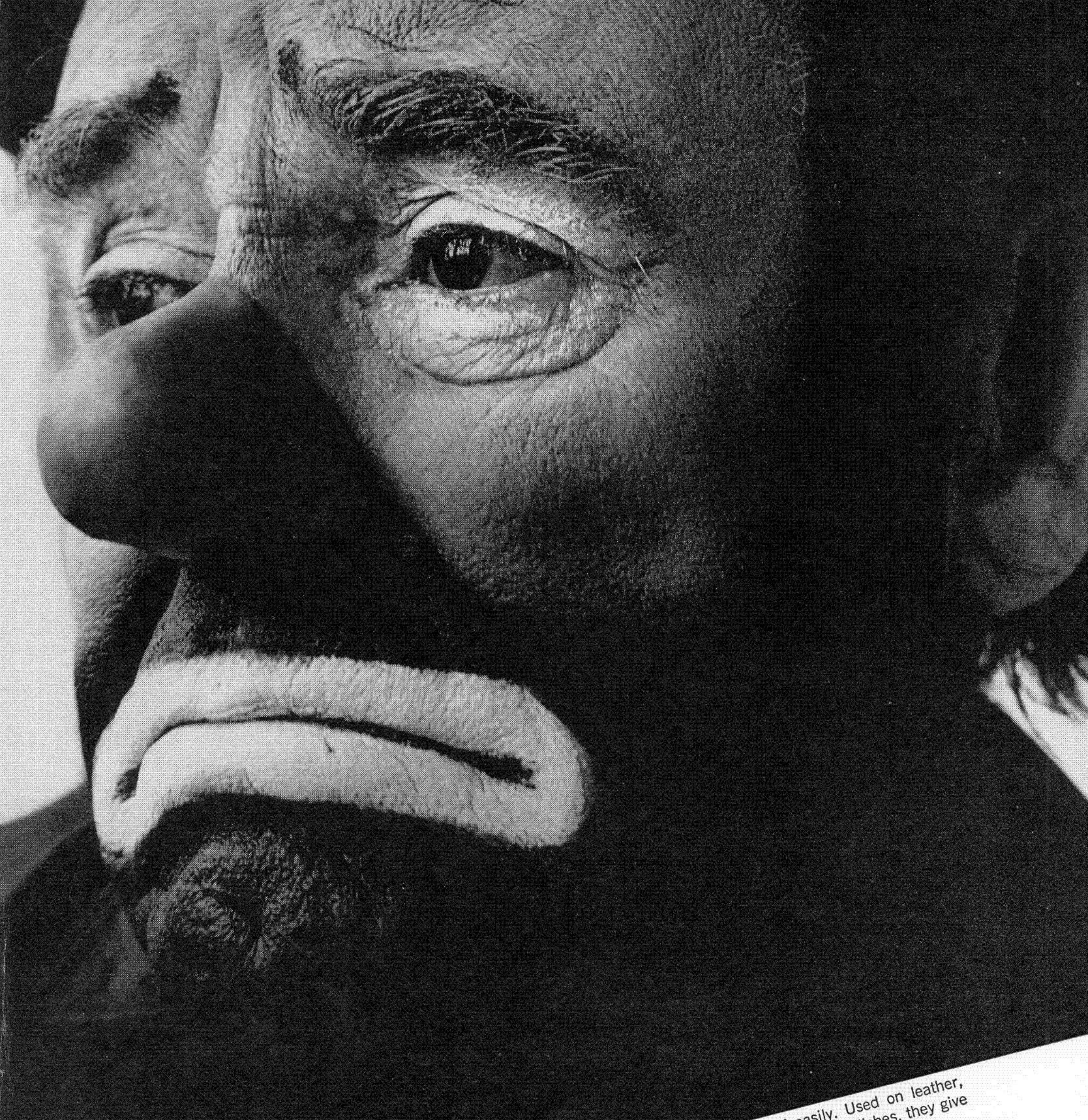
Reviewed by Fred C. Anson, associate professor of analytical chemistry

This new textbook is designed to provide an introduction to modern chemistry. It does so in quite a different way than is familiar to the legions of Caltech graduates who learned their freshman chemistry from Linus Pauling's classical text. Gray and Haight consider the old categories of physical, organic, inorganic, and analytical chemistry to have merged into oblivion and set out to treat the subject by considering the three main categories of current research in chemistry as proposed in the Westheimer Report: structural chemistry, chemical dynamics, and chemical synthesis. The result is a book containing very little of the descriptive material familiar to readers of freshman texts. There are, for example, no chapters titled "Group VI Elements," "The Halogens," or "The Transition Metals." Instead one finds an array of eclectic chapters which strive to present an integrated picture of chemical knowledge and how it is obtained. Heavy stress is placed on structural topics and chapter titles include "Concepts and Models of Molecular Structure: A Classical View," "Modern Theory of Atomic Structure," "Atomic Properties," "Chemical Bonds," "Molecular Orbitals," "Bonding in Condensed Phases," and "Coordination Chemistry: Structure, Reactivity and Equilibrium."

This book is impressively packaged and lively reading. It will certainly help to convey to beginning students the challenge and excitement in modern chemical research.

The book is amply supplied with sets of "Questions" and "Problems." A typical problem gives a good example of the book's verve: "Find someone who has not studied chemistry or physics, but who has a little number sense, and try to convince him that the evidence for the existence of atoms is sound."



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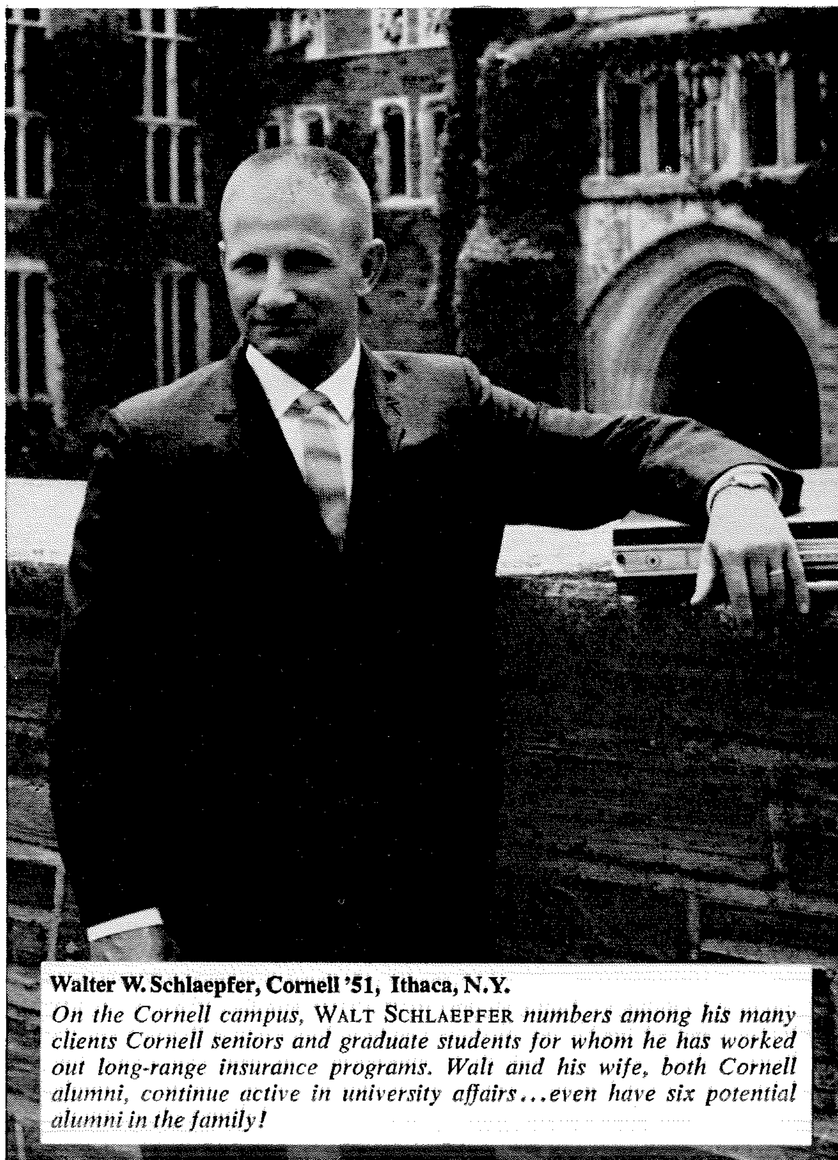

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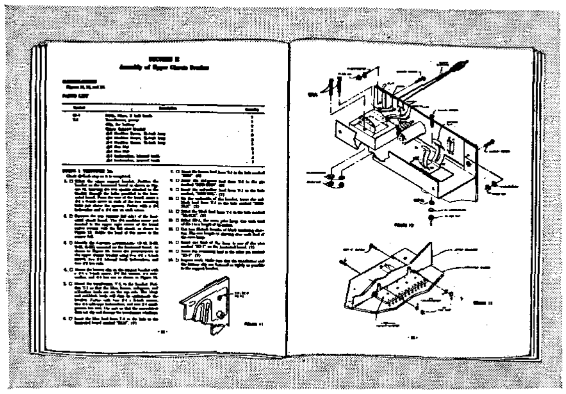

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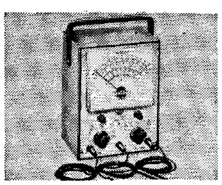

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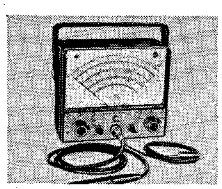

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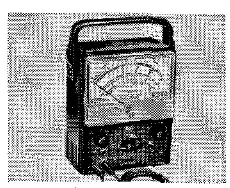

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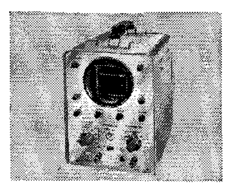

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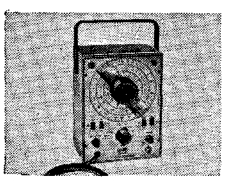

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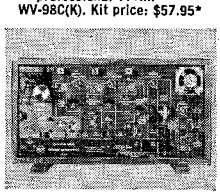

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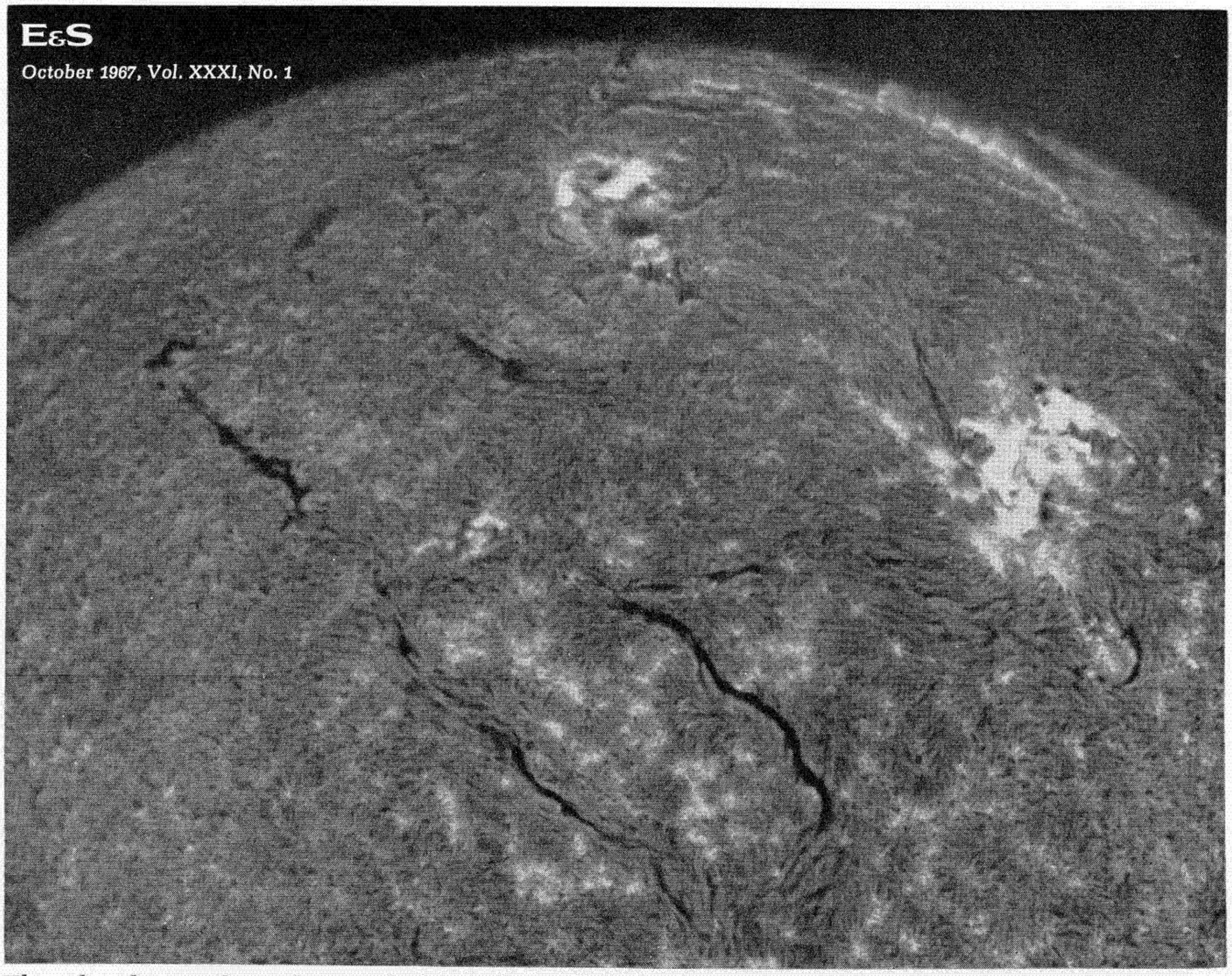


The solar chromosphere photographed in hydrogen light (Hα). The bright areas near the sunspots are plages. The dark filaments are prominences seen against the disk. Note the bright network structure. All bright features in Hα correspond to regions of enhanced light.

THE SOLAR ATMOSPHERE

by Harold Zirin

In the spring of 1966, Harold Zirin, Caltech professor of astrophysics and staff member of the Mount Wilson and Palomar Observatories, was invited to give a lecture for the Voice of America Forum series, "The Earth in Space." His contribution, "The Solar Atmosphere," which appears on the following pages, was one of 30 made by leading U.S. scientists dealing with the body of scientific knowledge about the earth and its cosmic environment. The lectures have now been collected and edited by Hugh Odishaw of the National Academy of Sciences. They will be published in November by Basic Books, Inc., under the title *The Earth in Space.*

Harold Zirin, professor of astrophysics and staff member of the Mount Wilson and Palomar Observatories.

The Solar Atmosphere

As the sun rotates about its axis every 27 days, its surface is constantly changing within a larger, more persistent structure. The surface sloshes back and forth every four minutes, and small granules appear and fade out in eight minutes; sunspots appear, grow, and fade in a few weeks or months, their lifetimes punctuated by the great outbursts we call solar flares. All of this activity rises and falls in the great 11-year sunspot cycle. These are phenomena of the solar atmosphere, but their effects reach out to the earth and beyond it through the solar system.

The sun is so hot that it is completely gaseous, and, therefore, its surface is not hard and sharp like the earth's. In fact, we define the surface of the sun as that level to which we may see in integrated light—the total visible white light. It is the level in the atmosphere at which the density has dropped so low that the gas is transparent. All, or most of, the radiant energy may now stream outward into space. At this boundary, which we call the photosphere, a number of remarkable changes in the behavior of the solar plasma occur.

Because the density drops off sharply and the radiant energy suddenly escapes, convective currents rising from below grow into energetic shock waves. At the same time the gas in the atmosphere sloshes back and forth and up and down just like water in a bathtub. Strong magnetic fields are generated, and these combine with the motions to produce heating of the atmosphere, so that the temperature, which has dropped all the way out from the center of the sun, rises rapidly to 1,000,000° Kelvin.

The tenuous million-degree atmosphere, called the corona, is seen as a halo of pearly light in total eclipses, when the bright light of the surface is blocked out by the moon. The corona reaches out past the earth.

The density at the surface of the sun falls off because the lower layers must bear the weight of the upper layers; they can only do this if the pressure is higher down below. This is called barometric equilibrium. The same phenomenon occurs in the earth's atmosphere; the density decreases quite sharply with height. We can calculate that at the temperature of the sun's surface—6,000°K—the density decreases twenty times at a height of 500 kilometers. When we look at the sun's limb from the earth at a distance of 150 million km, it looks quite sharp to the eye as well as to the telescope. The finest telescopes, under the best conditions, can only resolve objects about 700 km apart on the sun.

If we look at the sun in white light, we at once see several important features. First, the sun is darker near the edges, so the layers we see there must be cooler. Since we cannot see so deeply into the atmosphere when we look slantwise, we conclude that the temperature is still decreasing at the height defined by the edge of the sun. The temperature falls from 6,000°K at the levels which we see at the center of the sun to about 4,500°K near the edge.

The second important feature we see is the granulation, a fine pattern like corn grains about 1,000 km across. These grains cover the entire sun; each grain appears, lives about eight minutes, and breaks up or fades away. The granules appear to represent convective currents carrying heat outward from the interior. If we study carefully the velocities of the gases in the photosphere we find that there is a larger-scale pattern, the supergranulation, which has cells about 30,000 km across, in which the gases flow outward to the edges of the cell. Moreover, the gas at any point in the atmosphere rises and falls rythmically with a period of 250 seconds and a velocity of one-third km a second (1,200 km an hour).

Because of the continual outward flow in the supergranulation cells, magnetic fields accumulate at their edges. At these edges, gas pressure still is greater than the pressure of the magnetic field. But 1,000 km above the granule edges, the gas pressure has decreased by 400 times, and there the magnetic fields, which do not decrease so rapidly with height, restrain and organize the motions of the ionized gases. The result is that when we look at higher levels we see a very strong cellular supergranulation structure.

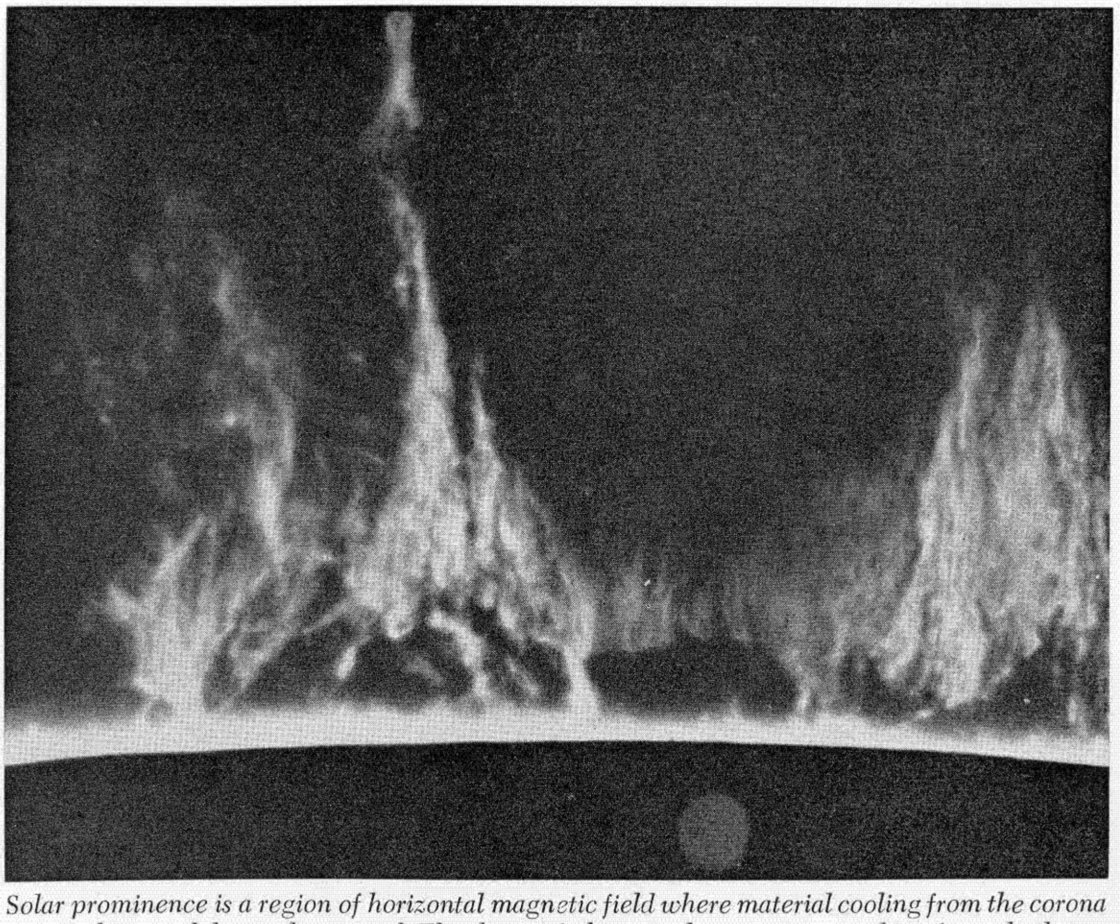
How do we look at higher levels in the atmosphere? These levels are easily accessible to our line of sight, but the gases are quite transparent, so we see right through them, just as we see through our own atmosphere. In order to see the tenuous atmospheric gases, we must use a technique which permits us to look in frequencies absorbed by the gases—for example, the spectrum lines of hydrogen may be used. Another way, much older, is to take advantage of a total eclipse when we can observe the very last crescent of the sun just as the rest of the surface is covered by the moon. At the instant before totality, a bright pink flash of light from the outer edge of the sun is seen; that layer is therefore called the chromosphere.

When we examine the chromosphere in hydrogen or calcium light, we may see the strong supergranulation pattern. The edges of the cells form a network of higher temperature and stronger magnetic fields. If we look carefully we see rapid jets of gas, called spicules, shooting up at the edges of the cells. Their velocity is about 30 km a second, and they rise about 5,500 km above the surface. Although there are not many of them on the disk, when we look at the limb the foreshortening merges them into a forest. It is from these jets that material flows into the corona above, and through them flows the energy that heats the corona.

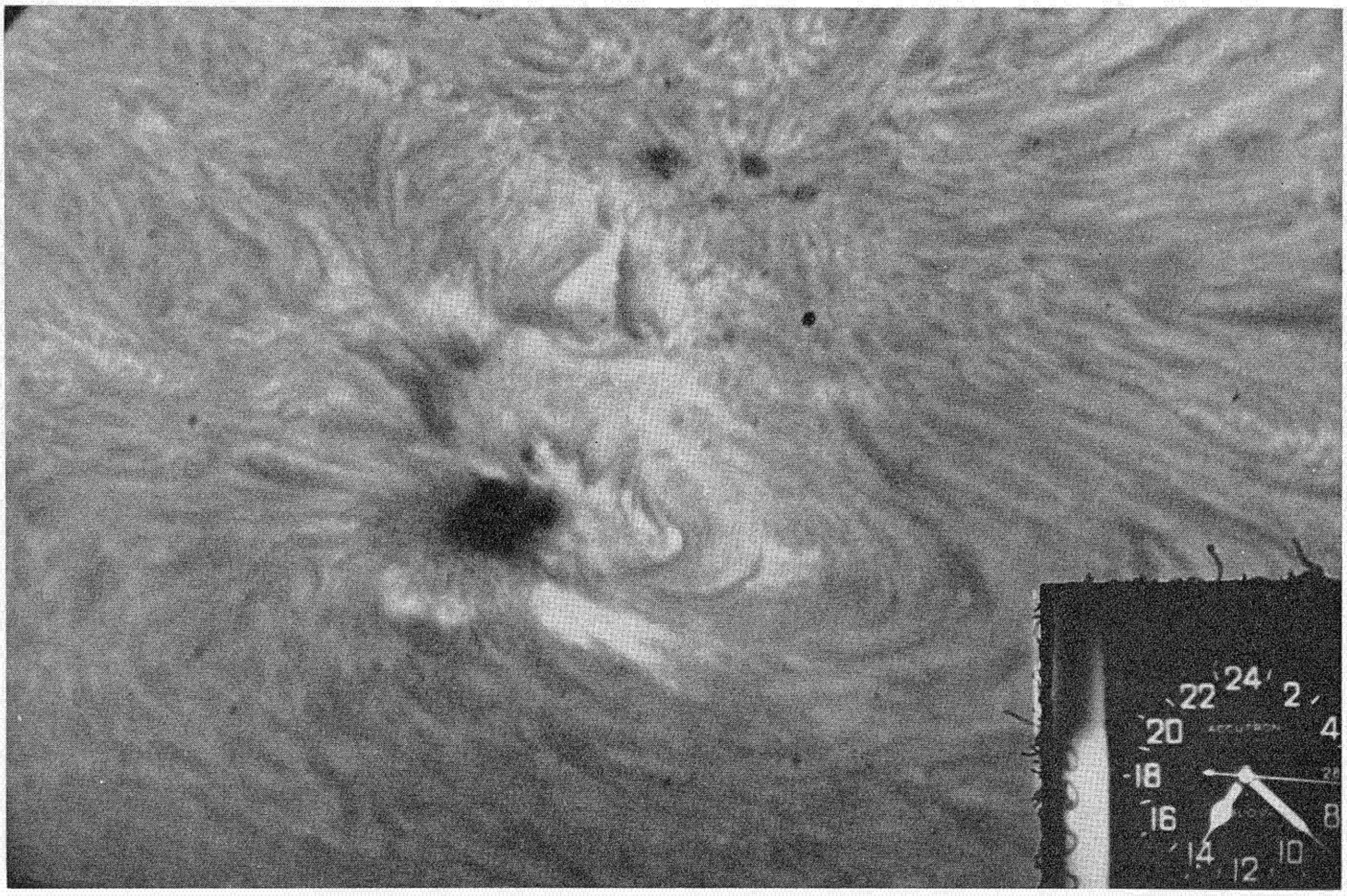
The corona is a very remarkable region. It can be studied only at eclipses, or at high altitudes with coronagraphs that block out the light of the sun itself. The corona is a million times fainter than the disk of the sun, so it is completely lost in a bright and hazy sky.

We know the corona is very hot because of the spectrum lines emitted there. From the radiation we find ionized iron with 13 or more electrons removed, ionized calcium with 14 electrons missing, and so on. Such high ionization can only be produced in very high temperatures. Although the corona is transparent to ordinary light, it is opaque to radio waves longer than five meters, and radio observations confirm its high temperature. We can also show that it produces scintillation in the light of distant radio stars even when they are 90° away in the sky, which proves that the coronal gas extends all the way to the earth.

Because the corona is so hot, it radiates a good



Solar prominence is a region of horizontal magnetic field where material cooling from the corona accumulates and drains downward. Thin layer of chromosphere is seen at edge of occulted sun.



Sunspot photographed in Hα shows the umbra (dark center) as a cup-like depression with bright surging regions around the edge. A small flare squirts out in the direction of the steepest magnetic field gradient.

deal in the ultraviolet. Accordingly, when we observe the ultraviolet spectrum from rockets or satellites, the spectrum is dominated by the lines of the highly ionized coronal atoms. By observing in this region, we can get some information on the corona as it appears on the disk of the sun, rather than just looking at the edge.

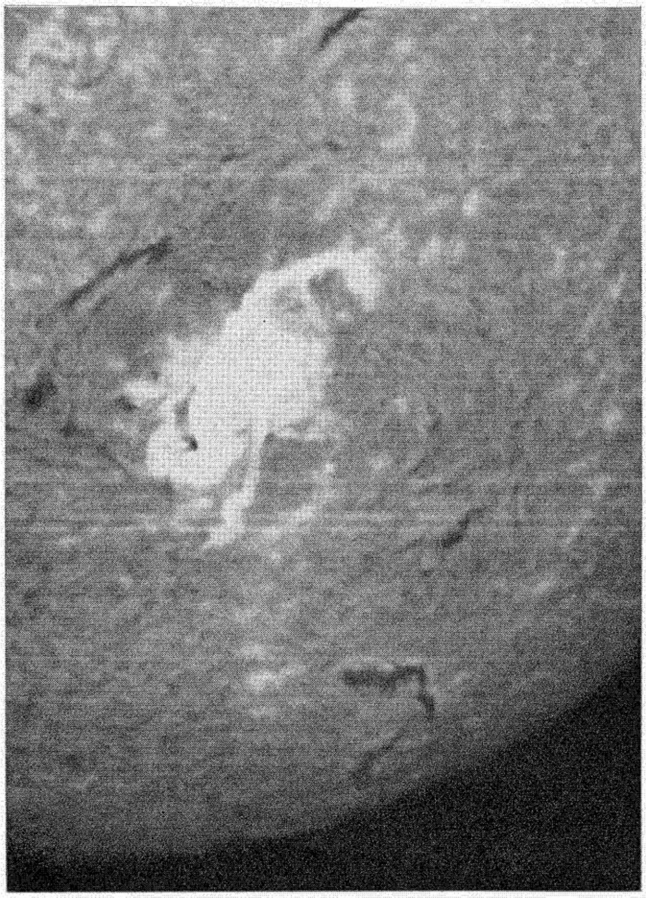
Although the corona is very hot, we often see much cooler clouds, called prominences, above the surface of the sun. These clouds are almost transparent except in hydrogen light, but at that wavelength they are considerably brighter than the corona. They are best seen against the sky with the disk light blocked out. But they may also be seen against the disk of the sun, where they appear dark. This is because they are darker than the disk but brighter than the sky.

When we study the positions of prominences on the sun, we find they are located on the boundary between large magnetic regions of north and south polarity. Magnetic lines of force rise up on one side and come down on the other, and in between the field is horizontal. Since the ionized gas cannot cross the field lines, it is supported above the surface. So the prominences are accumulations of cooled-off coronal material supported against gravity by horizontal magnetic fields. If we make movies of prominences, we may see material slowly moving downward. If the prominence is near a spot group, gas flows down to the spot along arching field lines. Sometimes the magnetic field changes abruptly, and the whole prominence blows out from the sun in a great arch.

I have so far been concerned with the quiet sun and the behavior of the atmosphere when undisturbed by transient activity. But the most exciting occurrences on the face of the sun are the phenomena connected with sunspots.

Sunspots are dark regions on the surface of the sun. They occur in many sizes, from little pores 1,000 km across to giants 100,000 km in diameter that may be seen with the naked eye. They occur between latitudes 5° and 40° in both hemispheres, although in the last ten years there have been very few spots in the southern hemisphere. The number of spots varies cyclically, with 11 years separating successive minima. At the beginning of a cycle small spots appear at high latitudes. As time goes on, the spots grow larger and more numerous, and they also occur closer to the equator. The last spots of a cycle are quite close to the equator.

Sunspots have very strong magnetic fields; their



The eruption of this large solar flare, photographed in 1959, filled the interplanetary space with cosmic rays and wiped out radio communication for days.

field is ten times stronger than an alnico magnet of the best quality, and one can imagine the strength of such a magnet 100,000 km across. The magnetic field is thought to suppress the convection of heat from below and thus make the sunspot cooler than its surroundings, which explains its darkness. Larger spots tend to occur in groups with one polarity on the east side of the group and the other in the west. The polarity of spot groups in the northern and southern hemispheres is opposite. With a new cycle, the polarity of the magnetic field changes, so that it takes two cycles—or a single 22-year full cycle—to come round to the same situation again. No one can explain this remarkable cycle.

Typically, large spot groups last two or three months. Because the sun rotates once in 27 days, we can see large spots come around several times.

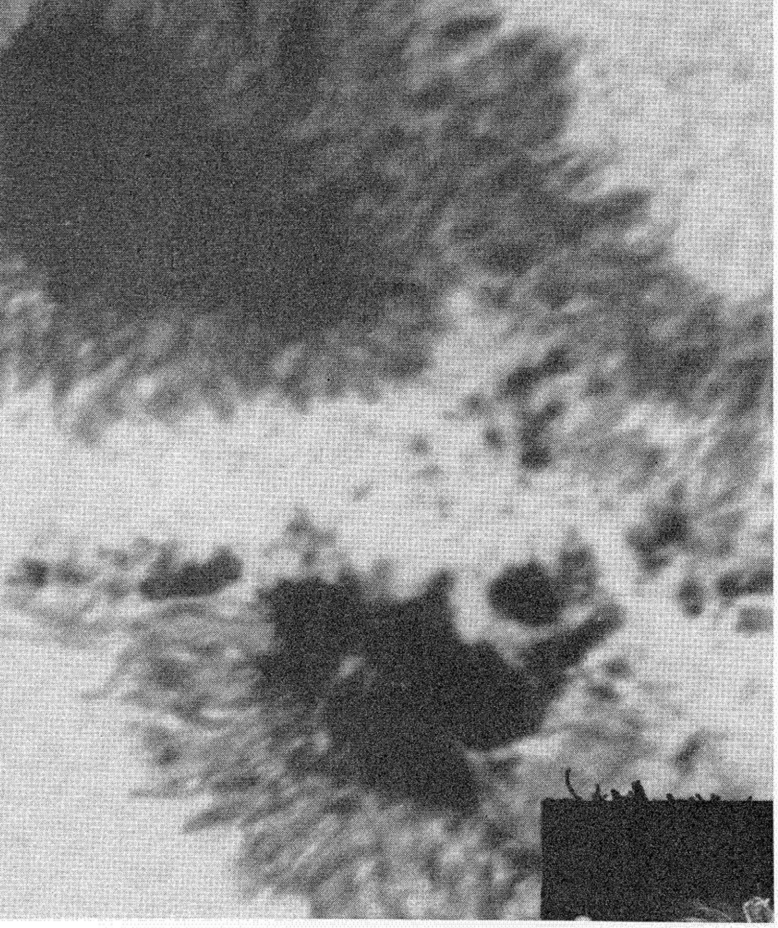
What happens to the sunspot fields when the spots die? The magnetic fields are dragged out by the motions in the surface and spread over the sun. This is helped by the fact that the sun rotates more slowly at higher latitudes, so that fields which drift poleward lag behind and are stretched over the surface. Soon large areas of the surface are covered with weak magnetic fields of one dominant polarity. These fields are marked by long streamers in the corona, and they are even detected in interplanetary fields near the earth.

Every once in a while—sometimes every few hours in particularly active groups—a great outburst of energy occurs in the neighborhood of a sunspot group. This is a solar flare, a truly remarkable phenomenon. Regions tens of thousands of kilometers across will brighten simultaneously in a matter of seconds. Great clouds of matter are thrown out with velocities of 500 to 1,000 km a second. Flares are transparent in ordinary light. Yet if we look in the extreme ultraviolet (the most energetic part of the spectrum), a flare covering 1/1000 of the surface emits more light than all the rest of the sun. Flares are most conveniently seen in the wavelengths of hydrogen light. By limiting ourselves to those wavelengths we reject most of the light of the surface but retain most of the flare emission, making it easily visible.

At the moment of most rapid brightening, energetic pulses of x-rays are emitted that change the earth's ionosphere so that radio signals fade out, and swarms of energetic cosmic rays are emitted that fill interplanetary space. To be sure, the biggest flares that severely disrupt the ionosphere and produce really hazardous cosmic radiation are infrequent—a few a year and only in the biggest spot groups. But even modest sunspot groups will have numerous small flares, each of which produces its own pulses of energy.

Careful observation of flares, particularly by cinematography, shows that they frequently occur in regions having a steep magnetic field gradient and that they are most common in very complex sunspot groups with intertwined regions of different polarity. To explain how flares occur, we must explain how their energy is stored up and then released very rapidly. The underlying sunspot and granulation structure is unchanged by the flare. Although flares have a lot of energy, it is miniscule compared to the enormous thermal energy under the surface of the sun. What makes the flares important is that a great deal of their energy is organized and concentrated in the most energetic part of the spectrum.

If we study the corona above an active sunspot group, we find a relatively dense cloud of hot gas at more than 3,000,000°. Each flare or eruption throws more material upward at high velocities, and these velocities are dissipated in a general heating of the atmosphere. The sunspot magnetic fields extend high above the surface, and often we see graceful loop prominences, which occur as the hot material thrown up by the flare cools, condenses, and



The dark centers in this large pair of sunspots are called umbra—the filamentary periphery, penumbra. Granulation appears on the outside and light bridges can be seen in the umbra.

rains down along the curving magnetic lines of force. The hot gas in these coronal condensations emits a considerable quantity of soft x-rays; in addition, we often find hard x-rays coming from this region. Such radiation is particularly noticeable when a flare occurs just over the edge of the sun, so we see the eruption in the atmosphere even though we don't see the flare itself. The fast-moving electrons produced in the flare are trapped in the atmospheric magnetic fields and radiate their energy in the form of x-rays.

Why do sunspots occur? This question has always fascinated astronomers. Early theories simply considered them as storms on the sun. If we look at atmospheric structure around sunspots in hydrogen light, we see strongly curved configurations, like the curved clouds around a hurricane. We now know that these clouds are elongated because matter is forced to flow along the magnetic lines of force. And we know that the strong magnetic fields in spots suppress motion, so that the spots are rather quiet although the atmosphere above them is very turbulent.

Many theories of the sunspot cycle connect it with the sun's differential rotation—the remarkable fact that the sun rotates faster at the equator than it does at the poles. Some astronomers have conjectured that this unequal rotation winds up the magnetic lines of force, greatly intensifying them, until sunspots break out.

Other astronomers feel that the differential rotation is due to the spots themselves. They suppose that the inside of the sun rotates somewhat more rapidly than the surface, which is slowed by the interaction of atmospheric magnetic fields with the interplanetary medium. The sunspots sink roots from the slowly rotating atmosphere into the interior and speed things up.

But we still don't know how the spots are produced, and we cannot see why they should return so regularly every 11 years.

We passed through a minimum of solar activity in 1964, and a new cycle began, with maximum expected in 1968. Astronomers have developed a variety of new instruments to observe the phenomena of this cycle. We are especially interested in rapid time-sequence observations so that we can observe the evolution of fast-changing phenomena, and in high-resolution observations so we can see exactly what is going on. One important source of information is data from rockets and satellites in regions of the spectrum that do not penetrate our atmosphere, particularly the ultraviolet. In this region we may directly observe the parts of the atmosphere, such as the corona, that are transparent in the visual spectrum. Also, the more energetic ultraviolet light, particularly x-rays, most closely reflects the energetic processes in flares. So we hope, with the further development of satellite and rocket astronomy, that we shall gain new knowledge from a different point of view.

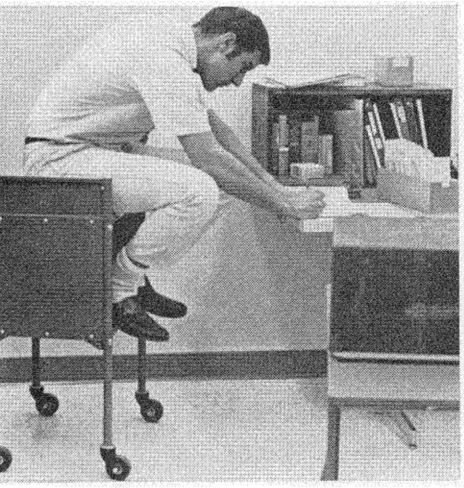
Another way in which we are gaining new knowledge about the sun is by the study of similar activity in other stars. Although the stars are so distant that we cannot see their surfaces (they appear as points), by studying the behavior of certain lines in their spectrum we can determine if they have chromospheres or solar activity. These lines are, of course, the same strong spectrum lines in which we study the solar chromosphere and flares. We can see how often and how strongly these phenomena occur in stars of different ages and sizes, and thus place these phenomena in the proper perspective in the lifetime of a star. On the other side, by studying the phenomena in the sun from the stellar point of view, we may explain to the stellar astronomers the meaning of these barely detectable phenomena, which we only can interpret by looking at the surface of our sun, the only star that we really can see in two-dimensional detail. Thus we use our own star, the sun, to help understand all the other stars of the universe.

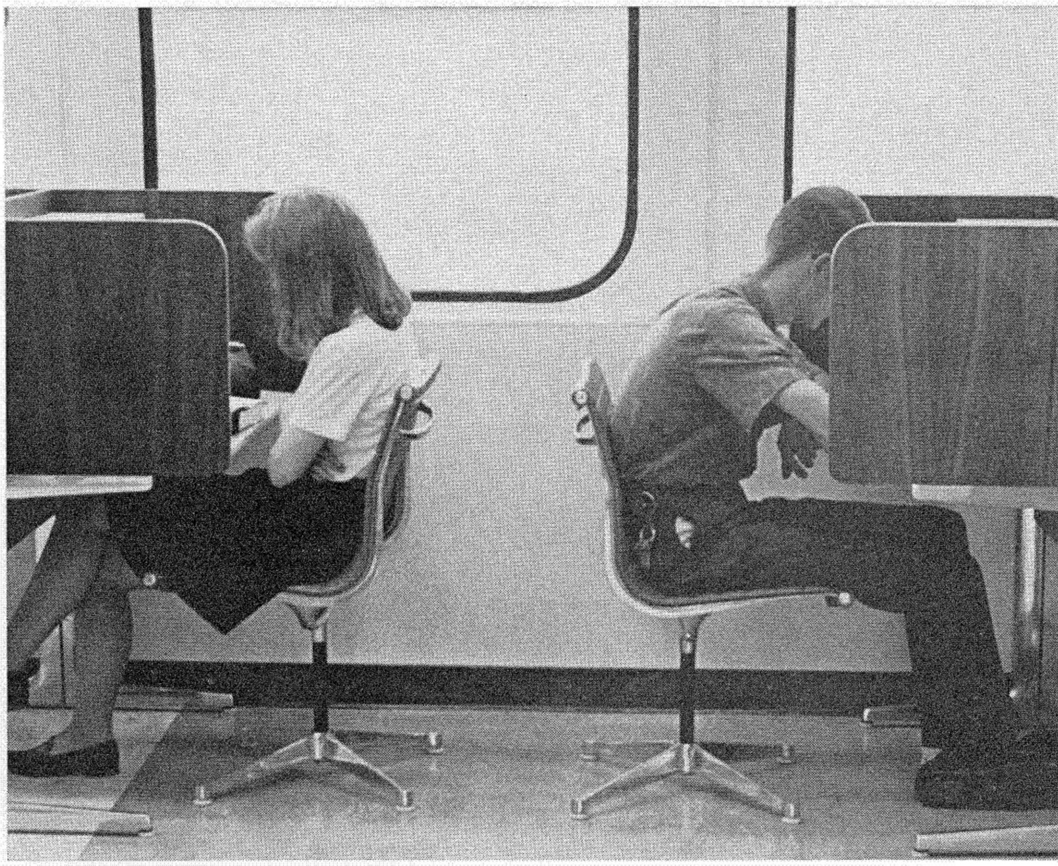
CALTECH'S HIGH-RISE LIBRARY

The first Caltech students to use the new Robert A. Millikan Memorial Library passed through its automatically opened doors this fall to find the facilities finished, furnished, staffed, and ready to use. The nine-story high-rise memorial is now a night-and-day center of academic activity. Every night, including Sundays and holidays, its lighted windows shine over Throop Hall mall until 2 a.m. Elevators carry passengers from the first floor information desk to the upper levels where 181,037 volumes—most of the Institute's collection—are shelved under one roof for the first time.

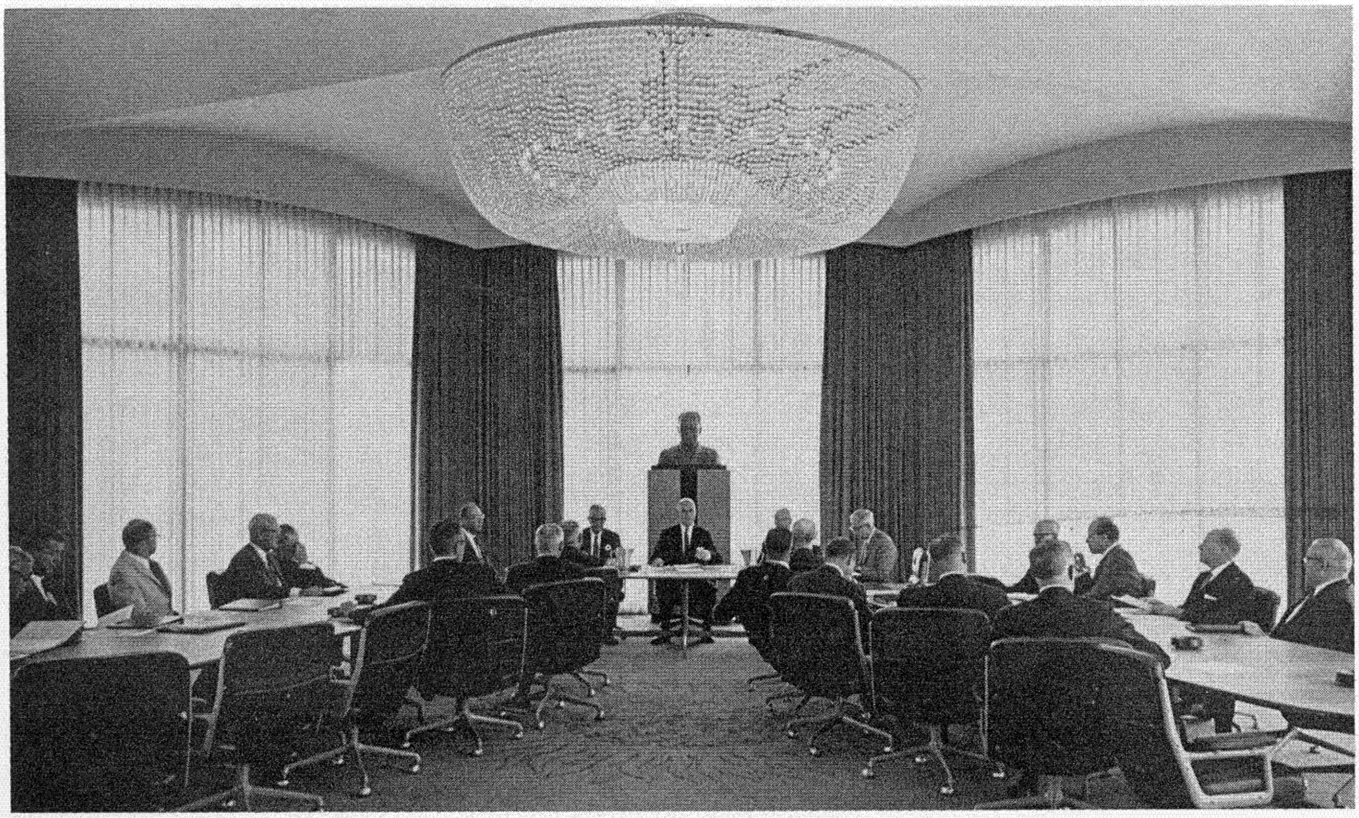
Harald Ostvold, Caltech's director of libraries, surveys his new domain.

INSIDE THE HIGH RISE





The Caltech trustees hold their first meeting in the all-glass, octagonal room especially designed for them.



THE IMPACT OF PROJECT 37

by John E. Sherborne

Project 37 was set up at Caltech in 1927 to investigate the retention of oil by sand. In time the work was directed toward the experimental study of the volumetric and phase behavior and the transport properties of hydrocarbons and their mixtures at pressures up to 10,000 pounds per square inch in the temperature interval between 40 and 460°F.

The project was originally directed by Robert A. Millikan and William N. Lacey and was supported by a grant from John D. Rockefeller and Universal Oil Products. After the first few years, support for the program was transferred to the administration of the American Petroleum Institute.

Bruce H. Sage, professor of chemical engineering, has been director of the project since 1959. He became associated with the work in 1930 when he was a Caltech graduate student and was made co-director with Dr. Lacey in 1942. Working with Dr. Sage since 1938 has been H. Hollis Reamer, senior research fellow in chemical engineering. Many research assistants have aided these two men through the years.

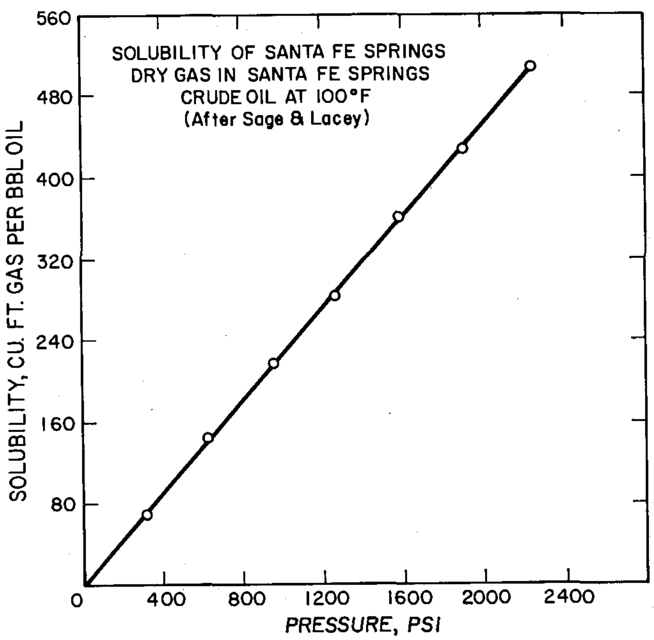
In July 1969, after 42 years of experimental work, this program will be brought to a close. "The Impact of Project 37" records some of the far-ranging effects it has had on the petroleum industry. The article has been adapted from a talk given by John E. Sherborne '34, associate research director of the Union Oil Company of California, on April 26 at a Conference on Hydrocarbon Research sponsored by Caltech's Office for Industrial Associates and the American Petroleum Institute. Mr. Sherborne served as an API research fellow on Project 37 from 1934 to 1936 and was chairman of the API advisory committee for the project for 1952 and 1953.

Oil is currently consumed in the United States at the prodigious rate of 12 ¼ million barrels per day--which is 37 percent of the free world's production. An appreciable part of this production would not be available today without knowledge of the behavior of hydrocarbons under oilfield conditions that has been developed by Project 37 in the chemical engineering laboratory at Caltech.

When Project 37 was initiated in 1927, little was known about the nature of oil-bearing formations and the fluids contained within them. In the early 1920's, Henry L. Doherty, an outstanding petroleum industry executive and engineer, speculated that oil and gas must behave differently in underground

Bruce H. Sage, professor of chemical engineering and director of the American Petroleum Institute's Research Project 37 conducted at Caltech since 1927.

reservoirs than they do at the surface. In response to these speculations, two important studies were made, and the results were reported in the technical literature of 1926.



Graphs showing the solubility of dry gas in crude oil at specific temperatures, such as this one for the Santa Fe Springs reservoir, illustrate early work of Project 37. The cubic feet of gas shown on the ordinate is measured at 60°F and 14.73 pounds per square inch (psi). The oil volume is that which the oil will have free of gas under those same conditions. There is roughly a linear relationship between the gas solubility and pressure for this particular crude oil and natural gas system. This is approximately true for most such systems.

The studies did show that oil and gas properties are not the same under the conditions of temperature and pressure existing in underground reservoirs as they are at the surface. They also pointed out the need for a great deal more knowledge about conditions existing in the reservoir. Project 37 was set up to obtain this knowledge.

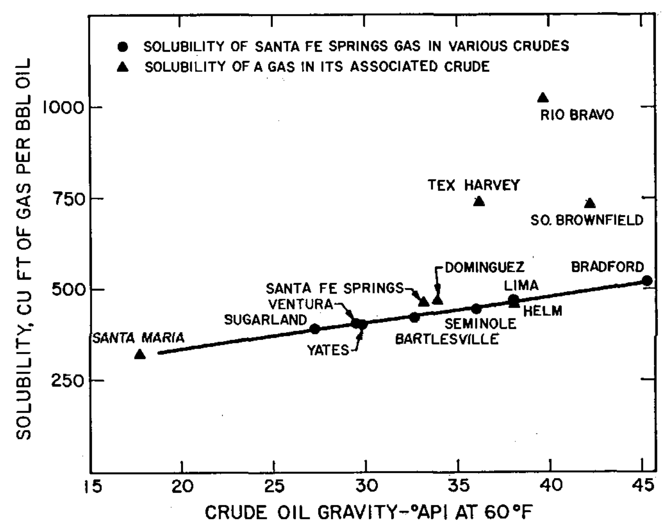
Among the early contributions of Project 37 was the investigation of oil and gas solubilities and the rates of solution of gas and oil at pressures and temperatures much higher than those previously reported. The two graphs on this page show some of the results of this work.

Early work of this sort led to the belief that it would be feasible to treat the petroleum in a producing reservoir as a binary system in which the produced gas was one of the components and the tank oil was the other component. This practice, although far from being scientifically rigorous, has worked very well for engineering purposes and is in current use.

During the early years of Project 37 a number of natural gas-oil systems were studied, and one of the main contributions of the project was the development of apparatus for making such studies. This equipment was eagerly adopted by the industry.

It soon became recognized that because of the large number of compounds present in crude oils and because of the great variation in the amounts and types of compounds in crudes from different fields it would be desirable to study simpler systems. As a consequence, Project 37 turned its attention primarily to the study of pure substances and binary or ternary mixtures of these pure substances, leaving the experimental study of natural systems to industry.

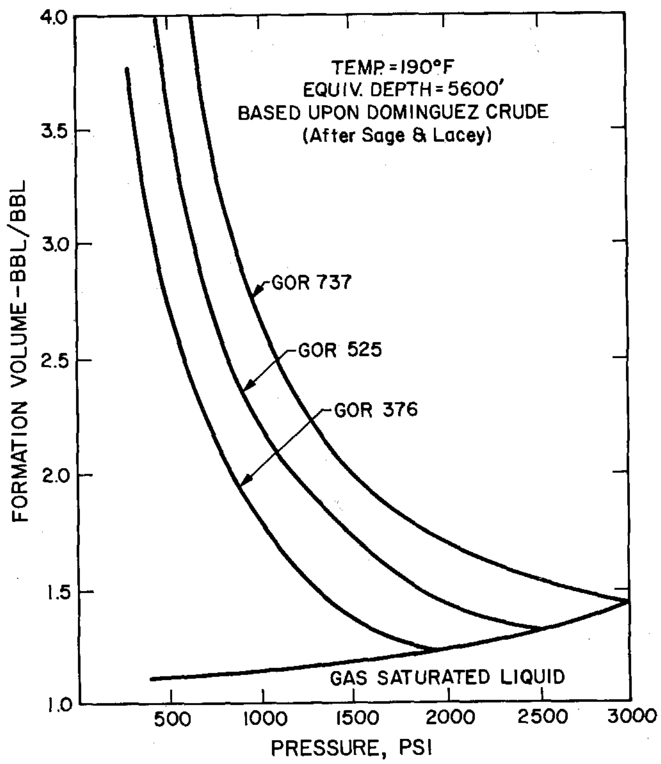
The PVT (pressure, volume, temperature) dia-



Graphs showing the solubility of natural gas in a variety of crude oils, shown here for 100°F and 2,000 psi, show some results of Project 37 research. Solubility of gas in crude oil is largely dependent on gas composition. For this particular gas there is a linear relationship between the solubility and the American Petroleum Institute (API) gravity of the oil at 60°F. However, gases of different composition have different solubilities, as can be seen from the triangles. When the gas is similar to Santa Fe Springs gas, the triangles fall near the line. In general, the greater the number of components of higher molecular weight in a gas, the greater its solubility.

gram below, typical of those first turned out by Project 37 and now in common use in the industry, shows the formation volume as a function of pressure and gas-oil ratio, in this case for a temperature of 190°F.

Formation volume is the ratio of the volume which would be occupied by the oil and its associated gas under reservoir conditions to the volume which the oil itself would occupy at 60°F and at atmospheric pressure.



The PVT (pressure, volume, temperature) diagram, now in common use in the industry, was developed to show the formation volume of the gas-saturated liquid as a function of pressure. In the diagram above, the formation volume, at pressures where both a liquid and a gas phase coexist, is shown for three gas-oil ratios (gor).

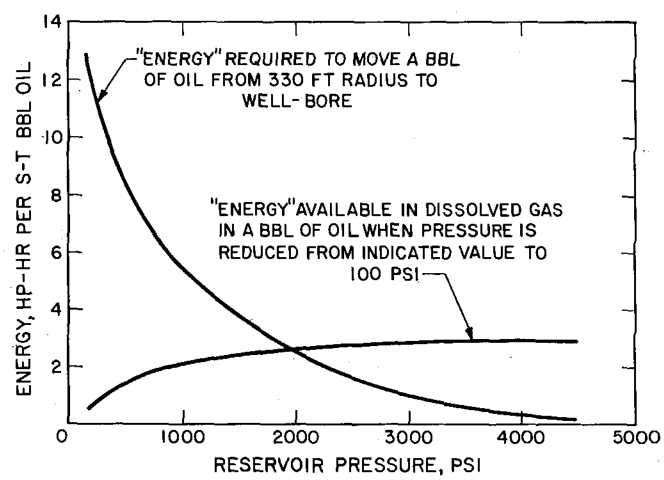
Assuming that the material in a reservoir is at 2,500 pounds per square inch (psi) and there is a gas-oil ratio of 525 cubic feet per barrel, then the material is at the bubble-point liquid condition. At this condition only a trace of gas exists. As material is withdrawn, the pressure declines. The formation volume of this system in the reservoir will follow the line for a gas-oil ratio of 525 cubic feet per barrel, showing an increase as the pressure goes down. The liquid, on the other hand, will decrease in formation volume, because gas is coming out of solution in the reservoir. The volume of the gas soon becomes far greater than that of the liquid, and hence there will be a relative displacement of gas to the well-bore. This will drive liquid with it; however, the producing gas-oil ratio will increase as the volume of gas in the reservoir increases relative to the oil volume.

It was apparent that, with large quantities of gas dissolved in oil in the reservoirs and the change in the formation volume of the oil, significant difference in oil viscosity could be expected. Project 37 was one of the first to produce a range of information on the change of viscosity of oil in reservoirs with pressure, temperature, and gas saturation. This, in turn, led to an appreciation of the very important role played by viscosity in the displacement of oil from the minute pore channels within the reservoir rocks.

At the inception of the project two methods were in use to estimate the quantities of oil available in a reservoir. The first of these, the volumetric method, attempted to define the total oil in place. The second, known as the decline-curve method, was used to help predict the amount of oil which could be economically recovered. These quantities are referred to as reserves, and engineers distinguish between reserves-in-place and producible reserves.

Neither of these methods of estimating reserves was satisfactory, although in 1927 the decline-curve method was the more useful. One fact was clear. There was a vast difference between the amounts of oil estimated to be in place by the volumetric method and that which would be produced as predicted by the decline-curve method. Results such as those produced by the project made it possible to reconcile these differences and to provide means to increase the recovery.

As more information became available, a number of investigators attempted to relate the volu-



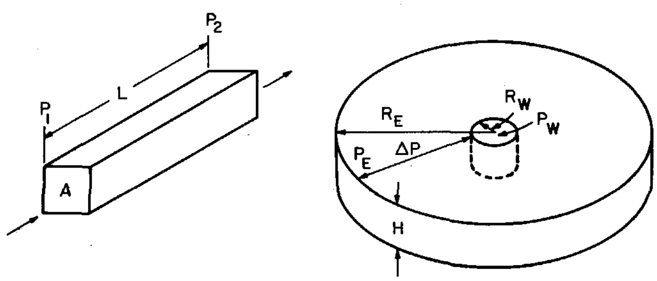
"Energy" diagrams aid in planning the production of oil. The "energy," as expressed in horsepower-hours per standard-tank barrel, of dissolved gas is shown as a function of reservoir pressure. The change in "energy" associated with one barrel of tank oil is plotted as a function of reservoir pressure for a crude oil of moderately high gravity.

metric data to the "energy" associated with the fluids which could be expected to be encountered in the reservoir and in the well-bore.

The significant thing illustrated by the "energy" diagram on page 22 is that, as the pressure decreases, less and less energy is available to drive the oil, and more and more energy is required to move it. By the time the pressure has dropped to 2,000 psi, the oil no longer contains enough energy to drive itself to the well-bore, and the situation rapidly deteriorates.

But "energy" is not the only factor which affects production. Data from Project 37 was also necessary for a quantitative evaluation of the microscopic displacement within the reservoir. The drawings below demonstrate the formula and conditions which pertain to the permeability of a formation for a single phase flow.

LINEAR FLOW　　　　RADIAL FLOW



$$Q = \frac{K \phi A (P_1 - P_2)}{\mu L} \qquad Q = \frac{K \phi H (P_E - P_W)}{\mu \log \frac{R_E}{R_W}}$$

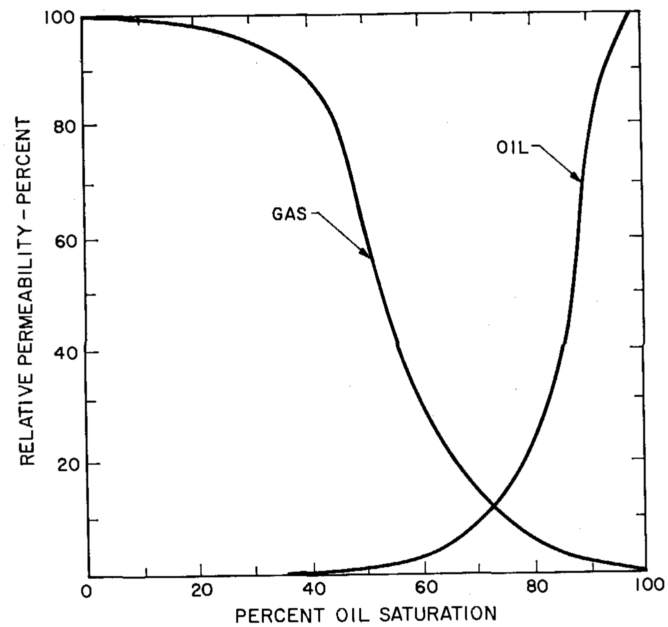
LEGEND

Q = RATE OF FLOW	μ = VISCOSITY
K = PERMEABILITY	P = PRESSURE
ϕ = POROSITY	R_E = DRAINAGE RADIUS
A = CROSS SECTIONAL AREA	R_W = WELL-BORE RADIUS

The effect of permeability is a factor in oil production. On the left is a porous matrix with a single fluid flowing in at A through the conduit and out the other end in a linear manner. While linear flow is important, primary concern in oil production is with radial flow, in which a well-bore is draining an essentially cylindrical drainage volume surrounding the bore, as shown in the drawing at the right.

When two or more phases are present in the pore spaces, it becomes necessary to introduce the concept of relative permeability. This concept may be described as the ratio of the permeability for a given fluid in the presence of other fluids to the permeability which would occur if only the one fluid were present and flowing as a single phase.

It has been shown by a number of investigators that relative permeability can be described as a function of the saturation of the porous medium. Assuming that no water exists in the pore space, then the space is filled with oil and gas, and the relative permeability (expressed as a percentage) is shown as a function of the oil saturation, as in the diagram below.



The relationship of the permeability to the percent of oil saturation is important in the production of oil. Starting at 100 percent oil saturation, as gas is liberated from solution, the permeability to gas is not very great for the first 10 percent of the gas liberated, but this 10 percent has a great effect on the permeability to oil, dropping it to about 40 percent. As more gas is liberated, the oil permeability is reduced to a negligible amount by the time the gas saturation has reached 50 percent, and the gas permeability is increased to within 70 percent of its single phase value.

The presence of a second fluid phase markedly affects the permeability to the other phase. Thus, the flowing gas-oil ratio increases rapidly with increased gas saturation, and the gas quickly becomes an inefficient driving mechanism. In the reservoir, in spite of the increasing gas velocity as pressure declines, most of the oil remains in the formation. In practice, oil recovery by dissolved-gas drive alone seldom produces as much as 20 percent of the oil originally in place. By means of relative permeability data and the associated volumetric data, it is possible to determine what the flow conditions will be at any point in the reservoir as a function of time or as a function of the pressure decline.

The work of Project 37 has thus provided information of great value to the reservoir engineer. It has made possible a quantitative evaluation of the change of specific volume of oil and gas in the reservoir with pressure; it has shown the effect on viscosity of the oil with change in composition under reservoir conditions and on the effect of this oil-gas relationship on the effective permeability.

With such information at his disposal, the reservoir engineer can now determine the maximum efficient rate of operation for a given oil field. Such calculations are routine today. Earlier these calculations led to the recognition that pressure maintenance would be a valuable means to improve the recovery of oil. The use of re-injected gas or water to maintain the pressure at or near the original value has, in many cases, doubled the amount of oil which was recoverable from a formation.

In many cases oil fields are found in which a substantial amount of gas exists as a gas cap above the oil phase. Sometimes the reservoir is so large that a number of wells may be drilled before it is established that the gas cap is in fact associated with appreciable amounts of oil. In the early days, the gas had little value, and great quantities of it were blown into the air to recover the small amount of oil produced from the gas cap.

One might expect that, for the gas cap production, the gas-oil ratio would increase with decreases in reservoir pressure, as it does in the production of ordinary oil. And such expectations are correct. However, it was *not* expected that the original gas-oil ratio for this material would be as high as 20,000 cubic feet per barrel or more, or that the oil would be an almost colorless liquid ranging in gravity from 20° to 60° API. Even more surprising was the observation that, as the gas-oil ratio increased, the gravity of the produced liquid also increased. This behavior was contrary to normal experience since it was accompanied by a pressure decline.

This occurred in so many very large fields that Project 37 was urged to examine the phenomenon. It was in this research that the project made one of its greatest contributions. It was discovered that this behavior was the result of retrograde condensation, the condensation of liquid from a gas associated with a pressure decline. One might expect that much of the liquid deposited from the gas as a result of retrograde condensation could be revaporized if the reservoir pressure could be lowered sufficiently. In most cases, unfortunately, the low pressures required are either physically or economically unattainable. As the pressure reaches very low values, some of the liquid revaporizes and is produced with the gas. However, even if the reservoir pressure were reduced to atmospheric pressure, almost 4 percent of the pore space would still be filled with liquid. In a large reservoir this could amount to many millions of barrels. On the other hand, by maintaining the reservoir pressure at or near the original pressure, virtually no liquid would be lost to the formation.

The fact that the work on retrograde condensation explained what was happening in the reservoir was of great importance. More important still was the fact that such research provided a quantitative means to determine the type and size of the processing plant necessary to perform the suggested cycling operation, as well as to establish the future field performance, and thereby to determine the cost and possible profit of such a venture. Since a cycling operation usually involves a capital expenditure of many millions of dollars and deferred income on trillions of cubic feet of gas (but, if done correctly, commensurate profits), the need for good engineering information is paramount.

The research of Project 37 has not only made it possible for engineers to increase the recovery of petroleum; it has added to the understanding of multiphase flow in the well-bore and pipelines. It has made possible the design of better flow strings and valves. The work has also thrown much light on the conditions under which bitumen and wax are deposited and hydrates are formed—and how to control their occurrence in production equipment as well as in the formation.

The volumetric data allow optimum design of oil-gas separators at the surface and of tank vapor recovery systems. The research has demonstrated the dependence of gas-liquid equilibrium coefficients on composition and has made possible much improved values of these coefficients. Valuable data on the thermodynamic behavior of systems involving hydrocarbons and such compounds as nitrogen, carbon dioxide, and hydrogen sulfide have been obtained. Similar experimental information on systems involving these substances and water has been made available. All of these are of importance in the production of petroleum.

The project's work on non equilibrium behavior and transport phenomena has been of value in better understanding fluid flow behavior. Equilibrium thermodynamic data which have been developed are finding increasing value as the industry turns to thermal methods of recovery.

Finally, the goal of all engineers is to have a neat bundle of graphs, tables, and equations which will aid them in predicting the consequences of a proposed undertaking. The work of Project 37 has materially advanced the development of equations of state for hydrocarbon systems and has laid a firm foundation for others working in this field.

There are many in the industry who feel that Project 37 is by far the most important fundamental research project sponsored by the American Petroleum Institute.

UNIVERSITY-INDUSTRY RELATIONS: A CONFRONTATION OF ANACHRONISMS

by George S. Hammond

"Industrial research is nonexistent."

"University people know nothing about the real world."

"X may not be an outstanding student, but he will burn up the league in some industrial lab."

"The biggest problem of industry is technical obsolescence of people."

"We really need much closer relations between industry and the universities."

Of these statements, only the last, which is no more than a pious sentiment, would have any chance of achieving consensus in both the academic and industrial worlds. For the most part there is little resembling a direct, working relationship between the two systems, despite the fact that neither could survive without the other. Education consumes an ever increasing fraction of our national wealth, and our industries produce most of that wealth. Conversely, it is widely accepted that progressive industrial competence is uniquely dependent upon a sophisticated and dynamic system of education at all levels. Since the two communities are mostly symbiotic and only mildly competitive, a visitor from some other society might wonder at the lack of direct dialogue between them. As a matter of fact, so do members of *this* society. Recently there have been a number of pleas, mostly from industry, for expansion of the scope of university-industry interaction.

What do industries and universities want from each other? The recognized needs are simple: Industry needs graduates, and universities and colleges need money. Unfortunately, most attempts to establish communication are based directly on these commodities and on little else. Regrettably, each group generally regards the needs of the other with contempt and condescension. University faculties still tend to look on students bound for industry as unfortunate fellows headed for a life of weary prostitution. Although individual industrialists may be personally dedicated in their support of specific institutions, the corporate view usually is that a little money doled out to support education may help the recruiting program and comfort a few consciences. Although these basic needs are not base, they are one-sided enough to become tedious fare for sustained conversation.

There should be much more substance to relations between industry and academia. Both are concerned with harmonious integration of the activities of large numbers of people; they need to evaluate and translate new ideas and new information; and they are eternally plagued by obsolescence of methods and products. Problems in the two communities are far from identical, but they are sufficiently related to generate a host of common interests. For the most part, this potentially broad base for discussion is rarely exploited.

A principal impediment to discussion lies in the reluctance of both academicians and industrialists to discuss their problems in a forthright manner. Within the privacy of their own organizations they grumble and brood over problems in human relations, information storage and retrieval, the lack of effective internal communication lines, the unruly and restive attitudes of employees (or students), and the conservative character of management (or the administration). However, in public both groups pretend that their problems are really superficial or nearly solved. Only rarely does one hear public confession by an educator that many university courses are badly outmoded—not just the methods of presentation but the actual content of the courses. Similarly, industrialists rarely discuss in public the fact that middle-level management is often in an untenable position, only vaguely aware of the objectives of the company, and barely able to discuss intelligently any nonroutine activities of its subordinates. The fact is that both industry and education are in need of major changes in their internal practices. They are saddled with stultifying traditions and are ashamed to discuss their problems outside their own walls. Since there are many interesting parallels in the problems, stimulating and novel suggestions for change might come from serious discussion.

An especially fertile field for interaction exists between technologically based industries and university research in science and engineering. Even in such a natural area, exchange of ideas is often desultory. I have the impression that interaction is better in relatively new fields, such as modern electrical engineering and space exploration, than in older fields, such as chemistry and geology. As a field becomes older, intercourse between universities and industry becomes more trivial. The two groups become set in their ways and really disinclined to make significant changes for any reason. They are especially loath to change their images of each other. Academicians tend to regard industrial researchers as a grubby lot of fellows who build better mousetraps to make a buck. They also have a strong suspicion that most industrial scientists have become intellectually soft and have little ambition to expand their competence by acquiring new ideas. The reciprocal sentiment of the industrialists is that university research is a game in which the researcher writes his own rules. A cardinal principle of the game is the premise that an observation becomes more fundamental as it becomes more difficult to relate to anything else. Industrial employers often criticize recent graduates on the grounds that students are now taught nothing of practical significance. The critics usually have in mind the good, solid material that they themselves learned in school 20 years ago. The same people are likely to gripe because the men in their laboratories are unable to keep up with the trends of modern science.

One reason for the persistence of such uncomplimentary impressions is the fact that they all contain a fair measure of truth. In a well-established field, academic scientists have a tendency to fasten onto old problems and solve them over and over again. Each round of investigation is designed to strike closer to the heart of some fundamental question, with the "heart" being defined as whatever happens to lie on the line of the thrust. In an entirely analogous manner, most industrial research really is aimed at improving some mousetrap by one percent.

Now there is nothing necessarily evil in research that lacks striking originality. Refinement of theoretical concepts by redoing experiments with minor modification is desirable and sometimes leads to important new concepts when people occasionally quit trying to force persistent deviations to fit existing theory. Similarly, slow improvement of industrial products and processes is not to be scorned. After all, the Stanley Steamer evolved into today's automobile by small, slow steps. However, discussion of the work may become dull rather rapidly. A matter that is properly of continuing concern within a university or industrial laboratory may not provide a basis for viable dialogue with an outsider.

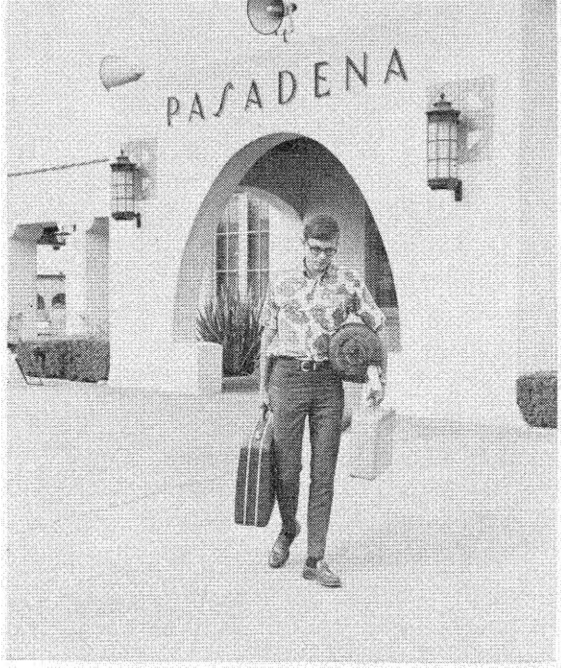
The failure of scientific discussion at the university-industry interface is only an example of a general problem. Scientists in old fields do not talk to each other. It is not uncommon to find that members of two different research groups within a given laboratory do not communicate at all. They speak different languages and will sometimes maintain they have fundamentally different kinds of brains.

Breaking the scientific communication barrier should be relatively simple. All that is required is to relinquish the foolish notion that one can talk science only by relating all the minutiae of his own work and thoughts. Astronomers seem to do especially well in discussing their work with other scientists and with the public. Although astronomers make fantastically precise measurements and work with complex mathematical models, I have never heard an astronomer attempt to relate such details of his work. I suppose that they do talk to one another in a private language, but they also have the grace to describe their most treasured observations and their grandest theories in common language.

Other men of science and technology should be able to do as well as astronomers. Why don't they? There are many reasons. Hardest to admit is the possibility that some "scientists" have never made a significant observation and have never understood a grand theory. Such a man is likely to be very comfortable hiding behind jargon and the notion that his work is too complex to be understood by ordinary mortals. Anyone who takes this view is almost certain to accord the work of a man in another part of his own field with the same sacrosanct respect. If the two men are an industrialist and an academician, they will begin any conversation with the tacit agreement than any real attempt to understand one another's work would be an affront to good taste.

At this point the industrialist may feel rather smug; after all, what can be more direct than the statement, "I am after a better mousetrap." But this is an illusion, and any industry that is engaged merely in a random hunt for better products will not survive long. The real job of the industrialist is to describe the models used to guide his search. This can be difficult and may lead to an embarrassing denouement. Some so-called scientists work with no model at all but are guided by a kind of experimental ritual. Others are unjustifiably ashamed of the simplicity of their models, even though they may be very effective. In any event, the model is usually made thoroughly incomprehensible by use of sophisticated language laid on merely to effect scientific respectability.

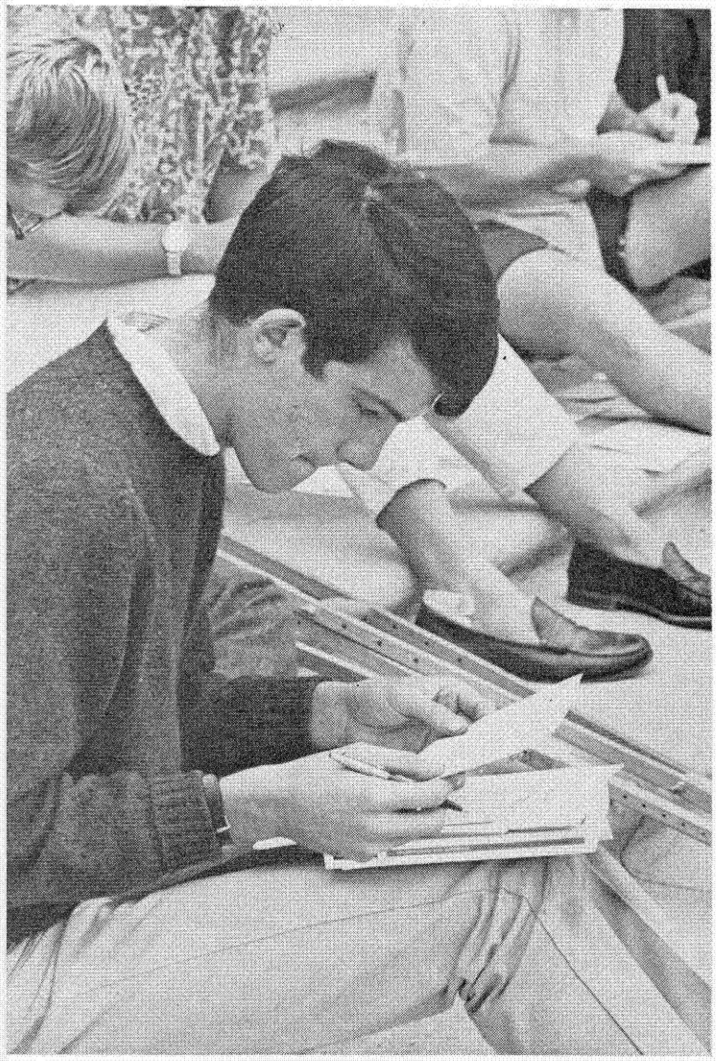
If scientists in universities and industries are to communicate, they must (1) develop more intellectual honesty, (2) strive to use language designed for communication of ideas rather than details, and (3) listen with the *intention* of understanding. When they can do this they will breathe more life into the relationship between the two communities. Unless I am sorely mistaken, the passage of students and money from one community to the other will also be accomplished far more graciously.

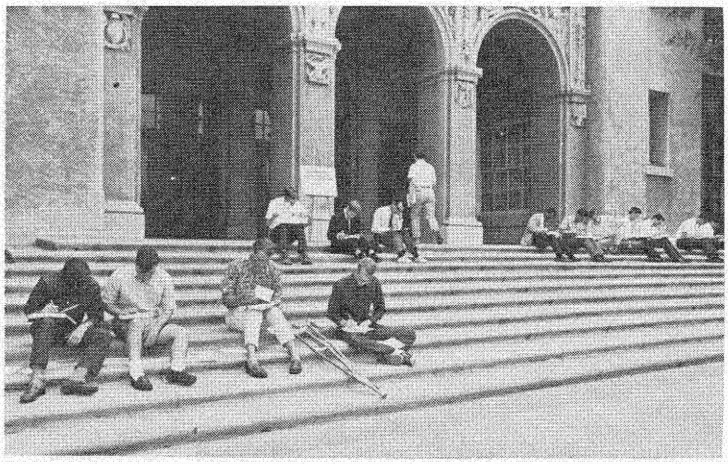


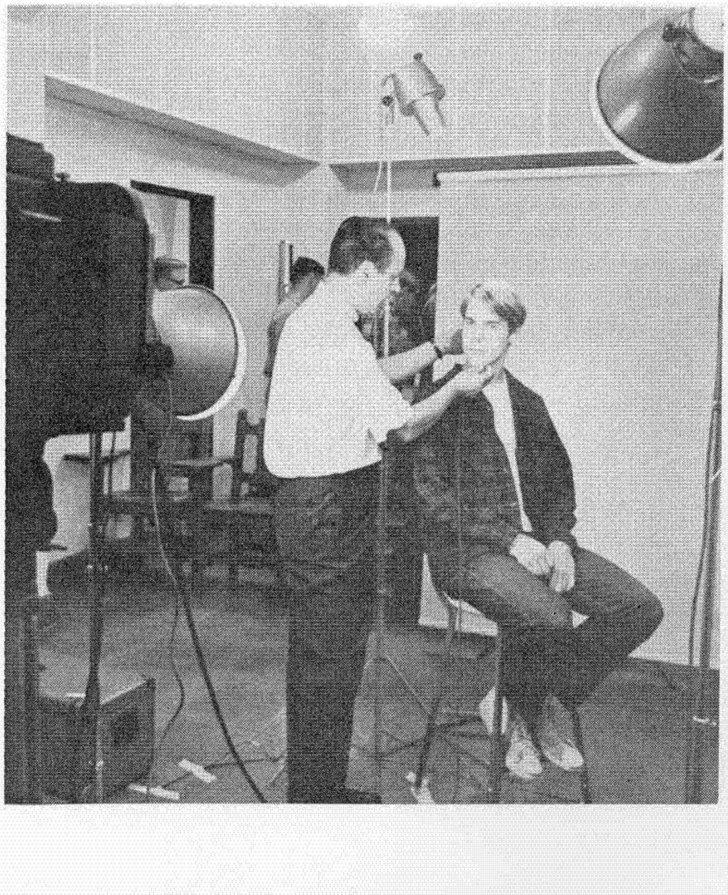
THE

EARLY DAYS

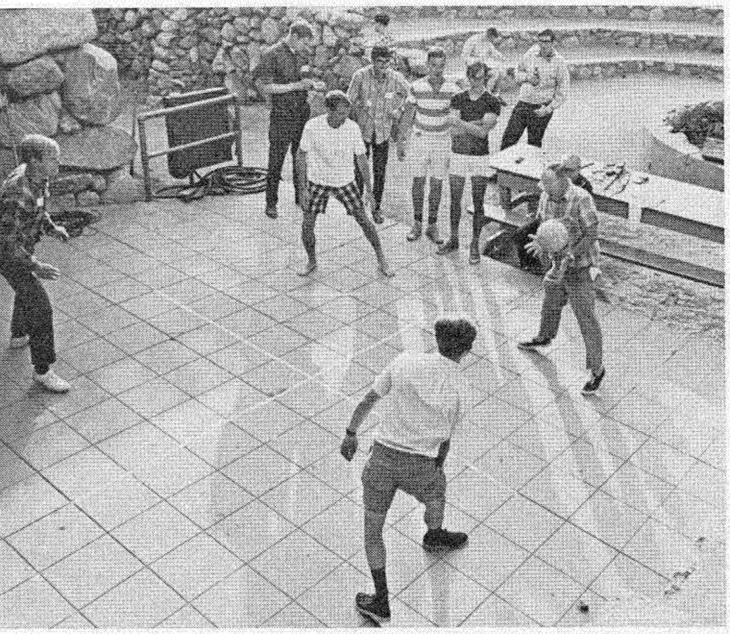
OF THE CLASS OF '71

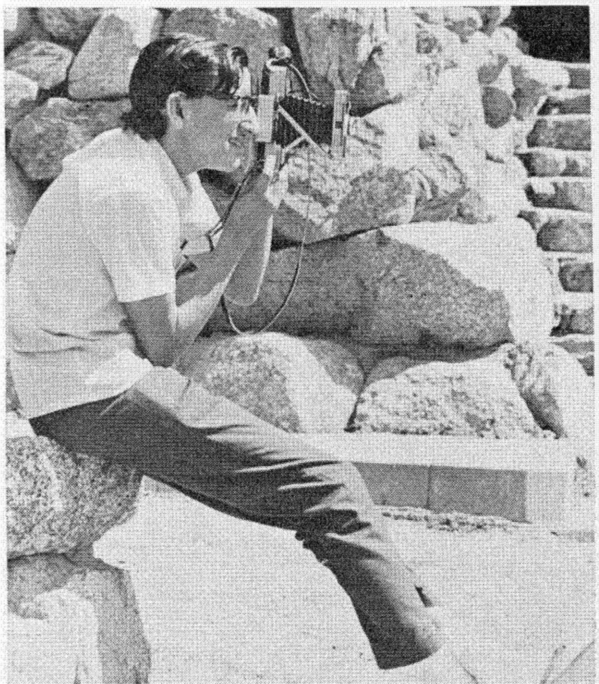


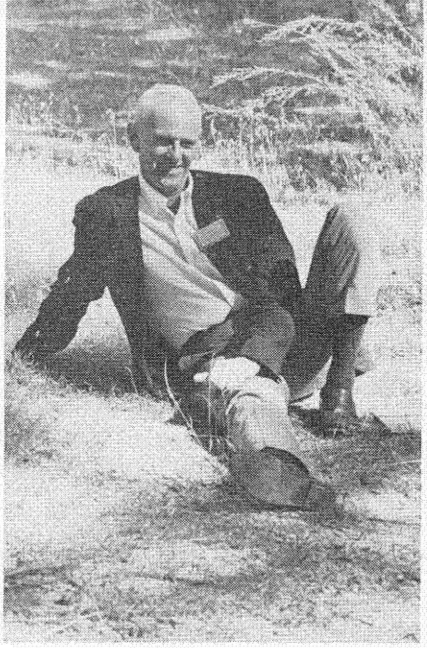




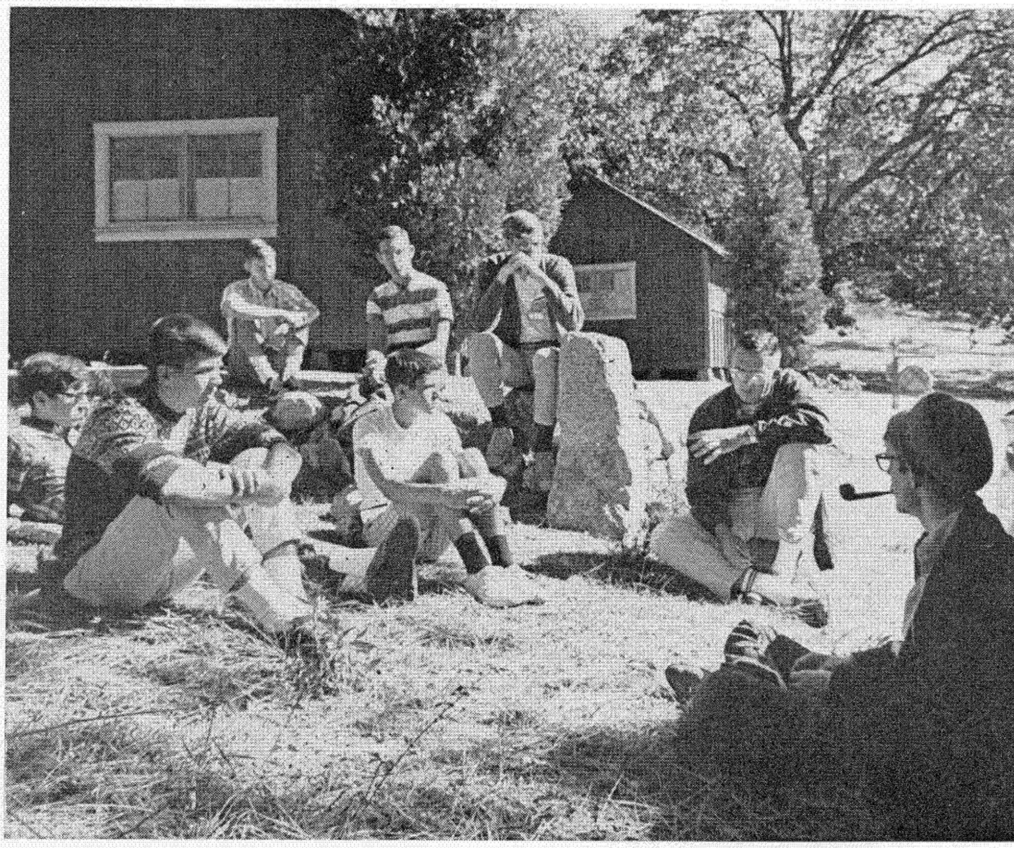
To ease freshmen into college life, after the rigors of registration (below), Caltech packs its newcomers off to Camp Radford for three days in the San Bernardino mountains. There they have a chance to meet faculty, upperclassmen, and each other, and to gain some insight into what lies ahead.

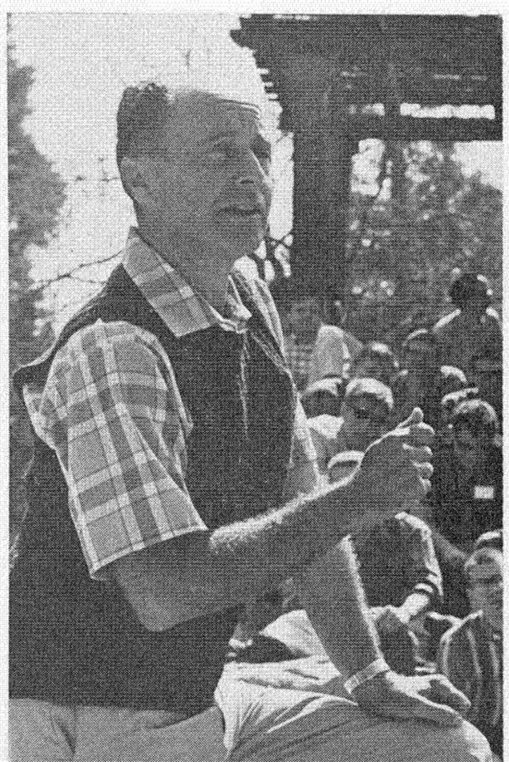


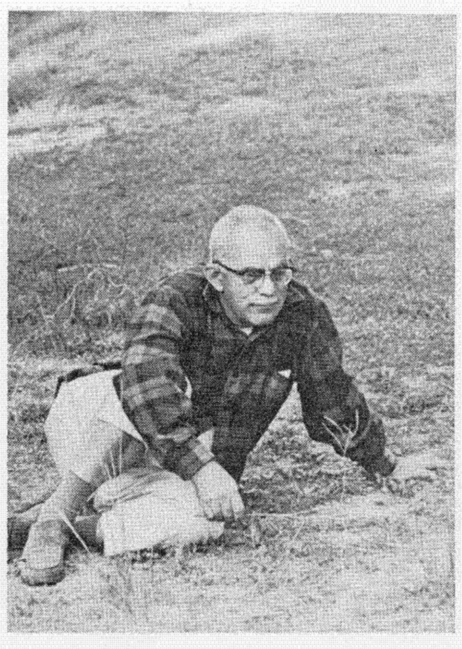


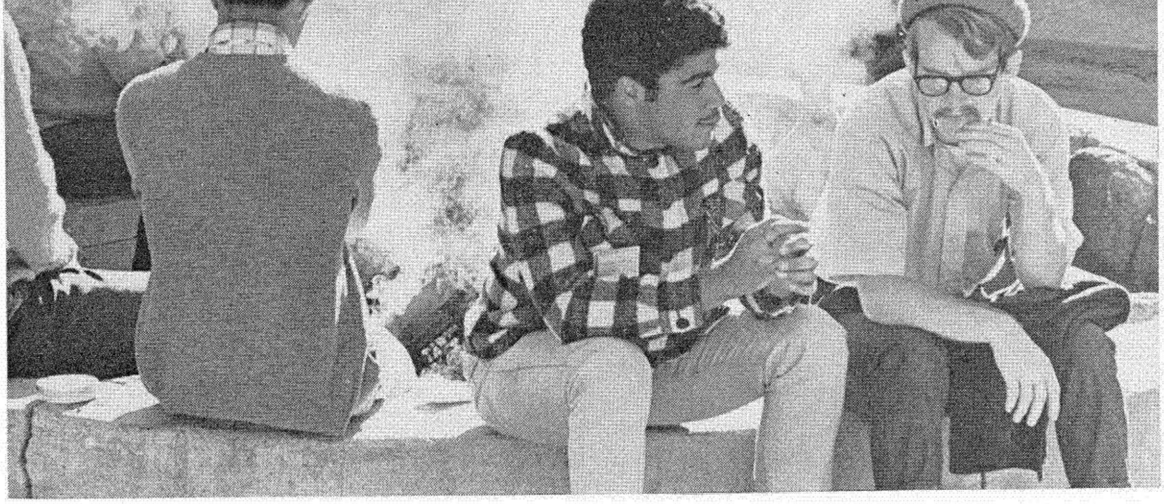


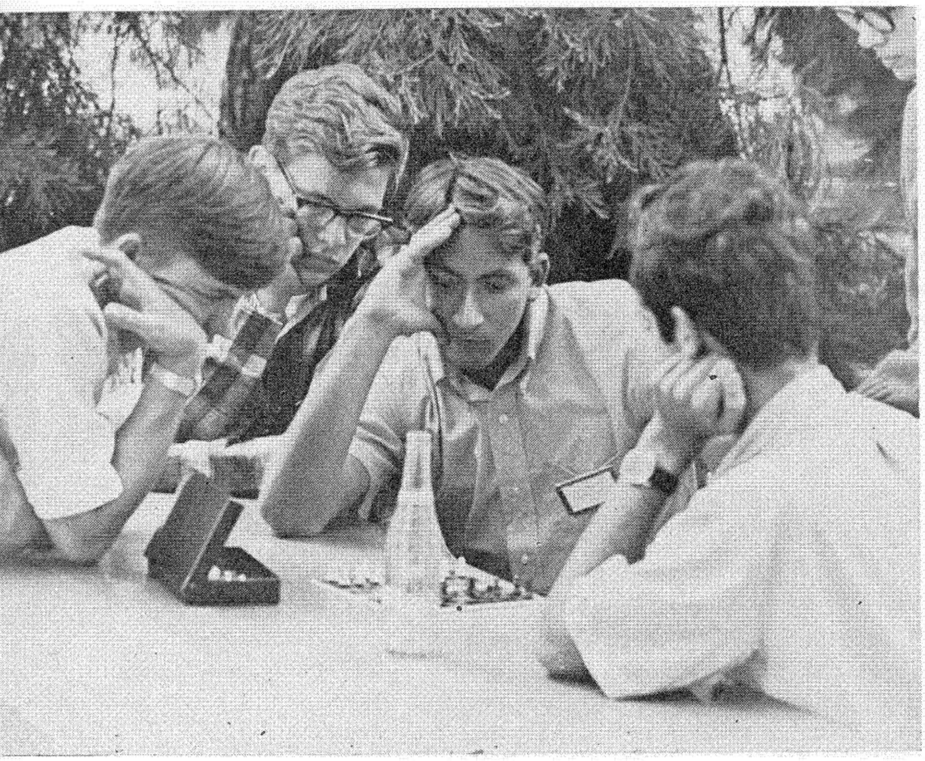
Engaged in informal discussions with the freshmen at Camp Radford are, counterclockwise from upper left: Peter Miller, lecturer in English and associate director of admissions and undergraduate scholarships; Robert Huttenback, professor of history and master of student houses; Peter Fay, associate professor of history; Norman Davidson, professor of chemistry and executive officer for chemistry; Wes Hershey, executive secretary for the YMCA; and William Corcoran, professor of chemical engineering and executive officer for chemical engineering.

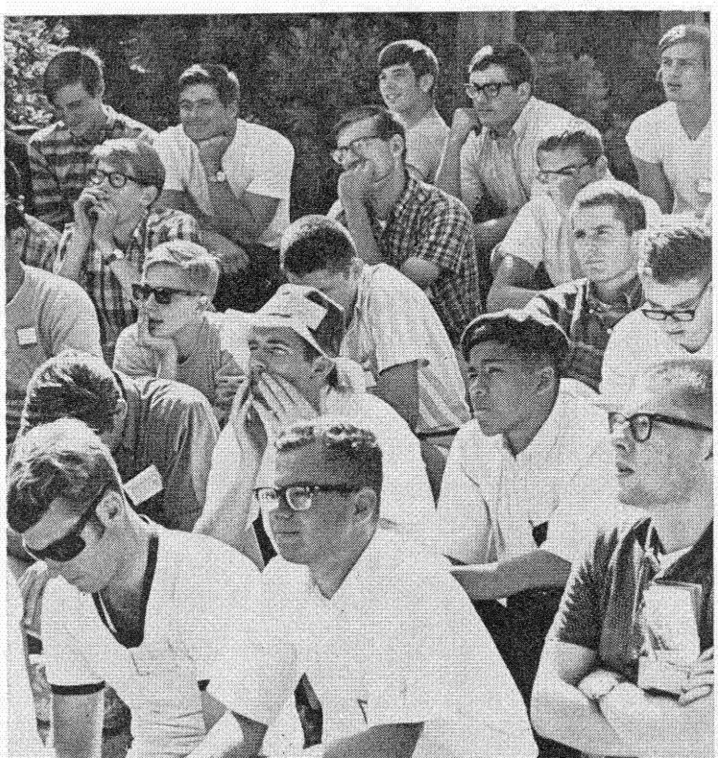


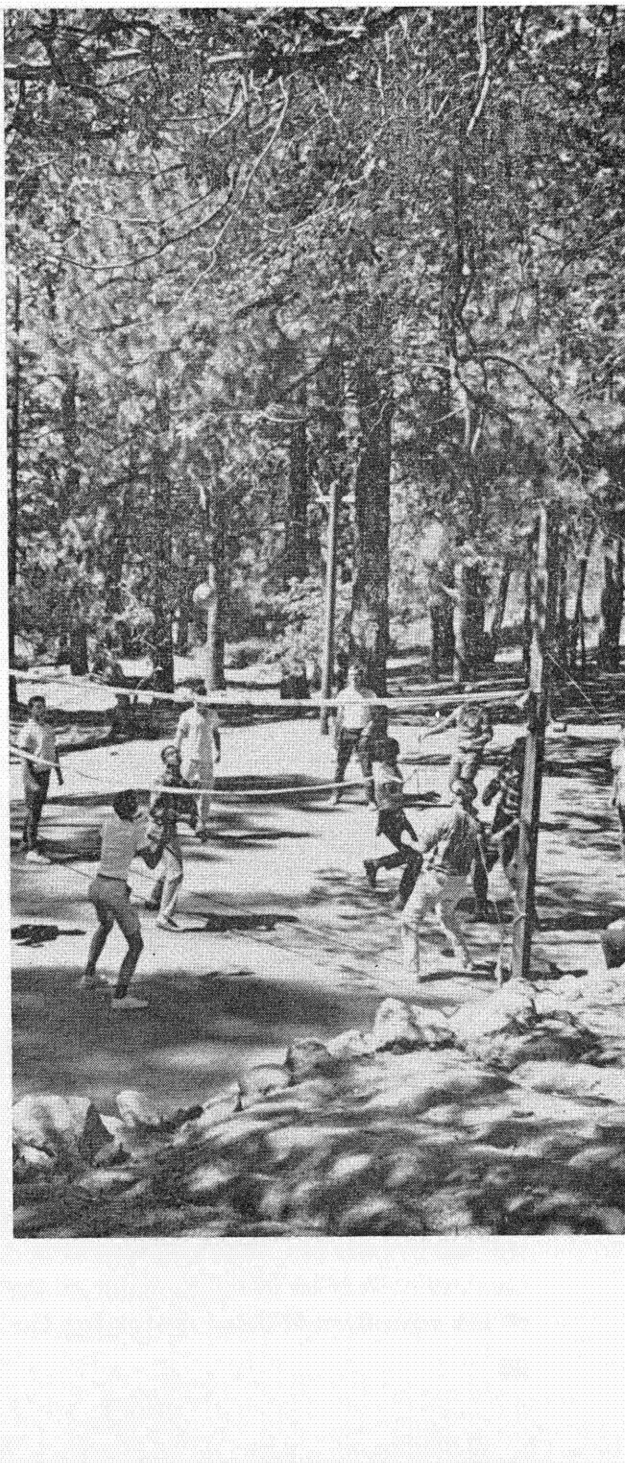












THE REVOLUTION

More than 400 people filed into Beckman Auditorium on the afternoon of April 19 for a general membership meeting of the Associated Students of the California Institute of Technology Corporation. ASCIT had not called a general meeting for years, and the number of undergraduates and faculty in attendance indicated special interest in the agenda.

Members of the student body had assembled to vote on four resolutions concerned with academic reform. As Joe Rhodes, newly elected student body president, explained, ASCIT had traditionally concentrated on athletic awards, finances, and decorations for dances. Now it was attempting to become more relevant to the individual student by representing him in more vital areas.

The ASCIT meeting and the events that led up to it have become known as "the revolution." Its grass roots were in the student houses and the coffee house, wherever groups of students got together to discuss Caltech. The seeds, however, had been planted almost entirely by one person—Joe Rhodes.

As a freshman, Joe's job as ASCIT activities chairman had earned him the reputation of being an exceptional student organizer with unlimited enthusiasm. He ran the student talent show and supervised the completion of the coffee house. When, as a sophomore, he decided to run for ASCIT president—a move which required amending the ASCIT constitution—the student body responded by electing Rhodes by a large majority.

As student body president, Joe was in an optimum position to find out how many students thought, as he did, that the undergraduate environment needed significant improvement. He hoped that he could stimulate students to critically examine Caltech's basic educational policies.

Most students agree that Caltech provides the most intensive technical education available anywhere. Some think, however, that the education is so intensive that it stifles enthusiasm. It forces too many students to "leave" Caltech, either by transferring to another school or by turning into a "Caltech hippie"—turning on to school work, tuning in to abstract technical concepts, and dropping out of everything else.

Many outstanding graduates have been produced at Caltech. But many graduates feel that they learned *in spite of* Caltech, as well as *because* of it. Can't some way be found to maintain the intensity of the education without destroying the student's enthusiasm? Can't Caltech do more to encourage the wealth of creativity in her students, instead of just teaching them to be competent?

BALLOT

1. The Associated Students propose that the Institute
   a) reduce the number of required courses
   b) eliminate the requirement for choosing an option
2. The Associated Students propose that an Academic Reforms Group of students and faculty be formed, consisting of the following groups: Leaders Group, Coordinating Group, Instructions Systems Group, Educational Exchange Group, Research Conference Group, Undergraduate Research Group, Advisors Systems Group, Teaching Techniques Group, and an Options Group, which would investigate into the possibilities of having a general science option and a combination of options. Each group will give a report by June 1, 1967.
3. The Associated Students propose that the students have a one-third representation on those committees concerned with student and academic life, such as Academic Policies, Freshman Admissions, Institute Assemblies and Programs, Relations with Secondary Schools, Undergraduate Student Housing, Undergraduate Student Relations, Upperclass Admissions, and *ad hoc* Divisional Curriculum Committees, and all other relevant *ad hoc* committees. The student members on the two Admissions committees will be liaisons (non-voting members), and the students on the other committees will be voting members. These students should be selected by the faculty from a list compiled by the ASCIT Board of Directors from those who have applied for positions.
4. The Associated Students request a faculty, a grad student, and an undergraduate student liaison (non-voting member) on the Board of Trustees.

Rhodes suggested a way to accomplish these things: Treat the undergraduates with more consistency. Students live in a very "laissez faire" extracurricular environment at Caltech. Few rules govern student behavior—so few that the Institute gives the impression that it is only concerned with the academic growth of the student, leaving him to grow socially and emotionally as he pleases.

This philosophy of letting the student decide for himself could easily be extended into the academic area. One merit of a small school is its ability to tailor the academic program to fit the individual student. Clearly, Caltech fails to capitalize on this ability. The uniform course structure could be deemphasized, leaving a curriculum flexible enough to respond to the individual student. For example, all freshmen are enrolled in a physics class which covers the *Feynman Lectures* at the rate of two chapters a week. Certainly not all students get a lot out of freshman physics when they have to cover it at such a hectic pace. Some students could be allowed to spend a little less time each week on physics and a little more in something else. Conversely, if a freshman was really thrilled by the big red physics book, it would do little harm to excuse him from one of the two weekly chemistry labs, giving him more time to pursue some of the side topics suggested by Feynman.

Research opens up other possibilities. One of the advantages of attending Caltech is the opportunity for undergraduates to do research or lab work. Currently this must be done above and beyond course work, when in some instances it could provide a profitable substitute.

Of course, not all students are in favor of making such changes in the academic program. They express varying degrees of hesitancy—and a few are opposed to any change at all. Two significant reservations seem to appear over and over again.

First, some students feel that undergraduates are not mature enough to decide for themselves how they will fulfill their academic responsibilities and, therefore, they welcome the Institute explicitly deciding for them. Second, some students raise the objection that these reforms would make Caltech a "trivial" school. They see a less-structured curriculum as a means for letting students get away with less work.

Despite these objections, student response to the idea of a change was generally favorable, and when ASCIT drafted specific resolutions and presented them at the April meeting, everything passed except the resolution to abolish the requirement for choosing an option.

Faculty reaction to "the revolution" was varied. A number were pleasantly surprised that Caltech students had actually worked themselves up over something. Some favored at least the spirit of the thing, claiming that students *should* be concerned about the educational process. But a great many faculty couldn't see why students wanted representation on faculty committees. Committees, they said, demanded hard, time-consuming work, and participation would be an added burden to students. Jesse Greenstein, 1966-67 chairman of the faculty, pointed out that the board of trustees had given the faculty complete control of educational policy and that putting students on committees would upset this arrangement and, probably, the trustees. He suggested "collateral non-voting committees" as a compromise.

Students gave two reasons for requesting membership on faculty committees. First, it would involve them in Caltech on a planning level, encouraging a maturity and responsibility which, it was hoped, would extend back into undergraduate life itself. Second, it would establish formal lines of communication between faculty members and students. Faculty insist that their office doors are open and that they are dismayed because few students drop in. So they resort to discussing academic changes predominately among themselves.

Dr. Greenstein had further reservations about "the revolution." He labeled the proposed changes "massive," and thought it would take many student generations to implement them. He pointed out that, since a student spends only four years here, his outlook must necessarily be short run. Dr. Greenstein also thought that only Joe Rhodes and a few others were generating all the excitement. He still saw the usual detachment and lack of concern among a large portion of the student body.

In the final analysis, however, Dr. Greenstein sees the same problem with undergraduate life as Joe Rhodes—it needs to be "humanized." He just doesn't see academic reform as a means to this end.

The faculty has approved two reasonably significant changes since the student vote last spring. Students now have essentially free choice in selecting humanities courses. Only two requirements remain: A student must take at least 120 humanities units in four years, of which 27 must be in English; and sophomores, juniors, and seniors can now elect to take one pass-fail course per term outside their option.

Meanwhile "the revolution" will probably continue to push its way into other areas. Rhodes is now thinking about a major research project, involving many undergraduates, which would deal with a social problem that requires a thorough technical background. Two problems already suggested are a research project on air pollution, and technical training of minority-group individuals. The student revolution will probably also tackle student house problems. Great changes in the living arrangements may be attempted in the hope that the houses can be transformed into more desirable places to live.

If it is to succeed, "the revolution" must be a revolution of Caltech students against themselves more than against Caltech as an institution. The undergraduate environment can change only as student attitudes and student modes of behavior change. The Institute, however, *can* provide the incentive and begin to encourage a healthy new climate. The result could make Caltech a very different but an even better place to get an education.

—Barry Lieberman, '68

HARVEY EAGLESON

1899 - 1967

A tribute by J. Kent Clark

When Arthur A. Noyes, Robert A. Millikan, and Clinton Judy recruited from Princeton a bright young PhD named Harvey Eagleson, they must have thought they were hiring an English professor. Certainly nothing in his official dossier could have indicated otherwise. His record showed a BA in English from Reed College, an MA in English from Stanford, four years of service as English instructor at the University of Texas, and finally a PhD in English from Princeton, with a dissertation on the medieval metrical romances. But the record was deceptive, and his employers were mistaken. Instead of an English professor they were getting an institution, an attitude, an anomaly, and 38 years worth of legend—a legend which did not end with his death in July.

Perhaps Harvey Eagleson's career at Caltech (1928-66) can best be described as a long series of paradoxes. His presence at Caltech was a paradox in itself. He never had the slightest use for science, which he considered a complicated bore. Furthermore, he regarded a career in science as a commitment to monotony—something like a life sentence in a jute mill. Where most of his humanities colleagues admired science and followed its achievements with interest, Harvey ignored it and hoped it would go away. On the other hand, he was devoted to his scientific colleagues, to the student body, and to the Institute as a whole. As the long list of his beyond-the-call-of-duty activities shows, no faculty member ever spent more time and energy in promoting the interests of the school.

Oddly enough, with his distaste for science, Harvey turned out to be a genius at selecting students for admission to Caltech. In interviewing applicants, he developed an uncanny knack for picking out the ones who would successfully complete a Caltech career. This knack, which was the envy and despair of his colleagues on the admissions committee, he explained very simply: "I can tell by their shoes." Just how he could judge success at Caltech by looking at shoes he never adequately explained.

Harvey never considered himself a scholar in the ordinary sense of the term. He used to boast to his colleagues that he was the only college professor who was unable to read his doctoral dissertation. The dissertation, he explained, was written principally in Middle English, which he could not remember, and on a subject he no longer cared about. He once summarized his scholarly career with the wry statement: "When I came to Caltech, I used to explain Gertrude Stein and T. S. Eliot to Clinton Judy. Now the new boys in the division explain Ginsberg and Ionesco to me."

In spite of his disclaimers, however, Harvey did a creditable amount of scholarly work. Besides co-editing three textbooks, he contributed significant articles in novel and poetry criticism, in graphic arts and costume design, and in American cultural studies. More important than his published work was the range of his reading and the wealth of critical comment he passed on to his students and colleagues. An enthusiastic student of the novel, particularly the modern novel, he was probably as well read in this area as any other man of his time. As a critic, he was incisive, perceptive, and individualistic. He was sometimes wrong, but he was never confused. *King Lear*, which many critics regard as Shakespeare's greatest play, Harvey considered the greatest dramatic monstrosity in the language.

Huckleberry Finn, often regarded as the great American novel, Harvey characterized as a trivial, silly bore. On the other hand, he had nothing but praise for *The Scarlet Letter,* which his colleagues regarded as a specific against insomnia.

Possibly his most remarkable literary feat occurred during the 1930's. Along with his friend Roger Stanton, he was assigned by Dr. Millikan the task of producing classical comedies for presentation by the student drama club. This involved translating the plays of Plautus and Terence, among others, into actable and speakable dramatic scripts. The task was immeasurably complicated because the final results had to meet the high moral standards of Mrs. Millikan. Eagleson and Stanton not only survived the moral-turpitude test but managed to produce some lively entertainment. Alumni still reminisce about the productions. A few years back one of them sighed: "I haven't been really happy since I was dressed up in a toga and leaping over the candles in Culbertson."

Although Harvey was primarily a literary man and although he accumulated books until they almost crowded him out of his office, his real passion as a collector was for Japanese prints. This taste, stimulated by a visit to Japan in 1932, resulted in an elegant collection which eventually included 101 prints. The collection was noted, even in Japan, for its rich holdings in the work of Hiroshigi. Harvey extended it from its intended 100 to 101 when he was able to acquire Hiroshigi's self-portrait. Ultimately he donated the entire collection to the Los Angeles County Museum.

The greatest paradox of Harvey's career was his devotion to and influence upon the students at Caltech. In approach, personality, and training, he was practically the anti-type of the traditional "Techer." Artistic in temperament, conscious of clothes and design, something of a gourmet, very much an Ivy Leaguer in manner, he seemed the man least likely to succeed in the student houses or in a Caltech classroom. Moreover, his unavowed aim of turning Caltech men into sophisticated, culturally oriented, verbally adroit men of the world seemed barely attainable. But contrary to all antecedent probability, the combination of Eagleson and the Tech men clicked immediately. It soon became hard to tell whether he had adopted the students or the students had adopted him. He was rechristened "Doc" and established as friend, counsellor, social arbiter, and wit-in-residence to the Caltech student body. He also became one of the most popular and stimulating instructors ever to meet a Caltech class.

During his long alliance with the students, Harvey spent 12 years (1931-43) as resident associate of Blacker House and two years as Master of Student Houses. Blacker House, incidentally, still carries on the yearly tradition of "Doc's Party"—an entertainment which Doc Eagleson invented. When he left the houses and moved to his apartment in South Pasadena, the social contact between him and students hardly lessened; it merely changed grounds. Besides receiving visitors from the houses, he instituted a seminar that was held in his apartment. This seminar, listed officially in the catalog as English 8, was known to the humanities division as "Eagleson 1" and to the students as "Beer and Cheese." It was looked upon as the grand prize for the literate and the deserving. The success of the undergraduate seminar led, at the urging of his

Harvey Eagleson . . . *continued*

alumni friends, to an alumni seminar. This also became famous and was expanded to include wives. It combined his noteworthy skill as a host with his enthusiasm as an instructor.

It should be mentioned that, although Reed College had cured Harvey of the pass-fail grading system and made him a passionate believer in letter grades, he was a notoriously easy grader. A "C" from Doc Eagleson was something like an official reprimand, and a "D" a nudge toward Camarillo. When chided by his colleagues for this soft spot in Caltech's reign of terror, he said: "What can I do? They're so good I have to give them A's and B's."

Part of the secret of Harvey's influence at Caltech lay in his transparent honesty and complete individuality, along with his fine flair for the dramatic. In an age of organization men, he was an original and confirmed nonconformist; in a culture full of fakes, he was a genuine article. Stories about him abound, and he is well remembered even by people who didn't know him personally. Some alumni recall, for instance, one of his lectures at student camp. Reclining on a camp cot, he delivered a disquisition on the evils of Physical Education. Others remember him as a master of ceremonies, or as a story teller, or as the center of a party. Recalling Harvey Eagleson at a party, incidentally, is particularly easy to do, since for years a party at Caltech—student or faculty—was hardly complete without him.

In retrospect, it appears that Harvey had a special talent for friendship. Although he considered himself the prince of all cynics, much more like Scrooge than Mr. Chips, he was in fact remarkably kind and considerate, with a deep interest in the people around him. He enjoyed his friends at least as much as they enjoyed him. They became, in effect, members of his family. Characteristically, his greatest complaint about the ill health that troubled his last few years was that it weakened his rapport with the students, spoiled social engagements, and put him out of touch with his friends.

One is tempted to close a sketch of Harvey Eagleson with the statement that they are not making professors like him any more and that Caltech will never have another one. But no friend of Harvey's could make such a statement without blushing. Although it is undoubtedly true, it would have made Harvey himself groan in protest. A lifelong enemy of Victorian sentimentality and Romantic nostalgia, he would never have held still for such slush. In fact, one can be reasonably sure that he would have despised any memoir of Harvey Eagleson—including this one.

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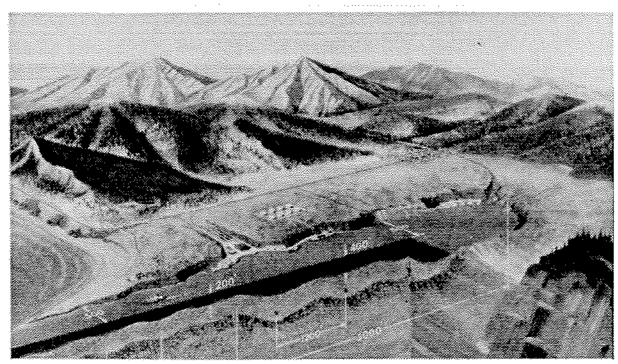

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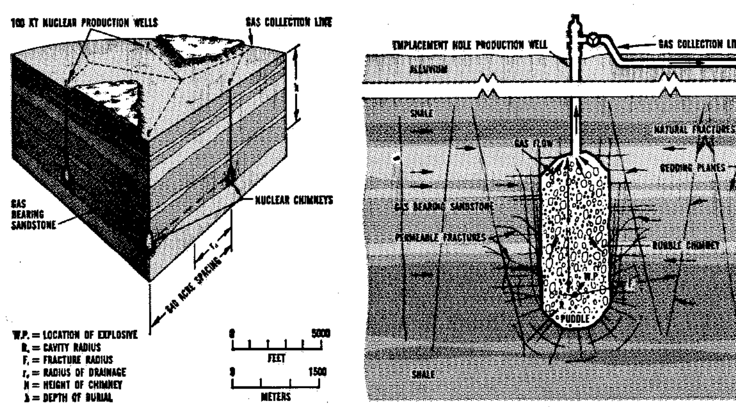

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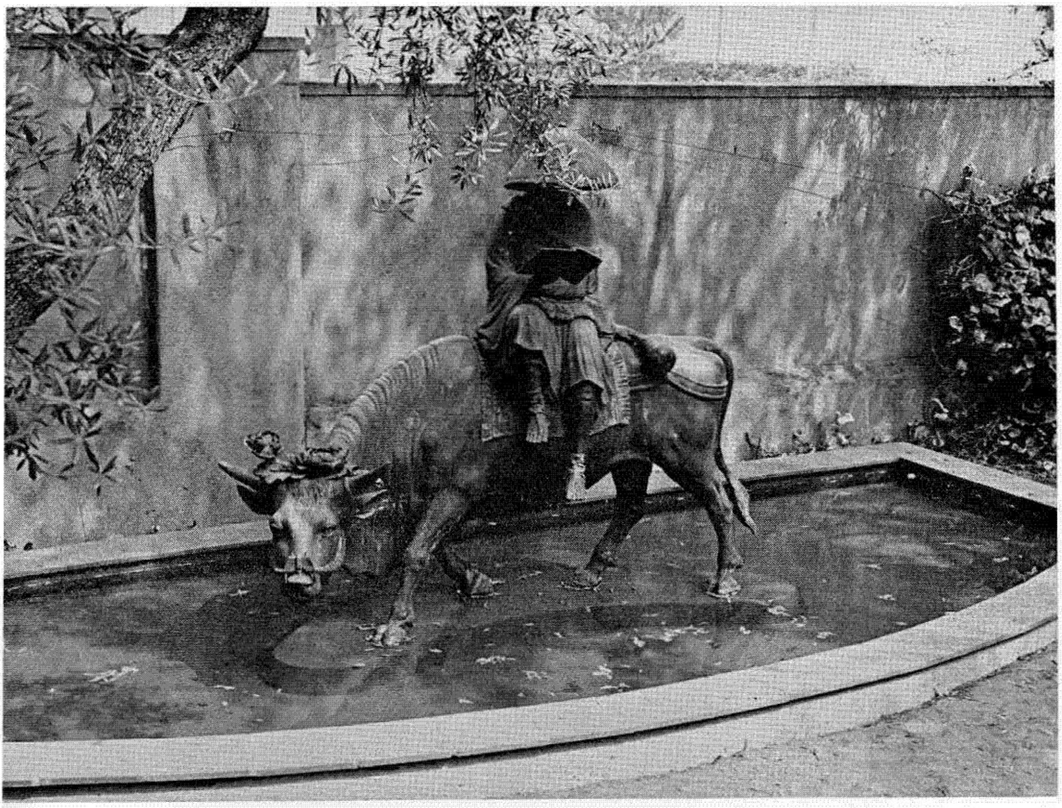


PHILOSOPHER
IN RESIDENCE

Ninth-century Chinese philosopher Tenjin and his sacred water buffalo recently arrived at Caltech for an indefinite stay. The 800-pound life-size bronze statue was presented to the Institute by art patron Edwin Schneider. The serene pair will reside in Dabney Hall gardens in the lily pond built especially for them.

THE SUMMER AT CALTECH

ADMINISTRATIVE CHANGES

Robert P. Sharp, chairman of Caltech's division of geological sciences for 15 years, has been granted a leave of absence from administrative duties to enable him to spend more time in teaching and research. Replacing him as interim director is Clarence Allen, Caltech professor of geology and geophysics, who has been serving as interim director of the Institute's Seismological Laboratory for the past two years. Don L. Anderson, associate professor of geophysics, will take Dr. Allen's place and becomes the new permanent director of the Seismological Laboratory.

Caltech's division of chemistry and chemical engineering has appointed two new executive officers: Norman R. Davidson, professor of chemistry, and William H. Corcoran, professor of chemical engineering. They will assist division chairman John Roberts in the development of new teaching programs and research projects, as well as in the implementation of existing plans.

HONORS AND AWARDS

Dan H. Campbell, Caltech professor of immunochemistry, has been awarded a certificate in recognition of his services as chairman of the standardization of allergens committee of the National Institute of Allergy and Infectious Diseases. He was also recently appointed representative of the American Association of Immunologists to the Commission on Undergraduate Education in the Biological Sciences, which promotes education in biology among students under college age.

Frederick C. Lindvall, chairman of Caltech's division of engineering and applied science, has been named a Fellow of the American Society of Mechanical Engineers, an honor reserved for members of the Society who have made significant achievements and who have had an active practice in the profession for 25 years or more.

Caltech President Lee A. DuBridge and Frederick C. Lindvall, chairman of Caltech's division of engineering and applied science, have been named to the advisory committee for the newly formed Institute for the Advancement of Engineering, Inc. IAE is an educational corporation formed by a group of Los Angeles engineers to encourage the wider use of engineering in solving educational, industrial, and human welfare problems.

Ernest E. Sechler, executive officer of Caltech's graduate aeronautical laboratory, has been appointed to the Secretary of the Navy's Advisory Board on Educational Requirements. This board, composed of distinguished scholars, scientists, industrialists, and naval officers, provides the Secretary of the Navy with policy guidance regarding Navy and Marine Corps educational programs.

George S. Hammond, Arthur Amos Noyes professor of chemistry at Caltech, is winner of the $1,000 James Flack Norris Award in physical organic chemistry sponsored by the northeastern section of the American Chemical Society. Dr. Hammond has done extensive research on the chemistry of high-energy compounds and is especially noted for his recent work in photochemistry.

Roger G. Noll, Caltech assistant professor of economics, is on a 1½-year leave-of-absence in Washington, D.C., as a member of the professional staff of the President's Council of Economic Advisors. Dr. Noll graduated from Caltech in 1962, received his PhD in economics from Harvard, and joined the Caltech faculty in 1965.

HIBBS TV HOST

Albert Hibbs, senior staff scientist at Caltech's Jet Propulsion Laboratory, will host the KCET (Channel 28, Los Angeles) television series "R & D Review" during the 1967-68 season. The weekly program, now entering its second year, reports on new developments in the aerospace industry and is aired Thursdays at 9:30 p.m. and Sundays at 9:00 p.m. After it is shown locally the series will be distributed to 17 other major cities.

NEW PUBLIC AFFAIRS SERIES

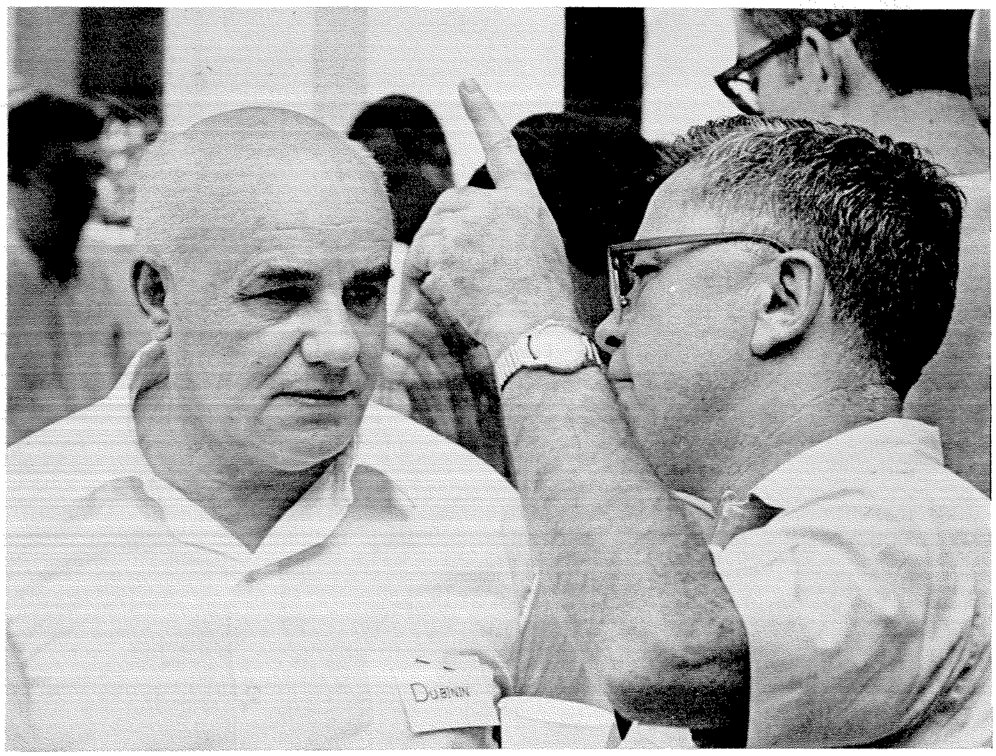
A new public affairs seminar series, sponsored by the Caltech faculty committee on programs, was initiated this month to present current events topics to the community, as well as to Caltech students and faculty. First in the series of speakers was Lord Bessborough, chairman of the board of governors of the British Society of International Understanding. The November speaker will be Philip E. Mosely, director of the European Institute of Columbia University, on "The Soviet Union at Fifty." The seminar series, held in Dabney Hall lounge, is informal and encourages audience participation in the discussions.

FALL LECTURE SERIES

The fall Caltech Lecture Series, presented Monday evenings in Beckman Auditorium, opened on October 16 with a discussion of the Huntington Library art collection by Robert Wark, art curator of the library and lecturer in art at the Institute. The remaining six lectures will cover a wide range of topics: Albert Tyler, Caltech professor of biology, on early development in animals; Harry B. Gray, Caltech professor of chemistry, iron-containing molecules; Milton Plesset, Caltech professor of engineering science, nuclear proliferation and international security; William Pickering, director of JPL, planetary exploration; Rochus E. Vogt, Caltech associate professor of physics, cosmic rays; and Allan R. Sandage of the Mt. Wilson and Palomar Observatories, on cosmic clocks and the creation of the universe.

TRUSTEES

Six new members were elected to the Caltech board of trustees this summer. They are: Robert O. Anderson, chairman of the board of the Atlantic Richfield Company; Roy L. Ash, president of Litton Industries; Stephen D. Bechtel, Jr., president of Bechtel Corporation; Fred L. Hartley, president and chief executive officer of Union Oil Company of California; William A. Hewitt, chairman and chief executive officer of Deere & Company; and Rudolph A. Peterson, president and chief executive officer of Bank of America.



N. P. Dubinin, director of a laboratory of genetics of the Soviet Academy of Sciences, Moscow, considers a point being made by E. B. Lewis, Thomas Hunt Morgan Professor of Biology at Caltech.

For Us, Pasadena Has Meaning

The quiet visit of four distinguished Russian geneticists to Caltech on August 24-27 has a place in history worth noting.

About three decades ago, a growing ideological antagonism to Mendelian genetics in Russia culminated in the elevation of T. D. Lysenko, an agronomist whose work had extended the areas in which wheat could be economically grown in the Soviet Union, to a position of great power in Russian biology. Lysenko was the chief opponent of genetics as it had developed in the western world and in Russia; he promoted a theory utilizing dialectical materialism and Marxist ideology based on a concept of "liquidation of the conservatism of the germ plasm." His doctrine became the official dogma of the Soviet Union; Lysenko was awarded two Stalin Prizes and the Order of Lenin and was made a Hero of the Soviet Union in May 1945.

Over the decades, Russian students of heredity became increasingly isolated from the exciting progress that was being made in molecular biology and genetics in the western world. A few Russians would appear at international congresses of genetics outside Russia; they were all Lysenkoists, uncomfortable, ill-matched, and defensive among their western colleagues. Mendel and Caltech's Thomas Hunt Morgan became the targets of Russian invective, with frequent attacks on "Mendelian, Morganian, bourgeois, capitalist genetics."

Some work comparable to what was going on in the West could be conducted in Russia over this interval, if it were talked about in Lysenkoist terms and if it could avoid coming into the ideological limelight. But Russian biology dropped further and further behind the progess in the West; men with excellent minds did not choose to go into a field in which the state dictated what they could believe or think, and rigid limitations on what could be

From left: E. B. Lewis, Thomas Hunt Morgan Professor of Biology at Caltech; D. K. Belyayev; N. P. Dubinin; S. I. Alikhanyan; R. S. Edgar, Caltech professor of biology; B. L. Astaurov; and Harrison Brown, Caltech professor of geochemistry, science and government.

thought or done largely sterilized the science.

The dominance of Lysenkoism receded and advanced again, but by the summer of 1961, when at long last there was an international biochemistry congress in Moscow, it became evident to everyone, including the Russians who made up much of the audience for the presentation of papers from the West, that Russian biological science was benighted.

Something, somehow, was done about it. When in 1965 the Mendel Centennial was held in Brno, Czechoslovakia, commemorating one hundred years since the presentation of Mendel's great papers that established genetics, there were rather numerous Russian geneticists in attendance. They gave papers on Mendelian genetic subjects, using Mendelian genetic terms and concepts freely; there was no Lysenkoism at all. Lysenko and his disciples had fallen from power. Now the revision of the power structure appears to be complete.

This summer, four of the most distinguished Russian Mendelian geneticists: B. L. Astaurov, president of the Genetics and Selection Society of the U.S.S.R.; S. I. Alikhanyan; N. P. Dubinin; and D. J. Belyayev accepted invitations to attend and participate in the annual meeting of the Genetics Society of America at Stanford University in late August and early September. Caltech was on their itinerary.

Driving from the Los Angeles International Airport to the Huntington-Sheraton with Ray Owen, chairman of Caltech's division of biology, and E. B. Lewis, Thomas Hunt Morgan Professor of Biology at Caltech, the visiting Russian geneticists saw the freeway signs that said "Pasadena." One of them asked whether the name had a meaning. Dr. Lewis said that some people thought it had, but it is most likely that "Pasadena" was just a made-up name for a city.

"Made up?" said Astaurov.

"Yes," Lewis said, "it probably has no meaning."

"For us," said Astaurov, "it has meaning."

"Oh," said Lewis, "does Pasadena mean something in Russian?"

"For us it means Morgan and Caltech and Genetics!"

Faculty Changes 1967-1968

PROMOTIONS

CLARENCE R. ALLEN — acting chairman, division of geological sciences.
DON L. ANDERSON — director of the seismological laboratory.
WILLIAM H. CORCORAN — executive officer for chemical engineering.
NORMAN R. DAVIDSON — executive officer for chemistry.

To Professor:

GIUSEPPE ATTARDI — *Biology*
CARVER A. MEAD — *Electrical Engineering*
JEROME PINE — *Physics*
RONALD F. SCOTT — *Civil Engineering*
NICHOLAS W. TSCHOEGL — *Chemical Engineering*
GEORGE ZWEIG — *Theoretical Physics*

To Associate Professor:

JOHN N. BAHCALL — *Theoretical Physics*
DONALD S. COHEN — *Applied Mathematics*
GEORGE R. GAVALAS — *Chemical Engineering*
THOMAS L. GRETTENBERG — *Electrical Engineering*
CLEMENS A. HEUSCH — *Physics*
WILFRED D. IWAN — *Applied Mechanics*
FREDERIC RAICHLEN — *Civil Engineering*
JEROME L. SHAPIRO — *Applied Science*
KIP S. THORNE — *Theoretical Physics*
THOMAS A. TOMBRELLO, JR. — *Physics*

To Senior Research Fellow:

GEORGE A. SEIELSTAD — *Radio Astronomy*
LEWIS G. BISHOP — *Applied Science*

To Assistant Professor:

WILHELM BEHRENS — *Aeronautics*
DAVID L. GOODSTEIN — *Physics*
ROGER G. NOLL — *Economics*
EDWARD C. STONE — *Physics*
JOHN S. ZEIGEL — *English*

NEW FACULTY MEMBERS

Professors:

SEYMOUR BENZER — *Biology* — from Purdue University, where he was Stuart Distinguished Professor of Biology.
HERBERT B. KELLER — *Applied Mathematics* — from New York University, where he was professor of applied mathematics.
BURTON H. KLEIN — *Economics* — from RAND Corporation, where he was head of the economics department.
MAJOR CHARLES J. LARKIN — *Aerospace Studies* — from Wiesbaden, West Germany, where he was stationed with the U.S. Air Force.
HERBERT J. RYSER — *Mathematics* — from Syrcause University, where he was professor of mathematics.

Associate Professors:

THOMAS J. AHRENS — *Geophysics* — from the Poulter Labs at the Stanford Research Institute, where he was chairman of the geophysics department.
JAMES W. MAYER — *Electrical Engineering* — from Hughes Research Laboratories, where he was head of the solid state studies section.

DUANE O. MUHLEMAN — *Planetary Science* — from Cornell University, where he was visiting professor of astronomy.

Senior Research Fellows:

M. P. WNUK — *Aeronautics* — from South Dakota State University, where he was assistant professor.

Assistant Professors:

DAVID BOYD — *Mathematics* — from the University of Alberta, where he was assistant professor.

KENNETH D. FREDERICK — *Economics* — from the AID Mission in Brazil, where he worked as an economist.

MOSES GLASNER — *Mathematics* — from UCLA, where he was acting assistant professor.

DAVID F. GOSLEE — *English* — from Carleton College, where he was an instructor.

ROBERT S. HARP — *Electrical Engineering* — from Stanford, where he was a research associate in plasma physics.

JOHN H. SEINFELD — *Chemical Engineering* — from Princeton University, where he just completed his PhD.

Lecturers:

MICHAEL P. SCHON — *Speech*, director of forensics — from Cal State, Fullerton, where he was co-director of forensics.

Instructors:

ROBERT G. BERGMAN — *Chemistry* — from Columbia University, where he was working as a NATO postdoctoral fellow.

JESSE L. BEAUCHAMP — *Chemistry* — from Stanford University, where he just completed the work for his PhD.

EBERHARD K. JOBST — *German* — from the University of Frankfurt, where he just completed his PhD.

ON LEAVE OF ABSENCE

HENRY BORSOOK, professor of biochemistry, to do research at the University of California, Berkeley.

PETER CRAWLEY, associate professor of mathematics, to Vanderbilt University as visiting associate professor.

MURRAY GELL-MANN, Robert Andrews Millikan Professor of Theoretical Physics, to do research at the Institute for Advanced Study at Princeton University.

FRANCIS B. FULLER, professor of mathematics, to do research at the University of Strasbourg in France.

ALAN J. HODGE, professor of biology, to the Orthopaedic Research Laboratories in Boston.

RALPH W. KAVANAGH, associate professor of physics, to the Laboratory of Nuclear Research at the University of Strasbourg in France.

RODMAN W. PAUL, professor of history, to complete research for a book.

RESIGNATIONS

EVERETT C. DADE, professor of mathematics, to the University of Illinois at Urbana.

ALBERT T. ELLIS, associate professor of applied mechanics, to the University of California at San Diego as professor of applied mechanics.

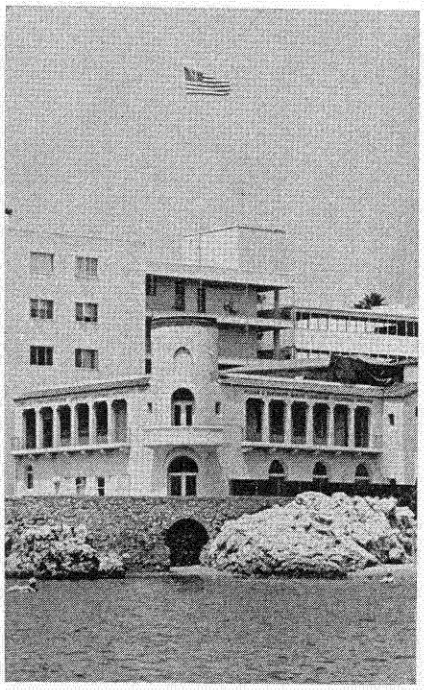
DANIEL G. KEEHN, assistant professor of applied science.

ROBERT P. KRAFT, staff member, Mt. Wilson and Palomar Observatories.

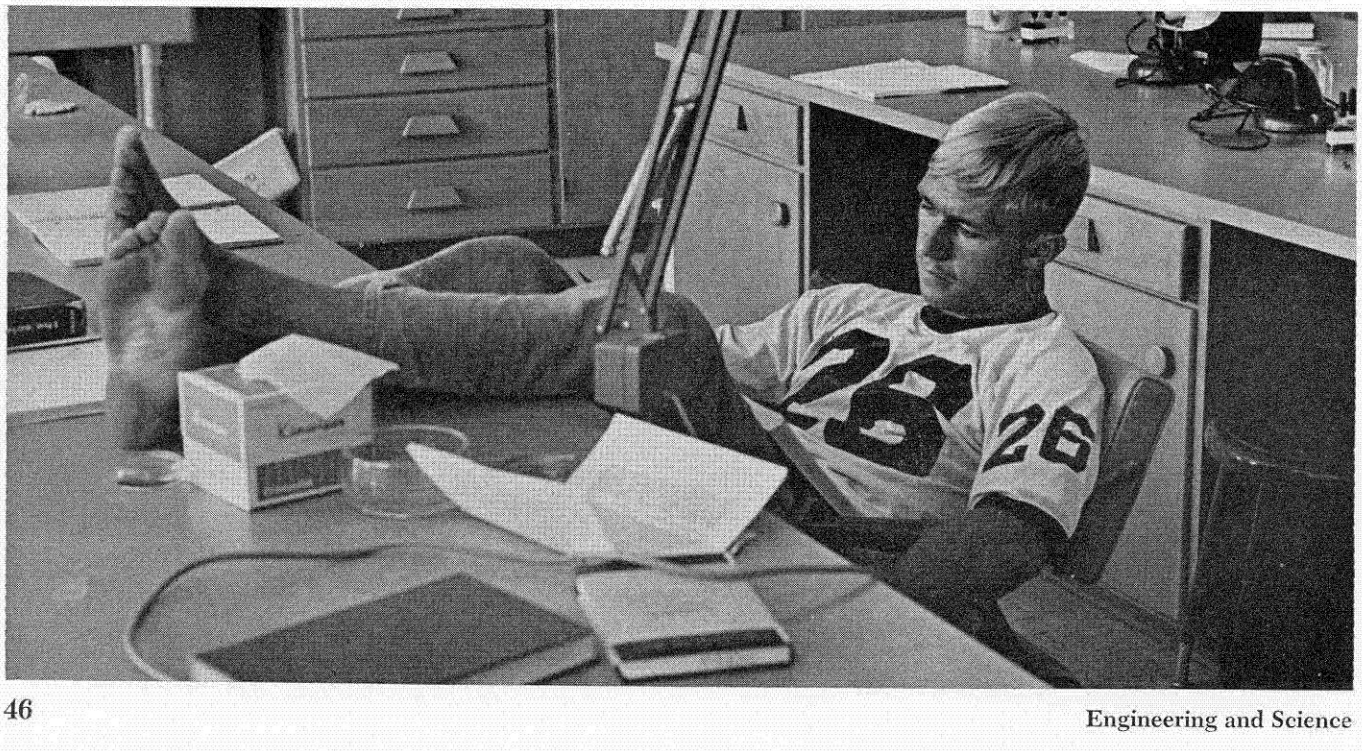
J. OWEN MALOY, senior research fellow in physics, to the Analog Technology Corporation in Pasadena.

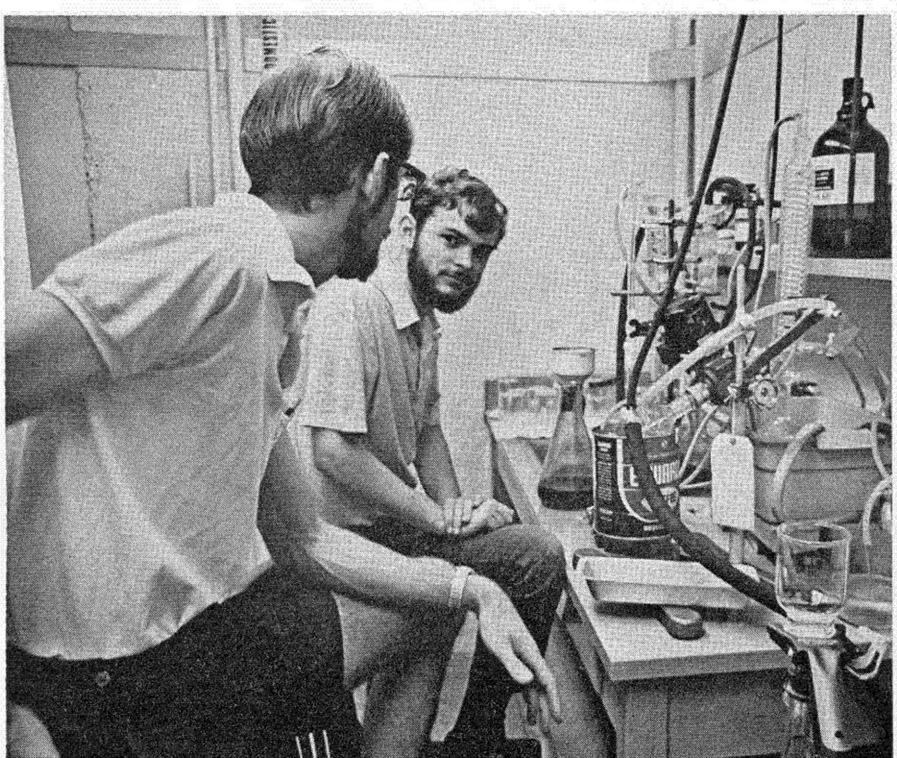
JOE. H. MULLINS, senior research fellow in physics, to the Bell Telephone Laboratories in New Jersey.

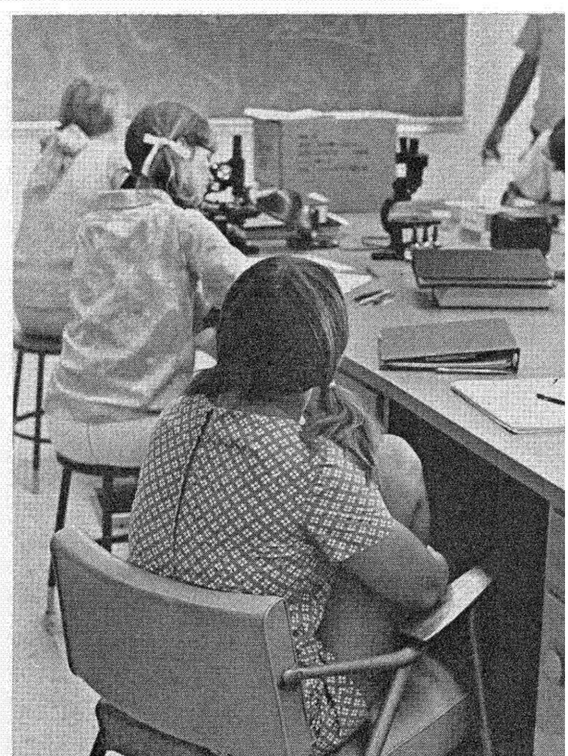
SEASIDE SUMMER SCHOOL



Caltech's Kerckhoff marine biology lab at Corona del Mar had a full house this summer. A co-ed group of 14 undergraduates from eight colleges moved in with the seven Caltech research students already in residence for a five-week, live-in marine biology course sponsored by Pomona College. The most active hours were between 1:00 a.m. and 6:00 a.m., the time of California summer low tides. The students roamed the waters and shores of Newport Bay, investigating, among other things, the population distribution of snails in the mud-flats and conducting a 36-hour continuous study of ocean plankton.







ALUMNI ASSOCIATION
CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, California

BALANCE SHEET
June 30, 1967

ASSETS		
Cash in Bank		$ 709.56
Investments:		
Share in C.I.T. Consolidated Portfolio	$122,901.81	
Deposits in Savings Accounts	19,373.88	142,275.69
Investment Income Receivable		6,140.85
Postage Deposit, etc.		181.05
Furniture and Fixtures, at nominal value		1.00
Total Assets		$149,308.15
LIABILITIES, RESERVES AND SURPLUS		
Accounts Payable		$ 324.62
Deferred Income:		
Membership Dues for 1967-68 paid in advance	$ 13,415.95	
Investment Income for 1967-68 from C.I.T. Consolidated Portfolio (earned during 1966-67)	6,140.85	19,556.80
Life Membership Reserve		73,100.00
Reserve for Directory:		
Balance, July 1, 1966	$ 538.60	
1966-67 Appropriation	3,000.00	
1966-67 Directory Expense	(232.81)	3,305.79
Surplus:		
Balance, July 1, 1966	$ 41,957.54	
Share of Gain on Disposal of Investments of C.I.T. Consolidated Portfolio for 1966-67	12,686.81	
Excess of Expenses over Income for 1966-67	(1,623.41)	53,020.94
Total Liabilities, Reserves and Surplus		$149,308.15

STATEMENT OF INCOME AND EXPENSES
For the Year Ended June 30, 1967

INCOME		
Dues of Annual Members		$ 20,628.60
Investment Income:		
Share from C.I.T. Consolidated Portfolio	$ 5,709.36	
Interest on Deposits in Savings Accounts	1,132.87	6,842.23
Annual Seminar		6,206.50
Program and Social Functions		1,690.70
Miscellaneous		36.35
Total Income		$ 35,404.38
EXPENSES		
Subscriptions to Engineering and Science Magazine:		
Annual Members	$14,425.25	
Life Members	3,377.50	$ 17,802.75
Annual Seminar		5,845.68
Administration (Directors' Expenses, Postage, Supplies, etc.)		3,433.95
Directory Appropriation		3,000.00
Fund Solicitation		2,203.00
Program and Social Functions		1,866.66
Membership Committee		1,475.75
ASCIT Assistance		1,400.00
Total Expenses		$ 37,027.79
Excess of Expenses over Income		$ 1,623.41

AUDITOR'S REPORT

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

I have examined the Balance Sheet of the Alumni Association, California Institute of Technology as of June 30, 1967, and the related Statement of Income and Expenses for the year then ended. My examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as I considered necessary in the circumstances.

In my opinion, the accompanying Balance Sheet and Statement of Income and Expenses present fairly the financial position of the Alumni Association, California Institute of Technology at June 30, 1967, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

CALVIN A. AMES
Certified Public Accountant

September 26, 1967

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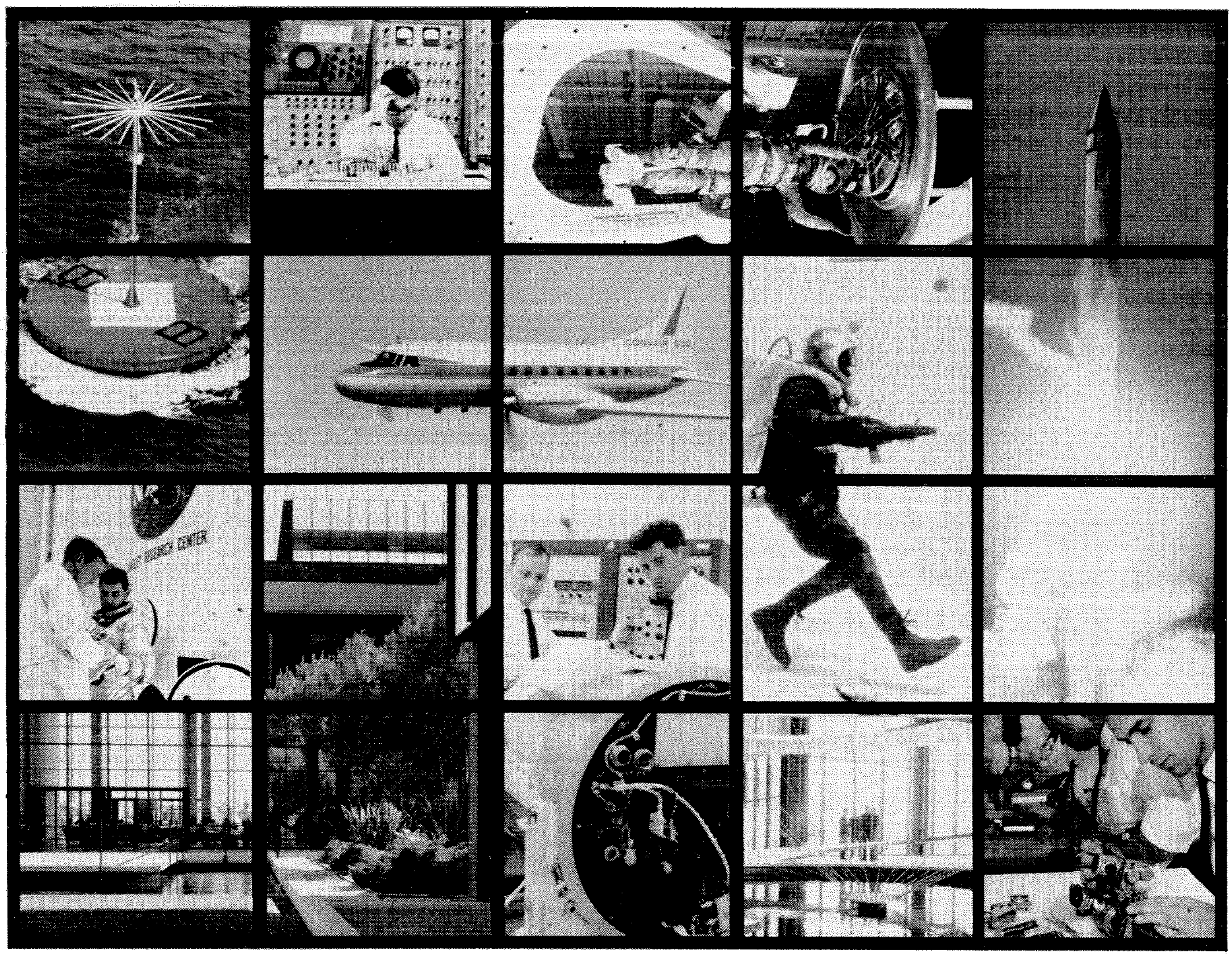

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Mr. J. J. Tannone, Supervisor, Professional Placement and Personnel, Convair Division of General Dynamics, 5625 Kearny Villa Road, San Diego, California 92112.

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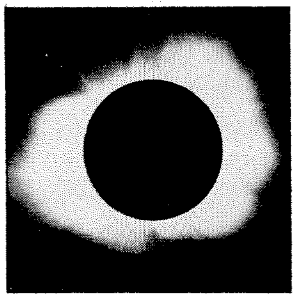
E&S

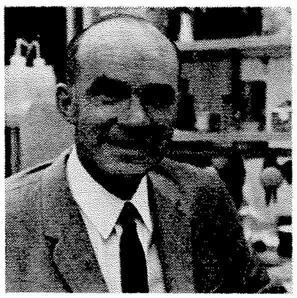
IN THIS ISSUE



ON THE COVER

This classic picture of the solar corona was photographed at the total eclipse of June 8, 1918, at Green River, Wyoming. Thin plumes mark the position of the poles. The corona and other phenomena of the sun are described in "The Solar Atmosphere," on pages 11-16, by Harold Zirin, professor of astrophysics and staff member of the Mount Wilson and Palomar Observatories.

UNIVERSITY-INDUSTRY RELATIONS



In the scientific community, there is an acute awareness of the communication problem that exists between the university and industrial researchers. George S. Hammond, Arthur Amos Noyes Professor of Chemistry at Caltech, outlines the problem and suggests some steps toward a solution on pages 28 and 29.

THE REVOLUTION

Barry Lieberman '68 is a physics major and an officer in the Caltech YMCA. He has been heard to say that he wishes he were an entering freshman at Caltech, because he thinks there are going to be a lot of positive changes in the life of a Caltech student—changes that may very well be due to "The Revolution" about which he writes on pages 34 and 35. The machinery for some of these changes is already in motion. Early this month Caltech's ad hoc committee on the freshman year made a recommendation to the faculty board that the Institute "proceed with all deliberate speed to the admission of women to undergraduate work at Caltech." The committee also recommended a change that the students rejected last spring—setting up a General Studies option.

TRIBUTE BY KENT CLARK

News of the death, on June 30, of Harvey Eagleson, professor of English, emeritus, brought many expressions of appreciation for Harvey's personal and academic contributions to Caltech. Kent Clark, professor of English and Harvey's friend and colleague for 20 years, put his tribute on paper with the wit and warmth for which he is known. It appears on pages 36 and 37.

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