# ENGINEERING | AND | SCIENCE

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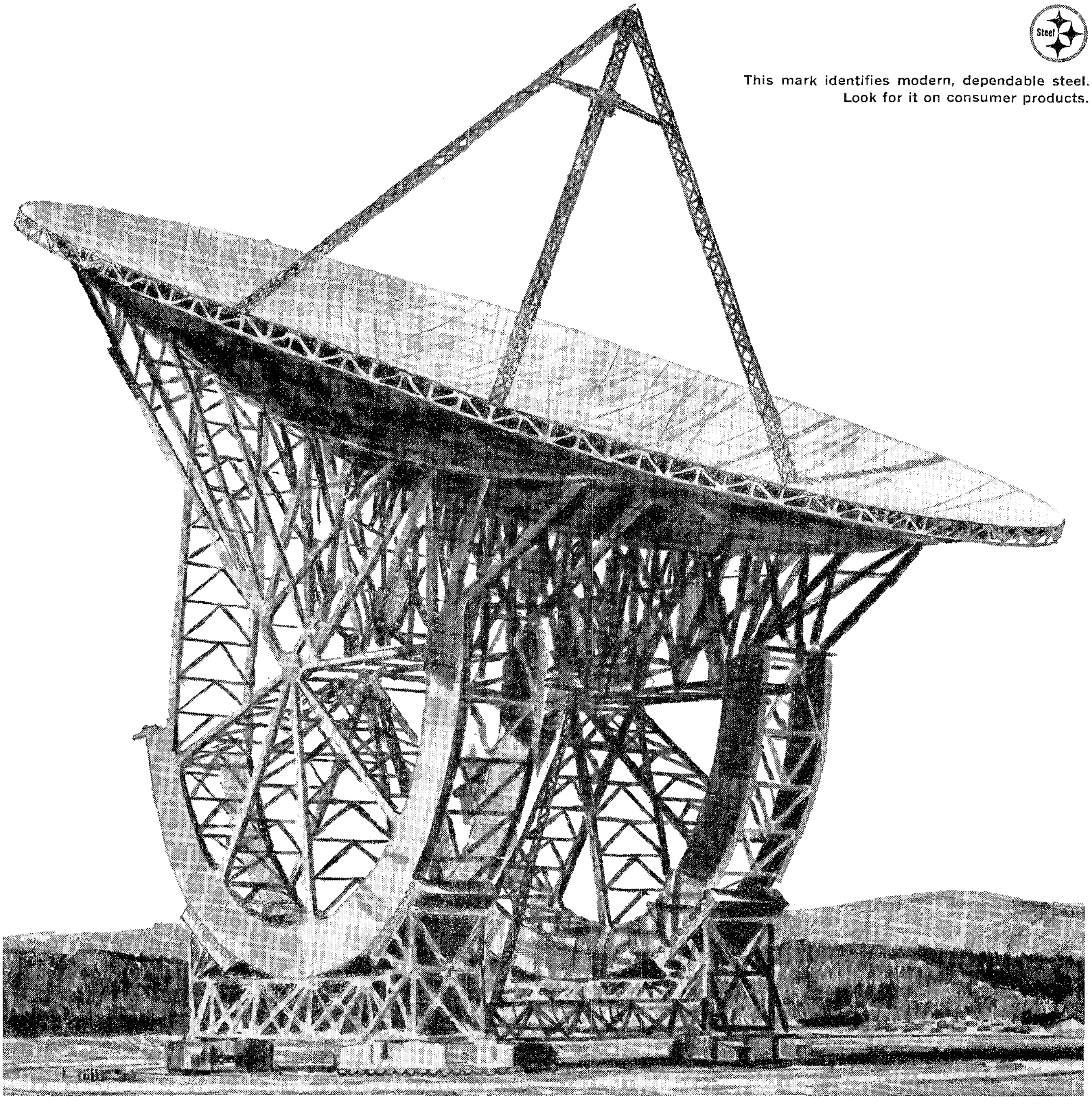

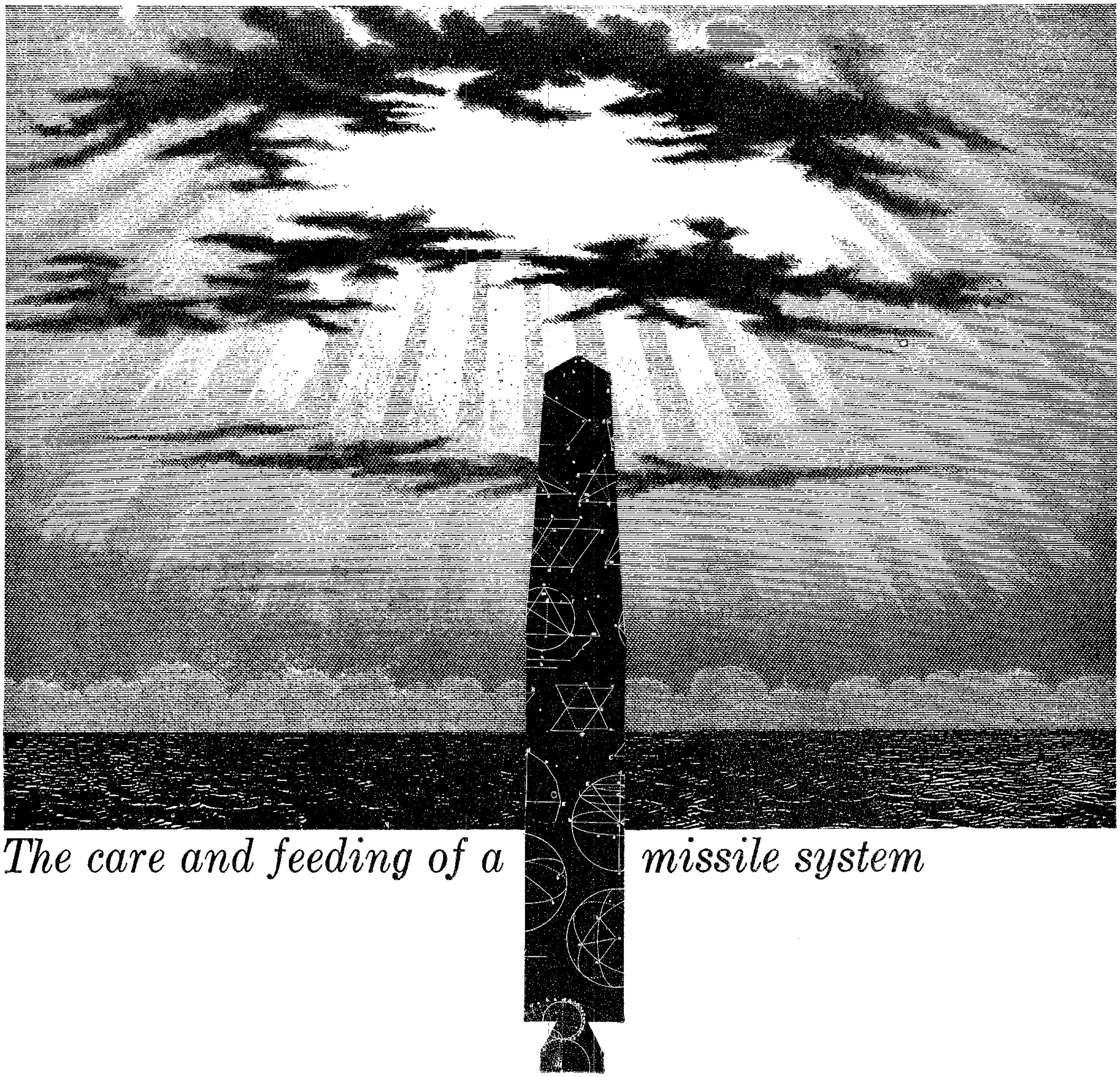

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# ENGINEERING AND SCIENCE

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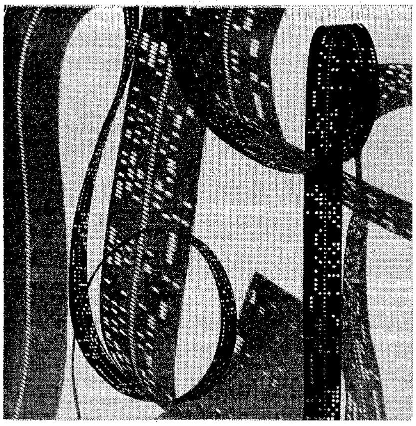

*On Our Cover*

a strip of the punched paper tape used in the Institute's Digital Computer. Information is contained in the punched holes using a seven bit code per character. This tape is read optically into the computer at 1,000 characters per second.

Information within the machine is also punched out on tape like this at 60 characters a second and is subsequently translated by an off-line printer. The computer has a high-speed direct-printing output as well that runs at 700 characters a second.

You'll get a closer look at this computer, and at some of the interesting research in progress in the Caltech electrical engineering department in the pictorial feature starting on page 17.

*"The Biological Clock"*

on page 11 tells about the unique timing mechanism built into most plants and animals. The author is Hendrik J. Ketellapper, research fellow in biology, and a native of Holland. Dr. Ketellapper received his B.Sc. in 1947, his D.Sc. in 1951, and his Ph.D. in 1953 from the State University of Utrecht. He has been at Caltech since 1957.

*Fritz Zwicky,*

an old hand at starting arguments, is sure to start another with his article on smog on page 22. Let it be noted that the opinions expressed in this article are those of the author; they do not necessarily reflect the editorial opinion of *Engineering and Science.*






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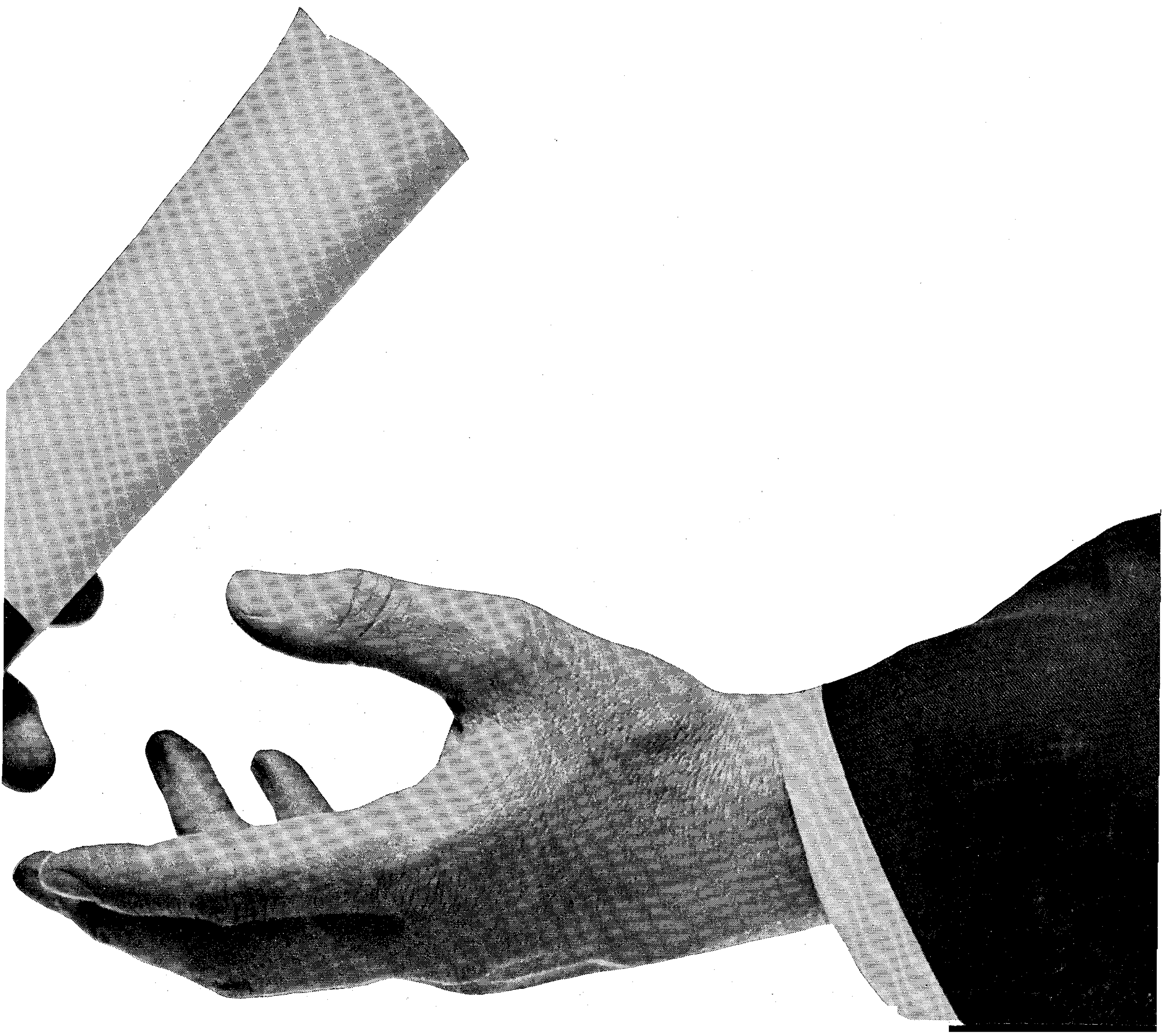

# Books

### *The Doubleday Library of Science*

*Doubleday & Co.* ............................*$9.95*

This initial volume in a new series of reference books for young people covers the physical sciences of chemistry, physics, and astronomy. (Mathematics will be in a later volume.) It uses far more pictorial material than the usual encyclopedia, and the entries are less compact and more informal. Also, the material is organized on a systematic, rather than alphabetic, basis – on the grounds that a young person is not just after a quick reference, but is interested in "the fascinating threads which run from a fact he wants."

It makes a handsome and useful reference book – and not only for young people either.

This volume of the Doubleday Library was produced under the direction of an editorial board headed by Dr. J. Bronowski. Volumes to come will cover the fields of Nature, Geography, World History, Society, The Arts, Technology, and Words and Ideas.

### *The Science of Mankind*

*by Jane Werner Watson*

*Golden Press* ...................................*$4.95*

Jane Watson – the wife of Caltech's former dean of the faculty, Earnest C. Watson – follows up her 1958 book, *The World of Science,* with this equally impressive survey of the social sciences.

As the introduction to *The Sciences of Mankind* says: "It seems likely that in the decade ahead the absolute increase in the number of scientists will also mean a relatively greater percentage dealing with the sciences of mankind. There is every indication that the social sciences will have their fair share of the able young people planning careers in these fields. While many social scientists are currently engaged in teaching, larger numbers must be added to the faculties of universities and colleges. More social scientists will be employed in industry, in international agencies, and in research institutes both public and private. Government agencies must recruit men and women with disciplinary training in economics, political science, statistics, geography, history, anthropology, demography, sociology, and psychology."

Mrs. Watson covers all these fields, and a few more besides, in *The Sciences of Mankind.* As in *The World of Science,* she tells her story, whenever she can, in terms of people, and with plenty of colorful pictorial material. The result is an admirable introduction to the world of the social sciences.

# Max Planck...on problems

"The world is teeming with problems. Wherever man looks, he encounters some new problem — in his home life and in his job, in economics and in technology, in the arts and in the sciences. And some problems are very stubborn; they refuse to leave us in peace. They torture our thoughts, sometimes haunting us throughout the day and even robbing us of sleep at night. If by lucky chance we succeed in solving a problem, we experience a sense of deliverance and rejoice over the enrichment of our knowledge. But it is a different story, and highly annoying, to discover after tedious efforts that the problem is incapable of solution — either because there exists no indisputable method of solving it or, because soberly looked at, it is void of meaning — a *phantom problem* on which our labors and thoughts were wasted. There are a good many such phantom problems — in my opinion, far more than is ordinarily assumed — even in the sciences."

— *Scheinprobleme der Wissenschaft, 1947*

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# The Biological Clock

*by Hendrik J. Ketellapper*

One of the interesting things that biologists have learned in recent years is that almost every creature and plant carries a built-in clock. This timepiece directs creatures to wake and sleep, to eat and drink, and even directs their sexual activities in some instances. Many living organisms carry out activities at a fixed time of the day: Birds sing at dawn, bats fly at night, many flowers open and close at regular times.

Plants and animals not only know the time of day; they are aware of seasonal changes, and they can measure the length of the daily light period as well. Trees know by the length of the daily light period when to start growing and when to stay dormant in order to stay alive.

Biologists have become aware of this phenomenon during the past 30 years or so, and they are now making many studies to determine how time influences the growing patterns of plants and animals, and how organisms measure time.

These studies have shown that creatures appear to act as though they possess not only timers, but also clocks which may run for days in the absence of any external time signal. The rate of many biological processes changes in a rhythmic manner – for example, the luminescence of Gonyaulax (one of the organisms responsible for the luminescent display sometimes observed in the ocean when the water is disturbed). The respiration rate of many plants also varies between a maximum and minimum in a regular manner, and when the rates are plotted against time the resulting graph suggests a rhythm. The maxima and minima occur at approximately the same time on successive days, so the period of the rhythm is 24 hours.

Research has shown that these organisms identify time of the day by an initial signal from the environment. Generally, the signal is a single factor or event in the environment, and with very few exceptions this signal is the light-dark or dark-light change. The organisms respond to this environmental signal after a certain period of time, and the length of that period is determined genetically – although it may depend somewhat on conditions.

All the examples that have been mentioned so far have one thing in common: The pattern of activity can be directly related to a single environmental signal, and the time interval between the signal and start of the activity is fixed. In such cases the only requirement for the time-measuring system is that it should be able to measure fixed time intervals, so the time-measuring device need not be very elaborate. In fact, an hourglass might well simulate this time-measuring element.

We can imagine how such a biological hourglass may work. The environmental signal starts some physiological process – for example, the synthesis of a hormone. When sufficient hormone has been accumulated the organism becomes active – the bird starts singing or the bat starts flying. This model can also be adapted to account for rhythmic processes.

The response of plant growth and development to the length of the light or dark period, called photoperiodism, can be explained in the same manner. Some plants (called short-day plants) can be made to flower when the length of the dark period is greater than a critical number of hours. Following the hourglass model, we can assume that something is being made by the plant in darkness which causes flowering. A minimum number of hours of darkness is required to make a sufficient amount of this substance, or to complete the synthesis of a stable product.

When the dark period is too short, the quantity made is too small, or synthesis stops at an unstable product. The experimental evidence supports the second alternative. In either case no flowering will occur.

In order to explain the absence of flowering when the night length is kept shorter than the critical one, we assume that any product made during such short nights is destroyed in the following light period.

There is ample evidence for such destruction, which will prevent the accumulation of an adequate supply of the flowering stimulus over a larger number of nights.

Is the time-measuring device of living organisms really an hourglass and can it explain all observations involving time measurement? In many organisms the measuring device appears to be more sophisticated than the simple hourglass. Take, for example, the complex performance of the honey bee. Bees are able to return to a feeding place on successive days at the precise time of the day at which they initially discovered it. Moreover, honey bees can be trained to come for food to a certain place at a fixed time of the day by offering them food at a certain hour – say, from 10 till noon – for seven days. Then an empty feeding dish is placed at the feeding spot. The trained bees continue to come to this spot between 10 and noon for many days, even though no food is offered. The bees even start coming back to the feeding spot again at the fixed time after they have been unable to fly for some days because of bad weather.

In these beautiful experiments we find that a bee can recognize any time of the day and that it does so by measuring the time elapsed since dawn. Apparently bees can also remember what happened at any given time. Although the honey bee measures time intervals, its performance is more complex than that of birds, bats, and flowers because the bee is able to look at its timing system at any moment of the day and draw conclusions about the time passed since dawn. In the time-measuring device of the other creatures, some activity always occurred at a fixed time after a signal. The time-measuring instrument of the bee has to be more refined than an hourglass unless the bee can accurately estimate how much sand has run through its hourglass at any one time.

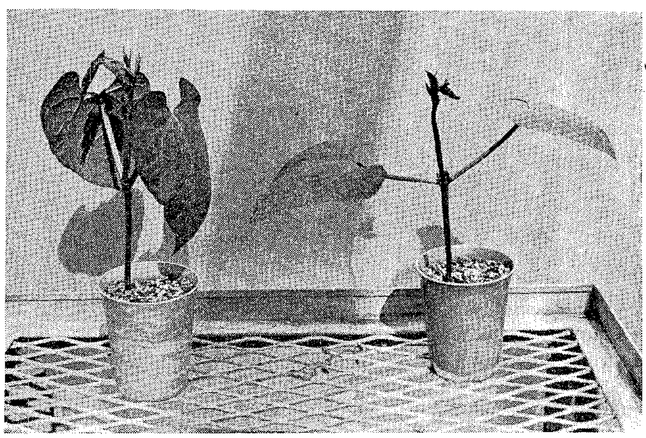
A second group of phenomena requires a similar timing mechanism. During the 1950's some remarkable cases of celestial navigation were discovered in birds and arthropods. These animals use the sun as direction-giver. In order to compensate for the shift in position of the direction-giver during the day, they make use of an internal timing system. The following experiment demonstrates this very elegantly: Two starlings, trained to look for food in a given direction, are placed in a room and subjected to a light-dark regime which is displaced by six hours in comparison with the natural regime. Thus the birds receive artificial light from six hours after sunrise until six hours after sunset, and they remain in darkness for the remainder of the 24 hours. Temperature conditions correspond to the new light regime.

After approximately two weeks of such treatment the birds are tested in the original environment and their behavior appears to be changed. A bird trained to look for food in a westerly direction now looks for food in a northerly direction. It seems as if the starling applies a wrong correction factor to the position of the sun and overcorrects by 90°. As the position of the sun shifts 90° in six hours, the logical explanation is that the timing of the starling is off by six hours. In other words, due to this abnormal treatment, the synchronization between the internal time-measuring device of the bird and the sun has been upset: The timing system of the bird is slow.

This experiment demonstrates that the starling is able to refer to its time-measuring device continuously and can tell at any moment the exact time elapsed since dawn, just as the bee does. It uses that information for its orientation in space. The same is true in other cases of celestial navigation which have been investigated so far. In all these cases it has been shown that the timing is very accurate.

A third group of phenomena also bears on the nature of time-measurement in living organisms. Many activities continue on a rigid time schedule in the absence of obvious signals from the environment. We will use the movement of bean leaves as an example, but there are many others to choose from. Bean leaves have a day and a night position. The position of the leaf changes in a regular manner between the two extremes shown in the photograph below. Normally the time interval between two peaks is 24 hours because the dark-light change is the signal which induces the leaf to start opening or rising.

What happens when bean plants are transferred to an environment which does not provide any obvious signals? Such an environment can be achieved by maintaining the temperature at a constant value and keeping the plants in continuous light or in continuous darkness. In the absence of obvious cues the rhythmic leaf movement continues for many days and the peaks are 27 hours apart. Rhythms which persist in the absence of environmental signals are called endogenous rhythms. Such rhythms have been known for many years.



*The leaves of the bean plant have a night (left) and a day position (right). The normal time interval between the two positions is 24 hours.*

*The rhythmic movement of bean leaves continues, with a period of 27 hours, in a signal-less environment. The peaks in this record, which covers 6 days, correspond to the night position.*

The earliest reports originate from Zinn (1759) and extensive studies were carried out in the last quarter of the 19th century. The persistence of rhythms in a cueless environment tells us that the time measuring continues under such conditions. It is not restarted every day by an environmental signal. Moreover, the time-measuring device apparently is cyclic in nature. In the case of the bean leaves, one cycle lasts 27 hours and any given leaf position recurs every 27 hours.

The study of the emergence of adult fruit flies (*Drosophila*) from puparia is an interesting aspect of internal rhythm. Normally the emergence occurs in bursts during the first few hours after dawn. It is inhibited during the rest of the day. The emergence pattern persists in continuous darkness and constant temperature, and the time interval between emergence peaks is 24 hours as expected. This in itself does not prove that the apparently cueless environment does not provide any signals, or that the rhythm can persist without external signals.

The probability that an external signal is received in continuous darkness and constant temperature is practically eliminated by the following experiment: It is possible to displace the rhythm in relation to the solar periodicity by using the environmental variable which normally functions as a signal. In the case of the emergence in *Drosophila* the signal is the dark-light change. One can subject a culture of *Drosophila* to a dark-light change at any time of the day — for example, midnight — by using artificial light. After transfer of such a culture to continuous darkness it will show a persistent rhythm, and the location of the emergence peak is determined by the experimentally established "dawn," which, in the example, is at midnight. Rhythms established in this manner will persist, even though they are completely out of phase with solar periodicity.

Cultures can be raised from eggs in continuous darkness and constant temperature. Such cultures have never experienced a 24-hour periodicity and the emergence is evenly distributed over the 24 hours. Yet, a single, unrepeated dark-light change starts off rhythmic emergence with 24 hours between peaks. The signal can be given by shining light for four hours on cultures which have been raised in darkness. This treatment offers two potential signals: a dark-light and a light-dark change.

Although it is known that a light-dark change is not effective in *Drosophila*, it would be more elegant to offer a single change. The experiment has been carried out by transferring cultures which have been raised in continuous darkness to continuous light. In this case the cultures receive one dark-light change. Immediately after the transfer such cultures, which did not show a rhythm before, start the rhythmic emergence with a period of 24 hours.

These striking observations strongly suggest that the clock is internal and that it has the inherent ability to measure off cycles of approximately 24 hours. It can do this without regular, external signals. What is the nature of the action of a single signal? Does the signal start the time measurement, or does it synchronize time measurement already in progress in the individuals? The problem cannot be resolved using the emergence of *Drosophila*, because the periodicity cannot be measured as a function of the individual. It is probable that a signal turns an aperiodic culture into a periodic one by synchronizing the time measurement in the individuals. However, this has not been proven rigorously.

The existence of persistent rhythms, the evidence from experiments with bees, and the role of time measurement in celestial navigation suggest that the biological time-measuring system is more complex than an hourglass. Rather we have to conclude that the time-measuring apparatus is cyclic in nature and that it can be continuously consulted. Therefore, animals and plants possess a real, and very good, clock.

Many other examples of accurate time measuring, besides the ones which have been discussed here, have been found, and in the last 5 or 10 years the word "clock" has become more and more common in biological literature. The biological clock is very accurate. This can be investigated in an environment without obvious signals. The period found in such environment is called the "free running" period. In many cases the free running period is different from 24 hours, and this is an additional indication that the environment really lacks cues as far as the clock is concerned. The free running period is very constant in any one individual and its length is determined genetically. It is maintained accurately for many days. In general the free running period is relatively close to 24 hours, although for the bean this period is 27 hours.

In their natural environment plants and animals are exposed to alternating periods of light and dark, the combined lengths of which are 24 hours. It does not matter very much that the free running period is different from 24 hours because every day the biological clock is synchronized with the outside world by some change in the environment. Light-dark changes or dark-light changes are most effective in this respect. However, synchronization is possible only to a limited extent.

This can be illustrated by two types of experiments which have been carried out at the Institute. It has been shown here that the growth of some plants, particularly tomatoes, is sensitive to the light regime. Tomato plants require a daily dark period for optimal development, and leaf injury appears very quickly when tomato plants are grown in continuous light and constant temperature. Obviously, such plants with small, yellow leaves will grow poorly. So alternating light and dark periods are the requirement for good and normal development of the tomato plant.

On the other hand, the combined length of the light and dark period, which we call "cycle length," must be relatively close to 24 hours; otherwise, again, leaf injury and reduced growth result. This suggests that tomato plants have an internal 24-hour periodicity which is involved in the growth process, and that for optimal growth the endogenous periodicity has to be properly in register with the external periodicity.

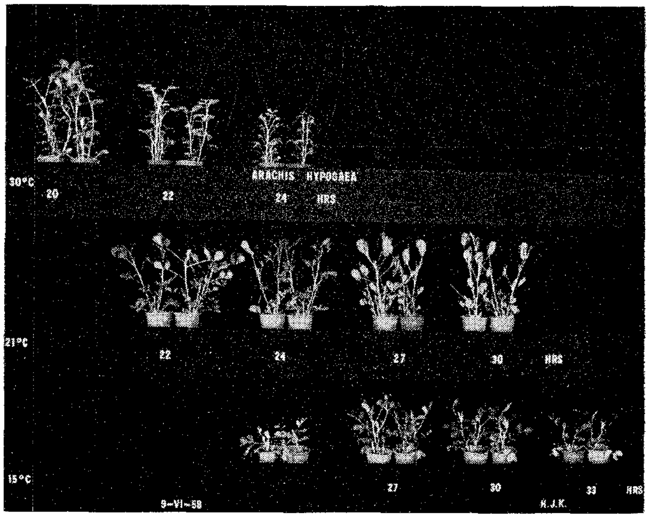
When the external periodicity differs from the internal periodicity, the plant is able to compensate for this difference to some extent, but when the two periodicities are too different, such compensation is not possible any more and injury results. For example, leaf injury results when tomato plants are grown under 18-hour or 36-hour cycles at 17°C instead of under the natural 24-hour cycle. However, growth is affected by changes in cycle length of as little as two to three hours. Such small deviations from 24 hours cause a reduction in growth. Experiments with the leaf movement of beans, where the period of internal periodicity can be measured directly, have also shown that the internal period can follow the external periodicity to a limited extent only.

## *Tomatoes, peas and peanuts*

Tomato plants are more sensitive to light-dark periodicity than other plants which have been investigated. Pea and peanut plants grow faster in continuous light than in any other regime, and they complete their life cycle more quickly. Apparently these plants do not require a daily dark period, while the tomato plant has an absolute requirement for a daily dark period. However, peas and peanuts respond to differences in the external cycle length: When an external periodicity is imposed, the cycle length has to be close to 24 hours, or else the rate of growth is reduced.

No visible symptoms of injury have been observed in peas and peanut plants grown in continuous light. Perhaps we may conclude that the bad effect of continuous light on tomato plants has nothing to do with the biological clock, because a number of plants, in which an endogenous 24-hour periodicity is definitely involved in the growth process, do not show such injurious effects. These experiments certainly indicate that plants are closely adapted to the natural 24-hour cycle.

A second type of experiment provides confirming




*The cycle length which allows best growth of peanut plants depends on temperature. At 30°C. (top row) plants grow biggest in a cycle length of 20 hours. At 21° (middle row) the optimal cycle length is 24 hours, at 15° (bottom row) 27 hours.*

data and points out an important property of the clock. Plants grow better at some temperatures than at others. This fact has been of considerable interest to plant physiologists at the Institute. Investigations into a possible chemical nature of the bad effect of temperature have gone on for some time and it has been found that temperature damage can be partially overcome in a few cases by supplying chemicals to the plants. Which substances are active depends on the plant and on the temperature conditions. However, another type of experiment has been carried out as well.

Peanut plants and tomato plants are grown in artificial light at three different temperatures — for example, 15°, 21°, and 30°C. The plants are grown under four different cycle lengths at each temperature. Again, cycle length is the combined length of a light and a dark period. Every cycle consists of equal periods of light and dark. Therefore, when we say that the cycle length is 27 hours, this means that the plants are receiving 13½ hours light and 13½ hours dark during every cycle.

The results of such an experiment with peanut plants appear in the photograph above. The plants respond strikingly to cycle lengths at the high and low temperatures, and the cycle length which gives best growth is different for the three temperatures — 27 hours at 15°, 24 hours at 21°, and 20 hours at 30°. At 21° the effect is not very obvious by just looking, but when one determines the increase in dry weight of the plants during the experimental period the differences are quite clear.

Leaf injury which occurs at the high and low temperatures under a 24-hour cycle disappears when the external cycle length is adjusted by as little as three to four hours. By adjusting the outside periodicity to the optimal value for a given temperature, very often

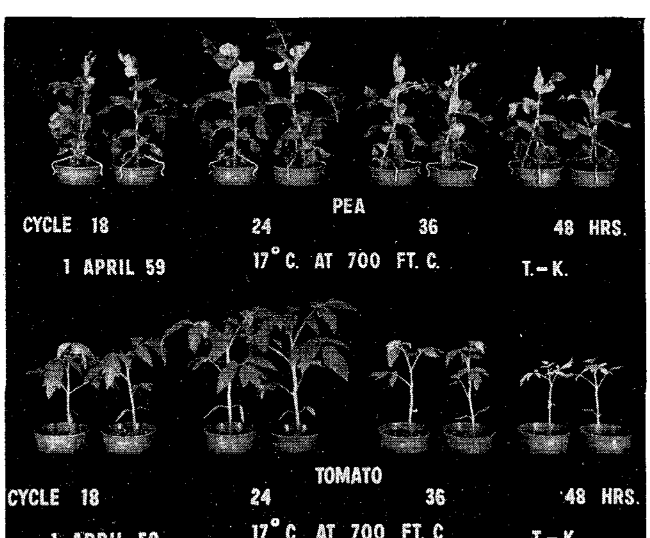
50 percent or more of the reduction in growth which would normally occur at that temperature can be prevented.

The optimal cycle length is dependent on the prevailing temperature and, interestingly enough, the amount by which the optimal cycle length changes with temperature approximates the amount by which the periods of internal rhythms change with temperature. The results support the notion that plants possess some inner, cyclical, time-measuring device, and that for optimal growth the external periodicity must be sychronized with the internal periodicity of the plant. The internal clock appears to run more slowly at lower temperatures and more rapidly at higher temperatures. At such temperatures it is not in register with an environmental 24-hour cycle, and it cannot be adequately synchronized with the environment.

Lack of synchronization between the internal and the environmental light-dark cycle is apparently the cause of at least part of the reduction in growth observed in plants grown under unfavorable temperature conditions. The experiment demonstrates that small changes in cycle length have a significant effect on plant growth and development.

Although temperature has an effect on the period of the clock, this effect is relatively small — certainly in view of the quite appreciable effects which temperature generally has in biological systems. It is quite possible that the effect of temperature on the clock is even smaller than indicated in these experiments, because it is difficult to determine the optimal cycle length exactly. In experiments where it is possible to determine the period of the clock accurately, it appears that the clock is only slightly affected by temperature. To all intents and purposes the clock is temperature-independent. This indicates a very sophisticated timepiece.

Temperature independence has been found in all




*Peas and tomatoes grow best when the environmental periodicity is close to 24 hours.*

internal rhythms. It also has been demonstrated in unicellular organisms, and it appears to be a basic property of the clock. This does not mean that the clock is insensitive to temperature — only that the effect of temperature on the period of the clock is small. The period may be changed for as little as 30 minutes by a change in temperature of 10°C. This is very remarkable for a biological system.

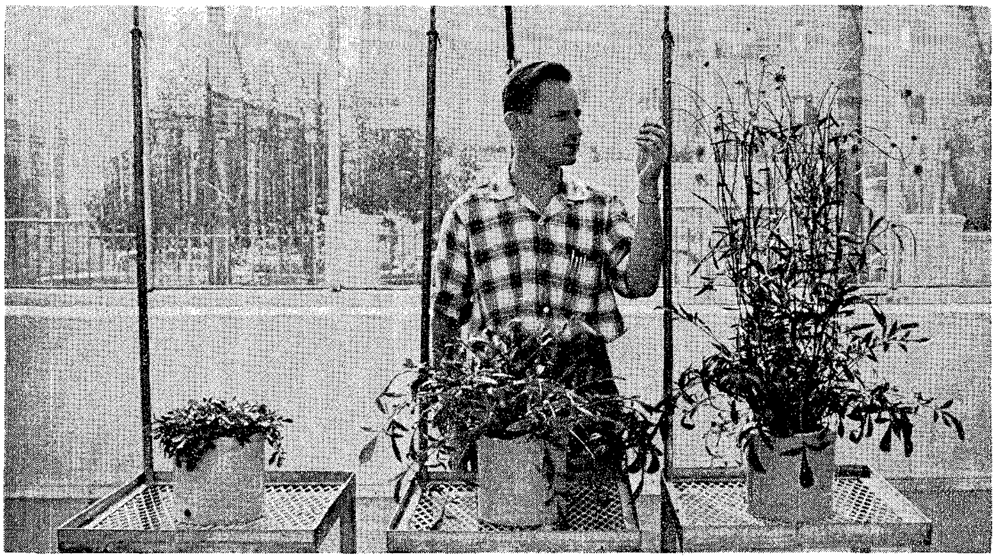
Temperature independence is a necessity for functional time-measurement by periods and the biological clock shares this property with our mechanical clocks. We have no idea how the organism achieves temperature independence. Presumably the clock is either a physical system or a temperature-compensated chemical system, component parts of which may be temperature-dependent. Although we know nothing about the mechanism of the biological clock, it is quite clear that living organisms possess a highly sophisticated timepiece.

## *Clocks and photoperiodism*

Apparently many — perhaps all — living organisms possess clocks. It may be worthwhile to look again at photoperiodism with this in mind. It will be very satisfying if it can be shown that the clock is responsible for every case of time measurement, including photoperiodism. A theory has been proposed which interprets photoperiodic responses as the result of an interaction between the endogenous clock and the environmental periodicity. According to this theory the dark-light change starts off a cyclic, or rhythmic, change in the physiological state of the plant. Once the rhythmic change has been initiated, its course is determined exclusively by the clock and it is not disturbed by a light-dark change, nor by brief periods of light during darkness. The change involves the sensitivity of the plant to light: The plant is supposed to pass through a phase during which light promotes flowering (and other processes affected by light) and a phase during which light inhibits flowering. During each of these phases the sensitivity to light changes quantitatively.

The explanation for the induction of flowering in short-day plants according to this model is as follows: The start of the light period (dark-light change) starts the phase during which light is promotive. After 10-12 hours the change in sensitivity, which is regulated by the biological clock, has progressed so far that light becomes inhibitory. Short-day plants will not flower when the external light period lasts so long that the plants receive light after they have changed into the state where light is inhibitory. Therefore, short-day plants will not flower when the light period is longer than 10-12 hours.

There is little direct evidence for this model, but a few observations suggest that internal rhythms may be involved in photoperiodic responses. A close correlation has been found in some plants between leaf



*Hendrik Ketellapper checks the effect of day-length on the Coreopsis plant. The plant on the left has been grown in short days (8 hours light), the one in the middle in long days (16 hours light). The plant at the right was grown in short days first, and then transfered to long days. This treatment makes the plant flower.*

movement and the sensitivity to light as measured by the flowering response. Supporters of the clock theory of photoperiodism claim that this proves that leaf movement and changes in light sensitivity are both regulated by the biological clock. Such coincidence, however, is of value only as an indication. It is not absolute proof.

Short-day plants flower when the dark period is longer than a critical number of hours. If the hourglass model is correct, one would expect that progressively longer dark periods will be better for flowering and that eventually a saturation point may be reached beyond which further increase of the dark period will have no effect. It has been found in experiments with the soybean – a short-day plant – that this is not true.

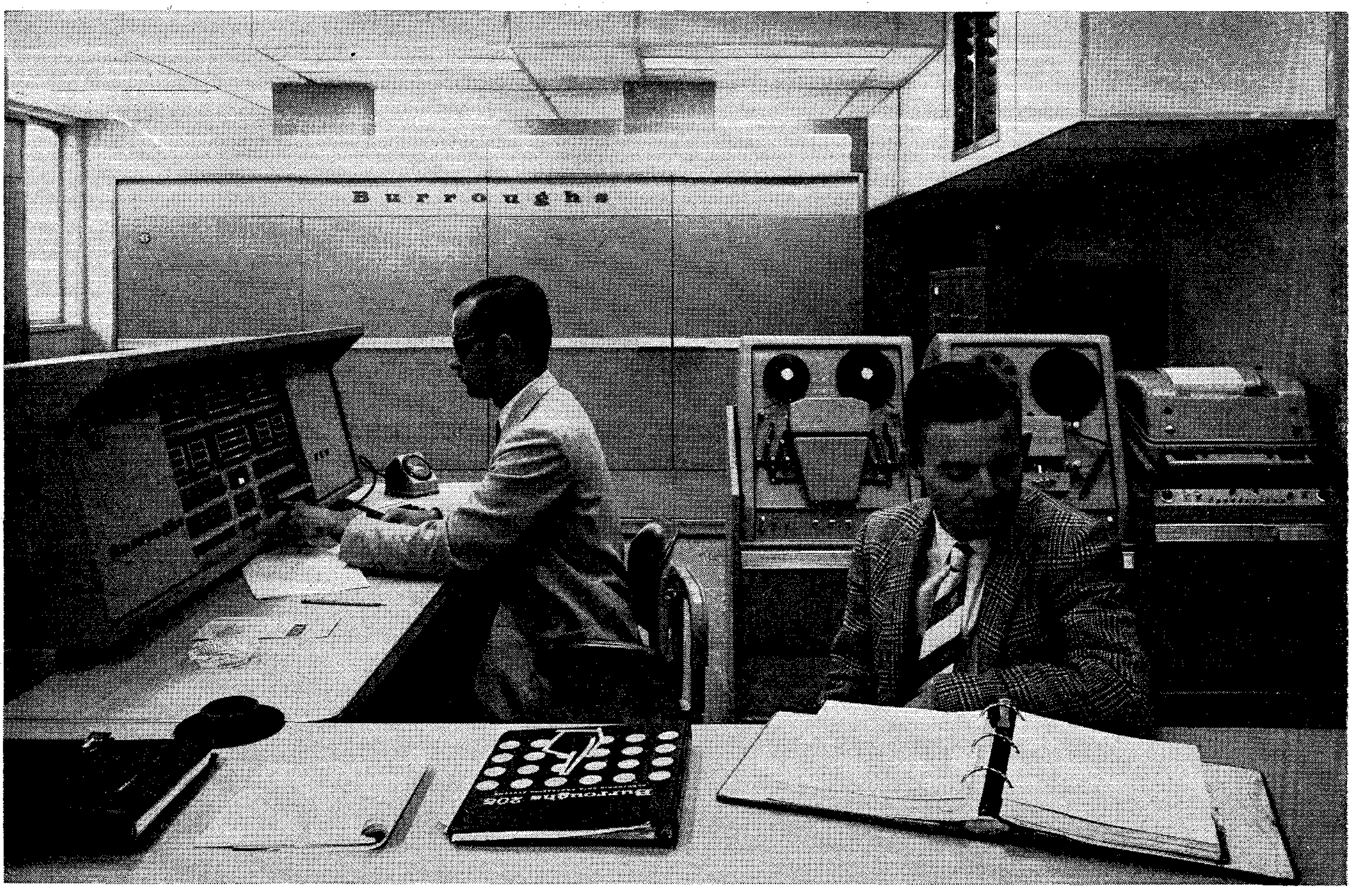
Soybeans receive an 8-hour light period, but then different groups of plants are exposed to dark periods varying from 12 to 48 hours. A 16-hour dark period causes excellent flowering, but when the length of the dark period is increased, the amount of flowering decreases and when the dark period is 36 hours, there is no flowering at all. Dark periods of 40-44 hours again cause excellent flowering. In fact, such dark periods are just as effective as 16 hours. No flowering at all is elicited by 48 hours darkness. Apparently a 24-hour periodicity is involved, and flowering is stimulated when the cycle length is 24 hours or multiples of 24 hours. Somewhat similar results have been obtained in other experiments.

At the present time it is not possible to decide between the two models for photoperiodism: the hourglass or the clock. There is no compelling reason to accept the model employing the clock. Many plant physiologists feel that by involving the clock we replace something we do not know much about by something which we understand even less. The hourglass model seems to be the simpler model and it is capable of explaining the vast majority of phenomena. Furthermore, it is quite possible that, in those cases where an endogenous rhythm seems to be involved, the involvement is at a secondary level. The merit of the model involving the biological clock is that it relates all instances of time measurement to a common cellular clock.

Time measurement plays a role in many aspects of plant and animal life in addition to the ones discussed so far. Only in the last few years has its importance been generally realized. However, the most interesting questions still remain. Where is the clock located? What does it look like? And how does it work? Unfortunately the answers to these questions are not known.

In plants, presumably every cell has its own clock, and the environmental events synchronize all these clocks so that the organism acts as a unit. In animals, many experiments indicate that the nervous system is involved and may be the site of time measurement. However, we have no idea of what the clock looks like or even what to look for. It is not known in what part of the cell it occurs, whether in the nucleus or in the protoplasm. The mechanism of the clock is not known either.

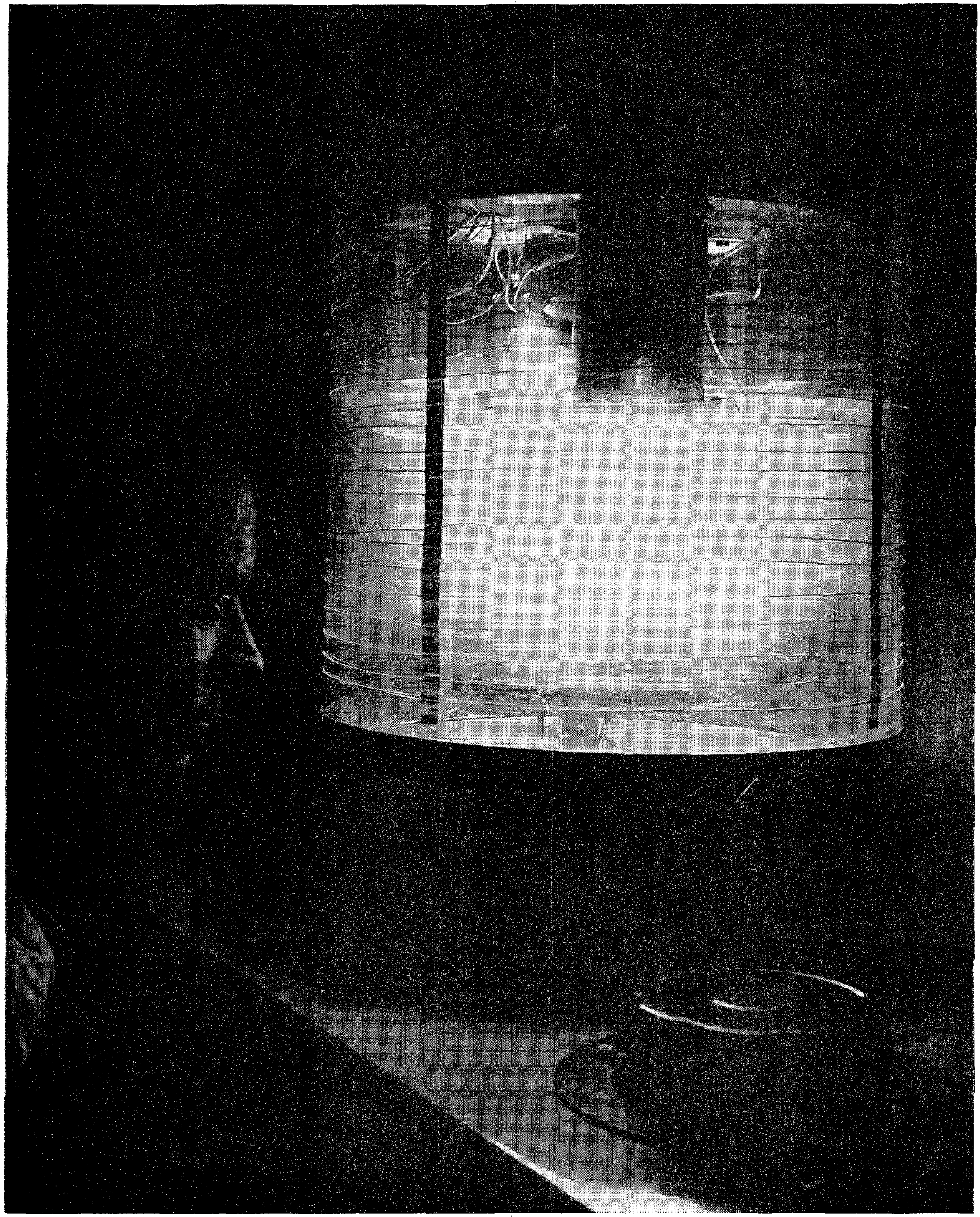
A number of model systems have been proposed and they are in the process of being tested. The model systems have a tendency to become more and more complicated and it is not clear what cellular systems could correspond to the model. The answers to these fundamental questions may not be found soon because of the difficulty of the task, both philosophically and technically. As so little is known about the clock, it offers a great challenge and the clock is now being investigated by many biologists. A large part of the work is descriptive and concerns itself with phenomena, but some investigators look for answers to basic questions. These answers will help our understanding of life and in time we may be able to make practical use of this knowledge.




*Large scale computers have become essential to modern science and technology. In Caltech's Computing Center, this Burroughs 220 Digital Computer serves as the Institute's computing facility for both general research and instruction in machine computing methods.*

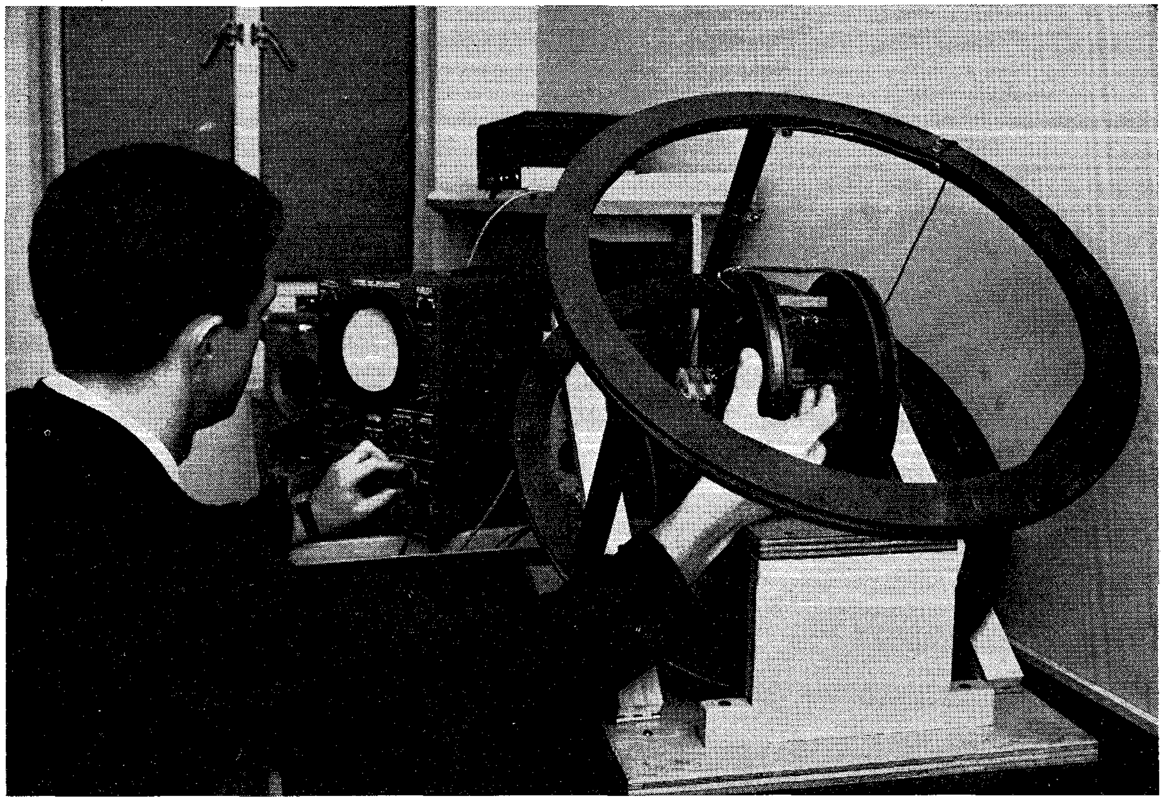
# ELECTRICAL ENGINEERING

Electrical Engineering, both as a profession and as an educational discipline at the Institute, has changed considerably in the last 15 or 20 years. It used to be confined largely to the generation and distribution of electrical energy and to communications, through the application of the classical physics of electricity and magnetism. Today electrical engineers are concerned with a number of different basic disciplines in the realms of physics and mathematics, and with many different applications. Some of the more important disciplines are plasma physics, solid state physics, stochastic processes, and Boolean algebra. They are being applied to such things as the development and application of new semiconducting devices, microwave tubes, new devices for energy conversion, and to new systems of automatic control, communications, and data processing. The pictures on these pages show some of the current and varied research in electrical engineering at Caltech.

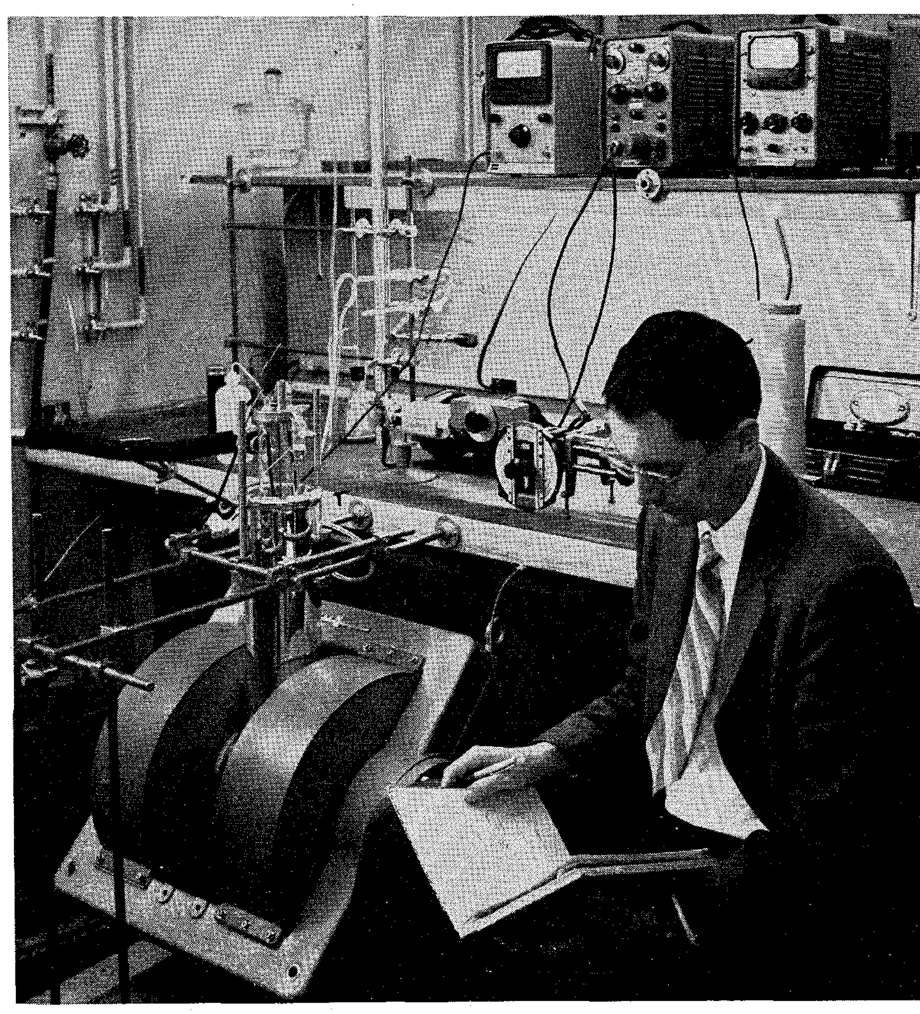


MAKING THIN MAGNETIC FILMS

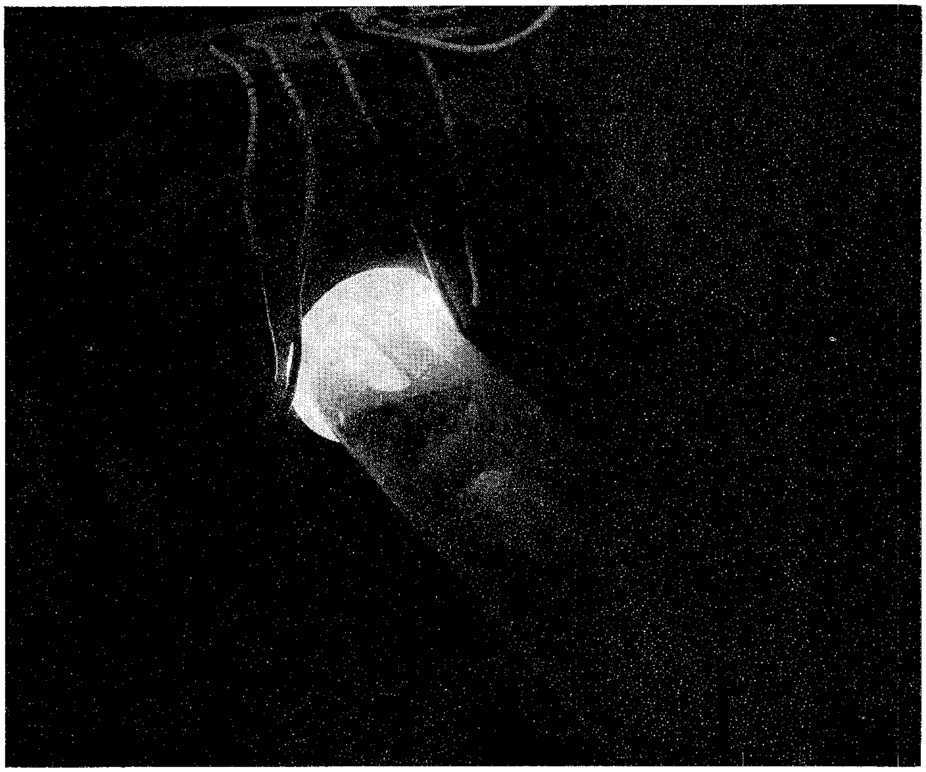
*In Caltech's electrical engineering laboratories, new methods for the fabrication of very thin conducting, insulating, magnetic, or other materials, at controlled thicknesses as small as several hundred angstroms, makes possible new kinds of electronic devices and microcircuits. Here a nickel-iron film about 1,000 angstroms thick is deposited by induction heating evaporation from a crucible.*



MAGNETIC FILM RESEARCH
*Magnetic properties of thin nickel-iron films are investigated with a "B-H Looper." These films can be used either as memory elements, or for switching logic circuits in a computer. They can be switched in only a few thousandths of a microsecond.*



LOW TEMPERATURE RESEARCH
*This apparatus is used to investigate the interaction of superconductors and electromagnetic fields. Temperatures near absolute zero are necessary for superconductivity, so glass dewars hold liquid helium in which the superconductor is immersed. The equipment on the bench generates microwave fields and measures their interaction with the superconductor. The large electromagnet in which the dewars stand is used to apply a fixed magnetic field in order to investigate its effect.*

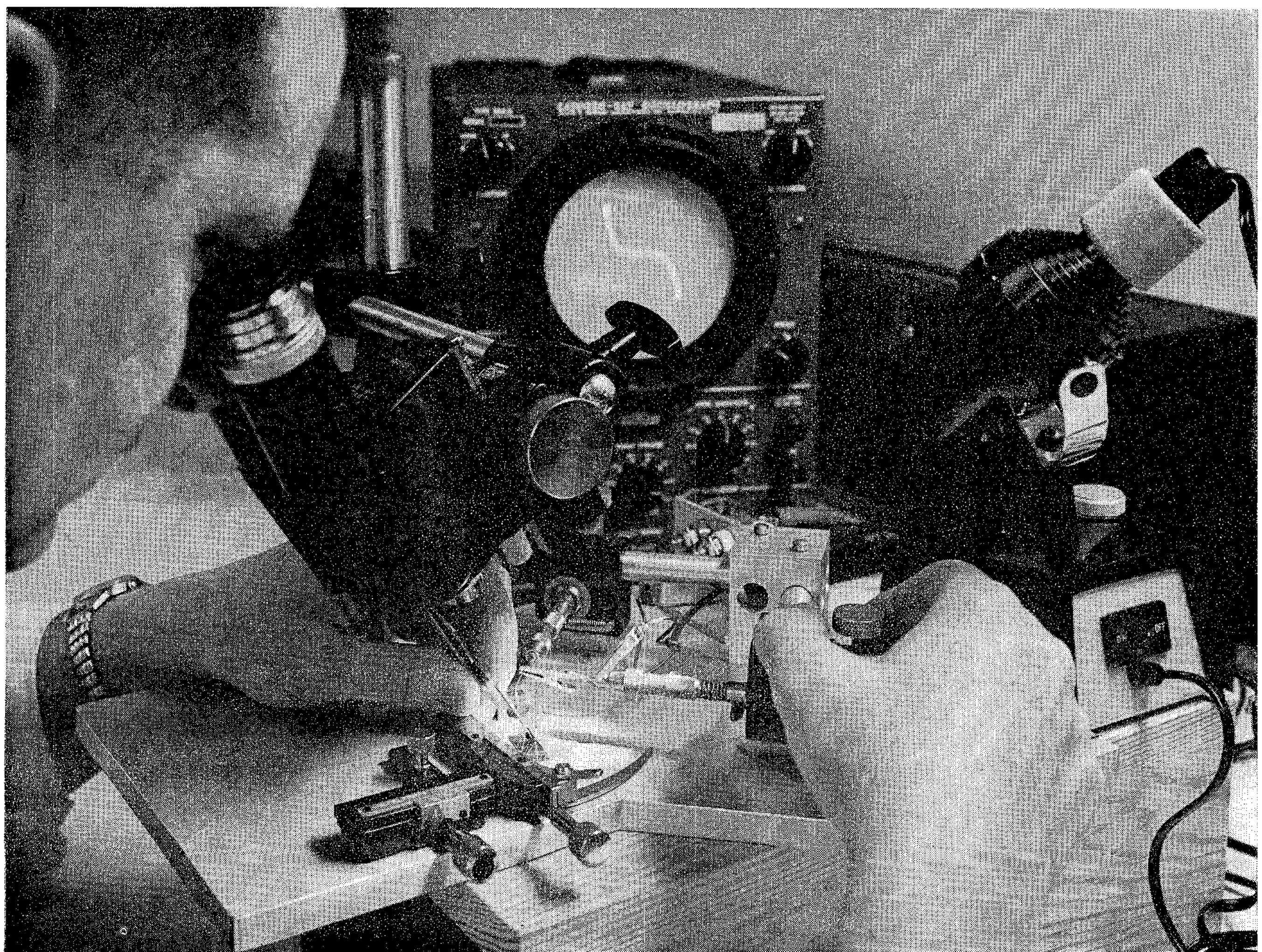


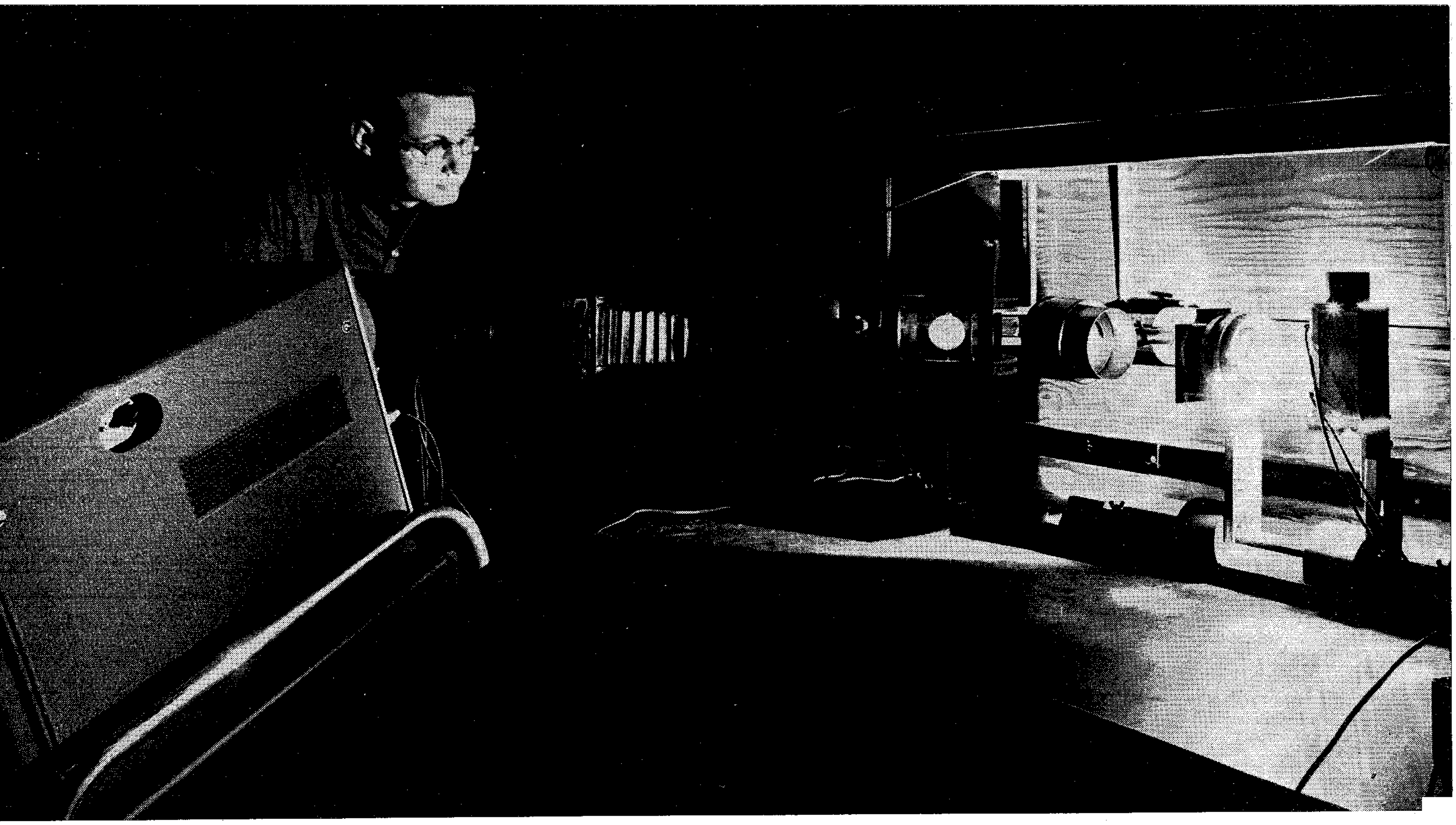
SOLID STATE TECHNOLOGY

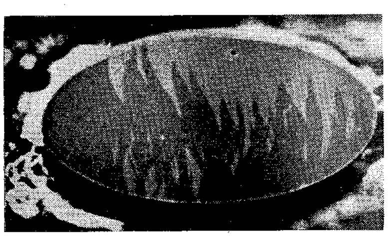
*"Zone refining" is a technique especially developed to provide the high-purity materials needed in making solid state devices. The material to be purified is placed in an inert environment and repeatedly passed slowly through a furnace. Impurities accumulate in the molten zone, thus gradually increasing the purity of the resolidifying region. Figures like one impurity in $10^{10}$ are now commonplace.*

SOLID STATE DEVICES

*Tunnel emission triodes, which were invented at Caltech, are theoretically capable of very high frequency performance and they may soon be appearing with other thin film components in micro-circuitry. Here, in the Caltech electrical engineering laboratories, a technician makes a connection to a tunnel emission diode with a micro-manipulator probe while the volt-ampere characteristic is displayed on an oscilloscope.*





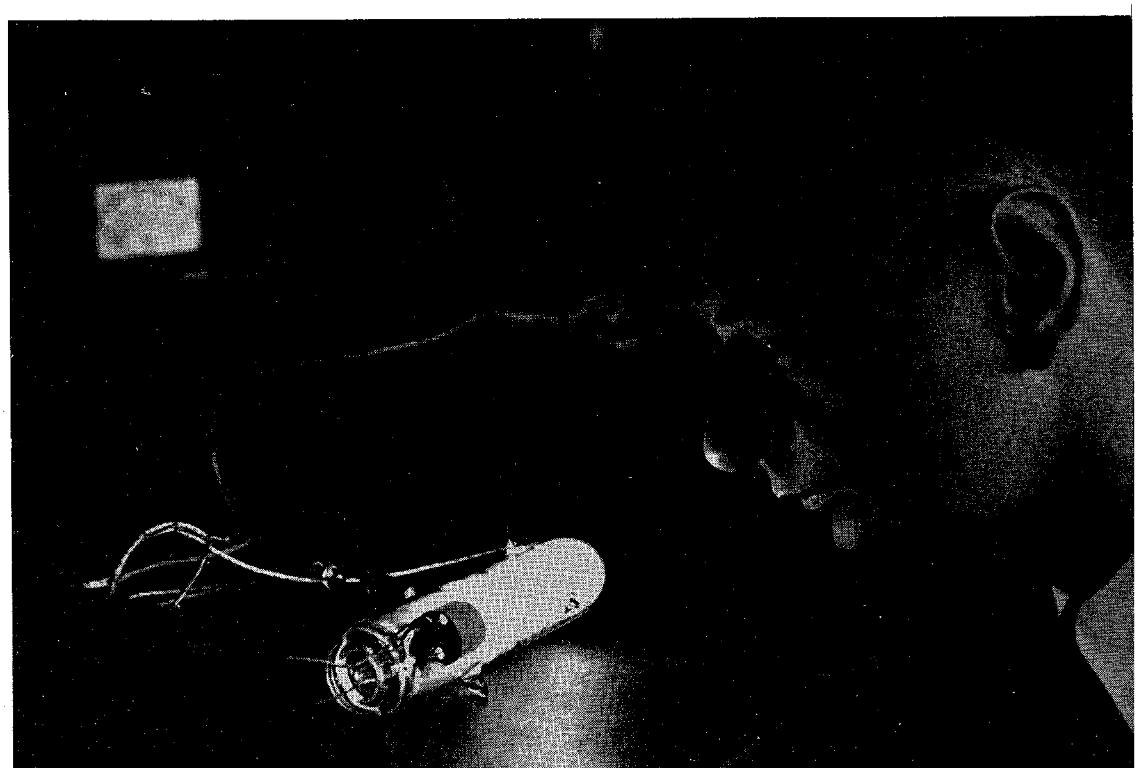


MAGNETIC DOMAINS

*Examination of the magnetic structure of nickel-iron material is made possible by using polarized light reflected from the metal surface. This is called the Kerr effect and utilizes differential rotation of the polarized light coming from regions of different magnetization – creating the dark and light portions shown in the film of the structure of nickel-iron at the left.*

PLASMA PHYSICS

*The interaction of hot plasma with electromagnetic radiation provides an important phenomenon for investigations. Many experimental discharge tubes have been made in Caltech's laboratories to study possible practical application of this interaction.*



# *A Morphologist Ponders the Smog Problem*

*by Fritz Zwicky*

Some problems are beyond the capability of mere scientific or technical specialists – streamlining the relations between nations, for example, or relations between different races; developing a truly adequate system of education; or eliminating crime.

And some problems that would appear to be solvable by known scientific and technical methods alone still cannot be liquidated satisfactorily. Among these we count the task of eliminating the smog in and around Los Angeles County.

*Fritz Zwicky: Morphologist*

Professor of astrophysics at Caltech, and staff member of the Mount Wilson and Palomar Observatories, Dr. Fritz Zwicky has always been an independent thinker – as anyone can see by sampling the accompanying article. Here, Dr. Zwicky applies the morphological method to the problem of smog – a method that is, basically, just an orderly way of looking at things. Dr. Zwicky has written extensively on applications of the morphological method to problems in jet propulsion and in astronomy – most recently in *Morphological Astronomy* (1957). In *Morphologische Forschung* (1959) he further discussed the applications of the method to sociological as well as scientific, technical, and military problems.

To solve this problem, much technical knowledge about the sources and the characteristics of air pollutants is of course necessary. But, beyond that, an integrated view which relates this knowledge to political, psychological, and ethical factors is likewise imperative. All of these factors add up to a complex task which is beyond the power of ordinary scientific, technical, or managerial experts. Specialists are at the added disadvantage that they are often too set in their ways, and too prejudiced, because of being unduly impressed by their accomplishments in relatively narrow fields. The problem of smog is thus a typical one which can be solved satisfactorily only through the so-called morphological approach.

For our present purposes it suffices to state that the morphologist, before all, and without any prejudice, attempts to visualize the *totality of all interrelations* which bear on the solution of a given problem. The stress is *first* on a survey without prejudice, which is far more difficult to achieve than most will care to believe; and *second* on a survey which includes all imaginable possibilities, before one attaches himself to any particular solution.

For a number of years many specialists have been at work determining the sources and the daily input of various pollutants into the atmosphere. Also the most important reactions have been traced (especially and most successfully by A. J. Haagen-Smit, Caltech professor of bio-organic chemistry) which take place between the pollutants, the constituents of the atmosphere, and sunlight as a photochemical agent. Some of the pertinent facts found are as follows. In orders of magnitude the daily input into the atmosphere of Los Angeles County includes:

| | |
|---|---|
| Organic compounds | — 1700 tons (1100 tons from automobiles, 450 tons from evaporating solvents, 150 tons from the petroleum industry). |
| Carbon Monoxide | — 10,000 tons (representing the totality of the products of incomplete combustion processes). |
| Nitrogen Oxides | — 700 tons (450 tons from automobiles, 220 tons from the combustion of gas and oil in homes and industrial plants, etc.). |
| Sulfur Dioxide | — 550 tons in winter (400 tons from fuel oils, 50 tons from automobiles, 45 tons from sulfuric acid factories, etc.). |
| Aerosols | — 100 tons. |

Because of the frequent persistence of a temperature inversion layer over southern California, and the absence of even moderately strong winds, these pollutants stagnate and may accumulate day after day.

Although these primary pollutants are disagreeable enough in themselves, they become outright dangerous as a result of subsequent reactions, many of which take place because of the photochemical action of sunlight on them. As Professor A. J. Haagen-Smit first showed through his singlehanded and profound research on this problem, a great number of the secondary reactions are triggered through the action of sunlight on nitrogen oxide. As a consequence, exceedingly active atomic oxygen is released from $NO_2$. The atomic oxygen in turn reacts with the organic components of the pollutants in the atmosphere and leads to the formation of various intermediate oxidation and reaction products, as well as to the production of ozone. These poisonous compounds constitute severe eye and throat irritants, and worse, dangerous hazards to the health of man, beast, and plant.

Although the nitrogen oxides, together with sunlight, produce the dangerous components of smog at a fast rate, even the complete elimination of nitrogen oxides would not eliminate the formation of the vicious compounds in smog, but would only change the size of the territory over which they are spread. Indeed, the oxygen of the atmosphere itself, with the aid of sunlight, would act on the organic pollutants much as the nitrogen oxides do. The rates of reaction, however, would be slower, and the vicious reaction products would have time to diffuse or to be spread over a large area.

## *A cooperative effort*

The few basic facts, as we have stated them, suffice to make it clear that the problem of smog is a most complex one and that, for its solution, cooperation from many quarters will be necessary. Therefore the morphologist must first list the character of these various quarters and the contribution they might make toward the elimination of smog. The following sources of cooperation and support immediately come to mind:

1. The general public.
2. The various official agencies, including the police departments.
3. The universities, and the scientists individually.
4. Various industrial enterprises, as well as engineers individually.
5. The medical profession and public health services.
6. Certain commercial establishments.
7. The politicians.
8. The press.

These possible agencies of aid and cooperation must be appraised with a view to the following three goals:

a. The achievement of immediate results.
b. Results in the near future.
c. Results of a permanent nature in a more distant future.

## *Measures for achieving immediate results*

"Immediate" implies that, in principle, the means in question could be effectively applied tomorrow. Again, in principle, these means can either be actual devices or they might be certain measures which will in one way or another regulate and streamline the activities of the public in southern California with a view towards the elimination of the smog.

I do not know of any devices which are immediately available and which guarantee the elimination of a substantial fraction of smog. On the other hand, many means already exist for influencing the daily activities of the public in such a way as to bring a marked decrease in the degree of air pollution. Among these measures the most effective would be the complete prohibition of driving any automobile with noxious exhausts, though this is hardly practicable. On the other hand, both the problem of smog and the streamlining of traffic as a whole could be substantially furthered by another plan.

With the view in mind of introducing immediately applicable measures we must try to influence the daily activities of the public as a whole — and, in particular, of the automobilists. One such measure, already passed by law, is the prohibition of burning trash in backyard incinerators. There are additional and even more effective means available. Among these, the most important and effective will be *to make it quite clear* to the public that each and every one among us must make his proper sacrifices and his contributions towards the elimination of the smog. For this reason, I advocate most strongly measures which will materially reduce the traffic through Los Angeles and, in particular, the traffic on all of the freeways.

*"Each and every one among us must make his proper sacrifices — and his contributions — toward the elimination of smog."*

Even casual observation during our daily driving shows that the majority of cars on the road carry only a single occupant. Now it is obviously preposterous to allow a single individual to pollute the atmosphere at his pleasure with dangerous nitrogen oxides, with carbon monoxide, and with the uncombusted or partly combusted organic compounds from the exhaust, the fuel feed lines, and the carburetor of his automobile. This promiscuity in polluting the air is actually far worse than allowing litterbugs to throw their cigarette butts, matches, papers, cans and other trash on the streets and highways. Since the litterbug has already been censored, and since he can be prosecuted by law, we are obviously far more justified in stopping individual drivers from polluting the air we breathe.

As a workable and effective measure of control, which can be put into action immediately, I propose that any driver who insists on driving on a freeway without carrying any additional passengers in his car must pay a certain toll, say one dollar a day, for his extravagance. In order to collect these dollars smoothly and without the mobilization of much personnel, stickers could be issued, with the dates printed on them and with different colors and shapes distinguishing the various days. These stickers would be purchased one or two days ahead of the day in question, at stations located at strategic points. Any driver who has no passengers must display the proper sticker on the proper day on his windshield. Police officers could then easily spot those drivers who are violating the regulation. For every such violation a fine of fifty or one hundred dollars could be levied. All trucks should be charged one dollar per day for driving on the freeways, regardless of the number of passengers they carry.

For driving on the *city streets* without any passengers, three stickers per month might be issued, valid for ten days each, and at a cost of perhaps a dollar each. The period for the levy might be restricted to from 9 a.m. to 3 p.m. This would allow everybody to get to and from work without any penalty. Physicians, of course, would be exempt at all times.

The following results would be achieved from the collection of these various levies:

(i) An estimated 20 percent of the smog would be immediately eliminated because of the reduction of traffic.

(ii) A sizable amount of money would become available each year for research on all aspects of the smog problem.

(iii) The public would be dramatically impressed with the fact that each and every one of us is responsible for the problem of air pollution and that all of us can and must help in eliminating it.

(iv) The reduction in the number of automobiles on the road would reduce the accident rate, eliminate many traffic jams, speed up circulation and deliveries, allow more people to meet their appointments on time, alleviate many psychological anxieties, and thus benefit the overall activities of the community.

(v) Finally, and probably most important, the health hazard inherent in smog would be reduced, and valuable manpower and working hours would be saved.

There are also other measures which can be introduced with relative ease. For instance, it will eventually become necessary to get tough with all drivers of mechanically defective cars which at the present time still merrily belch clouds of noxious fumes along the streets. There is obviously little hope that any smog reduction devices, such as afterburners, will help much unless we see to it that they are all really working properly. This means control of maintenance of these devices. Today such control is not even adequately exercised with regard to the smoky exhausts.

As a further immediate measure I propose that research institutions, such as the California Institute of Technology, the University of California at Los Angeles, the Stanford Research Institute, and others, which have for some time been given sizable grants for research on the smog problem, should be requested to produce, for each $100,000 of grant, a usable plan for getting rid of, say, one percent of the smog at the least. If these institutions cannot come forth with such results, the grants should be diverted to other more effective people. Also, the presidents of these institutions might be expected, as a contribution to the better life of the community, to exert themselves somewhat more ardently than hitherto in animating their faculties (and their chemists, physicists, and engineers in particular) in a cooperative endeavor toward the elimination of smog.

It should also be impressed on those of our scientific colleagues who have been shouting so much about the dangers of radioactive fallout that first things should come first and that their suddenly avowed love for humanity would be more convincing if they spent some of their time and effort on solving the problems at hand – the problem of smog being a most appropriate one to tackle.

Finally, in view of the tremendous quantities of carelessly evaporated solvents (450 tons a day, or almost half as much as come from automobiles) both the housewives and the professionals (painters, cleaning establishments, highway construction crews) who use them should be instructed how to handle solvents with greater care.

## *Measures for the near future*

Among the intermediate measures which will require some time for their effective development are the devices which would improve combustion in automobile engines and cut down the excessive discharge into the atmosphere of uncombusted or partly combusted hydrocarbons, nitrogen oxides, and carbon monoxide. Many of the devices in this category, such as afterburners, catalytic devices, recirculators of the exhaust gases, and extra oxygen feeders, are now being worked upon by many agencies. Depending on exhaustive tests to be made by official and critical examiners, some of these devices might soon become applicable. Also, it should not be too difficult for the automobile manufacturers to build engines and feed systems which will not leak gasoline at the atrocious rate of most of the present machines.

Further relief might be derived from an application of the principle that whatever cars put into the atmosphere cars can also extract or neutralize. Indeed, in the course of their travel cars sweep through and stir up immense quantities of air. Thus one million cars traveling as little as one kilometer a day will sweep through a volume of air in excess of four cubic kilometers – a very respectable volume. Possibilities for cleansing this huge amount of air are easily suggested. One of these means consists in either adsorbing or absorbing the pollutants from this volume of air and decomposing chemically or catalytically the noxious nitrogen oxides on specially treated external or internal surfaces in special ducts of the cars.

The second means is to let the cars, aided by differential heating through absorption of sunlight, create circulation through culverts and tunnels which already exist or which might be specifically constructed for the purpose. Also catalytic and chemical surfacing, followed by subsequent large-scale washing for removal of the smog products from the street surfaces themselves as well as from the surfaces of buildings, should be investigated in research projects. These could be amply financed by the funds collected from motorists.

## *Long-range measures*

Two outstanding possibilities suggest themselves here:

1. Without concerning ourselves at all with the sources of smog we may decide to work on large-scale means to eliminate the pollutants from the atmosphere or to neutralize them and turn them into harmless products.
2. As the second alternative we may carry out a complete survey of the sources of smog and then set out to eliminate or neutralize them one by one.

Working on large-scale means, we may either bring about reaction of the pollutants (that is, oxidize them or dissociate them) and end up with innocuous reaction products such as oxygen, nitrogen and carbon dioxide; or we may attempt to drive the pollutants out to sea, precipitate them to the ground, or drive them high enough into the atmosphere into strata where winds always blow vigorously enough to spread the pollutants over sufficiently large areas to render them harmless. Considerable research of course must be done, financed by the levies raised from the public, to develop methods which will enable us to achieve any one or all of our goals.

Actually, in working towards these goals, the smog itself should be of considerable assistance since, speaking energy-wise, it is potentially quite capable of exploding and thus destroying itself! Indeed, smog represents a chemically endothermic state and thus is literally an explosive. Actually, the oxidation of the 1700 tons of organics and the 10,000 tons of carbon monoxide into water and carbon dioxide would release daily 22 million and 29 million kilowatt hours of heat respectively. From the dissociation of the 700 tons of nitrogen oxides into nitrogen and oxygen an additional 650,000 kilowatt hours could be obtained daily. Figuring a thermodynamic efficiency of 25 percent for the conversion into mechanical or electrical power, about thirteen million kilowatt hours are therefore wasted daily through the discharge of unreacted fuels and of endothermic compounds into the atmosphere in and around Los Angeles. It is clear that it would be best to save this energy by not discharging it into the air at all. As a second best solution we might use it with a sufficiently cleverly conducted series of operations to extract the smog from the atmosphere.

## *Tracking down the sources*

Our *second* alternative must be to track down the sources of smog and to eliminate them one by one. Automobile exhausts being by far the worst and most persistent offenders, let us survey what might be done about them.

The most radical solution would be to outlaw automobiles altogether and to construct a general transportation system, such as underground electric subways. With a view to survival in a possible nuclear war, a solution of this character has much to recommend it and should therefore be analyzed in detail.

Working on the automobile engines themselves, the exhausting of dangerous pollutants could either be eliminated completely, or greatly diminished by one of the following developments, which are of immense interest for the generation of power from carbon or hydrocarbons in general. The first possibility refers to the use of *fuel cells* which generate electricity *directly* from the oxidation of the fuels in electrolytic reactors. How to accomplish such reactions with high efficiency has been attempted for over a hundred years, but only recently have successful inroads been made. Replacement of the internal combustion engine by fuel cell electric generators would eliminate all vicious gaseous exhaust products altogether.

Much cleaner exhaust products could also be achieved through a combustion which approximates a more isothermic character, in contradistinction to the conversion of heat into mechanical power by adiabatic expansion of the combustion gases, which necessitates high combustion pressures and temperatures, and which, because of the rapidity of the processes involved, always leaves unreacted products. In this connection it may be pointed out that the oxidation of food in living bodies takes place isothermally. One way to approximate isothermal combustion was pointed out many years ago as a consequence of my work on power conversion in jet engines. The processes to be used are a succession of combustions and expansions or, in other words, so-called *reactions on the flow.* In fact we successfully operated such jet engines with hydrogen and oxygen as the propellants. Our attempts to interest the builders of combustion engines in the principles of reactions on the flow, however, have mostly fallen on deaf ears.

Our experiences in this respect call for a few comments on some aberrations of the human mind which have been greatly responsible for our failure to deal effectively with the problem of smog, or, for that matter, with such problems as an adequate civilian defense and the issues involved in our competition with the communists. Indeed, in the present case, the automobile industry, instead of developing better engines and smog suppressors, concerned itself largely with the styling of mammoth cars, which are about as useful as the towering and elaborate hairdos preceding the French Revolution, but which are much more wasteful and dangerous.

As director of research of the Aerojet Engineering Corporation in 1943 I attempted to obtain from the automobile industry information about the topological performance characteristics of automobiles. No pertinent information could be obtained about how far a car of given weight could be driven with one liter of gasoline on a road of given characteristics. That is, the industry had never concerned itself with the exact evaluation of the maximum thermodynamic efficiencies possible; with the minimum heat and fuel losses; with the minimum possible transmission losses from the engine to the wheels; with the rolling friction losses of various types of tires; with the aerodynamic drag; or with the characters of the various parasite losses. In fact, I wonder if such an overall evaluation of the automobile as a complete propulsive power plant is even available today.

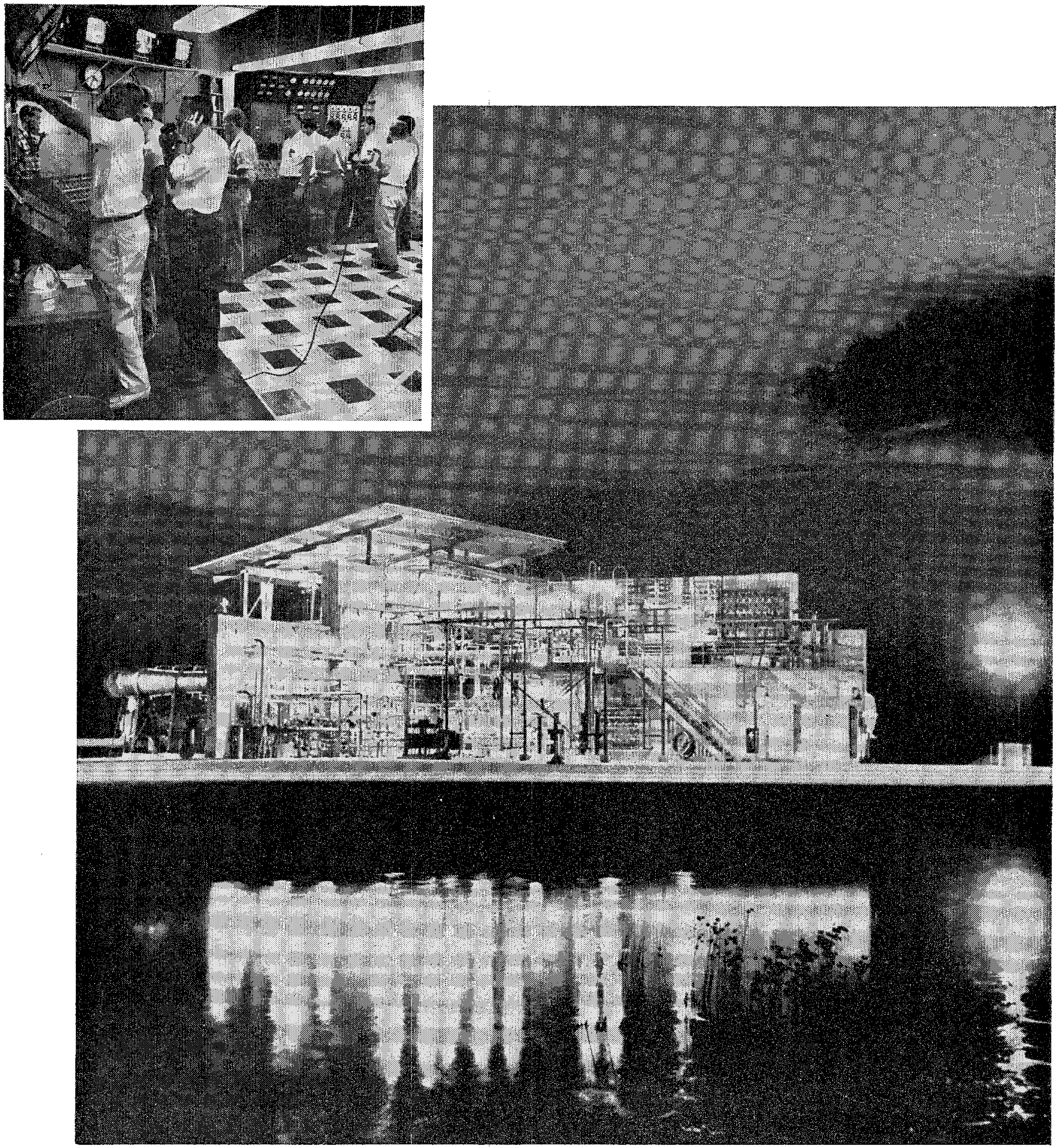
## *Who's to blame*

It is, however, not only the moguls of industry which are to be blamed. The scientists themselves and, in particular, the administrators of scientific institutions, both governmental and private, have dismally failed in their responsibility to organize their manpower and technical resources toward making a concerted attack on such problems as the elimination of smog. Individuals like Professor A. J. Haagen-Smit are therefore highly to be commended. Individual efforts alone will, however, not be sufficient for success, although they must act as the indispensable spearheads. What is needed is the cooperation of scientists, engineers, the public, the press, and the various agencies of the local, state and federal governments.

In conclusion I therefore suggest that, as a first step, the presidents of the local universities call some of their men together to work out an overall morphological attack on the problem of smog. I have attempted to point out a few promising avenues, but far more can and will be done if a group of men of good will and of technical knowledge can be called together to make an uncompromising attack on the problem of smog. The success of such an attack will in my mind not only be of immense economic value; it will also eliminate a tremendously growing health hazard; and it will, directly and indirectly, aid our efforts in stemming the tide of communism through the proof that ours is an immensely sounder world than theirs.

# What would *YOU* do

# as an engineer a



Development testing of liquid hydrogen-fueled rockets is carried out in specially built test stands like this at Pratt & Whitney Aircraft's Florida Research and Development Center. Every phase of an experimental engine test may be controlled by engineers from a remote blockhouse (inset), with closed-circuit television providing a means for visual observation.

# Pratt & Whitney Aircraft?

Regardless of your specialty, you would work in a favorable engineering atmosphere.

Back in 1925, when Pratt & Whitney Aircraft was designing and developing the first of its family of history-making powerplants, an attitude was born—a recognition that *engineering excellence* was the key to success.

That attitude, that recognition of the prime importance of technical superiority is still predominant at P&WA today.

The field, of course, is broader now, the challenge greater. No longer are the company's requirements confined to graduates with degrees in mechanical and aeronautical engineering. Pratt & Whitney Aircraft today is concerned with the development of all forms of flight propulsion systems for the aerospace medium—air breathing, rocket, nuclear and other advanced types. Some are entirely new in concept. To carry out analytical, design, experimental or materials engineering assignments, men with degrees in mechanical, aeronautical, electrical, chemical and nuclear engineering are needed, along with those holding degrees in physics, chemistry and metallurgy.

Specifically, what would *you* do?—*your own engineering talent* provides the best answer. And Pratt & Whitney Aircraft provides the atmosphere in which that talent can flourish.

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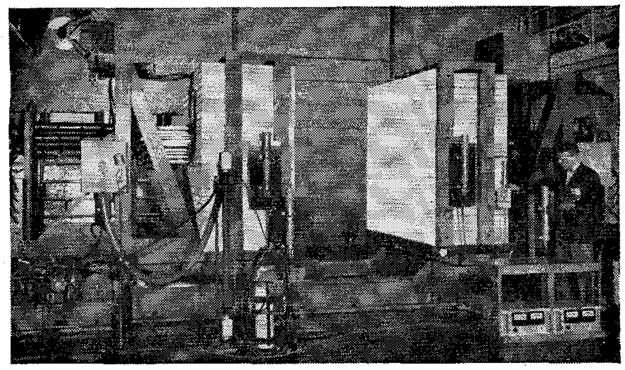
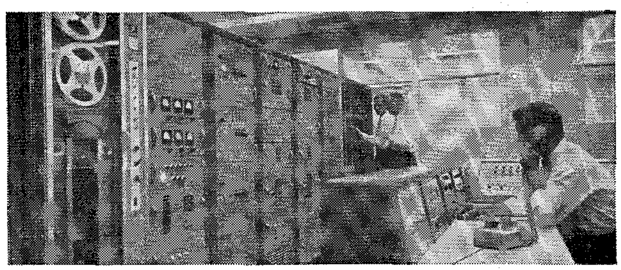
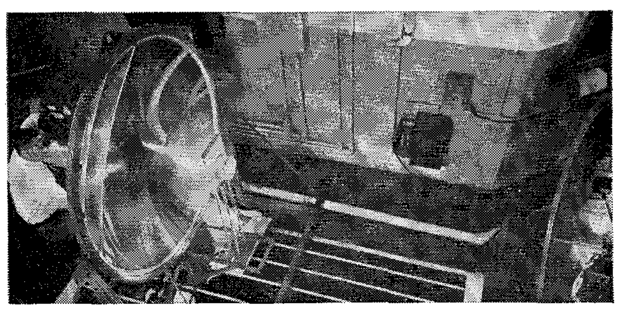
For further information regarding an engineering career at Pratt & Whitney Aircraft, consult your college placement officer or write to Mr. R. P. Azinger, Engineering Department, Pratt & Whitney Aircraft, East Hartford 8, Connecticut.



At P&WA's Connecticut Aircraft Nuclear Engine Laboratory (CANEL) many technical talents are focused on the development of nuclear propulsion systems for future air and space vehicles. With this live mock-up of a reactor, nuclear scientists and engineers can determine critical mass, material reactivity coefficients, control effectiveness and other reactor parameters.



Representative of electronic aids functioning for P&WA engineers is this on-site data recording center which can provide automatically recorded and computed data simultaneously with the testing of an engine. This equipment is capable of recording 1,200 different values per second.



*Studies of solar energy collection and liquid and vapor power cycles typify P&WA's research in advanced space auxiliary power systems. Analytical and Experimental Engineers work together in such programs to establish and test basic concepts.*

**PRATT & WHITNEY AIRCRAFT**

Division of United Aircraft Corporation

**CONNECTICUT OPERATIONS — East Hartford**

**FLORIDA RESEARCH AND DEVELOPMENT CENTER — Palm Beach County, Florida**

# The Month at Caltech

## *Franklin Thomas Engineering Laboratory*

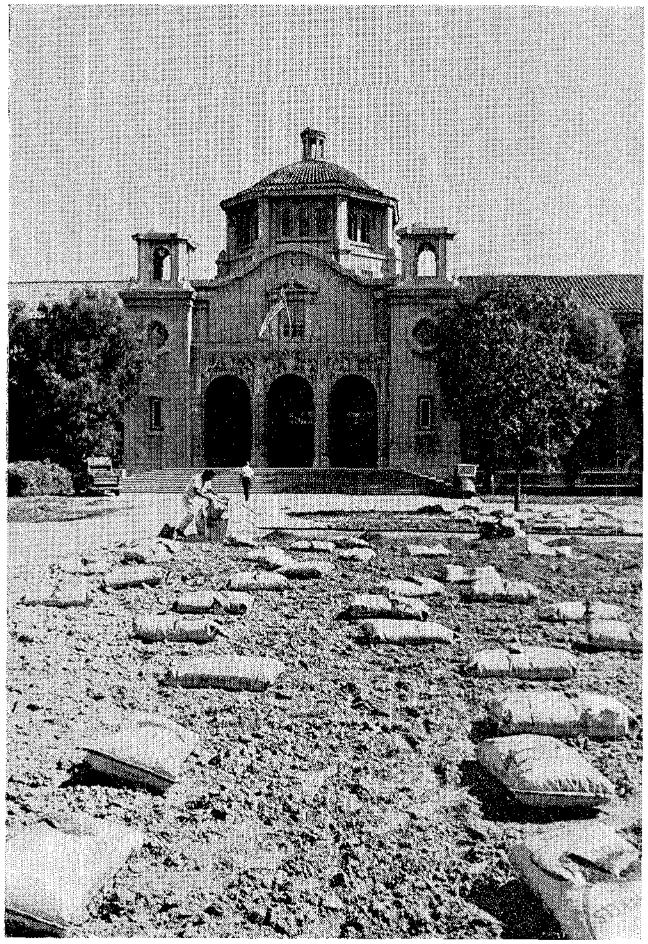
Caltech's five-story engineering building has simply been known as "Engineering" ever since it was built. This month it got a name — the Franklin Thomas Engineering Laboratory, in memory of the Caltech civil engineer and dean of students who helped solve some of southern California's major water problems and who was a leader in Pasadena's city government and cultural affairs.

Dean Thomas came to Caltech in 1913 and started a department of civil engineering. In 1924 he was appointed chairman of Caltech's division of civil and mechanical engineering, and he became dean of students in 1944. He died in 1952 at the age of 67.

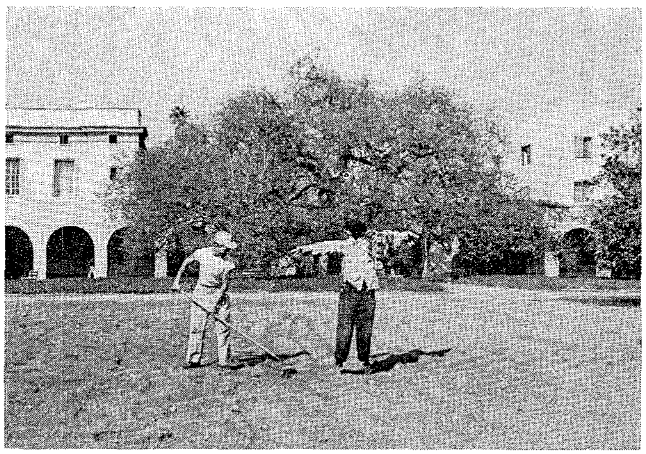
The building named for Dean Thomas was built in three sections — the eastern third during World War II, the western two-thirds after the war. Its laboratories house research in civil engineering, applied mechanics, jet propulsion, and some mechanical and nuclear engineering.

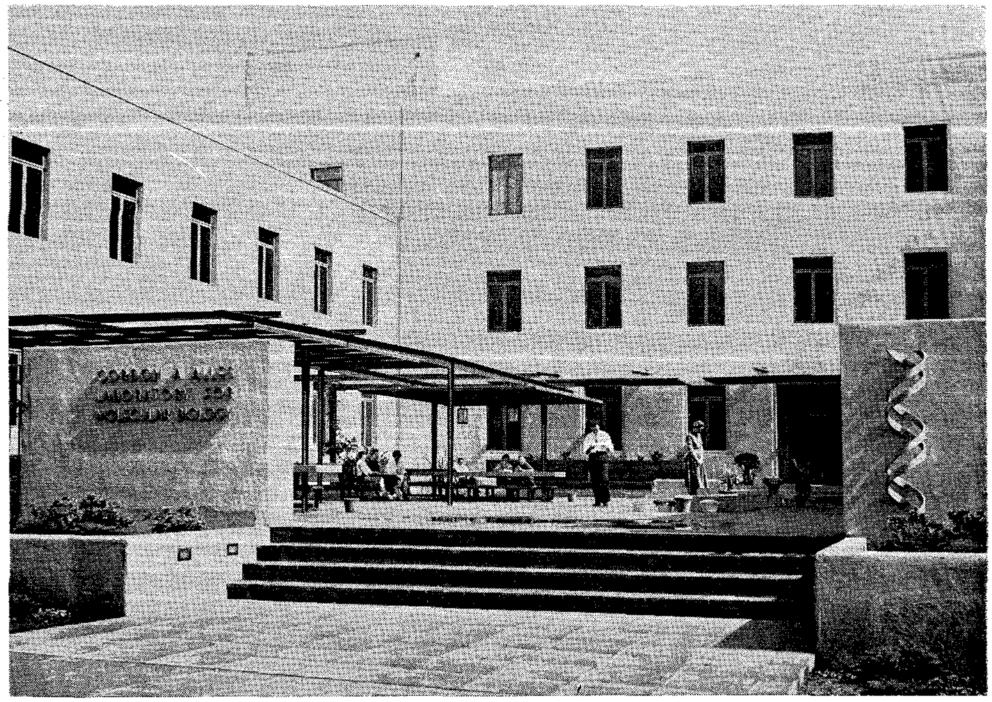
## *Three New Trustees*

Three new members have been elected to the Caltech Board of Trustees — Thomas V. Jones, president



DOWN ON THE FARM
*Caltech's development program has even been extended to the planting of the central campus, where the ancient iceplant has now finally given way to sweeping green lawns. This happy transition was accomplished with a good deal of agricultural horseplay on the campus, including an overpowering amount of fertilizer and the constant attention of an over-dressed scarecrow.*





DEDICATION
*Caltech's new Gordon A. Alles Laboratory, dedicated formally on November 3, is one of 18 new buildings rising on the campus as part of the Institute's development program.*

of the Northrop Corporation; Howard B. Keck, president of the Superior Oil Company; and Dr. Seeley G. Mudd of Pasadena.

Mr. Jones has been with Northrop since 1953, when he joined the company as assistant to the chief engineer. In April 1960 he became chief executive officer. He is a consultant to the Scientific Advisory Board of the U.S. Air Force, and is a member of the Board of Directors of the Los Angeles World Affairs Council, the Southern California Symphony Association, and the Welfare Federation of Los Angeles.

Mr. Keck has been in the oil business since 1932. He became president of The Superior Oil Company in 1953. He is a director of the City National Bank and the Gulf Interstate Gas Company, both in Houston, Texas; of the Canadian Superior Oil Company and the Canberra Oil Company in Canada; and of the European Oil Marketing Corporation in Switzerland.

Dr. Mudd, a physician and medical educator, received his MD from the Harvard Medical School. He was a research associate at Caltech from 1931 to 1935 and from 1935 to 1945 he was professor of radiation therapy at the Institute. He is now research associate in medical chemistry. From 1941 to 1943 he was dean of the Southern California Medical School.

Dr. Mudd's father, the late Seeley W. Mudd, and his brother, the late Harvey S. Mudd, both served as Caltech trustees. Dr. Mudd has been a member of the Caltech Associates since 1928. He has been a trustee of the Carnegie Institution of Washington since 1940.

## *John G. Bolton*

John G. Bolton, professor of radio astronomy, leaves Caltech next month to return to Sydney, Australia, as research officer in the division of radiophysics of the Commonwealth Scientific and Industrial Research Organization. He served as research officer at the CSIRO for ten years before coming to Caltech in 1955.

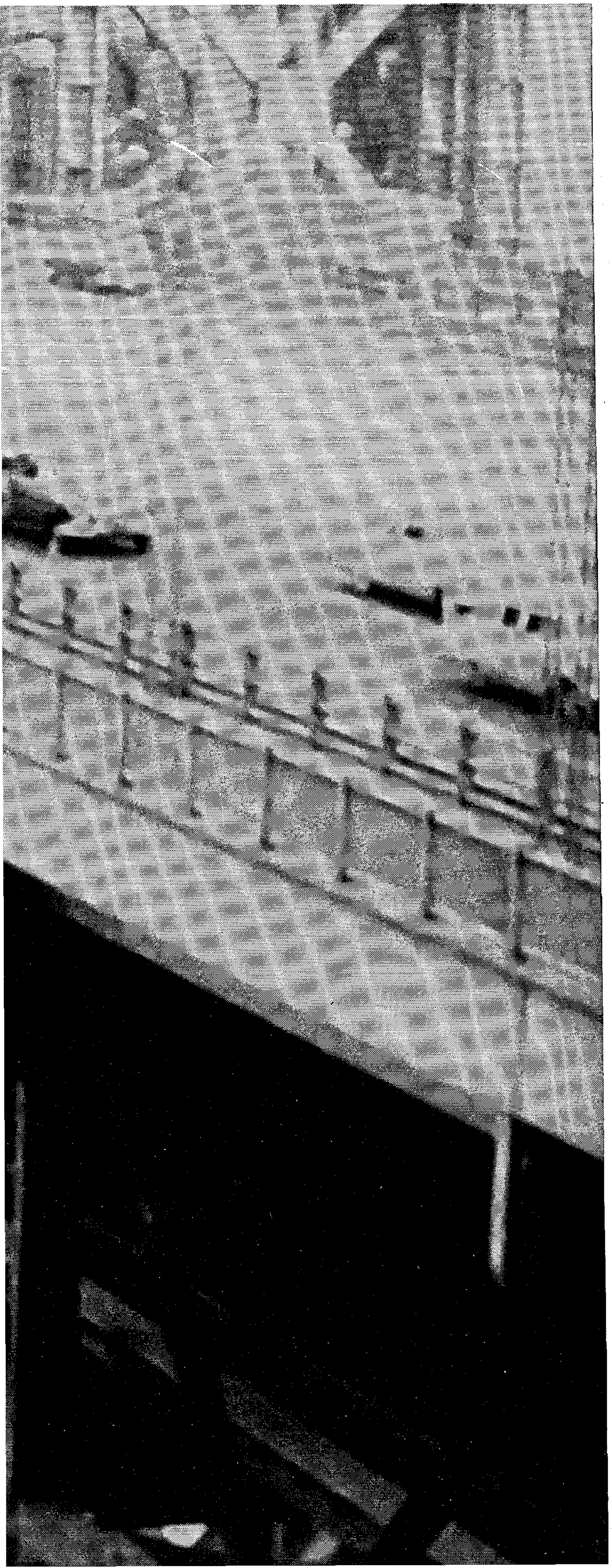
Dr. Bolton has been scientific director of Caltech's new Radio Observatory in Owens Valley since its inception. Operated by Caltech and financed by the Office of Naval Research, the observatory has the world's most versatile telescope – twin 90-foot reflectors which pinpoint radio signal sources millions of light years away. More than 50 distant radio stars have been located since the Observatory was built.

## *Nobel Prize Winner*

Donald A. Glaser, who got his PhD from Caltech in 1950, has received the 1960 Nobel Prize in physics for his invention of the bubble bath chamber, which is used to photograph atomic particles. Superheated liquid in the chamber slows down the high-speed particles until they appear in photographs as a string of bubbles. Dr. Glaser will receive a check for $43,627 from the trust fund left by Alfred Nobel, the inventor of dynamite.

Dr. Glaser was born in Cleveland in 1926, and was graduated from the Case Institute of Technology in 1946. He went to the University of Michigan in 1949 as an instructor, later becoming a professor. Last year he joined the physics department at the University of California in Berkeley.

In 1958 the U.S. Chamber of Commerce named Dr. Glaser as one of the 10 outstanding young men of the year. In 1959 he was awarded the first $2,500 prize of the American Physical Society for his bubble chamber.



Thomas O'Connell (B.S. in M.E., Notre Dame, '54; M.B.A., New York University, '60). Recently, as part of his job in marketing at IBM, he found himself assisting the customer technicians with the design problems of one of the world's busiest bridges.

# WHAT'S AN IBM MAN GOT TO DO WITH REDESIGNING A BRIDGE?

Tom O'Connell is an engineer working in marketing areas as an IBM Data Processing Representative. His job is to introduce management to the advantages of electronic data processing. Once they have acquired an IBM system, he acts as a consultant on new uses for the system.

**A Spectacular Engineering Achievement.** How is he helping to redesign a bridge? One of his clients is the agency which constructs and operates transportation facilities in the New York-New Jersey area. Recently, they began to add a lower deck to the George Washington Bridge. It has been a spectacular engineering achievement. Sections were brought up the Hudson River on barges and hoisted hundreds of feet into position. All this while heavy traffic continued in both directions.

This double-decking of one of the world's busiest bridges took complex planning. An IBM system materially aided in the verification of bridge design calculations and in suspension bridge truss analysis under various loading conditions. Tom O'Connell supplied many of the computer programs that were used in conjunction with other programs developed by the customer. Tom now knows a lot more about the problems of bridge design.

**A Job That Makes News.** One of the exciting aspects of Data Processing Marketing at IBM is this wide diversity of systems application. Using the knowledge a man has gained in college, and backed by the comprehensive training he receives at IBM, he moves into many kinds of application areas. The areas are always interesting, sometimes newsworthy. In fact, almost every day newspapers carry stories about new applications of computer systems in important areas of business, industry, science and government.

If you would like to find out in more detail about the many kinds of marketing opportunities at IBM, our representative will be visiting your campus soon. He'll be glad to sit down with you and discuss the reasons why marketing is a career with a virtually unlimited future. Your placement office can make an appointment. Or you may write, outlining briefly your background, to:

**Charles A. O'Malley**
**IBM Corporation**
**3424 Wilshire Blvd.**
**Los Angeles 5, Calif.**

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# Alumni News

*Alumni Development Program*

The alumni phase of Caltech's Development Program is now completed. With the receipt of $1,008,994 in pledges, one of the most interesting and certainly the most effective of alumni crusades comes to an end. Since active solicitation began in April 1958 it is estimated that some 700 alumni worked on the program in one capacity or another; nearly 1800 attended at least one of the several dinner meetings and more than 3600 participated in pledging the $1,008,994. A complete and final roster of all donors to the Development Program will be published shortly.

Even though the alumni goal has been exceeded, contributions are still being received for the program. Gifts from new donors are welcome, of course, and will be gratefully acknowledged. Such gifts, however, will be credited to the Alumni Fund rather than to Development, to be held by the Institute. The principal amount of these gifts, and any interest derived therefrom will not be expended until such time as the Board of Directors of your Alumni Association and the Trustees of the Institute shall agree on a suitable purpose for these funds.

Those who plan to make payments against outstanding Development Program pledges this year should do so soon. With the rush of the holidays almost upon us, this reminder that the tax year ends at midnight, Saturday, December 31, seems to be in order. Payments received on or before this date will be receipted to reflect a tax-deductible 1960 gift.

During the past 32 months thousands of words have been written about the progress of the alumni toward their $1,000,000 goal. Whenever periodic alumni totals were published they reflected the total sum of pledges only, paid or unpaid. Now that the Institute has reached the halfway point in their building program, having actually erected nine new structures, the amount paid toward the 1.009 million dollars pledged is of considerable interest. The aura of success which has accompanied the program thus far still remains, for cash and securities received during the past 32 months total $800,000. This figure takes on added significance when converted to an annual basis. Alumni have given at the rate of $300,000 yearly since the first Development Program gift was recorded in March of 1958. And "they said it couldn't be done . . ."

*— Donald S. Clark, Secretary, Alumni Association*

# Personals

### 1928

*Francis Noel* retired last July as district right of way engineer for the Department of Highways of the State of California, and is now living in Santa Barbara. He and his wife recently completed an 11,000-mile camping tour of Alaska.

*Richard G. Folsom,* MS '29, PhD '32, president of Rensselaer Polytechnic Institute, has been elected to the board of directors of the Air Reduction Company, Inc., in New York.

### 1929

*Emerson M. Pugh,* PhD, professor of physics at the Carnegie Institute of Technology in Pittsburgh, Pa., is the author of a textbook, *Principles of Electricity and Magnetism,* published in April by Addison-Wesley.

### 1931

*George Langsner* has been promoted from engineer of design to assistant state highway engineer in the administration department of the California Division of Highways.

### 1933

*John C. Monning* is now general manager and superintendent of building for the Department of Building and Safety of the City of Los Angeles. He has been with the Department since 1936. The Monnings have two children – Barbara and Bill.

*Robert C. Kendall,* MS, area geophysicist at the Shell Oil Company in Denver, has been elected vice president of the Society of Exploration Geophysicists. He has been with Shell since 1936.

*John R. Pierce,* MS '34, PhD '36, director of research in communications principles at the Bell Telephone Laboratories, received a Stuart Ballantine Medal from The Franklin Institute in Philadelphia last month. He and Rudolf Kompfner, also of Bell, each received medals for their joint invention of the traveling wave tube amplifier.

### 1935

*Norwood Simmons,* MS, is now manager of the West Coast division of Eastman Kodak Company in Los Angeles. He was formerly assistant manager and has been with the company since 1937. He is also currently president of the Society of Motion Picture and Television Engineers. The Simmonses live in Pasadena and have five children.

### 1937

*Wesley T. Butterworth,* MS ME, MS AE '38, is now the manager of vehicle engineering at the Columbus, Ohio, division of North American Aviation, Inc. He has been with the company since 1951.

*Harold F. Wiley,* MS, director of the analytical and control division of the Consolidated Electrodynamics Corporation in Pasadena, has been named a vice president of the firm. He has been with the company since 1937.

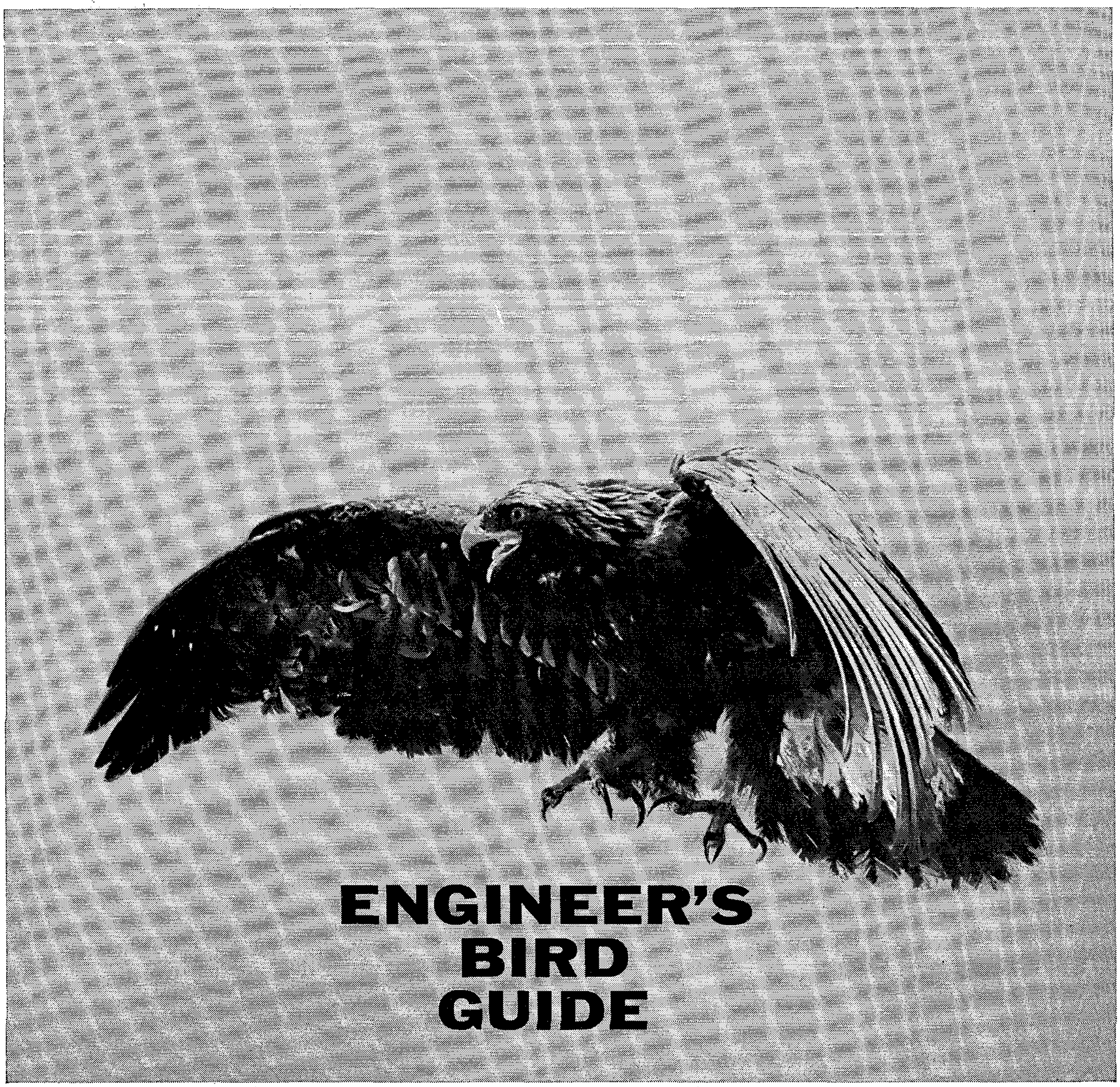
### 1938

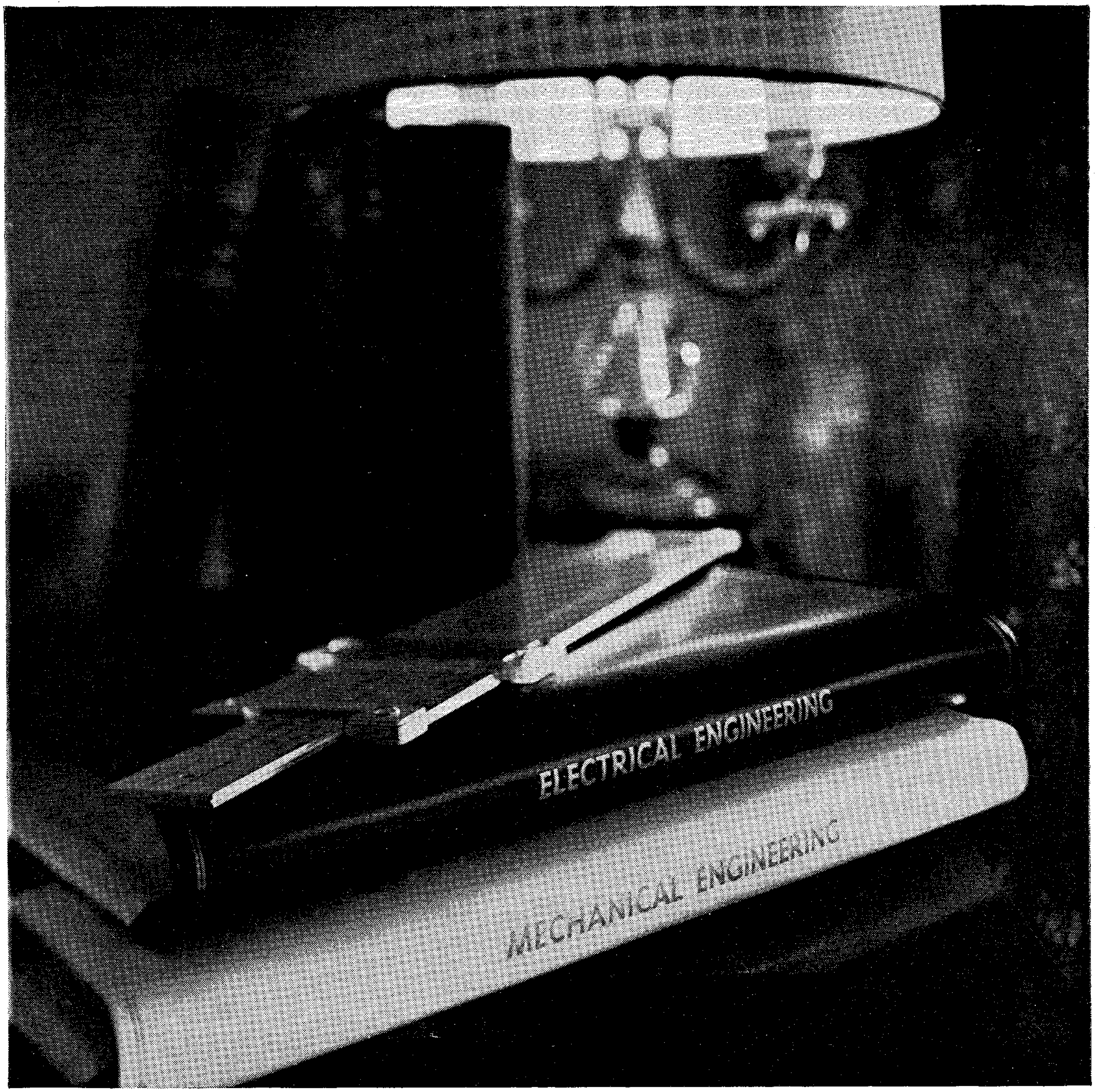
*John C. Lilly* is now director of the Communication Research Institute at St. Thomas in the Virgin Islands. He is working on the research possibilities of interspecies communication in dolphins in Florida at the present time. John was married last year to Elizabeth Bjerg.

### 1940

*Robert C. Brumfield,* MS '41, PhD '43, writes that he is now part owner of

*continued on page 42*


ENGINEER'S
BIRD
GUIDE


ELECTRICAL ENGINEERING
MECHANICAL ENGINEERING

MHD Research, Inc., in Newport Beach. The Brumfield's daughter, Cynthia, who would have been 12 in August, died of leukemia in September 1958. They have two other daughters – Corinne, 15, and Lisa, 1.

*Bernard M. Tobin*, MS '41, is now advisory engineer in Navy Systems Research at IBM's Federal Systems Division in Owego, N.Y. He has been with IBM since 1956.

*Jerome Kohl* is now coordinator of special products at the General Atomics Division of General Dynamics in La Jolla. He was formerly manager of engineering and development at Tracerlab Inc., in Richmond. The Kohls and their two daughters are now living in the San Diego area.

*Donald H. Kupfer* is associate professor of geology at Louisiana State University in Baton Rouge.

*Robert L. Wells*, MS, is now director of a newly-created management and professional personnel services department of the Westinghouse Electric Corporation in Pittsburgh. He was formerly general manager of the atomic power department, and has been with the company since 1940. The Wellses have one daughter and three sons.

*Harrison Storms*, AE '41, received an honorary PhD from Northwestern University in June. He is chief engineer at North American Aviation in El Segundo.

## 1942

*Stanley Corrsin*, chairman of the mechanical engineering department at Johns Hopkins University in Baltimore, is teaching the 92nd graduate-level course presented in the Humble Oil & Refining Company's Lectures in Science and Engineering program. The course in fluid mechanics is being taught at the company's Baytown, Texas, refinery.

## 1943

*Roland S. Saye* is chief project engineer for Thor systems at Douglas Aircraft Company in Santa Monica. He has been with the project since 1956, after working as a hydraulic specialist on the company's Nike missile project.

*Robert P. LeVine* is now vice president and a director of Brand, Grumet & Seigel, Inc., in New York, members of the New York Stock Exchange. He was formerly with the National Brick Corporation.

*Robert M. Sherwin*, MS '50, ChE '52, is now technical manager of the Western Chemical Division of the Hooker Chemical Corporation in Tacoma. He was plant engineer until the new post was created. The Sherwins have two sons and a daughter.

## 1944

*J. Bruce McNaughton*, assistant to the executive vice president of the Jeffrey Manufacturing Company in Columbus, Ohio, is now also president of the alumni body of Culver Military Academy in Culver, Indiana. The McNaughtons, who live in Columbus, have two sons and a daughter.

*Charles R. Rikel*, MS, is division manager of the northeast division of the Southern California Gas Company. He has been with the company since 1946. The Rikels live in Pasadena with their two sons – Chuck, 16, and James, 13.

*Max L. Panzer, MS '45, PhD '48,* is now a consulting engineer in partnership with *Glynn Lockwood*, '46, in Monterey, Calif. Their merger is known as the Del Monte Technical Associates and they are currently designing a precision film measuring system for the White Sands Missile Range.

## 1945

*Hugh S. West* is now a Chartered Life Underwriter, one of the top professional designations in the life insurance field. He is assistant secretary of the agency department of the field services division of the Connecticut General Life Insurance Company in Hartfield. The Wests, who live in Bloomfield, have four children.

*Duane T. McRuer*, MS '48, president of Systems Technology, Inc., in Inglewood, won a Louis E. Levy Medal from The Franklin Institute in Philadelphia last month. The award was one of two given for a joint paper on "The Human Operator as a Servo System Element."

## 1948

*Max Garber* is marketing vice president of Consolidated Vacuum Corporation, a Bell & Howell/CEC subsidiary in Rochester, N.Y.

*William A. Drew* has been promoted from assistant actuary to associate actuary at The Lincoln National Life Insurance Company in Fort Wayne, Indiana.

*Jack S. Anderson*, MS, PhD '53, is now director of engineering in the newly-formed systems and controls group of the Crane Company. He is presently headquartered at the Hydro-Aire facility in Burbank. The Andersons and their three children live in Pasadena.

*Col. Elmore G. Lawton*, MS, and *Lt. Col. Douglas K. Blue, MS,* are attending The Army War College at Carlisle Barracks, Penn., which is the senior school that prepares selected officers for future assignments to top staff and command positions in the Armed Forces and other key government positions.

*continued on page 46*

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*If personal interview is not possible send resume and grade transcript to B. L. Dixon, Engineering Personnel Administrator, Dept.* CM-602 *Pomona, California.*

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## GENERAL DYNAMICS CORPORATION

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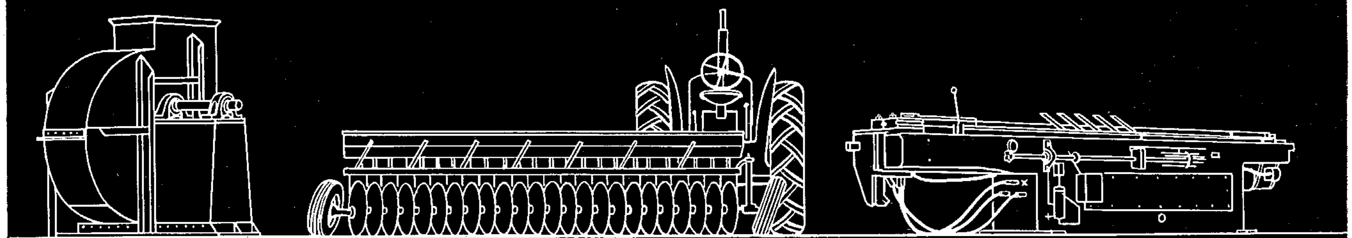
# SEALMASTER BALL BEARING UNITS



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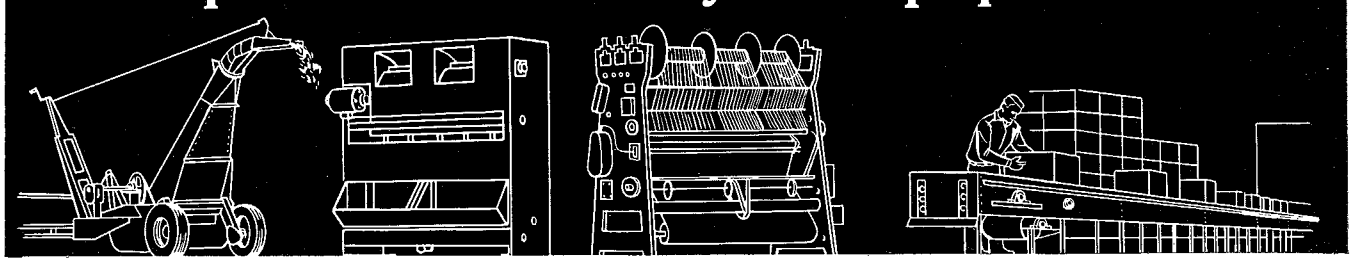

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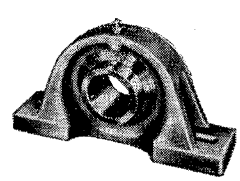
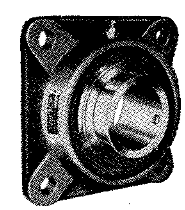
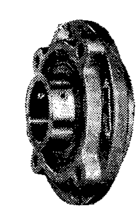


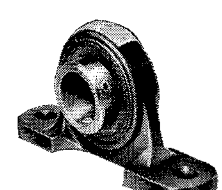
Normal-Standard-Medium Duty
PILLOW BLOCKS



Standard-Medium Duty
FLANGE UNITS



FLANGE CARTRIDGE UNIT



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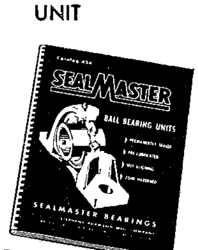
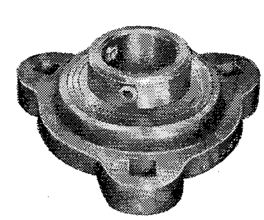



WRITE FOR CATALOG 454 and BULLETIN 359



LF FLANGE UNIT

PLANTS LOCATED IN: LOS ANGELES, CALIFORNIA • CLARKSDALE, MISSISSIPPI • BELLEVILLE, ONTARIO

## Personals . . . *continued*

*1949*

*Marvin Abramovitz,* MS, is now working at the Flight Research Center of National Aeronautics and Space Administration in Edwards, California.

*Lloyd P. Geldart,* GeE, is professor of applied geophysics at McGill University in the department of mining engineering in Montreal, Quebec. He was formerly chief geophysicist at the California Exploration Company in San Francisco.

*Richard Patterson* is now project engineer at the Bechtel Corporation in Los Angeles.

*John Heath, Jr.,* writes that he is district manager for northern California, Nevada, and Utah, at the American Appraisal Company in San Francisco. The Heaths have two children — Leon, 9, and Kathy, 3.

*1953*

*Michael Lourie,* technician at the University of California's Radiation Laboratory in Berkeley, died of a self inflicted gunshot wound on September 9. He had been working as a programmer with the theoretical physics group.

*1954*

*C. Richard Smith,* MS '55, instructor at El Camino College, is now doing graduate work in mathematics at the University of Missouri in Columbia. Dick writes that he was one of 120 cyclists at the Olympic trials in New York. Dick finished 8th and only 3 minutes behind the winner on the 112-mile course.

*1955*

*Edwin J. Furshpan,* PhD, is associate in neurophysiology and neuropharmacology at Harvard University. He was formerly an instructor in opthalmic physiology at Johns Hopkins University.

*Arthur E. Lewis,* MS '55, PhD '58, was appointed a scientist at the Santa Barbara Science Center of Hoffman Electronics Corporation last May. For the past two years, he had been a senior engineer at the Santa Barbara division of the Curtiss-Wright Corporation.

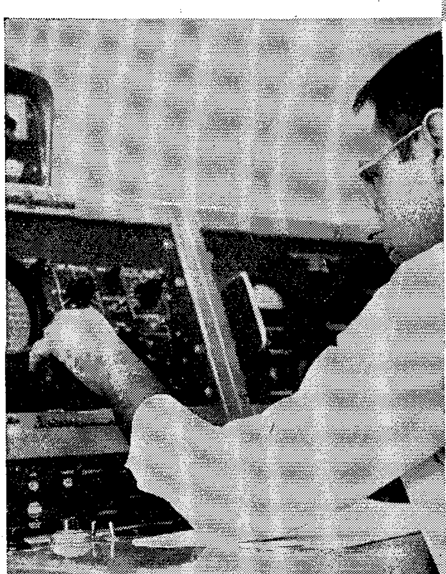
*1956*

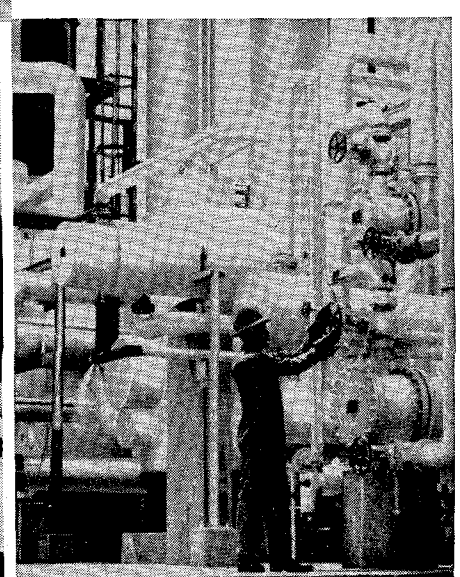
*William K. Purves* is now a postdoctoral fellow of the National Cancer Institute at UCLA, in the botany department. The Purveses now have a son, David, who was born during their stay at the Universität Tübingen in Germany.

*Peter O. Lauritzen* is now in Zurich on a fellowship at the Swiss Federal Institute of Technology.

*1958*

*William G. Tifft,* PhD, is research associate in astronomy at Vanderbilt University in Nashville.





# Lost Alumni

*The Institute has no record of the present addresses of these alumni. If you know the current address of any of these men, please contact the Alumni Office, Caltech.*

**1906**
Norton, Frank E.
**1911**
Lewis, Stanley M.
**1915**
Soyster, Charles J.
**1918**
Lavagnino, John F.
**1921**
Arnold, Jesse
Fletcher, Harold O.
**1922**
Cox, Edwin P.
**1923**
Hickey, George I.
Skinner, Richmond H.
**1924**
McKaig, Archibald
Mercereau, James T.
Tracy, Willard H.
**1925**
Waller, Conrad J.
**1926**
Chang, Hung-Yuan
McCarter, Kenneth C.
Yang, Kai Jin
**1928**
Chou, P'ei-Yuan
Hicks, Hervey C.
Martin, Francis C.
Morgan, Stanley C.
Wingfield, Baker
**1929**
Briggs, Thomas H., Jr.
Burns, Martin C.
Nelson, Julius
Robinson, True W.
Wolfe, Karl M.
**1930**
Allison, Donald K.
Chao, Chung-Yao
Douglass, Paul W., Sr.
Janssen, Philip
Lea, William F.
Shields, John C.
White, Dudley
**1931**
Hall, Marvin W.
Ho, Tsien-Loh
Voak, Alfred S.
West, William T.
Woo, Sho-Chow
Yoshoka, Carl K.
**1932**
Brass, P. D.
Patterson, J. W.
Schroder, L. D.
Wright, Lowell, J.
**1933**
Applegate, Lindsay M.
Ayers, John K.
Downie, Arthur J.
Hsu, Chuen Chang
Kitusda, Kaneme
Koch, A. Arthur
Larsen, William A.
Lockhart, E. Ray
Michal, Edwin B.
Murdock, Keith A.
Rice, Winston H.
Shappell, Maple D.
Smith, Warren H.
**1934**
Harshberger, John D.
Liu, Yuan Pu
Radford, James C.
Read, John
Rooke, Donald R.
**1935**
Becker, Leon
Bertram, Edward A.
Huang, Fun-Chang
McNeal, Don
**1936**
Chu, Djen-Yuen
Creal, Albert
Dunn, Clarence L.
Kelch, Maxwell
Kurihara, Hisayuki
Nelson, Loyal E.
Ohashi, George Y.
**1937**
Burnight, Thomas R.
Cheng, Ju-Yung
Easton, Anthony
Fan, Hsu Tsi
Jones, Paul F.
Lotzkar, Harry
Maginnis, Jack
Moore, Charles F.
Munier, Alfred E.
Nojima, Noble
Penn, William L.
Rechif, Frank A.
Servet, Abdurahim
Shaw, Thomas N.
**1938**
Ackerman, John B.
Elliott, Bruce C.
Gershzohn, Morris
Goodman, Hyman D.
Gross, Arthur G.
Kanemitsu, Sunao
Li, Yuan-Chuen
Lowe, Frank C.
Ofsthun, Sidney A.
Okun, Daniel A.
Porter, Edwin J.
Tilker, Paul O.
Tsao, Chi-Cheng
Wang, Tsun Kuei
Watson, James W.
**1939**
Asakawa, George
Brown, William Lowe
Easton, R. Loyal
Gombotz, Joseph J.
Liang, C. Chia-Chang
Neal, Wilson H.
Oppenheimer, Frank
Robertson, Francis A.
Tatom, John F.
Tsien, Hsue-shen
Wilson, Harry D.
**1940**
Batu, Buhtar
Gentner, William E.
Gibson, Arville C.
Green, William J.
Hosmer, Clark L.
Hsu, Chang-Pen
Karubian, Ruhollah Y.
Kennedy, David H.
Lester, Raymond T.
Menis, Luigi
Paul, Ralph G.
Peterson, Norman L.
Tajima, Yuji A.
Tao, Shih Chen
Torrey, Preston C.
Ustel, Sabih A.
**1941**
Arnold, John K.
Clark, Morris R.
Dieter, Darrell W.
Easley, Samuel J.
Geitz, Robert C.
Green, Jerome
Harvey, Donald L.
Hubbard, Jack M.
Kuo, I. Cheng
Noland, Robert L.
Robinson, Frederick G.
Stanridge, Clyde T.
Taylor, D. Francis
Tiemann, Cordes F.
Waigand, LeRoy G.
Whitfield, Hervey H.
Yui, En-Ying
**1942**
Bebe, Mehmet F.
Chastain, Alexander
Curtis, Thomas G.
Emre, Orhan M.
Go, Chong-Hu
Hughes, Vernon W.
Johnston, William C.
Levin, Daniel
MacKenzie, Robert E.
Martinez, Victor H.
**1943**
Angel, Edgar P.
Bethel, Horace L.
Bridgland, Edgar P.
Brown, James M.
Bryant, Eschol A.
Burlington, William J.
Carlson, Arthur V.
Colvin, James H.
Daniels, Glenn E.
Hamilton, William M.
Hillyard, Roy L.
Hilsenrod, Arthur
King, Edward G.
Koch, Robert H.
Kong, Robert W.
LaForge, Gene R.
Lee, Edwin S., Jr.
Leeds, William L.
Ling, Shih-Sang
Lobban, William A.
Lundquist, Roland E.
Mampell, Klaus
McNeil, Raymond F.
Mixsell, Joseph W.
Mowery, Irl H., Jr.
Nesley, William L.
Neuschwander, Leo Z.
Newton, Everett C.
O'Brien, Robert E.
Patterson, Charles M.
Pearson, John E.
Rambo, Lewis
Rivers, Nairn E.
Roberts, Fred B.
Rupert, James W., Jr.
Scholz, Dan R.
Shannon, Lesile A.
Smitherman, Thomas B.
Tindle, Albert W., Jr.
Vicente, Ernesto
Walsh, Joseph R.
Washburn, Courtland L.
Weis, William T.
Wood, Stanley G.
**1944**
Alpan, Rasit H.
Arreguin-Lozano, Barbarin
Baranowski, John J.
Barriga, Francisco D.
Bell, William E.
Benjamin, Donald G.
Berkant, Mehmet N.
Birlik, Ertugrul
Burch, Joseph E.
Burke, William G.
Cebeci, Ahmed
Cooke, Charles M.
De Medeiros, Carlos A.
Fu, Ch'eng Yi
Harrison, Charles P.
Hu, Ning
Johnson, William M.
Kern, Jack C., Jr.
Labanauskas, Paul J.
Leenerts, Lester O.
Lin, Chia-Chiao
Marshall, John W.
Onstad, Merrill E.
Ozkaragoz, Ethem
Pi, Te-Hsien
Pischel, Eugene F.
Rasof, Bernard
Ridlehuber, Jim M.
Shults, Mayo G.
Stanford, Harry W.
Stein, Roberto L.
Sullivan, Richard B.
Sunalp, Halit
Trimble, William M.
Unayral, Nustafa A.
Wadsworth, Jos. F., Jr.
Wight, D. Roger
Williams, Robert S.
Wolf, Paul L.
Writt, John J.
Yik, George
**1945**
Ari, Victor A.
Budney, George S.
Bunze, Harry F.
Fanz, Martin C.
Fox, Harrison W.
Gibson, Charles E.
Jenkins, Robert P.
Knapp, Norman E.
Kuo, Yung Huai
Levy, Charles N.
Pooler, Louis G.
Romney, Carl F.
Tseu, Payson S.
Turkbas, Necat
Yank, Frank A.
**1946**
Allison, Charles W., Jr.
Barber, John H.
Behroon, Khosrow
Bowen, Mark E.
Burger, Glenn W.
Chen, Ke-Yuan
Childers, Kenan C., Jr.
Dethier, Bernard
Dyson, Jerome P.
Esner, David R.
Foster, R. Bruce
Halvorson, George C.
Hayne, Benjamin S., III
Huestis, Gerald S.
KeYuan, Chen
Lewis, Frederick W.
Lowery, Robert H.
Maxwell, Frederick W.
Olsen, Leslie R.
Parker, James F.
Prasad, K. V. Krishna
Simmons, George F.
Sledge, Edward C.
Smith, Harvey F.
Tung, Yu-Sin
Weldon, Thomas F.
Winson, Jonathan
**1947**
Asher, Rolland S.
Atencio, Adolfo I.
Clarke, Fredric B.
Clements, Robert E.
Clock, Raymond M.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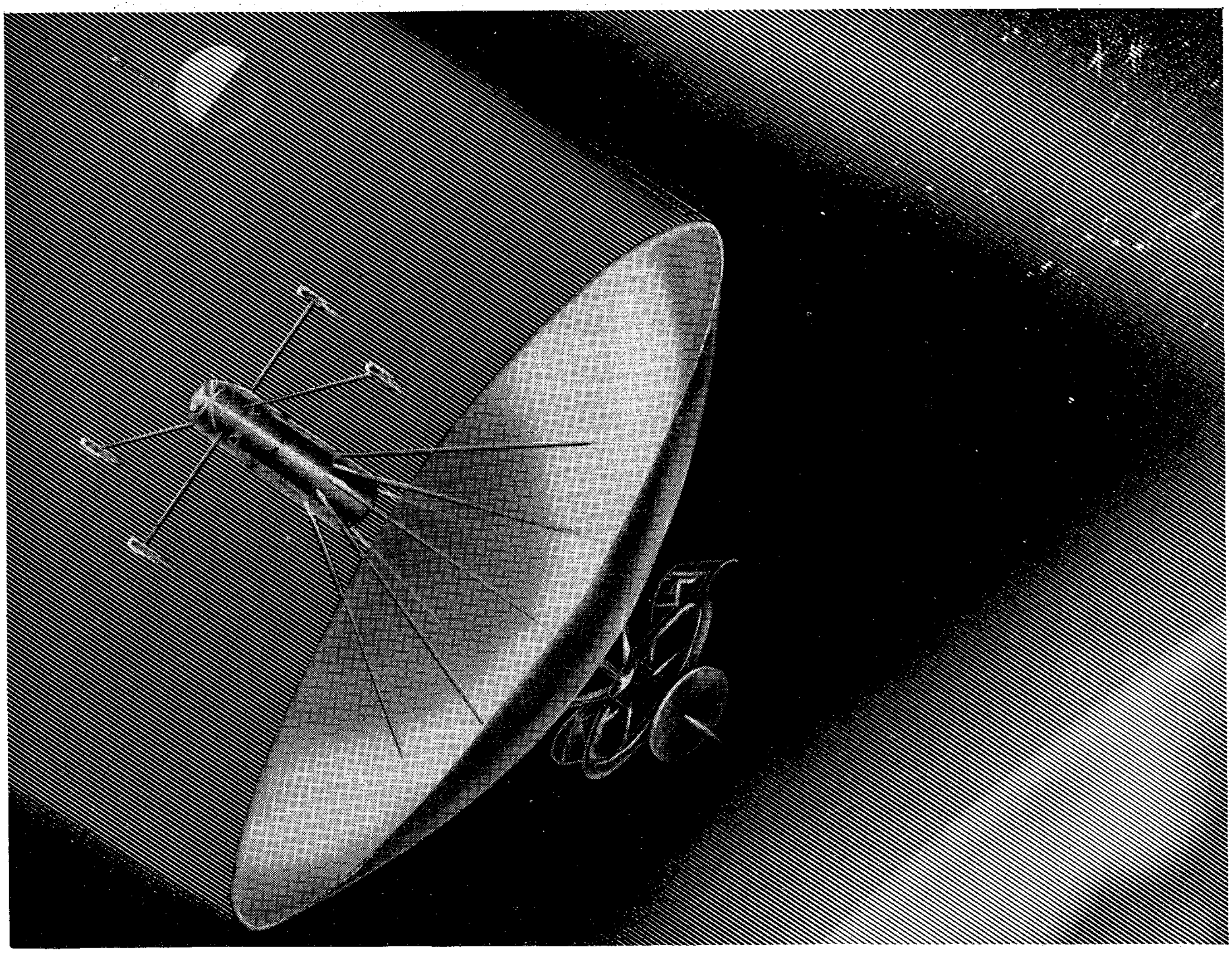

# Lost Alumni . . . *continued*

Dagnall, Brian D.
Darling, Donald A.
Hammerle, William G.
Hsu, Chi-Nan
Hsueh, Chi-Hsun
Huang, Ea-Qua
Lane, James F.
Leo, Fiorello R.
MacAlister, Robert S.
Manoukian, John
McClellan, Thomas R.
Miller, Curtis E.
Molloy, Michael K.
Monoukian, John
Moorehead, Basil E. A.
Olson, Raymond L.
Orr, John L.
Ramaswamy, Guruvayur S.
Ray, Kamalesh
Ruderman, Malvin A.
Sanders, Lewis B.
Sappington, Merrill H.
Torgeson, Warren S.
Vanden Heuvel, George R.
Wan, Pao Kang
Wellman, Alonzo H. Jr.
Wimberly, Clifford M.
Ying, Lai-Chao

1948

Agnew, Haddon W.
Bunce, James A.
Collins, Burgess F.
Cotton, Mitchell L.
Crawford, William D.
Hager, James W.
Hsieh, Chia Lin
Hsiao, Chien
Kelley, Roy S.
Latson, Harvey H., Jr.
Leavenworth, C. D.
Mason, Herman A.
Morehouse, Gilbert G.
Oliver, Edward D.
Rhynard, Wayne E.
Swain, John Sabin
Swank, Robert K.
Voelker, William H.
Winniford, Robert S.
Woods, Marion C.
Yanak, Joseph D.

1949

Barker, Edwin F., Jr.
Bauman, John L., Jr.
Baumann, Laurence I.
Burkholder, Joseph F.
Clancy, Albert H., Jr.
Clendening, H. C.
Cooper, Harold D.
Foster, Francis C.
Galstan, Robert H.
Heiman, Jarvin R.
Ismail, Hassan M.
Krasin, Fred E.
Laberge, Jerome G.
Lowery, Richard O.
MacKinnon, Neil A.
McElligott, Richard H.
Merrell, Richard L.
Orme, Eric C.
Petty, Charles C.
Rinehart, Marion C.
Ringness, William M.
Stappler, Robert F.
Weiss, Mitchell
Yu, Sien-Chiue

1950

Bryan, William C.
Dowd, Thomas E., Jr.
Edelstein, Leonard
Li, Chung Hsien
McDaniel, Edward F.
McMillan, Robert
Merrifield, Donald P.
Nelson, Robert C.
Pao, W. K.
Paulson, Robert W.
Petzold, Robert F.
Roberts, Morton S.
Scherer, Lee R., Jr.
Schneider, William P.
Vivian, James A.
Whitehill, Norris D.
Wright, Amos L.

1951

Arosemena, Ricardo M.
Chong, Kwok-Ying
Davison, Walter F.
Denton, James Q.
Hawk, Riddell L.
Lafdjian, Jacob P.
Li, Cheng-Wu
Merkel, George
Padgett, Joseph E., Jr.
Pfeiffer, Walter F.
St. Amand, Pierre
Summers, Allan J.

1952

Abbott, John R.
Arcoulis, Elias G.
Cook, Samuel P.
Gerington, Thomas E.
Harrison, Marvin E.
Helmuth, James G.
Loftus, Joseph F.
Long, Ralph F.
Lunday, Adrian C.
Munson, Albert G., Jr.
O'Brien, Joseph
Primbs, Charles L.
Robieux, Jean
Schaufele, Roger D.
Shelly, Thomas L.
Sutton, Donald E.
Wiberg, Edgar
Wilson, Howard E.
Woods, Joseph F.
Zacha, Richard B.

1953

Clark, David J.
Lennox, Stuart G.
Mishaan, Alberto
Vidal, Jean L.

1954

Feuchtwang, Thos. E.
Mertz, Charles, III
Quiel, Norwald R.

1955

Crowe, Thomas H.
Lim, Macrobio
Moore, William T.

1956

Hershberger, Edw. E.
Hsu, Nan-Teh
Marcy, William L.
Spence, William N.
Tang, Chnng-Liang

1957

Howie, Archibald
Leader, Elliot
Lee, Wonyong
Soux, Luis B.
Stuteville, Joseph E.
West, Clinton
Wong, Chi-hsiang

1958

Pierrou, Gerald M.
Rieunier, Jacques M.
Schumann, Thomas G.

1959

Graham, Wm. R., Jr.
Greenberg, Joel D.

1960

Funada, Albert T.

# what is gravity?

Earth's attraction for an apple?

Free fall in relativistic space?

A complex meson field?

Built-in return power for project Mercury?

How is it related to binding energy?

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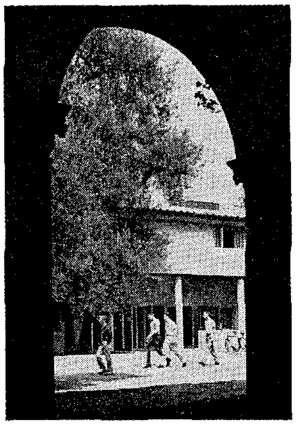

## ALUMNI EVENTS

| | |
|---|---|
| November 12 | Interhouse Dance |
| December | Fall Dinner Meeting |
| January | Winter Dinner Meetnig |
| March 4 | Annual Dinner Dance |
| May 6 | Annual Seminar |
| June 7 | Annual Meeting |

## ATHLETIC SCHEDULE

### SOCCER

November 12
UC Riverside at Caltech
November 18
Redlands at Redlands
November 23
Pomona at Caltech
December 1
UCLA at Caltech

### WATER POLO

November 15
L.A. State at Rosemead Hi
November 18
Redlands at Caltech
November 22
Occidental at Caltech

### BASKETBALL

December 1
Naval Training Station at San Diego
December 2
Cal Western at San Diego
December 6
Upland College at Caltech

## FRIDAY EVENING DEMONSTRATION LECTURES

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

November 18
Tandem Machines and Research
– Ward Whaling

December 2
Conditions and Life of the Oceans of the Past
– Heinz Lowenstam

December 9
The World's Radioactive Carbon and Nuclear Explosions
– Milton Plessett

December 16
Scientific Significance of New Kinds of Lunar Observations
—Bruce Murray



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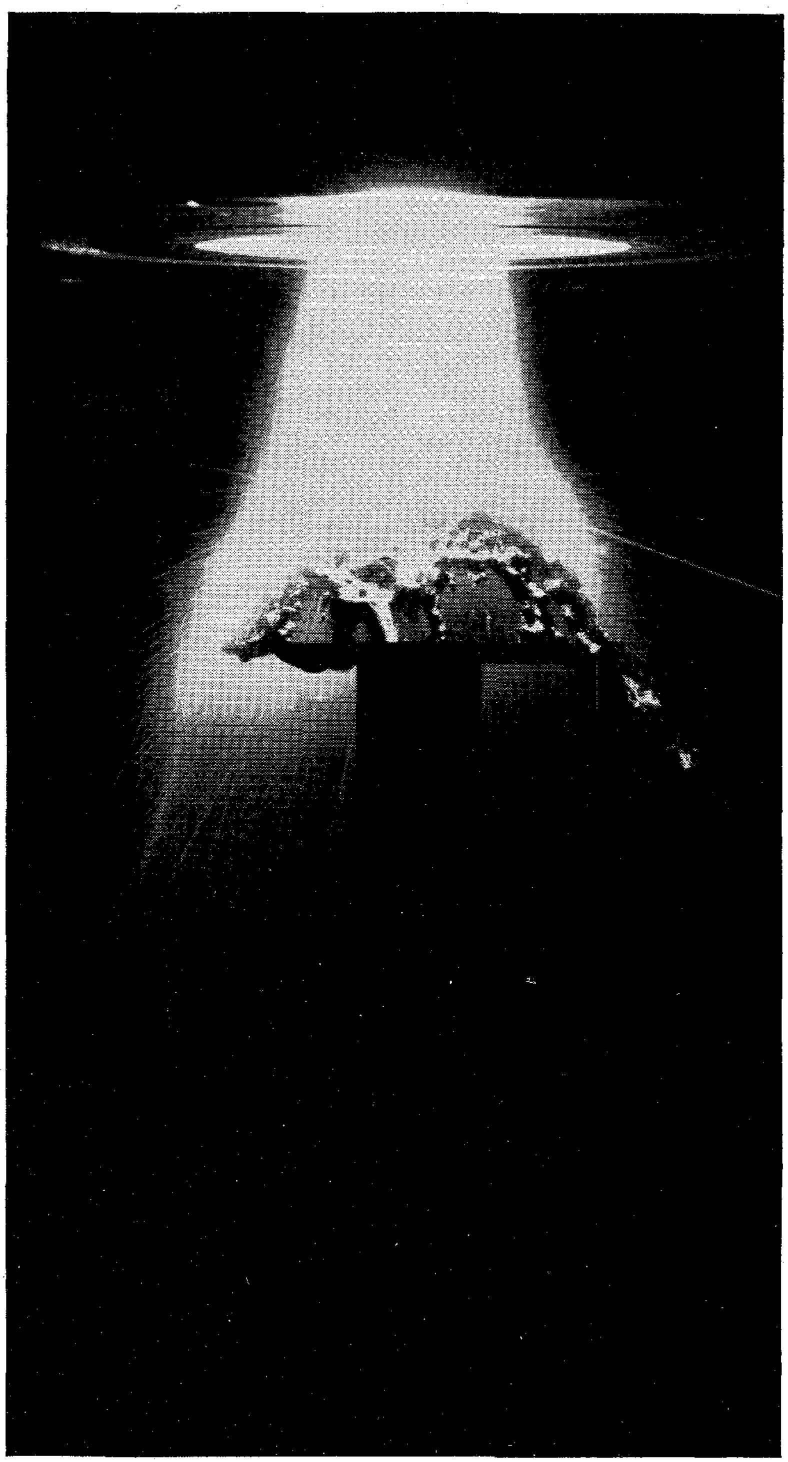

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One of a series*

## Interview with General Electric's Charles F. Savage Consultant—Engineering Professional Relations

# How Professional Societies Help Develop Young Engineers

**Q. Mr. Savage, should young engineers join professional engineering societies?**

**A.** By all means. Once engineers have graduated from college they are immediately "on the outside looking in," so to speak, of a new social circle to which they must earn their right to belong. Joining a professional or technical society represents a good entree.

**Q. How do these societies help young engineers?**

**A.** The members of these societies—mature, knowledgeable men—have an obligation to instruct those who follow after them. Engineers and scientists—as professional people—are custodians of a specialized body or fund of knowledge to which they have three definite responsibilities. The first is to *generate* new knowledge and add to this total fund. The second is to *utilize* this fund of knowledge in service to society. The third is to *teach* this knowledge to others, including young engineers.

**Q. Specifically, what benefits accrue from belonging to these groups?**

**A.** There are many. For the young engineer, affiliation serves the practical purpose of exposing his work to appraisal by other scientists and engineers. Most important, however, technical societies enable young engineers to learn of work crucial to their own. These organizations are a prime source of ideas—meeting colleagues and talking with them, reading reports, attending meetings and lectures. And, for the young engineer, recognition of his accomplishments by associates and organizations generally heads the list of his aspirations. He derives satisfaction from knowing that he has been identified in his field.

**Q. What contribution is the young engineer expected to make as an active member of technical and professional societies?**

**A.** First of all, he should become active in helping promote the objectives of a society by preparing and presenting timely, well-conceived technical papers. He should also become active in organizational administration. This is self-development at work, for such efforts can enhance the personal stature and reputation of the individual. And, I might add that professional development is a continuous process, starting prior to entering college and progressing beyond retirement. Professional aspirations may change but learning covers a person's entire life span. And, of course, there are dues to be paid. The amount is graduated in terms of professional stature gained and should always be considered as a personal investment in his future.

**Q. How do you go about joining professional groups?**

**A.** While still in school, join student chapters of societies right on campus. Once an engineer is out working in industry, he should contact local chapters of technical and professional societies, or find out about them from fellow engineers.

**Q. Does General Electric encourage participation in technical and professional societies?**

**A.** It certainly does. General Electric progress is built upon creative ideas and innovations. The Company goes to great lengths to establish a climate and incentive to yield these results. One way to get ideas is to encourage employees to join professional societies. Why? Because General Electric shares in recognition accorded any of its individual employees, as well as the common pool of knowledge that these engineers build up. It can't help but profit by encouraging such association, which sparks and stimulates contributions.

Right now, sizeable numbers of General Electric employees, at all levels in the Company, belong to engineering societies, hold responsible offices, serve on working committees and handle important assignments. Many are recognized for their outstanding contributions by honor and medal awards.

These general observations emphasize that General Electric does encourage participation. In indication of the importance of this view, the Company usually defrays a portion of the expense accrued by the men involved in supporting the activities of these various organizations. Remember, our goal is to see every man advance to the full limit of his capabilities. Encouraging him to join Professional Societies is one way to help him do so.

*Mr. Savage has copies of the booklet "Your First 5 Years" published by the Engineers' Council for Professional Development which you may have for the asking. Simply write to Mr. C. F. Savage, Section 959-12, General Electric Co., Schenectady 5, N. Y.*

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