ENGINEERING AND SCIENCE

JANUARY/1953

The Planets . . . page 9

PUBLISHED AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY

How two inches of steel made a yardstick

HERE is one of the busiest machines in our research laboratories. It is a *constant-pressure* test lathe that quickly provides an indication of how fast a steel can be machined.

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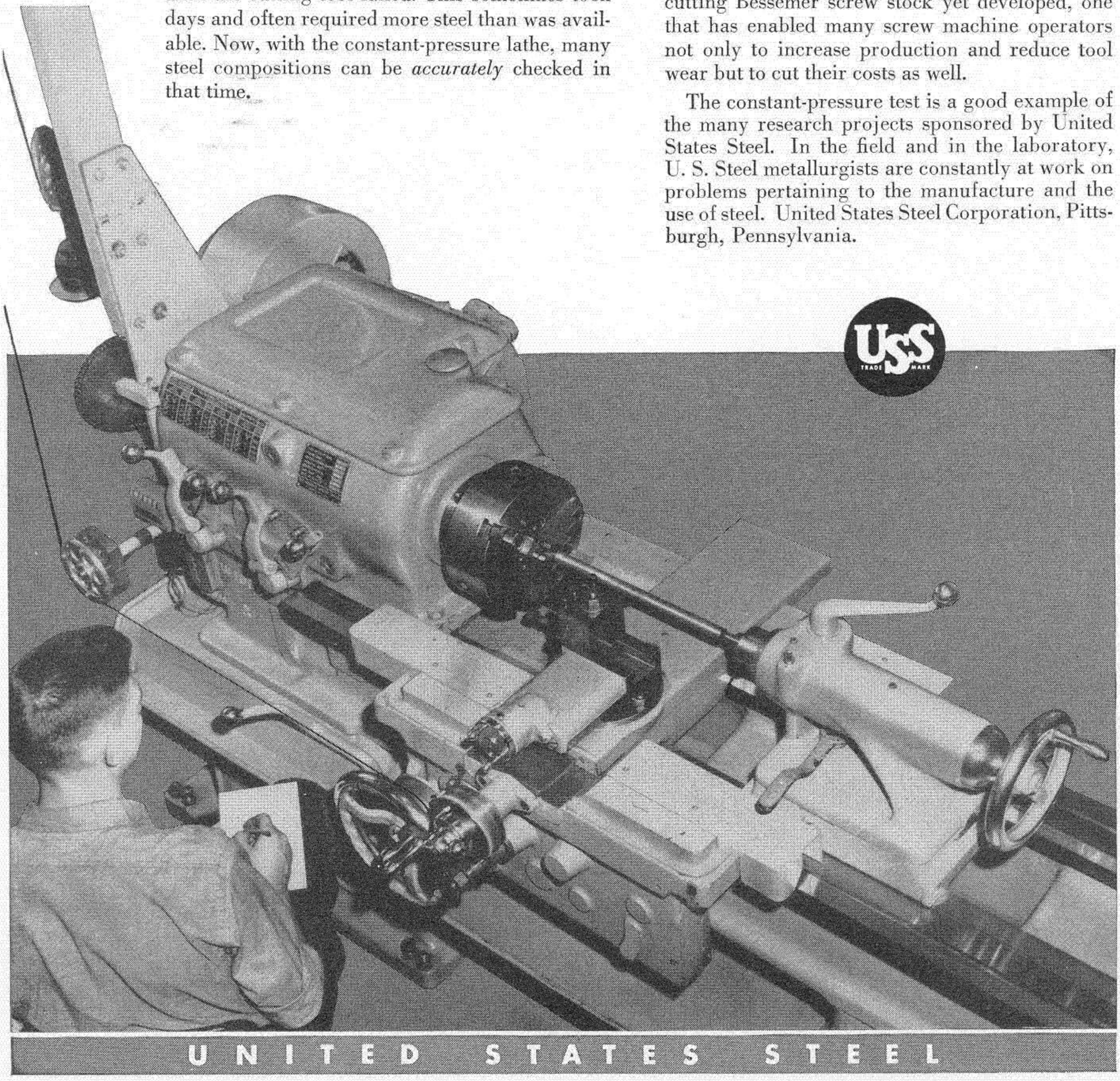
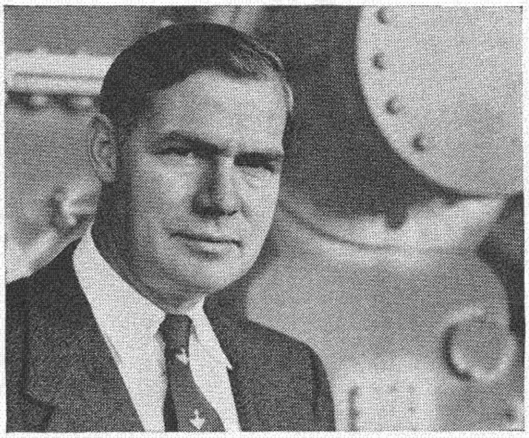
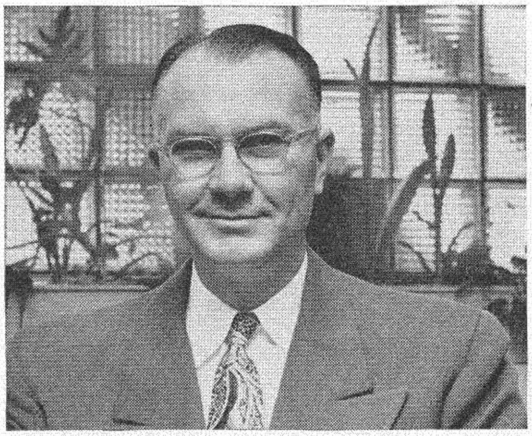
The constant-pressure test is a good example of the many research projects sponsored by United States Steel. In the field and in the laboratory, U. S. Steel metallurgists are constantly at work on problems pertaining to the manufacture and the use of steel. United States Steel Corporation, Pittsburgh, Pennsylvania.



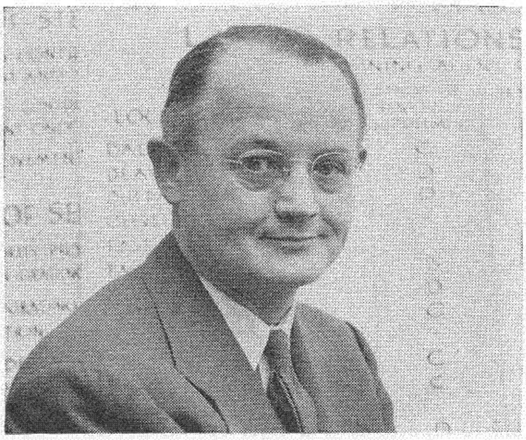
UNITED STATES STEEL



Lee A. Kilgore, *Assistant Manager*
Westinghouse Generator Engineering
A graduate of the University of Nebraska, he enrolled in the Westinghouse Graduate Student Training Course in 1927. He has contributed much to the design and development of large generators, motors and rectifiers and has authored many technical articles on these subjects.



W. H. Dickinson, *Director*
Westinghouse Headquarters Manufacturing Engineering
Enrolled in Westinghouse Graduate Student Training Course after graduation from Texas A & M in 1930. He came up through a variety of manufacturing positions in the company and was appointed to his present post in 1951.



Clark C. Frame, *Director*
Westinghouse Labor Relations
Enrolled in the Westinghouse Graduate Student Training Course after graduation from Penn State in 1930. Prior to appointment to his present post, he was Manager of Industrial Relations for Westinghouse East Pittsburgh divisions.

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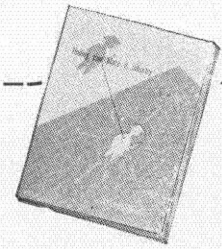

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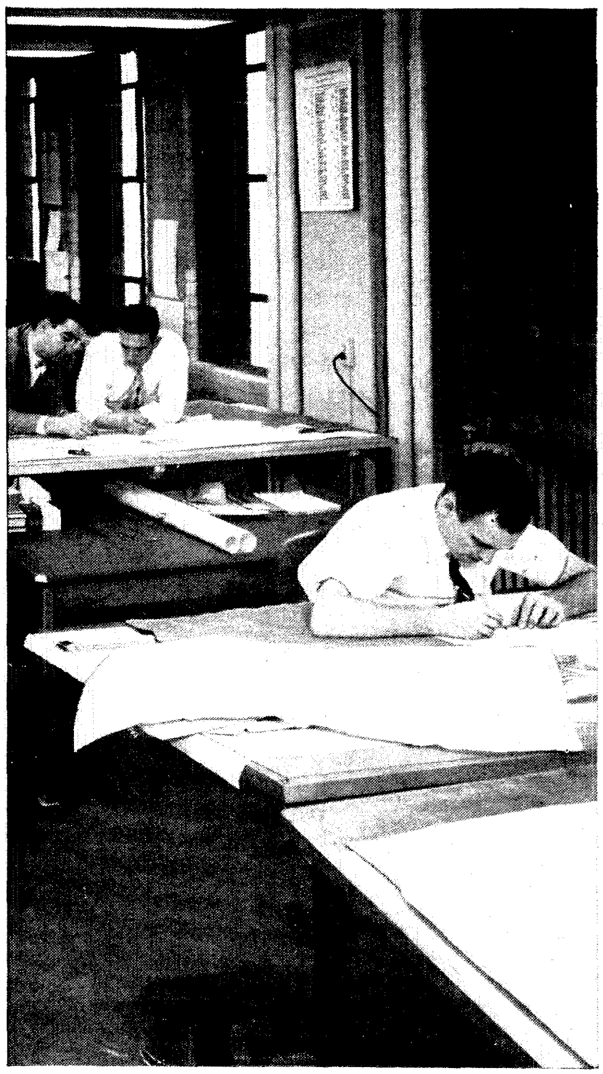

Takes a lot to lay a carpet in the jungle

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Around the World

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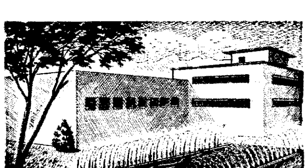

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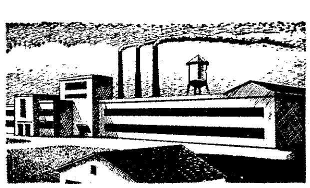

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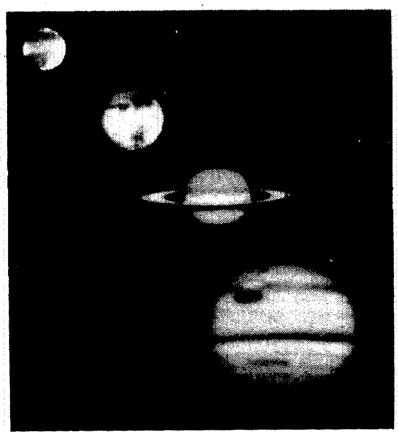
ENGINEERING AND SCIENCE

IN THIS ISSUE



This month's cover shows several of the planets, as photographed by the 200-inch Palomar telescope. Our cover, however, shows them in an arrangement never seen by any astronomer, living or dead—or anyone else, for that matter. Call it a piece of science fiction; a teaser, heralding the photographs which appear on pages 9-11 of this issue.

Early in November, at its 32nd annual meeting in Chicago, the American Petroleum Institute presented Certificates of Appreciation to two Caltech scientists who have cooperated on an API research project for the past 25 years. Drs. William N. Lacey and Bruce H. Sage are associated with Research Project 37, one of the oldest of the basic studies which the API has sponsored through the years to probe the mysteries of petroleum and shed some light on its occurrence and composition. The story of the work that has been done on this valuable project appears on page 12 of this issue—and some notes on the men behind the project, Dr. Lacey and Dr. Sage, are on page 15.

What's all the shouting about chlorophyll? A Caltech plant physiologist comes up with some answers on page 17 . . . and on page 20, the first report in five years on research on artificial meteors.

PICTURE CREDITS

Cover, pps. 9-11	Mount Wilson and Palomar Observatories
pps. 15, 19	William V. Wright
p. 24	Ross Madden-Black Star
pps. 28, 30	Mike Boughton '55

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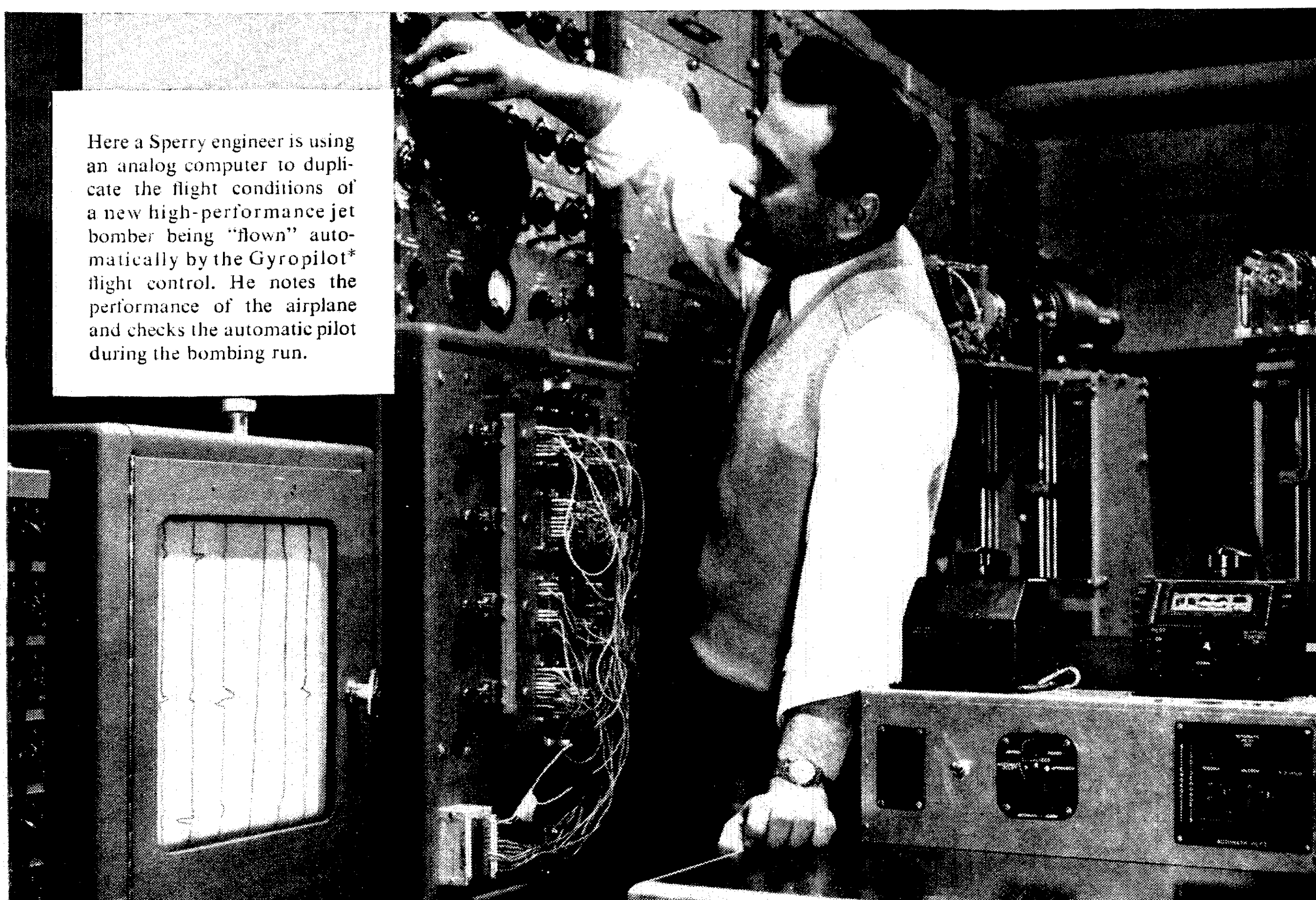

Here a Sperry engineer is using an analog computer to duplicate the flight conditions of a new high-performance jet bomber being "flown" automatically by the Gyropilot* flight control. He notes the performance of the airplane and checks the automatic pilot during the bombing run.

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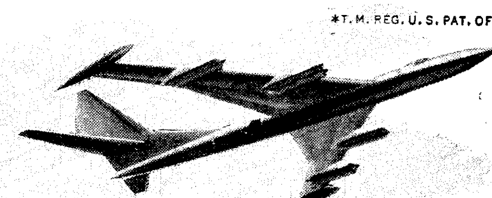

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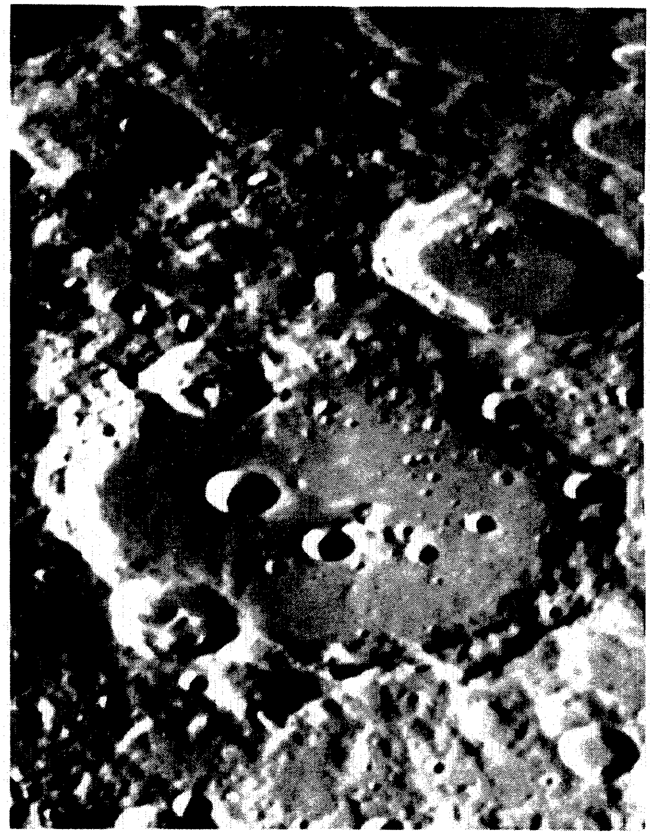
First moon photograph taken with the 200-inch telescope shows the crater Clavius (just below the center of the picture), 150 miles across and circled by walls 12,000 feet high. Even the smallest of the pits or craters on the floor of this large walled plain are two to three miles in diameter. Because the moon has no atmosphere, it is possible to obtain clear, sharp pictures of its surface.



THE MOON AND THE PLANETS

The 200-inch telescope at the Palomar Observatory takes its first look at them. The resulting photographs are shown on these pages.

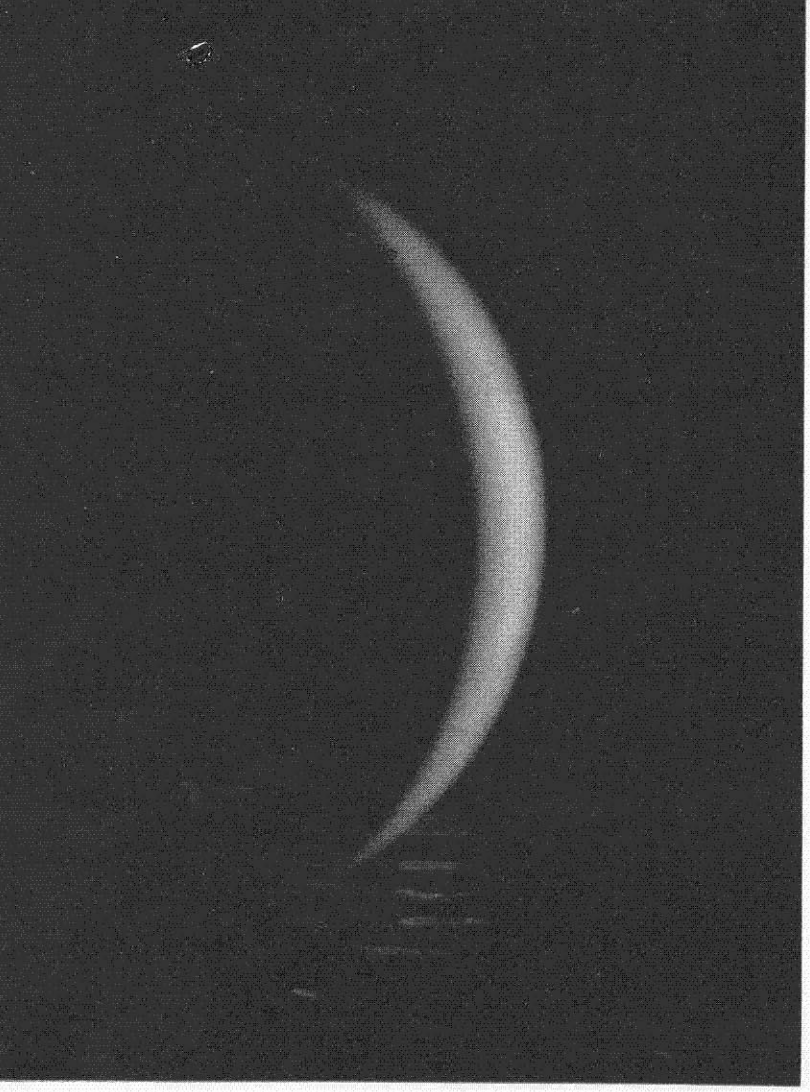
SOME OF THE FIRST photographs of the moon and planets made with the 200-inch Hale Telescope at the Palomar Observatory were released by the Mount Wilson and Palomar Observatories last month. Some impressive samples are shown on this and the following pages.

The 200-inch telescope was expressly designed for, and is engaged in a systematic study of far-off objects, rather than the planets—which are, relatively speaking, earth's next door neighbors. However, photographs of the moon and several planets have been made with the telescope during the past two years, as time permitted. Public interest, coupled with the fact that several years may pass before finely-detailed pictures can be taken, led to release of the best pictures available at this time.

This new series of pictures includes the planets Venus, Mars, Jupiter, and Saturn—which are more interesting pictorially than the distant Uranus, Neptune, and Pluto. These latter show little detail and on photographs appear as pinpoints or very small disks of light. Mercury is so close to the sun that it is seen rarely, and then appears low on the horizon during the half-light of dawn or twilight.

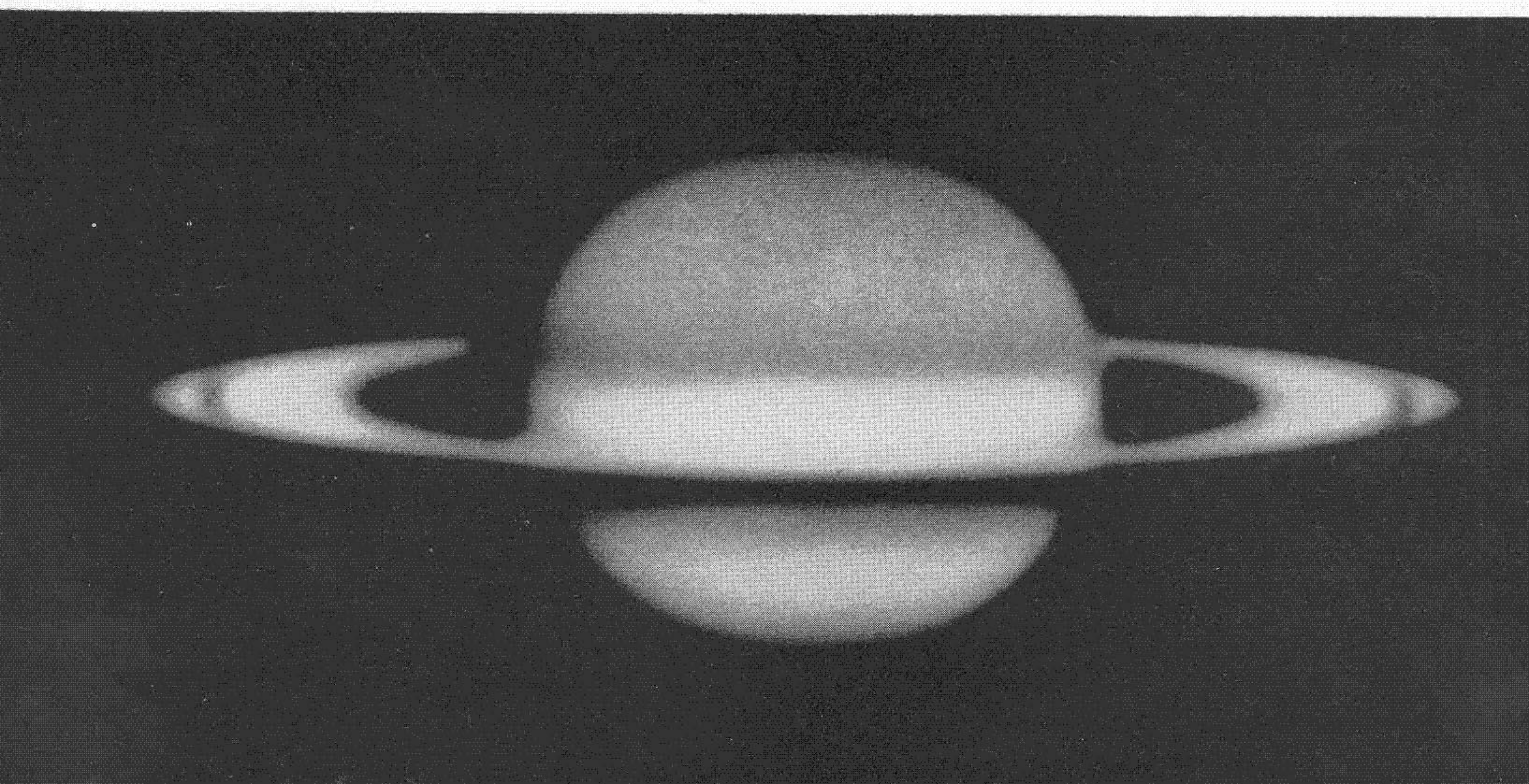
Turbulence in the earth's atmosphere—the mixing of hot and cold air—makes it hard to get good photographs of heavenly objects, whether the telescope used is large or small. Astronomers are always concerned about "seeing," a term they use to estimate the steadiness and sharpness of the image, both of which vary with the degree of turbulence.

"Seeing" has nothing to do with cloudiness and, oddly enough to the layman, the poorest seeing occurs on clear, windy, wintry nights when the stars twinkle brightly. Then the image dances wildly in the telescope, it is ill-defined, and photographs are fuzzy. Good seeing occurs more often in late spring, summer, and early autumn; excellent seeing—needed to bring out the fine details of nearby objects such as planets—may occur on only a few nights during the year.



VENUS *is similar in size and other physical characteristics to the earth. At intervals of about a year and a half, this planet becomes the evening star—at which time it is a spectacular sight. When it is bright near Christmas time, people always call the Observatories to ask if it is the Star of Bethlehem reappearing. Like the moon, Venus shows phases, and in this photograph looks like the new moon.*

SATURN *is encircled by a three-ring system, 171,000 miles across, but only 10 miles thick. Each ring is clearly separated from the others, and is composed of countless small particles the size of bits of dust. Saturn takes about 30 years to revolve around the sun. During this time its rings can be seen twice, edge-on, by an observer on the earth. It was only recently that they opened up enough to permit a photograph like this to be taken.*



JUPITER *(above) is the largest of the planets. It has an equatorial diameter of 88,800 miles—about 11 times that of the earth. None of its markings are permanent, indicating that they are atmospheric in character. The belts running parallel to Jupiter's equator change their shape and position constantly. The Great Red Spot (upper left) moves about slowly, disappears and reappears. No explanation for the spot has been established. The small bright spot outside Jupiter is Ganymede, one of the 12 known Jovian satellites. Ganymede's shadow appears as a black circle on the upper rim of the planet, just above the Great Red Spot.*

MARS *(below). Left photograph, taken with a plate especially sensitive to blue light, shows the variable atmospheric conditions and clouds, or haze, in the atmosphere of Mars. In the upper portion of the planet, and at its lower left, the haze is thin. At the top and bottom are the polar caps, which appear in the fall season of Mars, and disappear in the spring. Right photograph was taken in red light 30 minutes before the blue-light picture was made. Because red light penetrates atmospheres, this shows the permanent surface features of Mars. Some of these features show seasonal changes, are green in spring, brown in fall.*

PETROLEUM PRODUCTION

The story of Project 37, a fundamental research program which has produced some spectacularly practical results in the petroleum industry

In 1927 the Institute became interested in a study of the behavior of the fluids produced from oil wells. The industry was familiar with the properties of natural gas, crude oil, and brackish water as they were collected at the well head. However, little was known as to their states under conditions prevailing before they entered the bottom of the well. This situation seemed to offer an opportunity for providing some basic knowledge which would be of practical interest both to science and to technology.

The study program was initiated under a research grant from funds furnished jointly by John D. Rockefeller and the Universal Oil Products Company, administered through a central committee of the National Research Council.

Research Project 37 at the Institute was one of some forty researches supported by this fund during its limited life. When the original fund was depleted, the American Petroleum Institute took over administration of the program, but because it was necessary to operate on annual donations from individual oil companies, a sharp cut-back in support resulted. The program was reduced to three investigations and Project 37 in the chemical engineering laboratory of the Institute was very fortunate in being retained in active service.

This form of cooperation between the American Petroleum Institute and the California Institute has continued without interruption for nearly twenty-six years, and its largest annual budget to date has already been allotted for work during the twenty-seventh year. During this period the API research program has expanded to a total of nine projects with an annual budget of nearly half a million dollars.

The term "oil field" usually applies to an area at the surface of the earth within which a number of wells are located. Beneath this location may lie a series of "reservoirs" at increasing depths below the surface. Often these reservoirs are essentially completely segregated from each other at time of discovery. The reservoir or producing formation consists of a slightly porous stratum in the earth's crust in the interstices of which hydrocarbon fluids have collected during geologic time.

Not all porous strata contain hydrocarbons: in fact, only are they so enriched when a combination of factors happens to prove favorable. These factors include nearness of organic sediments which can be changed to hydrocarbons, suitable conditions for this change, and channels for movement of the hydrocarbons to the collecting "trap"—such as that offered by an anticlinal fold in a porous stratum.

The mineral material making up favorable strata for petroleum collection is of sedimentary origin and varies in constitution from lightly cemented coarse sandstone to hard, shalelike rock, with exceedingly small pore spaces between the fine grains of clay. In some cases porous or shattered limestone formations serve as a collecting zone.

As a well is drilled deeper into the earth's crust, the temperature and pressure at the bottom of the hole are found to increase. Wells have been driven to depths of approximately 20,000 feet while subsurface temperatures exceeding 350° F and pressures approximating 9000 pounds per square inch or more have been measured.

Although these extreme conditions had not been encountered at the time Project 37 was started—when shallower wells were sufficient to supply the demand—it nevertheless seemed likely that a mixture of crude oil, natural gas, and water, when subjected to high pressure and temperature, would have decidedly different properties than when existing at normal room conditions. The available knowledge regarding this situation at that time was very meager.

The petroleum production engineer, who is in charge of the economic and effective exploitation of any given petroleum reservoir, bears a heavy responsibility to his company and the nation because, by improper manipulation, it is very easy to permit a severe loss of a vital natural resource by leaving unnecessarily large amounts of oil in the formation in an economically unrecoverable condition. In order to avoid such losses, the engineer requires not only skill, but an accurate knowledge of the behavior of the materials with which he is working, under all the conditions to be met in practice. It was the objective of Project 37 to add as much as possible to his fund of information.

The hydrocarbons found in a petroleum reservoir comprise a very large number of compounds of carbon and hydrogen, made up of molecules containing from one carbon atom to many tens of them, and varying correspondingly in physical properties. Those with the smallest molecules are gaseous under ordinary conditions, or at least highly volatile; whereas the largest molecules correspond to viscous liquids of low volatility, or even to solids when in the pure state. Because of a family similarity between these compounds, they are all soluble in each other to some extent.

The behavior of the mixture

It might at first be thought that in mixtures of hydrocarbons, each one might contribute to the composite properties of the mixture in direct proportion to the fractional part its molecules contribute to the whole. This relationship does hold in a semi-quantitive way, and it has been very useful to the industry in predicting properties of complex hydrocarbon mixtures when applied under the most favorable conditions. However, the very important compounds of low molecular weight digress markedly from such behavior, particularly at high temperatures and pressures. Under these latter conditions, which have come more to be the rule than the exception in petroleum production, the behavior of mixtures is very complex, and not susceptible to accurate prediction by means of any simple relation.

These facts were determined early in the life of the project, and it became evident that much information would have to be collected before the problem could be solved. One way to approach the investigation would be to make direct measurements of the important properties of all the complex mixtures found in the underground reservoirs. However, because of the wide variation in composition found in these mixtures, and the great differences in temperature and pressure between reservoirs, this attack did not seem to offer as much chance of giving fundamental understanding of the individual effects of composition, temperature, and pressure, as did an approach consisting of studying first the behavior of single hydrocarbons, then of mixtures of various pairs, to be followed by studies of ternary systems. This procedure would serve to ascertain the contribution of each hydrocarbon to the behavior of the mixture.

The project developed equipment and experimental methods for measuring the volume occupied by known weights of hydrocarbon material under pressures from that of the atmosphere up to 10,000 pounds per square inch, at temperatures ranging from little above the freezing point of water to over 450° F. It was also possible to ascertain quantitatively how much of this volume was occupied by liquid and how much was gas phase.

This type of information was needed by the petroleum engineer for a number of reasons. From a knowledge of the composition and volume of material withdrawn from a well and gauged at surface conditions, he had need to know the corresponding volume of the material when still in the reservoir, and also how much of it had been liquid and how much gas under the conditions prevailing there. If he knew the extent of the reservoir and the porosity of the "sand", he could then estimate the reserve of petroleum contained in the reservoir, and to how much oil and gas at the surface it would correspond. If the reservoir was one of fixed total volume, he could estimate the rate of decline of pressure to be expected for a given rate of withdrawal through wells.

The project also studied the energy involved in changes of state of hydrocarbons. These thermodynamic properties are important to the production engineer because, in many cases, the energy stored in the hydrocarbons under high pressure is relied upon to force the material up the bore of the well a number of thousand feet above its original location. If this stored energy is unnecessarily dissipated by poor production practice, the costly process of pumping must be resorted to earlier in the life of the field. Also, in many cases, this stored energy must be used in moving petroleum fluids through the fine pore channels toward the well in order that they may be lifted thence to the surface.

Theory and practice

As an example of the use which could be made of these types of information by men in the industry, there can be cited the case of a deep well drilled in Texas which showed what was thought to be very peculiar behavior. Wells drilled to the bottom of this particular reservoir produced a relatively heavy brown crude oil, and only moderate amounts of gas, when the mixture was brought to the surface.

On the other hand, wells which only went down to the upper part of the reservoir produced a large quantity of gas, and a smaller amount of liquid which was entirely different from the oil issuing from the same formation through deeper wells. This liquid was pale yellow, relatively non-viscous, and rather volatile. The ratio of gas to this light liquid stayed constant with different rates of production, although most wells vary in gas-to-oil ratio under these conditions. Project 37 was able, by drawing upon its findings from studies of simple systems, to explain this anomaly to the production men.

Under conditions of high temperature and pressure, when both gas and liquid phases are present, the dense gas phase will hold much greater quantities of intermediate hydrocarbons than under normal surface conditions. As a result. when some of this rich gas is brought to the surface, and its temperature and pressure lowered thereby. a separation occurs which results in a normal natural gas, together with some liquid consisting only of the intermediate hydrocarbons formerly held in the reservoir gas.

This liquid. which was later called condensate. was not greatly different from gasoline. and was thus of more than average value. The heavy brown oil produced from the deep wells of the same reservoir was drawn from the liquid phase underground, and. when brought to the surface at lower pressure. some of the gas constituents which were dissolved in it underground separated. giving a comparatively small gas-to-oil ratio.

Another peculiarity of this well was that the water produced with the hydrocarbons from the upper part of the reservoir was fresh water. whereas that coming out with the heavy oil was brackish, as is usually the case. Here again an explanation was available. because the dense gas phase underground was able to contain more water vapor than normal. and when the material was brought out to surface conditions this excess water condensed out, thus producing substantially distilled water.

The project was able to point out to the industry that. in the case of fields containing rich gases of this type. if the pressure in the reservoir was allowed to decrease to any great extent, the same sort of deposition of liquids would occur underground. and the valuable liquid would be partially lost in the pores of the rock.

The cycling process

As time went on. a large number of fields of the condensate type were discovered. and in nearly all cases it was possible. because of understanding the necessary procedures. to arrange to operate a whole field as a single production unit and carry out the process known as cycling. This consisted in making the separation of condensate at the surface. recompressing the resulting natural gas to a pressure higher than that in the reservoir. and then reinjecting the gas underground in order to keep the pressure there high enough to prevent premature condensation.

Today many millions of dollars have been invested in cycling plants. and undoubtedly very large quantities of liquid hydrocarbons have been recovered which would otherwise have been lost.

Because the project elected to take the long range approach. its early experimental results were of necessity only applicable in principle to the complex problems of the field. Enough work was done with field samples to show their general behavior and to test various ways of sampling the fluids from producing wells. The experimental methods and apparatus developed were of immediate interest to the industry. and in a relatively short time a number of producing companies had set up laboratories to study their own immediate problems. Upon graduation. a number of students who had had experience with the project took an active part in these developments.

In addition to the volumetric and energy characteristics of hydrocarbon mixtures there are several properties which are of direct interest to the engineer. One of these is the interfacial tension between liquid hydrocarbons and gaseous hydrocarbons. water. or rock solids. Although Project 37 has made no measurements of this sort. some work done under one of the earlier projects carried out at the Institute indicated that when the hydrocarbon liquids were in equilibrium contact with gas at high pressure. the tendency to drain from wetted pore spaces increased with increase in pressure. This points to an advantage to be gained by keeping the formation pressure as high as practicable.

Effects of temperature and pressure

A second important property is the viscosity of the fluids, particularly the liquids, because high viscosity tends to lower the mobility of the oil through the minute rock channels toward the well. and increases the energy required to accomplish the movement. Project 37 studied the effect of pressure and temperature upon the viscosity of gases and liquids under the conditions characteristic of petroleum reservoirs. From these measurements also appeared good reasons for pressure maintenance. because a molasses-like crude oil. when saturated with natural gas at reservoir conditions. can have its viscosity lowered almost to that of kerosene—a tremendous gain for ease of movement in flow channels.

The findings of the project in favor of pressure maintenance came at a time when conservation measures in petroleum production were becoming much more important. and they served to reinforce the belief of forward-looking engineers that, whenever possible. field operations should be unitized for each reservoir as soon as possible after discovery. and steps should be taken to avoid unnecessary decrease in formation pressure.

In the case of reservoirs in which the pressure had already declined. consideration was given to the desirability of trying to restore higher pressure by injection of natural gas from other sources. The project found that. although energy for movement of oil could thus be supplied. it was by no means as simple to restore in solution in the oil. the gas which earlier gave the liquid desirable drainage and flow properties. When thin films of oil were exposed to gas at higher pressure they were quickly saturated with dissolved gas. but if high-pressure gas were to be brought into contact with the limited surface of a large body of oil. such as is to be found in some of our reservoirs. completion of the process of dissolving—and thus affecting the properties of *all* the oil—would require hundreds or even thousands of years. Despite this discouraging outlook for massive bodies of oil. repressuring operations have been carried out in certain fields and the recovery of much oil has thus been accomplished.

If the oil in a reservoir is originally saturated with gas at the existing pressure. and withdrawals are made through a producing well, the pressure near the well will drop somewhat below the original value. This decrease of pressure tends to cause dissolved gas to separate from the liquid to some extent. As production from a well proceeds, the zone of lowered pressure extends farther back into the formation surrounding the well. The gas separating from the liquid in the very small pore spaces in the rock forms small bubbles. Energy is required to force these bubbles through the minute, devious channels toward the well and flow of oil to the well is thus impeded. A certain amount of this difficulty is unavoidable, but it again points to the desirability of keeping gas in solution in the oil just as long as possible in its travel through the reservoir. Lower rates of production require less pressure differential near the well, and are therefore desirable for the sake of better long-term recoveries. Other means of keeping formation pressures high are also helpful in this regard.

Project 37 pointed out to the industry that, with suitable precautions, the pressure upon a saturated solution of gas in oil could be lowered by several hundred pounds per square inch without the evolution of any gas bubbles. This type of supersaturated solution could, in many cases, be maintained so long as no agitation or turbulence occurred in the liquid. The advantages of this phenomenon in keeping the oil as long as possible in its most mobile condition are sufficiently great that the project is now undertaking an extensive program of research and investigation of this particular type of behavior.

The scientific information gathered by the workers of the project over a period of twenty-five years has been made available to the public through technical publication channels. In addition to two book-length works, some 130 scientific journal articles have appeared, and the series is extending at the rate of about five each year. Considered broadly, this form of cooperation between industry and educational institutions offers interesting opportunities for benefit to all.

THE MEN BEHIND PROJECT 37

THE AMERICAN PETROLEUM INSTITUTE, at its 32nd annual meeting in Chicago in November, celebrated the 25th anniversary of Project 37. The high point of this celebration was the presentation of Certificates of Appreciation to two Caltech scientists, for their work on the project—Drs. William N. Lacey and Bruce H. Sage, Professors of Chemical Engineering.

Dr. Lacey has directed this hydrocarbon research at Caltech since it was first begun 25 years ago. Dr. Sage has co-sponsored the research since 1937. In making its awards to the two men the American Petroleum Institute noted that their work "has been of untold value to refiners and others because it enabled them to predict accurately how hydrocarbon mixtures would react under given circumstances" and "to save tens of millions of barrels of high-grade distillate which otherwise might have been lost forever."

This is not the first time Dr. Lacey and Dr. Sage have been honored for their hydrocarbon research. In 1946 Dr. Lacey received the Hanlon Award of the Natural Gasoline Association of America "for meritorious service to the natural gas industry." In 1947 he was given the Anthony F. Lucas Gold Medal of the American Institute of Metallurgical Engineers.

In 1949 Dr. Sage was named the first recipient of the Precision Scientific Company Award of the American Chemical Society for achievement in petroleum chemistry for his "contributions to the knowledge of petroleum and its products."

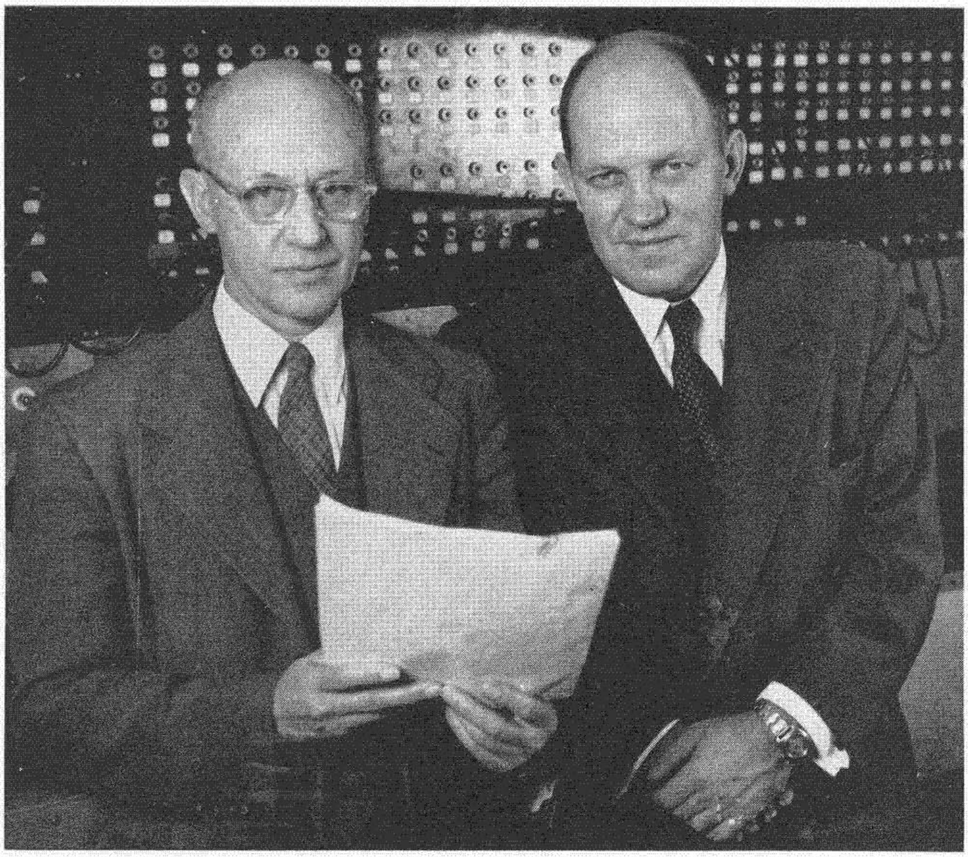
At Caltech, the Chemical Engineering department is under the joint direction of Dr. Lacey and Dr. Sage. Though the hydrocarbon work is, and always has been, their chief research project, it is certainly not the only activity they are engaged in.

Dr. Lacey, for example, successfully manages to fill out a large portion of his time by serving as Dean of Graduate Students at the Institute. Like all good deans, most of the work he does in this position is above and beyond the call of duty. He functions variously as career consultant, financial adviser, substitute father, and court of final appeal to the Institute's 600-odd graduate students.

One of his minor chores is to read every thesis presented by every candidate for Engineer and Ph.D. degrees at Caltech. There are about 90 of these theses every year running to a total of about 10,000 typed pages, and covering, of course, a rather wide range. In one sitting, for example, Dr. Lacey may run through "Complex Function Theory for Functions with Values and Arguments in Locally Convex Linear Topological Spaces," and top it off with "The Course of Vitamin B_1 Metabolism in Man as Indicated by the Use of Radioactive Sulfur, a New Synthesis of 4-methyl-5-beta-hydroxyethylthiazole, and a Demonstration of Anti-coincidence Radioactive Counting Techniques."

Dr. Lacey came to Caltech as an instructor in Chemistry in 1916. A graduate of Stanford (1911), he received the degree of Chemical Engineer there in 1912. He served as an assistant in Chemistry at the University of California from 1912 to 1915, while studying for his doctorate there. After he received his degree in 1915 he worked for a year as a research chemist for the Giant Powder Works in San Francisco, then served as a Research Associate at MIT before joining the Caltech faculty in 1916.

He became a full professor at Caltech in 1931, and was made Dean of Graduate Students in 1946, succeeding the late Richard C. Tolman. He was Chairman of



W. N. Lacey and Bruce H. Sage, Caltech Professors of Chemical Engineering, and the men behind Project 37.

the Faculty in 1944-45, and is a member or past member of the Faculty Board and Faculty Committees on the Science Course, Student Relations, Registration, Industrial Relations, Graduate Studies, Contracts and Patents.

During the first world war Dr. Lacey served as a First Lieutenant in the Ordnance Department Reserve, and saw active duty from 1917 to 1919 at the Rock Island Arsenal, in Illinois, where he was assigned to the design, construction and operation of artillery shell and fuze-loading plant.

In World War II he was a supervisor under the OEM contract covering the National Defense Research Council's research and development on artillery rocket ammunition at Caltech. In 1948 he was awarded a Presidential Certificate of Merit for this work.

Dr. Lacey is a member of the American Chemical Society, the American Institute of Chemical Engineers, Sigma Xi, Tau Beta Pi, and Phi Lambda Upsilon. He is a past-chairman of the Southern California Section of AICE, and a councilor and past-chairman of the Southern California Section of ACS.

Dr. Sage has been quoted as saying, "There is nothing like the combination of several part-time jobs to stimulate the mino and to keep busy." He should know.

Aside from his research, Dr. Sage teaches several graduate courses at the Institute. Until recently he served as Associate Director of Engineering and head of the Explosives Department at the Naval Ordnance Test Station, Inyokern. He is now Senior Consultant there.

Though he thrives on keeping as many jobs going as possible, Dr. Sage has all his life found time to indulge in his favorite hobby—which is to roam over isolated portions of the Southwest on pack trips. And, though his work required him for a number of years to maintain homes in Altadena and Inyokern, he had—and still has—a cattle ranch in central New Mexico to round out his activities.

New Mexico is Dr. Sage's home state. He was born in State College, and was graduated in 1929 from the A & M college. He received his M.S. in 1931 and his Ph.D. from Caltech in 1934, and has been associated with the Institute ever since. He has been a full professor here since 1944.

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

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

Dr. Sage is co-author with Dr. Lacey of *Volumetric and Phase Behavior of Hydrocarbons*, *Thermodynamic Properties of Hydrocarbons*, and *Thermodynamics of One-Component Systems*. He is a member of the American Institute of Mining and Metallurgical Engineers, the American Chemical Society, the American Institute of Chemical Engineers, and the California Natural Gasoline Association, as well as Tau Beta Pi and Sigma Xi.

A plant physiologist casts a critical eye on the current chlorophyll craze

AN UNCOLORED VIEW OF CHLOROPHYLL

By ARTHUR W. GALSTON

I HOPE THAT THE person who proposed as the title of this talk*, "The Magic of Chlorophyll," had his tongue well in his cheek, because I come not to praise chlorophyll, but to bury it.

I should make it clear at the outset that I have nothing against chlorophyll per se. As a plant physiologist I am aware that my livelihood depends upon the fact that plants are green, upon the fact that there is a substance known as chlorophyll which possesses certain wonderful—one might say even magical—properties.

Chlorophyll, as you know, is the green pigment of plants. It is universally distributed in green leaves and stems, but is absent from most roots and the white areas of variegated leaves.

Chemically speaking, there are at least two chlorophylls, differing from each other in only minor respects. They are both composed of carbon, hydrogen, oxygen, nitrogen and magnesium, and the organic chemist knows them as substituted tetrapyrroles grouped around a central core of magnesium.

In the plant, chlorophyll does not occur randomly dispersed throughout the leaf, but, rather, is localized in little bodies called chloroplasts, which are about the size and shape (but not the color) of our red blood corpuscles. Chlorophyll in the chloroplasts is closely bound to other chemicals which are important to its stability and function.

Now, every student of elementary plant physiology knows how to get chlorophyll out of the chloroplasts and out of the leaf. He merely immerses a leaf in some appropriate solvent such as methyl alcohol or acetone, and the green pigment readily passes out into the solvent. The solvent may then be evaporated away, leaving the chlorophyll-containing pigments behind.

The chlorophyll thus extracted is quite unstable, especially in light, and is also insoluble in water. It may be readily converted into a stable water-soluble derivative known as chlorophyllin by first treating it with alkali to remove the long-chain phytol substituent, and then by replacing the magnesium core of the molecule with copper or nickel. It is these simple procedures, long known to plant physiologists, which have resulted in the booming new multi-million-dollar chlorophyll industry.

What is it about chlorophyll that is so exciting and interesting? We know, in the first place, that it is chlorophyll which absorbs the light energy that makes possible the fixation and reduction of atmospheric carbon dioxide to sugar. This process of photosynthesis is of basic importance to all of us, for without it, animal life on earth would be impossible.

The sugars and other organic materials formed by green plants constitute the basic fuels for all of us, for when we walk, pound a typewriter, or sing a lullaby,

* *This article has been adapted from a talk, "The Magic of Chlorophyll," given before the Caltech Management Club*

we are using the energy released by the combustion of sugars in our body. Thus we are all essentially machines operating on solar energy. The green plant is the gear that makes that solar energy available to our bodies. and chlorophyll. in some way that we do not yet completely understand. is a key component of this gear.

Recently. it has become quite clear that what chlorophyll does is. in a way. magical. Everyone knows what a stable material water is. You can apply great quantities of heat to water and you don't decompose it: all you do is vaporize it. If you take hydrogen and oxygen. which are the components of water. they will ignite explosively to make water. If you want to tear water apart. you must expend just as much energy to do it as was liberated by that explosion. You have to electrolyze it or do something else very drastic.

It has now been found that chlorophyll does. in fact—with the aid of light energy—tear this stable water molecule apart. The oxygen produced from this disruption of the water molecule is released into the air. This. incidentally. is very fortunate for us because we all require oxygen. and if plants didn't release it. we would run out of it eventually. The hydrogen which is left behind after the release of oxygen furnishes a sort of reservoir of reducing power which somehow gets funneled to the carbon dioxide. converting it eventually to sugar.

What chlorophyll does in a plant

I do not mean to deliver a lecture on elementary plant physiology. but I should like to sum up here again what chlorophyll does in a plant. It dismembers a water molecule. using light energy to do the job. This results in the liberation of oxygen and eventually in the formation of sugar. both of which products make our existence possible. We may not actually eat sugar. of course: we may eat. instead. the protein of a cow. But. after all. the cow in turn has eaten a plant product to make the meat we eat. Ultimately. as the Bible says. all flesh is grass.

Chlorophyll doesn't accomplish this tremendous job by itself. In the chloroplasts there is an abundance of protein and fat. and the chlorophyll cannot function. so far as we know. without being firmly attached to the protein and fat. This fact immediately makes us a bit suspicious of so-called water-soluble. unattached chlorophyll—which is added to toothpaste. for instance.

An analogous situation exists in the red pigment of our blood. which we call hemoglobin. The heme. or the red part of this compound. is chemically very similar to chlorophyll—but it is attached to a protein. or globin. to make hemoglobin. In the same way. you have a chlorophyll protein which is completely analogous with the hemoglobin. and unless the protein is there you get no chemical activity.

We know. then. that chlorophyll is necessary for green plants. What does it do to animals? There are—I am pleased to state—at least two recognized medical uses for chlorophyll—though I had to do a good deal of digging in the literature to find them.

First. chlorophyll is known to stimulate the production of healing tissues—so-called granulation tissue—in certain types of lesions. If you have a peptic ulcer. for instance. some doctors will recommend a preparation of chlorophyll. together with aluminum hydroxide and magnesium trisilicate. This is mixed up into a paste. which you take into your stomach and. if you are lucky. you will lose your ulcers.

I do not speak from personal experience. but I would guess that there are probably better things to take for ulcers. However. this is a use of chlorophyll which has in the past been recommended. and one can claim that it has medical validity.

The second accepted use is the one that has given rise to the current fad. Gangrene. as you may know. is essentially a rotting of the flesh in deep-seated wounds. Certain gangrenous lesions. usually incurred as a consequence of military activity. may become rather foul-smelling. It was found some years ago that the application of chlorophyll pastes to this particular type of lesion would decrease the unpleasantness of the odor associated with them.

You now have the necessary background for understanding the chlorophyll boom. and for seeing how a bright brain. in an effort to "make an honest buck" could launch an attempt to deodorize the American public. You begin with two scientific facts:

1. Certain kinds of lesions that smell bad are made less obnoxious if you smear chlorophyll poultices on them.

2. Chlorophyll in the plant results in the production of oxygen. thus "purifying the air."

Clearing the air

The manufacturers of air-purifiers were the first to take advantage of these facts. I think you are familiar with the use of these products. You take the magic bottle and put it in the corner of the room in which. let us say, you are cooking onions. Now that magic little bottle. containing miracle-working chlorophyll. absolutely kills the odor of the onions in the room.

How does this magic bottle work? As a matter of fact. it operates on a very old principle: If you can't lick 'em—join 'em. They can't really lick that onion odor. but they *can* prevent you from smelling it—or from smelling anything else. as it turns out. What they accomplish is the deadening of your sense of smell by means of a volatile anaesthetic. such as formaldehyde. The job is done. and *you* won't smell any onions. but the smell is still there. Thus chlorophyll appears to have nothing whatever to do with the deodorizing effect of this preparation.

After the air-purifiers came the production of water-soluble chlorophyllin from alfalfa—apparently by the classical methods well known to students of elementary plant physiology. It is this water-soluble product which

The author—and subject. Dr. Galston, a plant physiologist, is Associate Professor of Biology at the California Institute of Technology. In the laboratory picture at the right he is holding a separatory funnel containing an extract of leaf pigments. The chlorophyll appears as the dark liquid at the top of the funnel.

has now found its way into soaps, toothpastes, gargles, hair tonics, inner soles for shoes, dog food, baby diapers, and other products almost too numerous to mention.

Frankly, I don't think any of these products containing either chlorophyll or chlorophyllin do what they are represented as doing. But my feeling definitely represents a minority opinion, for about $100,000,000 worth of chlorophyll-containing products were sold during the last fiscal year. I think that our most charitable appraisal must be that we have here a case of a little bit of truth going a very long way.

Recently, the American Medical Association and the American Dental Association felt called upon to issue statements on this subject. Cautiously, and in diplomatic language, they have said that present evidence does not indicate that the claims made for these various products are in fact justified. To my knowledge, no refutation of this statement has ever been made by any company manufacturing a chlorophyll product.

A question of ethics

This brings up a question of ethics—and perhaps a question of the duties of government. Here are the American people willingly parting with a good deal of money for products that are, to put it mildly, not what they are represented as being. Should this waste be permitted?

I don't know whether most people would feel they were being imposed upon if such products were compulsorily withheld from the market until their claims were proved. Americans are very jealous of their freedom, and probably the freedom to be gypped is one of the freedoms we all treasure. However, we do have a Pure Foods and Drugs Administration, and a Federal Trade Commission, and these organizations do have some jurisdiction over such matters.

You may remember back to the days when a certain "vegetable compound" was sold as a cure for almost any feminine ailment. A lot of extravagant claims were made for the compound, but the only effective principle in it turned out to be ethyl alcohol. Eventually, as a result of the intervention of federal agencies, the manufacturers were required to state this fact.

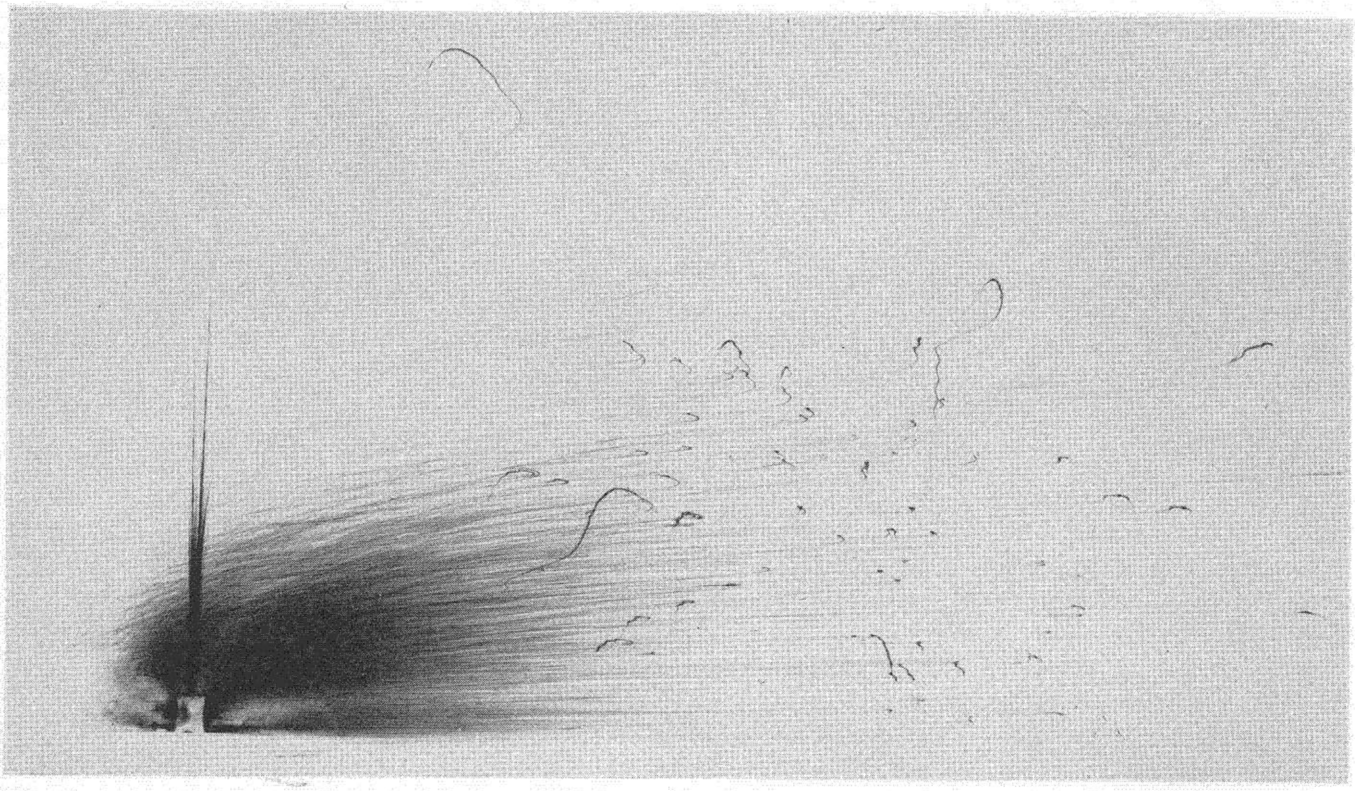
Many extravagant claims have similarly been made by cigarette manufacturers—and are now being made by manufacturers of chlorophyllin-containing products. Perhaps, if we are going to have a Pure Food and Drugs Administration, we ought to support it to the extent that it can conduct policing operations effectively.

Get your chlorophyll here

What if I am wrong in this one man's appraisal of chlorophyll? Suppose that chlorophyll does all these things that manufacturers claim for it? If that is the situation, I have a very simple recommendation. You undoubtedly have some green plants growing around your home; there is abundant grass on the Caltech lawns; and there is lots of spinach in the market. Just buy some, or pick some, and eat it. You will get more chlorophyll that way than you will in any of the chlorophyll products.

I think the best summary and conclusion that I can make of this problem is contained in a little poem that appeared recently in *Chemical and Engineering News.* It went like this:

"Why reeks the goat on yonder hill
Who seems to dote on chlorophyll?"



Ultrafast particles extruded from 1¼-inch copper cone liner of a commercial shaped charge, such as is used in oil-well drilling operations. Photograph was made with a rotating camera. The great plume of luminous particles whose paths appear flattened out because of the camera's rotation are fragments of the container of the shaped charge. The few particles whose tracks are almost vertical have tremendous speed; tracks are hardly bent despite fast rotation of camera.

ARTIFICIAL METEORS

A progress report on research in this field—and a look at its future.

by FRITZ ZWICKY

SOME TIME AGO tests were made with artificial meteors[1], extruded from metallic inserts in detonating *shaped charges*[2]. Experiments with these objects give the following basic information:

1) Artificial meteors in air with speeds of several kilometers per second fall into the category of motion called *ultra-flight*[3] during which either the projectile or the medium which it traverses suffers physico-chemical changes.

2) Artificial meteors expelled from cavity charges may be solid, liquid or "gaseous." Launched from high flying balloons or rockets they constitute pencil jets with possible ranges of thousands of kilometers. The observation of their trajectories and their spectra should give us information on the upper atmosphere as well as on the electric and magnetic fields at great heights.

3) Finally, artificial meteors can be imparted velocities greater than 11.2 km/sec. This suffices to have them permanently escape from the earth, if properly launched from great heights.

Using uniform explosives and accurately machined, axially symmetrical inserts[2], jets of ultrafast particles are extruded from these inserts, which follow each other accurately on a straight line trajectory.

It was observed from the start[4] that the trajectories of solid particle jets in a normal atmosphere are not uniformly bright but appear to consist of irregular pulses of light interrupted by short non-luminous parts. It was found that each individual ultrafast particle brightens and darkens intermittently. On being projected into the atmosphere the artificial meteors first heat up and then melt or evaporate superficially, processes which cause them to cool down.

This sequence of events, which often repeats itself many times, was first recorded with a simple but effective device, *a camera or a telescope in motion* [3] [5]. In the case of artificial meteors ejected from metal-lined shaped charges, results obtained with a camera rotating around an axis parallel to the jet of meteors proved most revealing—as evidenced by the photographs on these pages. Other investigators are using rapidly moved films, but this method seems to me more difficult than rotating the camera.

It is seen from the diagram below (right) that two groups of particles are ejected. Those in the first group have velocities in the range from 5 to 10 km/sec. Group two mainly consists of a large slug with a velocity of about 2 to 3 km/sec. The range of the fastest particles, depending on their nature, may be of the order of 100 meters in air at sea level.

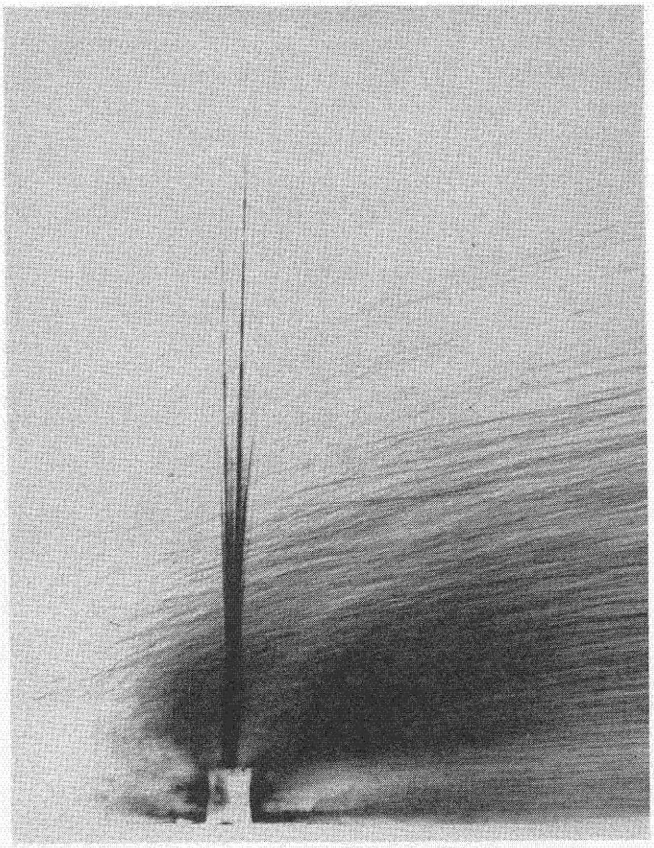
During the bright flashes, material is sprayed from these particles into the surrounding atmosphere, as shown in the diagram. Spectra of these flashes contain the emission lines of the elements which constitute the liners, as well as of their oxides[6]. There may be one flash, or groups of two and more flashes repeating themselves regularly, as shown schematically for the tracks a, b and c in the diagram. This presumably means that, in addition to periodic flashes, spinning of irregularly shaped particles contributes to the varying light intensity along the trajectory.

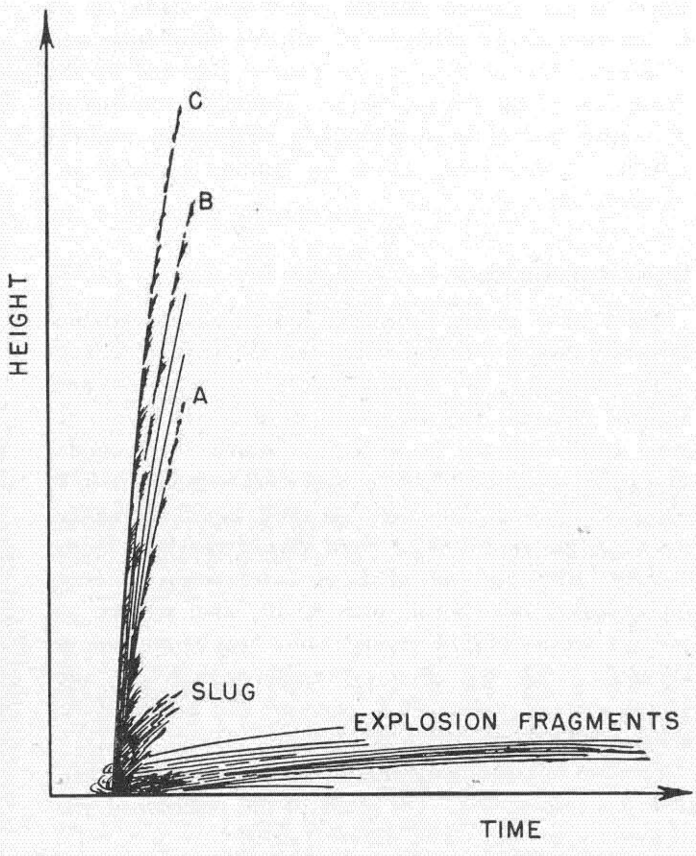
A few years ago Dr. A. G. Wilson and the author, working with the Palomar Schmidt telescopes, also discovered the rather frequent occurrence of natural *regularly pulsating meteors*[3] [4].

Recently some investigators[7] have succeeded in propelling individual ultrafast pellets whose masses were of the order of a fraction of a gram to several grams, and whose drag characteristics, spectra and color temperatures could be determined. The latter were found to be of the order of 2900°K for Al pellets moving through air with 5 to 6 km/sec.

Upper atmosphere and interplanetary space

In 1946 a program[8] for the launching of artificial meteors from high flying rockets was initiated, which was at first privately financed. With the cooperation of US Army Ordnance, the first night firing of a V-2 rocket took place on December 16, 1946. Six shaped changes were installed in this rocket. Unfortunately the firing mechanism failed at the crucial moment. No further attempts have been made since then to launch artificial meteors[9] from great heights for the purpose of projecting them into interplanetary space, because neither the necessary funds could be raised nor were firing facilities readily available.





In the enlargement (left) of the picture on the opposite page some of the ultrafast particles (potential artificial meteors) clearly exhibit the pulsation which is schematically shown in the diagram at the right.

In particular, three objections were raised against any further experimentation with artificial meteors[9]. These objections are: 1) Artificial meteors are too slow and too small to be seen in the tenuous upper parts of the atmosphere since they cannot be expected to heat up enough. 2) They are also too slow to leave the earth or even to reach great heights. 3) It was feared that the launching of artificial meteors within the United States might conceivably endanger people because of falling fragments.

The great progress which has been made toward the elimination of objections 1 and 2 will be described below. As far as objection 3 is concerned, artificial meteors could be fired at sea, on the extended Australian rocket range, or in the Sahara desert, if this type of experimentation is not desirable in this country. For this purpose I have already established successful contacts in Australia and in France.

Intensification of brightness

For a particle of given size and speed the brightness can be increased in two ways. First, one may choose particles (Tracers) which, when heated by the initial extrusion process, will *react* vigorously with the oxygen or with the nitrogen of the air. Secondly, when air is completely absent this method will not work; but one may heat the meteors through the initiation of *internal solid-solid chemical reactions* in order to make them visible.

This can easily be accomplished through the choice of liners in the shaped charges which are made up of highly compressed mixtures of suitable solid fuels and oxidizers. The reaction in the liner is initiated by the detonation of the shaped charge. Thermit, composed of aluminum and of iron oxide, is a well-known reactive mixture of this kind, which on ignition becomes extremely hot.

Chemical heaters

Much more potent "chemical heaters" are available, however, even if we do not tap the resources of "Fragment Chemistry" or "Metachemistry"[10]. For instance, suitable elements may be mixed stoichiometrically with solid oxidizers such as $KClO_4$, or similar compounds. Through the choice of the proper fuel component it is possible to produce intensely hot solid, liquid or gaseous jets from the explosion of lined shaped charges. Using elements at the two ends of the periodic system one may, for instance, mix Boron with $KClO_4$ and achieve an average density of 2.51 gr/cm^3 and a heat of reaction of about 12 Kcal/cm^3; or mix tungsten with $KClO_4$ and get an average density of 5.7 gr/cm^3 and a heat of reaction of 3.8 Kcal/cm^3.

The two mixtures will produce gaseous and solid particle jets respectively. The study of the reaction of jets of these types with air of different density, or with solid and liquid media, promises to open up some interesting new fields. In particular, it is to be foreseen that because of internal chemical heating the drag of projectiles through different media may, interestingly enough, be both decreased or increased.

Particles which are internally heated during their flight produce luminous trajectories even when flying in high vacuum outside of the earth's atmosphere. Through the ejection from shaped charges of suitably chosen materials one also has the means to experiment reactively with the various constituents of the upper atmosphere[10].

Increase of speed

With commercially available shaped charges and liners one may eject fast solid particles whose speeds seldom surpass 10 km/sec. The velocity of escape from the earth at the poles is 11.2 km/sec. Obviously, in attempting to project small slugs into interplanetary space one would prefer to have some extra speed available.

There are two general possibilities to speed up the jets from lined shaped charges:

1) Higher speed of the ejected particles can be achieved with conventional explosives and proper liners if one improves on their design and the method of initiating the detonation. With this approach velocities as high as 90 km/sec have now been achieved with beryllium liners[11]. 2) In the not-too-far future, conventional chemicals in shaped charges will no doubt be replaced by much more potent explosives which liberate more energy, at detonation velocities superior to those which can now be achieved. These unconventional explosives will be made up of *fragments* or *radicals* of chemical molecules or of *metastable* states of such molecules. The stabilization of macroscopic density of such fragments and metastable molecules is the task of two new branches of chemistry for which I have proposed the designations Fragment Chemistry and Metachemistry[10]. Work in these fields was initiated only a short time ago, but important results may be forthcoming shortly.

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THE MONTH AT CALTECH

AUFS Men Report In

On January 12 Richard H. Nolte comes to Caltech to report to the faculty, students and friends of the Institute on current conditions in Egypt. He will be on campus until January 21.

On January 26 Lawrence W. Witt will arrive here to report on Brazil, remaining until February 4.

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

Richard Nolte, born in Duluth, Minnesota, was graduated from Yale in 1942, served as a Naval aviator from 1943 to 1945, then returned to Yale, where he received his M.S. in international relations in 1947. Awarded a Rhodes Scholarship, he continued his studies at Oxford University from 1947 to 1950 in the Faculty of Oriental Studies—specializing in Arabic and Turkish language, history, and literature; and in Muslim law and other social and religious institutions.

Mrs. Lilian Morgan, Research Associate in Biology, working with Drosophila in the Kerckhoff Laboratories.

Under the auspices of the Institute of Current World Affairs, the organization which fathered the American Universities Field Staff, Mr. Nolte made field trips to the Middle East in 1948 and 1950. Since April, 1951, he has lived in Lebanon and in Egypt, studying cultural, social, economic, and political affairs.

Lawrence Witt grew up in Milwaukee, and received a B.S. in agricultural economics at the University of Wisconsin in 1937. He took an M.S. at the University of Chicago and was awarded a Ph.D. by Iowa State University in 1941.

From 1941 to 1943 Mr. Witt was associated with the Institute of Current World Affairs, which enabled him to work in Brazil and study particularly the changes in methods of production and their impact on trade patterns and political relations between Brazil and the United States.

He then joined the staff of the Office of Foreign Agricultural Relations, U. S. Department of Agriculture, where his assignments included the direction of an Agricultural Resources Mission that was sent to Colombia in 1944-45, and of a study group of the Inter-American Coffee Board.

Since 1947 Mr. Witt has been on the faculty of Michigan State College, for the past four years as Professor of Agricultural Economics. He was a consultant to the Food and Agricultural Organization in 1951 and has written numerous articles in the field. Currently he is editor of the *Journal of Farm Economics.*

He comes to Caltech this month fresh from a short study tour in Brazil.

Mrs. Thomas Hunt Morgan 1891-1952

Mrs. Lilian V. Morgan, 82, Research Associate in Biology at the California Institute of Technology and widow of Dr. Thomas Hunt Morgan, Caltech geneticist who received a Nobel Prize in 1933, died in a Pasadena hospital on December 6.

A native of Hallowell, Maine, Mrs. Morgan was graduated from Bryn Mawr College in 1891 and received the M.A. degree there in 1892, after which she spent a year studying in Switzerland. She published four papers on zoological subjects before she married Dr. Morgan in 1904. She then left scientific work until her four children began to grow up. After returning

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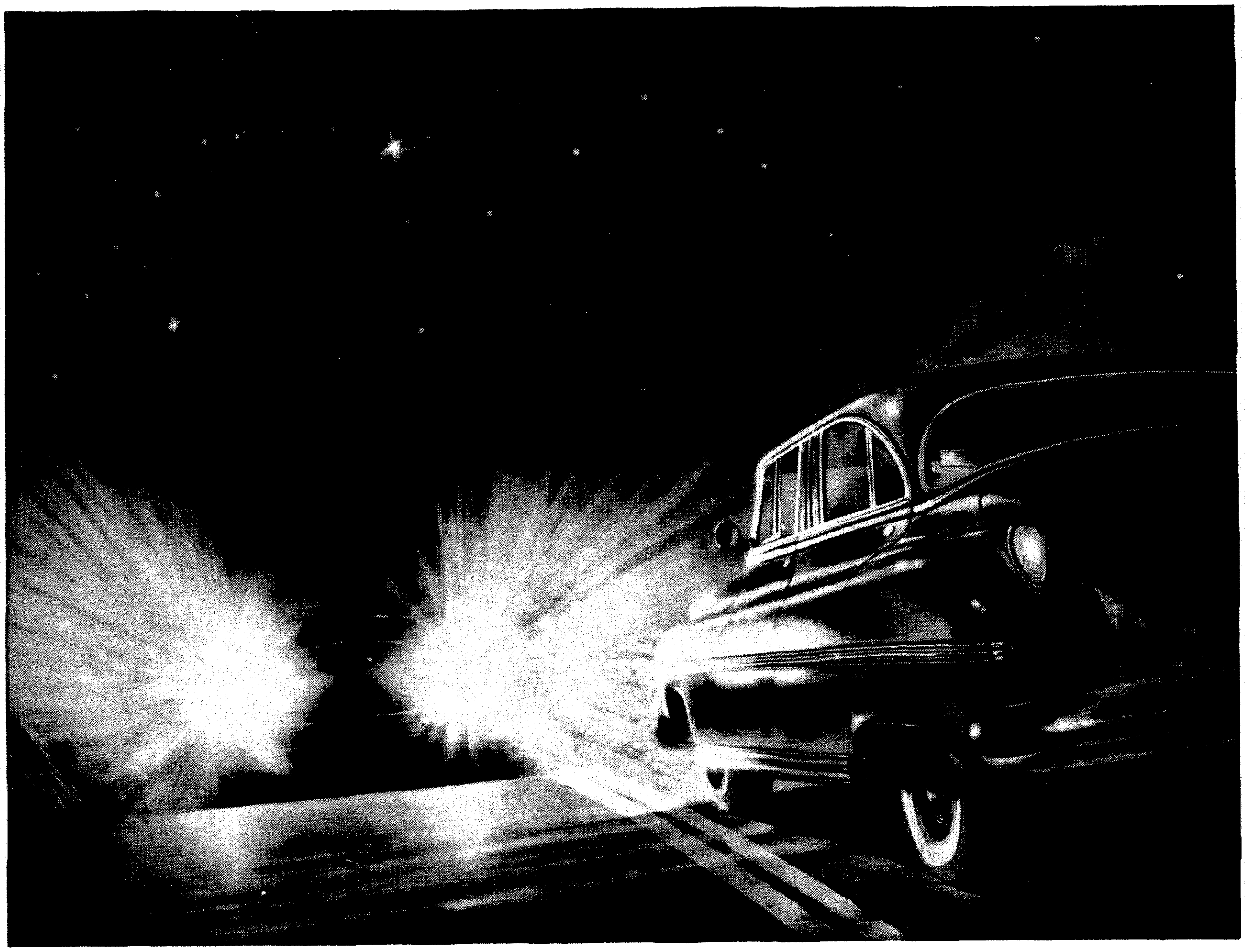


to the laboratory in about 1920 she published seven scientific papers and continued to make important contributions to the genetics of Drosophila, a field in which her husband was eminent.

Mrs. Morgan lived at 1149 San Pasqual Street, Pasadena. She is survived by four children, Howard K. Morgan, Mrs. Edith Whitaker, Mrs. Lilian Sherp and Mrs. Isabel Mountain; six grandchildren; two nieces; and a sister-in-law.

Sea-Water Research

PRESIDENT L. A. DUBRIDGE has been named as one of nine advisers to aid the Department of the Interior in a research program designed to discover an economical method of converting sea water into fresh water.

This program calls for government-industry cooperation, and the actual research will be handled by private organizations on a contract basis. The appointment of the nine-man advisory committee is a preliminary step in getting work started on a five-year $2,000,000 job.

Other members of the advisory committee include Robert G. Sproul, president of the University of California; J. J. Cronin, vice-president of General Motors Corp.; Louis Koenig, director of research at the Southwest Research Institute in San Antonio, Texas; Henry J. Schmitt, editor and publisher of the Aberdeen (S. D.) *American-News*; George D. Humphrey, president of the University of Wyoming; Sheppard P. Powell, Baltimore consulting engineer; Frederick L. Hovde, president of Purdue University, and James D. Killian Jr., president of Massachusetts Institute of Technology.

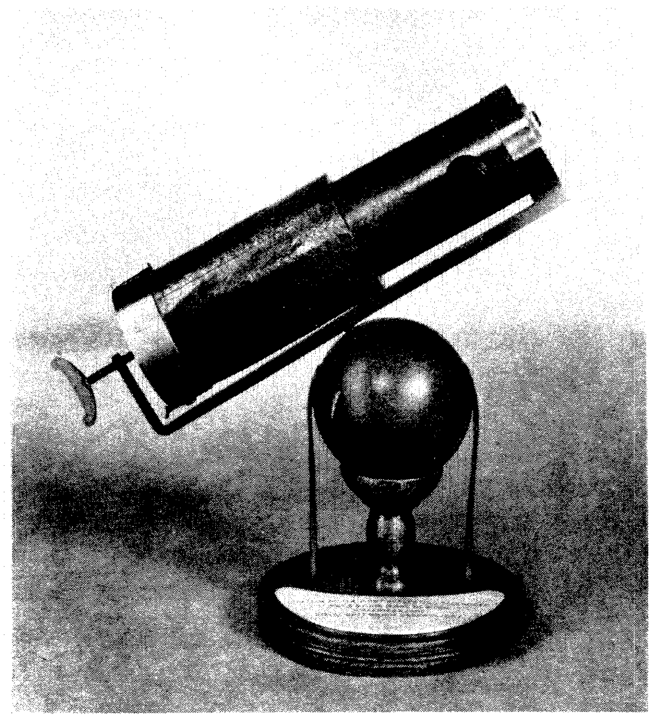
Newton Telescope

A FULL-SIZE REPLICA of the original Newton reflecting telescope, earliest ancestor of the 200-inch Palomar telescope, was presented to the Mount Wilson and Palomar Observatories last month by the Royal Greenwich Observatory in England.

The 10-inch high model is an exact copy of a telescope Sir Isaac Newton, famed mathematician and physicist, presented to the Royal Society in London in March, 1672. The replica is built of wood, cardboard, and metal, as was the original.

Newton built his first telescope when he was 26 years old. He replaced the lenses used in previous refracting telescopes with a concave mirror to bring light to a focus. This eliminated the chromatic aberration or blurring caused by different wavelengths of light arriving at slightly different focuses when lenses were used.

Newton's original reflecting telescope had a 6 1/3 inch focal length, a magnifying power of 38 diameters and a mirror slightly more than two inches in diameter. This mirror was too small to compete successfully with the existing refracting-type instruments. The first reflecting telescope to be used for serious astronomical work was built by John Hadley in 1722 and had a mirror about six inches in diameter. This compared favorably in both magnification and resolving power with the largest refracting telescopes then in existence.



Replica of Newton telescope presented to Observatories

Larger and larger reflecting instruments were built through the years, culminating in size and light-gathering power in the 100-inch Hooker telescope on Mount Wilson and the 200-inch Hale, now in operation on Palomar Mountain.

Newton's pioneering telescope is housed in the Royal Society in London. Sir Harold Spencer Jones, British Astronomer Royal, arranged for presentation of the replica to the Observatories after a visit here last summer. The instrument will eventually be exhibited in the museum of Palomar Observatory.

Tau Beta Pi

SEVENTEEN STUDENTS were initiated into the Caltech chapter of Tau Beta Pi, national honorary engineering scholastic fraternity, on December 4.

The Caltech chapter selects its members from students in the upper one-fifth of the senior class and the upper one-eighth of the junior class who also have excelled in extracurricular activities.

The new members are: From Los Angeles—Gordon D. Seele, Walter H. Thorson, Robert W. Stanton, Morris A. Robkin, David F. Stevens, Rolf W. Weglein, George Johnston and William Autrey; George H. Moore, Pasadena; Charles E. Benjamin, Evanston, Ill.; Edward H. Daw, Temple City; Donald P. Snowden, Sherman Oaks; Kenneth R. King, Phoenix, Ariz.; Robert L. Easton, Long Beach; Bruce L. Scott, Van Nuys; David Tilles, Berkeley; and James Crosby, Manila, Philippines.

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Ever wonder what you'll be like when the class of '53 holds its 10th reunion? If you started to work for one of the Bell System telephone companies after graduation, we can give you a pretty good idea.

POSITION IN THE WORLD: On the way up! A Development Engineer with the Bell Laboratories. Perhaps exploring the application of fundamental new electronic inventions to telephone communications. A Transmission Engineer, helping to provide the telephone needs of an entire state. A Supervisor in the Traffic Department, responsible for the speed and quality of local and long distance service in several cities and for the personnel relations of a large number of employees. In the telephone company, jobs such as these are held by relatively young men and women.

FUTURE: Unlimited! The Bell System continually progresses and expands and its personnel grows with it. In the past 25 years, the number of telephones has almost tripled. In the past 5 years, telephone companies have introduced such things as network television transmission, radiotelephone service and dialing of Long Distance calls. And the best is yet to come.

FRAME OF MIND: Confident and proud! You'll be satisfied because you have a rewarding job . . . not only in pay and security . . . but in service. You'll be proud of your share in helping provide and develop a telephone service vital to the country's social and economic life.

Like the picture? For further information see your Placement Officer. He will be glad to give you details regarding the opportunities for employment in the Bell System.

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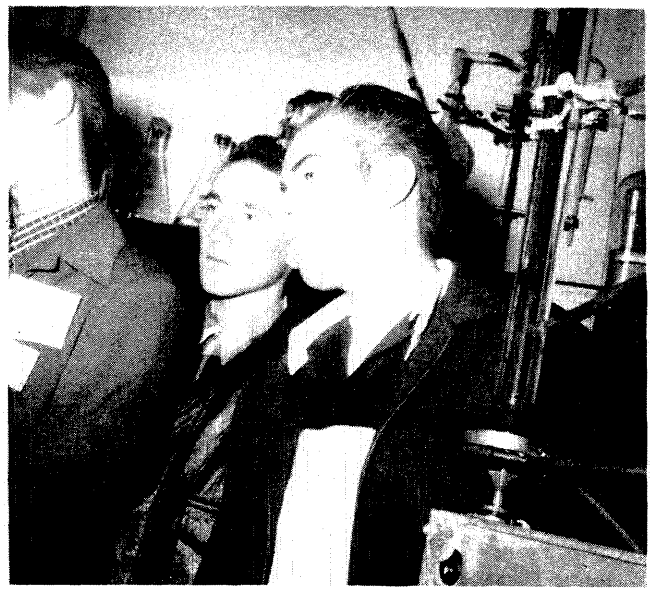
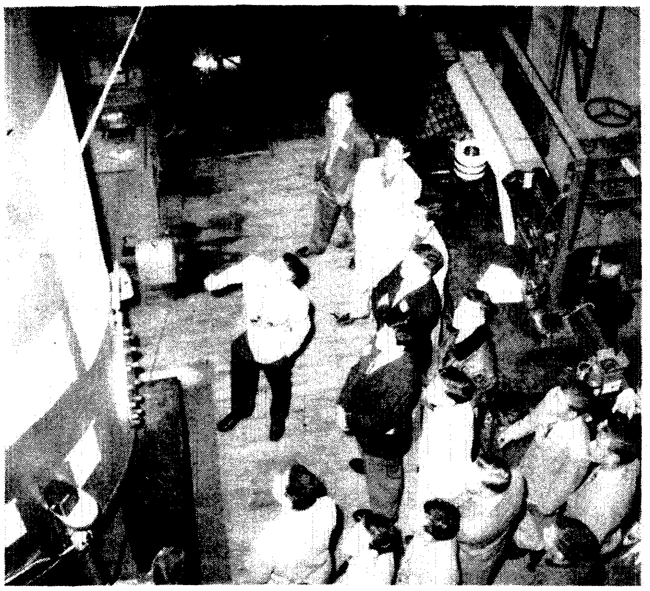


Science is wonderful

STUDENTS' DAY 1952



Van de Graaf Generator

Hydrodynamics Laboratory

GOSH, ISN'T SCIENCE wonderful! These words sum up the reactions of some eight hundred high school and junior college students to Caltech's third annual Students' Day, held on December 6. The visitors, all from schools in southern California, were given a day-long introduction to activities at the Institute in the form of demonstrations, lectures, and just plain bull-sessions.

Caltech's guests, who were all recommended by their school science teachers as being interested in science and engineering, arrived early in the morning and started on a tour which lasted until lunch time. Divided into groups of twenty, they were herded by harried undergraduate guides through a series of exhibits demonstrating technical facilities and research methods at Caltech.

Every academic department at the Institute was represented in Students' Day with at least one exhibit or demonstration. The Humanities Division produced a demonstration debate: Caltech versus UCLA.

Men and machines

In general the exhibits were viewed with interest and wonder, although a few skeptics appeared among the visitors. In particular, one erudite student watched with interest a short demonstration of the electric analog computer, and then found the courage to tell the demonstrator that he thought the machine was getting the wrong answers.

As usual, the High Voltage Laboratory proved of great interest to the sightseers. Most of them enjoyed the spectacular exhibit, although more than one student turned a little green after seeing a man-made lightning bolt leap from a rail a few feet away.

Another popular exhibit was the giant magnet in the

CONTINUED ON PAGE 30

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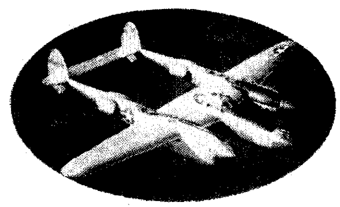

The P-38 Lightning – first 400 mile per hour fighter-interceptor, the "fork-tailed Devil" that helped win World War II.

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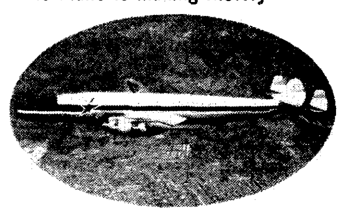

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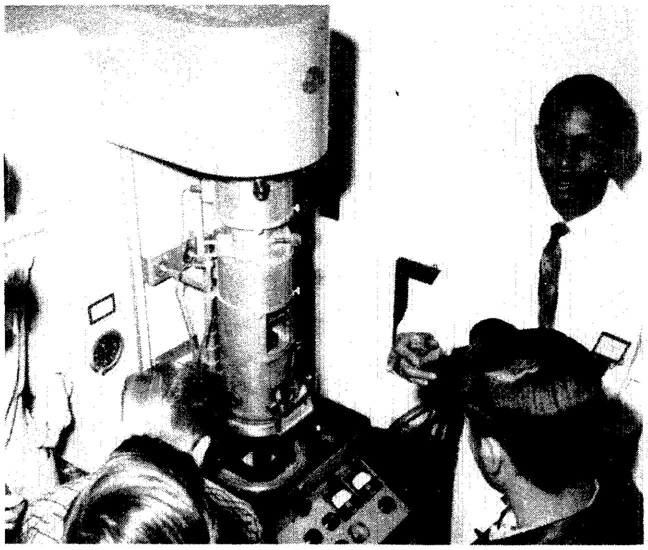
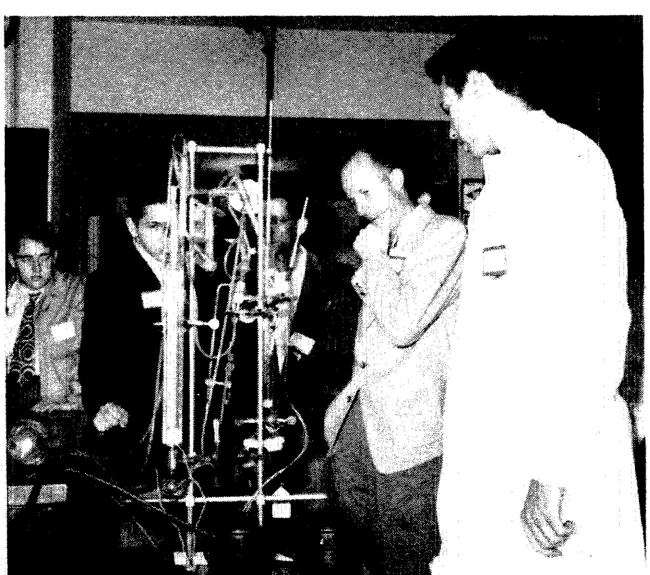


Electron microscope

Molecular structure



Organic chemistry

Physics Department. Viewers were fascinated by its powerful attraction for iron objects, but a few unwary onlookers walked too far into the magnetic field and were seized and held fast by the magnet, which attracted the keys in their pockets.

Most of the demonstrations were planned and given by undergraduates. There were many demonstrators who had learned their speeches especially for the occasion, and more than one of these was completely stumped by an intelligent question from his audience.

Most important exhibit of all

Having been amazed by the computer, awed by the synchrotron, and stunned by the high voltage demonstration, Caltech's guests proceeded to the most important exhibit of all, the student body. A leisurely box lunch in the student houses gave them an opportunity to get acquainted with their undergraduate hosts and to learn something about student life at Caltech. In casual conversation with student house members, most of them received a good impression of what living at Tech is like.

On the lighter side, many an apprehensive visitor became even more apprehensive when he was jokingly told that most Caltech students average eight hours of studying per night. The know-it-all attitude was much in evidence among the Freshmen, many of whom were prone to take their bewildered guests aside and give them paternal advice.

Speeches on the student house lawn were the next step in introducing the visitors to Caltech. ASCIT president John Gee and Dr. Linus Pauling of the Chemistry Division addressed the group. Later in the afternoon several scientific lectures were offered as the final event in the day's program. Talks were given on subjects ranging from aeronautics to liquid air, but many preferred instead to remain in the student houses and get better acquainted with the undergraduates.

A student's Students' Day?

The general attitude of the Caltech undergraduates toward Students' Day was summed up by the Freshman who said, "I wish they would do this for *us*." For many, it was the first opportunity to see much of Caltech's advanced equipment, and most of those who guided students learned almost as much as their charges.

Students' Day fulfills a great need at Caltech—the need to interest high school students in the possibility of becoming undergraduates at the Institute. It is unfortunate that those who come to Caltech on Students' Day cannot learn as much about student life as they do about facilities for study and research. This side of life at the Institute is the hardest to present to prospective undergraduates, but it is perhaps the most important.

—*Gordon Reiter '56*

RADIO ASTRONOMY

The 200-inch Palomar telescope and the 100-inch telescope on Mount Wilson collaborate with the radio telescope to investigate "radio stars."

THREE SOURCES of "radio noise" in the cosmos have been identified. after months of study. by the 200-inch Hale Telescope at Palomar and the 100-inch Hooker Telescope at Mt. Wilson. working in collaboration with one of the world's newest tools of astronomical research, the radio telescope.

Announcement of the discoveries was made last month by the Carnegie Institution of Washington and the California Institute of Technology. which jointly operate the Mount Wilson and Palomar Observatories.

Two of the sources identified appear to be turbulent gas clouds in the Milky Way. and the third the scene of a collision on a scale so gargantuan that it could occur only beyond the borders of our own galaxy and out in space. The identifications were made by Drs. Walter Baade and Rudolph L. Minkowski, staff members of the Observatories. working in close international co-operation with the active radio research centers in England and Australia.

The astronomers have identified the two outstanding radio sources so far discovered in the heavens—Cassiopeia A and Cygnus A—and a fainter one. Puppis A. (Radio sources are named for the constellation in which they appear. with the letter indicating the relative intensity of the signal emitted. Cassiopeia A. for instance. is the strongest source in that constellation.)

Two of the three newly identified objects—Cassiopeia A and Puppis A—are in our galaxy: Cygnus A is definitely outside it.

Cassiopeia A coincides with the center of a remarkable emission nebula, or galactic gas cloud. This is not just a quiet cloud suspended motionless in space. as are most of the galactic nebulae. It contains many filaments having highly random motions. like a crowd milling about. but at speeds of about 31 miles (50 kilometers) per second. and the filaments themselves apparently are in a high state of internal turmoil.

Spectrographic evidence secured by Dr. Minkowski indicates that the velocities of atoms within one filament vary over a range of roughly 1.800 miles per second. There is no evidence. however. to show that the nebulosity as a whole is blowing up. Hence. he says. the pattern of this peculiar nebula is almost the opposite of a supernova. or exploding star. in that the nebula formed by a supernova expands rapidly while the random motions within that nebula are minor.

A sizeable discovery

The optical diameter of the emission nebula coinciding with Cassiopeia A is roughly 5.4 minutes of arc. While this is about one-sixth of the moon's diameter. the Cassiopeia A nebula is at an enormously greater. though undetermined. distance from us than the moon. and consequently our entire solar system would merely be a pinpoint in it. The optical figure agrees closely with subsequent radio measurements at the Cavendish Laboratory and the University of Manchester. England.

At the position given for Puppis A. a relatively weak radio source. Dr. Minkowski has found another mass of peculiar filaments in an emission nebula. The condi-

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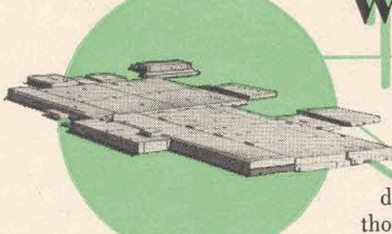

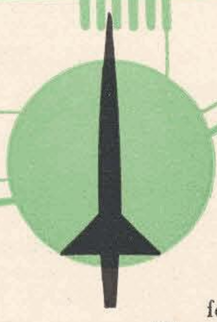

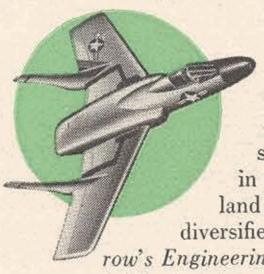

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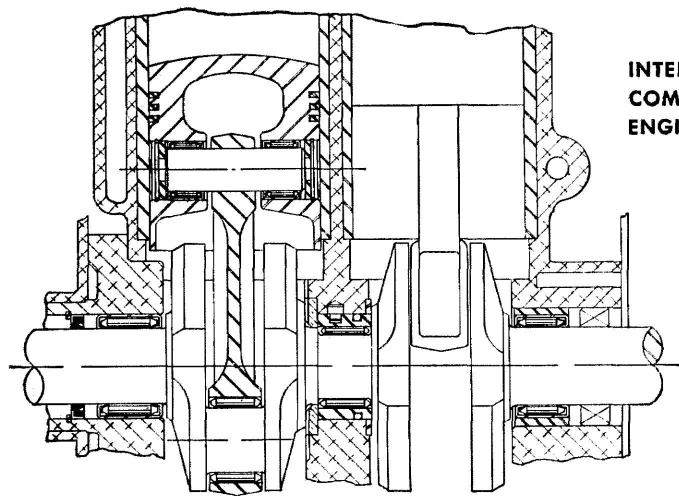

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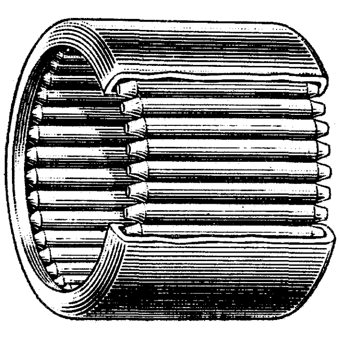
These advantages, plus its high radial capacity, have made the Torrington Needle Bearing particularly attractive to the designers of aircraft, portable power tools, small gasoline engines and many other products where weight and space are important factors.

In future advertisements of this series, other features of Torrington Needle Bearings will be discussed. The new Needle Bearing catalog will be sent on request.



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tions existing in these filaments are very similar to those in the Cassiopeia source but on a much smaller scale.

Cygnus A is located about 100 million light years, or 600 million million million miles away. This source coincides with an extragalactic nebula (a large stellar system like our Milky Way, but outside it) which is the brightest member of a great cluster of nebulae.

The structure of this spiral object, says Dr. Baade, appears to make sense only if he assumes that he is dealing with two extragalactic nebulae in actual collision. The radio emitter at the scene of this mammoth collision has a power of about 400,000,000,000,000,000,000,000,000,000,000 kilowatts. This is trillions of quadrillions of times more powerful than all the radio stations on earth put together.

Spectrographic findings

If red shifts in the spectrum of this source represent velocities of recession, as many astronomers believe they do, the source is moving away from us at more than 10,000 miles per second.

Spectra obtained by Dr. Minkowski at both the 100- and 200-inch telescopes suggest that something highly unusual is going on at the source of Cygnus A. They are emission spectra indicating high atomic excitation which would be characteristic of colliding gases.

Significant in the spectrum are lines traceable to neon V, a form of neon from whose atom four outer electrons have been stripped. This extreme stripping, or ionization, can occur only at very high energy atomic collisions, in which the atoms involved are traveling at speeds greater than 620 miles per second. The spectrographic findings thus support the assumption of a nebular collision.

A new field of astronomy

Optical telescopes and their auxiliary devices for study of astronomical bodies are sensitive to radiations from stars and other objects which are in the visible or near-visible range—that is, to light whose wave length is anywhere from about one- to four-100 thousandths of an inch.

With the advent of radar during the second world war, new short-wave radio receivers were developed, which are sensitive to electromagnetic radiations in the range from a few twenty-fifths of an inch to a few yards in wave length. Radio men call these the "microwave" and the "very high frequency" ranges. The general range of wave lengths in the ordinary broadcast beam is about a quarter of a mile.

Before the war a few investigators had picked up radio signals coming from the general region of the Milky Way. When the new ultrasensitive short-wave receivers were directed to the sky it was found that radio waves were reaching the earth from the sun and from out in space in all directions. This opened a whole new field of astronomy—the systematic investigation of radiations in the radio range coming from a large number of relatively small sources in the heavens. These sources were called "radio stars" for want of a better name, although scientists engaged in radio astronomy research did not maintain that they actually were stars.

Astronomers recognized the great importance of identifying a radio source with a known object in the sky. This would make it possible to correlate the data gained from radio observations with those derived by the ordinary optical methods. Thus we would increase our understanding of how the object in question behaves and what are its properties.

The ratio of reflector diameter to wave length in an optical telescope is so large that it permits the precise location of an object in the sky. But radio telescopes have a much smaller ratio because radio waves are so much longer than those of light. Hence the determination of the position of a radio source is necessarily less accurate.

Collaboration

The Mount Wilson and Palomar Observatories are equipped only for optical, and not for radio observations. But they early became interested in the optical correlations with radio astronomy, partly because one of the first objects identified as a radio source was the Crab Nebula. This remnant of a supernova—a giant stellar explosion which occurred in the year 1054—had been investigated extensively with the optical instruments on Mount Wilson just before the last war. A few other radio sources also were identified by radio astronomers during the past several years.

The two strongest sources, however, had not been identified and it was these that Drs. Baade and Minkowski set out to find. They arranged with Australian and English radio astronomers to supply them with the locations of these and other relatively accurately located sources.

Though the accuracy with which such determinations can be made is rather low, auxiliary methods can improve this accuracy for a few exceptionally strong radio emitters. And about two years ago a radio group at Sydney, Australia, under Dr. E. G. Bowen, found that many of the strong radio sources are not stars at all, but rather, they are extended objects whose diameters are measurable.

This latter fact makes a positive identification possible—if it can be shown that the radio and optical diameters agree and that the position of the astronomical object coincides with that of the radio source within the error of measurement of that source.

By these two yardsticks, and with spectrographic evidence, Drs. Baade and Minkowski have now identified Cassiopeia A, Cygnus A, and Puppis A with objects in the heavens.

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ALUMNI NEWS

1953 Seminar

THE SIXTEENTH ANNUAL SEMINAR will be held on the Institute campus on Saturday, April 11. Though that seems like a long way off right now, plans are already under way for the occasion. Kenneth F. Russell '29 is the Director in Charge of the Seminar this year, and C. Vernon Newton '34 is Chairman of the Seminar Committee. Members of the committee are being selected now, and will probably be announced next month.

San Diego Dinner

ALUMNI IN THE San Diego area are planning a dinner meeting Friday, January 23 at 6:30 p.m. at the San Diego Club (1250 Sixth Avenue). President DuBridge will speak on "What's Going on at Caltech," and John E. Sherborne, President of the Alumni Association, will be on hand to report on alumni affairs.

John Pearson

JOHN M. PEARSON, Ph.D. '30, director of the Sun Oil Company's physical research and development laboratory in Newton, Pa., died on November 16 at his home in Swarthmore of coronary occlusion. He was 48 years old.

A graduate of the University of Chicago, and a former instructor at Tech, Dr. Pearson had been associated with Sun Oil at intervals since 1929, when he joined the firm's Dallas plant.

He held 15 patents for electronic measuring instruments, and was an authority on corrosion engineering. In 1946 he received the Frank Newman Stellar award of the National Association of Corrosion Engineers.

Detroit Alumni

DETROIT-AREA ALUMNI met for the first time on October 17 at a dinner held at the Rackham Memorial Building in Detroit. Seventeen, including wives, attended the affair, which featured a discussion of politics by Mr. Homer Martin, a local businessman who has had a varied career as minister, labor organizer, UAW-CIO president, and Republican Congressional candidate.

The meeting was so successful that it was decided to have another social gathering in the spring—and to hold off any formal organization of the group until a more complete picture of alumni interest could be obtained at that time.

Albert Chapman '25 is to be thanked for conceiving and organizing this much enjoyed get-together.

—Herbert C. Sumner, M.S. '40

PERSONALS

1918

A. E. Davidson, Ex., who has been with the Bureau of Reclamation since 1933, is now supervisor in the substation section of the electrical branch, in the division of design and construction. For the past three years he has been coordinating the designs of substations and switchyards for electrical power generation and distribution in both the great Missouri River Basin and the Colorado-Big Thompson Projects. The Reclamation Bureau is proposing a $2,000,000,000,000 *(that's what the man says—Ed.)* six-year program, which, if authorized by Congress, will include the largest development in its history.

1923

F. Fred Roberts says they have just moved into their new home at 2640 E. 8th Street in Tucson, Arizona. He extends an invitation to any alumni passing through or visiting Tucson to drop in.

1926

Sterling B. Hendricks, Ph.D., received the Geological Society of America's Arthur L. Day Medal in November for his outstanding contribution in the application of chemistry and physics to geological problems. Sterling, who is with the Bureau of Plant Industry, USDA, received the medal at a joint meeting of the Geological Society of America, the Mineralogical Society of America, the Paleontological Society and the Society of Vertebrate Paleontology held in Boston November 13 to 15. In 1937, he received the Hillebrand prize of the Washington Section of the American Chemical Society.

1927

F. A. Nickell, M.S. '28, Ph.D. '31, a consulting geologist, has his headquarters in Pasadena, but doesn't seem to spend much time in these parts. He's just returned from a tour of Europe and the Middle East, where he inspected hydroelectric power and irrigation systems and projects.

The tour included a stretch in Jerusalem, where Frank is a consultant to the Israeli government on the development of irrigation and power projects that ultimately will transfer water from the Jordan River to the coastal plains and the Negev area. According to Frank, the economic security and well-being of this new nation depend to a large extent on the country's being able to achieve a measure of independence in food requirements.

Frank is also a member of the board of consultants for the Bhakra Dam being built by India on the Sutlej River in the Himalayan foothills about 250 miles north of New Delhi. After the holiday season he's due to take off on an extensive tour of power projects in Japan.

1929

Tom Evans, M.S. '30, is Dean of Engineering at Colorado Agricultural and Mechanical College. He and his family revisited southern California in November, when Tom attended a meeting of the National Reclamation Association in Long Beach. While there he got in on a party of members of the old Gnome Club, just preceding the Oxy game.

Charles Bosserman writes from Seattle that his work at Boeing as B-52 Project Staff Test Engineer keeps him pretty busy. The work is administrative and includes engineering flight and laboratory test programming, and scheduling and coordination of test parts with purchasing and manufacturing. He's been on this assign-

CONTINUED ON PAGE 42

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ment since November, 1949. The Bossermans' older son, Charles, is in the Army doing M. P. duty in Texas. A second son, Peter, is a sophomore at St. Martin's College in Olympia, Washington; and Anne, their daughter, is a junior at Holy Names Academy High School. This year the Bossermans have a foster daughter, Friedericke (Riki) Eitler, an exchange student from Vienna. She's a junior at their daughter's high school in Seattle.

Lawrence J. Grunder has just been appointed manager of the fuels and lubricants development department at the Richfield Oil Company in Los Angeles. This is a new department, superseding the company's products research and development department.

Homer Reed, M.S. '30, formerly chief engineer for Union Oil Company of California, was named president of Brea Chemicals, Inc., the new wholly owned subsidiary of Union Oil in Brea, Calif.

1933

Trent R. Dames, M.S. '34, of Dames & Moore, soil mechanics investigators, is now president of the L. A. section of the American Society of Civil Engineers. Dames & Moore have recently opened two new offices—in Salt Lake City, Utah; and in London, England.

1937

Martin H. Webster lectured before the Taxation Institute of the University of Southern California in November. This Institute attracts attorneys and accountants from all over the West who are interested in keeping abreast of current tax developments. Martin also recently received an appointment to the Federal Income Tax Committee of the American Bar Association—being the only southern California attorney to be thus anointed.

1938

Robert J. Barry, who has his own consulting management engineering firm in Los Angeles, has changed the firm name to Barry and Company with the addition of Theodore M. Barry, his brother, as a partner.

1940

Willis G. Worcester, M.S., returned in September to the University of Colorado as Associate Professor of Electrical Engineering, after a two-year leave of absence. This time was spent at Stanford University, where he received his Ph.D. last April, and then stayed on as a Research Associate in the Electronics Research Laboratory through the summer.

1942

Warren Gillette reports a new addition to his family, Owen Lewis, born on June 23. The Gillettes also have a new house in Boulder, Colorado, where Warren, an M.D., is in general practice.

P. W. Pichel and his wife have a seven-year-old daughter, Robin. Pichel is now a project engineer in the liquid engine division of the Aerojet Engineering Corp. in Azusa.

1946

John F. Lance, M.S., Ph.D. '49, is now in his third year in the Geology Department at the University of Arizona. He says he enjoyed visits with a good many Caltech geologists when his department hosted the annual meeting of the Cordilleran section of the Geological Society of America last April.

Norman A. Gottlieb is principal engineer in charge of the cost and progress branch in the engineering and control department of Peter Kiewit Sons' Co. in Portsmouth, Ohio. The company is the prime construction contractor building a $1,200,000,000 gaseous diffusion plant for the AEC. This plant, located about 20 miles north of Portsmouth, will take about four years to complete and will require some 34,000 construction workers. Norman expects to be located there until the project's finished.

1947

Floyd K. Becker, M.S., is now in the Navy doing research work, with headquarters in Washington, D. C.

1948

Frank J. Wolf writes that his Army tour has come to a close, and he hopes to be in California to celebrate the coming of the New Year. His time in the Army was spent in Pine Bluff Arsenal, Arkansas, a chemical corps arsenal where he was employed under the Scientific and Professional Personnel Program. (In Frank's opinion, this program seemed to be the Army's first major step in the direction of efficient utilization of available manpower.)

Frank says they hope to settle in the L. A. area if his coming job-hunt works out right. The "they" includes his wife, the former Noreen Vedder of Milwaukee, whom he met while working for Allis Chalmers in 1948, shortly after graduation.

George R. Scott is assistant manager of the special weapons flight test for Northrop Aircraft, Inc., where he is in charge of flight test activities at the Florida Test Base for NAI. The Scotts have a 2½-year-old daughter, and are expecting another

CONTINUED ON PAGE 44

addition to the family in May. George says the fishing's great in Florida, but otherwise the place can't touch God's Country.

Warren Marshall has been recalled by the Navy to forecast weather. This activity he finds somewhat remote from the job he has had since graduation with the Shell Oil Company. "Prior to leaving Shell," Warren writes, "I was working on methods of 'secondary recovery' of oil—or, more specifically, injecting water into the oil reservoirs to flush additional oil to the surface.

"After one month of refresher training in San Diego, I am now stationed at the Whidbey Island Naval Air Station, Oak Harbor, Washington, and am serving as the assistant aerological officer with the rank of Lt. (jg). There is no flying involved in my duties. The weather here is, as everyone knows, a little colder and wetter than southern California, and I look forward eagerly to the day when I can hang up the Navy uniform again and return to sunny California."

Warren expects his wife, Carol, and two children (son, 18 months, and daughter, 2 months) to join him shortly.

1949

Joseph R. Curray has a son, Michael Ross, born May 23, 1952. Joe has been a research geologist with the Carter Oil Company in Tulsa, Oklahoma, since July 1951.

Aaron N. Fletcher writes that his first child was born on November 7—a red-haired, blue-eyed girl named Clixie Louise. Aaron is a chemist with the Southern Pacific Railroad in Ogden, Utah.

1950

Galt Booth married Rosemary Dillenburg of Highland Park, Calif., and a graduate of Immaculate Heart College, on February 3, 1952. Galt is at present a project engineer working on servomechanism control systems for electromagnetic vibration exciters in Short Beach, Connecticut. He says the work is both interesting and challenging and allows him to keep up on new developments in both electrical and mechanical engineering. He also says they're enjoying the maple leaves of autumn and sailing on Long Island Sound in the summer, but the slush of winter and spring will eventually drive them back to California.

1951

Brad Hauser and his wife Ruth announce the birth of twin girls last May.

"We now have three girls," writes Ruth. ("Poor Brad," she adds.) The Hausers are living in Pearl City, Oahu, Territory of Hawaii (Box 233, to complete the address).

"We love it here," says Ruth. "Brad is working in the design division of the shipyard, as is *Dick Libbey* '51. Our best to all our friends at Tech. We sure miss the place."

1952

John E. Anderson, M.S., is working towards a Ph.D. in chemical engineering at Iowa State College. He has a wife and two children—a girl 27 months old and a boy 3 months old. Says he hasn't been made president of anything lately, and, in fact, has hardly moved out of his niche trying to get his thesis work done.

Richard Von Herzen is doing graduate work at the University of California at Berkeley.

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California Research Corp., 576 Standard Ave., Richmond

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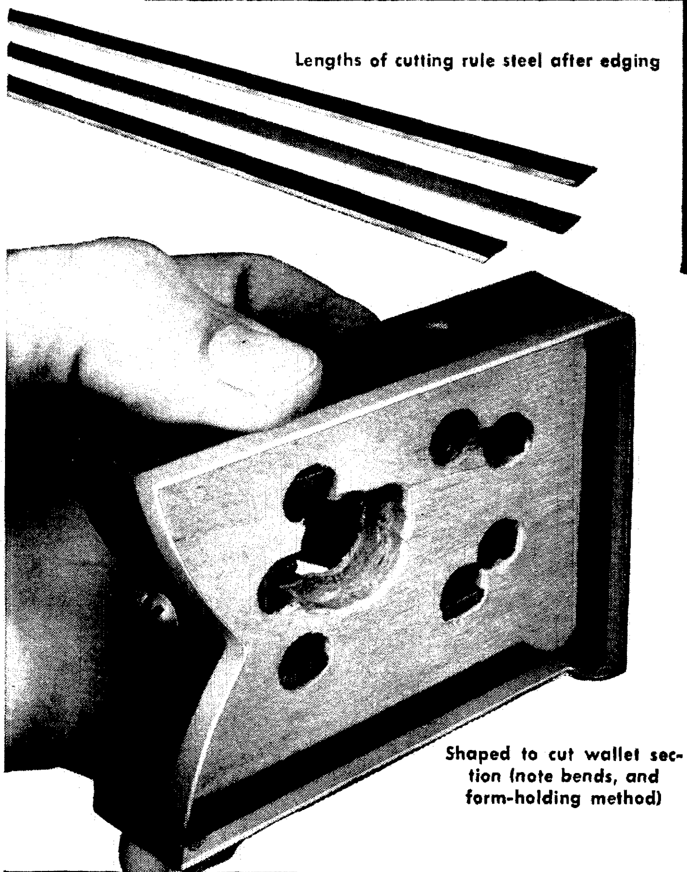
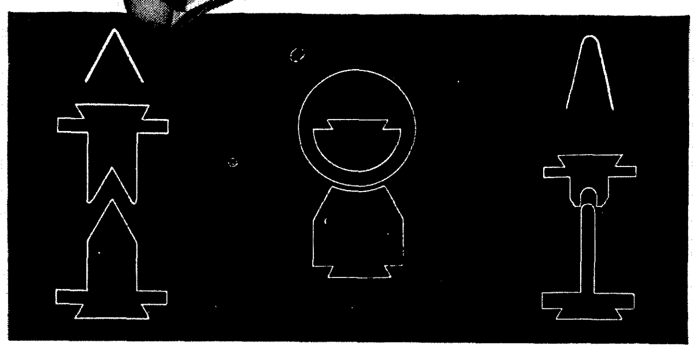
about scoring and cutting rule steel



Lengths of cutting rule steel after edging

Shaped to cut wallet section (note bends, and form-holding method)



Some examples of the many shapes of bends needed

Scoring and cutting rule steel is a cold-rolled specialty steel for use in preparing dies for cutting paper, leather, rubber and other materials.

It is a pre-tempered product manufactured by skilled workmen, using precision rolling and hardening equipment, to close limits for chemistry, grain size and hardness. This product must also be capable of meeting intricate bend requirements in the hardened and tempered condition.

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LOST ALUMNI

The Institute has no record of the present addresses of the men whose names appear in the list below. If you find your own name here—or that of someone you know—please drop a card, giving the current address, to the Alumni Office, C.I.T., 1201 E. Calif. St., Pasadena 4.

1906
Norton, Frank E.
1911
Lewis, Stanley M.
1912
Humphrey, Norman E.
1913
Hovey, Chester R.
1917
Mosher, Ezra D.
1918
Pease, Francis M.
1920
Hoenshell, Howard MS
Mosher, Frank R.
1921
Arnold, Jesse
1922
Bruce, Robert M.
Cox, Edwin P. MS
Fagin, Verne A. 'ex
1923
Little, Fred G.
Skinner, Richmond H.
1924
Lovering, Frank R.
McKaig, Archibald
Miller, Palmer
Young, David R. 'ex
1925
Dent, William U.
McProud, C. G.
Miller, Leo M.
Merrill, Robert A. 'ex
Smith, Dwight O.
1926
Barnes, Orrin H.
Foster, Alfred
Hastings, James W.
Huang, Jen Chieh
Jaffray, George R.
Keech, Douglas W.
Kingsbury, William S.
McCarter, Kenneth C.
Remington, Harry L.
Schueler, Alfred E.
Ward, Edward C.
Yang, Kai Jim
1927
Gilliland, Ted R.
Jackson, Wm. D. 'ex
Kaye, George R.
Langer, R. Meyer PhD
Peterson, Frank F.
1928
Chou, P'ei-Yuan PhD
Clark, Alexander
Martin, Francis C. MS
Morgan, Stanley C. MS
Preble, Bennett
Reinen, Otto F. Jr. 'ex
Shaffer, Carmun C.

1929
Briggs, Thos. Jr. MS
Elder, John D. PhD
Kuert, William F. 'ex
Lindhurst, Roland W.
Lynn, Laurence E.
Nagashi, Masahiro H.
Nelson, Julius (Espinosa)
Reed, Albert C.
Robinson, True W.
Sandberg, Edward Ms
Wiley, Charles A. 'ex
1930
Allison, Donald K.
Brandon, Hugo
Chao, Chung-Yao PhD
Ellis, Eugene
Fracker, Henry
Croch, Fred
Horton, Warren B. 'ex
Janssen, Philip
Kelley, William
Leppert, Melvin L.
Moyers, Frank N.
Murphy, Franklin MS
Russell, Lloyd W.
Sarno, Dante H. 'ex
Smith, Richard H. 'ex
Suzuki, Katsunoshin
White, Dudley
White, Fletcher H. 'ex
Wilkinson, Walter Jr.
Zah, Franklin Jr.
1931
Dickey, Walter L.
Ho, Tseng-Lo MS
Matison, Harry
Newby, Oscar M.
Stein, Myer S.
Voak, Alfred S.
Webb, Glenn M.
West, William T.
Woo, Sho-Chow PhD
Yoshoka, Carl K.
1932
Fraps, A. W. MS
Gregory, Jackson Jr.
Griswold, Edward A. 'ex
Huntley, Walter P.
Marshall, Donald E. MS
Schroder, L. D. MS
Watson, George G.
1933
Applegate, Lindsay MS
Ayers, John K.
Davis, Edwin N. MS
De Laubenfels, C. MS
De Milita, Joseph
Eisen, Nathan
Hsu, Chuen Chang MS
Kitusda, Kaname MS
Koch, Albert A. MS
Larsen, William A. MS
Lockhart, E. Ray

Lyons, Ernest Jr. MS
Magden, John L. MS
Michal, Edwin B.
Murdock, Keith MS
Newmeyer, Wm. L. Jr.
Pauly, William C.
Rice, Winston H.
Schlechter, Arthur MS
Shappell, Maple D. PhD
Skaredoff, Nikolas N.
Smith, Warren H.
1934
Carrick, Thomas H. 'ex
Chawner, William D. MS
Cook, David E. MS
Core, Edwin J.
Judson, Jack
Liu, Yun Pu PhD
Lutes, David W.
Marmont, George H.
Newcombe, Dennis A.
Nivens, Francis A. 'ex
Paxson, Edwin W.
Radford, James C.
Read, John PhD
Rassieur, W. T. MS
Stevenson, Arthur L.
Willard, Kenneth A.
1935
Antz, Hans M. MS
Becker, Leon
Ehrenberg, Gustave
Frazee, John L. 'ex
Gelzer, John R.
Gross, Siegfried MS
Harney, Patrick MS
Jackson, Oscar MS
King, Fred C. Jr.
Malina, Frank J. MS
McCoy, Howard M. MS
McNeal, Donald MS
Medlin, William PhD
Mills, Roscoe H. PhD
Obatake, Tanemi
Parr, Warren S. MS
Rivas, Dagoberto
Scott, Claude T.
Wilson, Harry D. 'ex
1936
Bassett, Harold H. MS
Borys, Edmund MS
Breen, John M. 'ex
Brink, Frank MS
Chu, Djen-Yuen MS
Creal, Albert
Fleming, Morton Jr. MS
Hartlein, Robert L.
Kelch, Maxwell MS
Kurihara, Hisayuki
Lawrence, Franklin 'ex
Lovett, Benjamin MS
McKillip, John MS
Ohashi, George Y.
Onaka, Takeji MS
Paller, Jack

Scheer, Bradley T.
Stern, Benjamin MS
Stern, Benjamin MS
Watt, Chauncey W.
Weber, Bruce T.
1937
Bennett, Foster MS
Butterworth, Wesley T.
Buxton, Alfred C. MS
Cheng, Ju-Yung MS
Church, Harry, Jr. MS
deGrummond, Lyle 'ex
Dusel, Alvin K. 'ex
Easton, Anthony MS
Geyecker, Vernon MS
Hsu, Tsi Fan MS
Jones, Robert C.
Maginnis, Jack MS
Mason, Jack 'ex
Miller, Shirley MS
Moore, Charles K. MS
Munier, Alfred E. MS
Murphy, Joseph N. MS
Nojima, Noble
Odell, Raymond MS
Park, Noel R. MS
Parry, H. Dean
Penn, William L. Jr.
Quinn, Eugene H. MS
Rechif, Frank A.
Rinehart, John S. MS
Schombel, Leonard F.
Servet, Abdurahim MS
Shaw, Thomas N.
Shuler, Ellis W. MS
Tsubota, George Y. MS
1938
Cowie, Roger H.
Davidson, Robert C.
Elliott, Bruce C.
Gershzohn, Morris MS
Goodman, Hyman MS
Hughey, Albert H. MS
Jetter, Ulrich MS
Kanemitsu, Sunao MS
Kazan, Benjamin
Lowe, Frank C.
McLeish, Charles MS
Moorman, Thomas MS
Ofsthun, Sidney A. MS
Okun, Daniel A. MS
Scoles, Albert B. MS
Stone, Wm. S. MS
Tilker, Paul O.
Tsao, Chi-Cheng MS
Wang, Tsun-Kuei MS
Wang, Hsih-Heng MS
Watson, James W.
1939
Asakawa, George
Burns, Martin C. MS
Carter, Robert T.
Coates, Leonidas D. MS
DeLong, James H. MS

Griffiths, John R.
Hall, Marcus A.
Hendry, Noel W. MS
Hsueh, Chao-Wang MS
Jones, Winthrop G. MS
Liang, Carr C. MS
Morikawa, George K.
Mouat, Thomas Jr. MS
Neal, Wilson H. MS
Poon, Yuk Pui
Rainwater, James
Robertson, Francis A.
Shields, Alex M. 'ex
Sinclair, George W.
Streckewald, Paul MS
Tatom, John F. MS
1940
Akman, Mustafa S. MS
Anderson O'Dean MS
Batu, Buhtar MS
Brettell, Geo. Jr. MS
Cabell, John B. MS
Gentner, Wm. E. MS
Green, William J. MS
Guerin, Jack T. MS
Helfer, Robert PhD
Hofeller, Gilbert W.
Horne, Riley Jr. MS
Howell, William MS
Hulett, Richard B.
Lewis, William MS
Pai, Shih-I PhD
Paul, Ralph G.
Stowell, Ellery C. Jr.
Tao, Shih Chen MS
Wang, Tsung-Su MS
Wild, John M.
1941
Baumgarten, W. PhD
Bruce, Sydney C. MS
Buchzik, Charles M.
Carlmark, Carl W. MS
Clark, Morris R.
Damberg, Carl F. Prof.
Dieter, Darrell W. MS
Easley, Samuel J. MS
Farquhar, John P. MS
Feeley, John M.
Fellers, Walter E. MS
Goode, John E. Jr. MS
Green, Jerome
Hamway, Daniel S. MS
Hayes, Wallace D.
Hight, Charles T.
Ikeda, Carol K.
Lakos, Eugene A.
Lewis, Lloyd A. MS
Peters, Ralph
Richardson, John M.
Shelton, Edward E. MS
Truesdell, Clifford A.
Vartikian, Onick
White, John R.
Whitfield, Hervey MS
Yui, En-Ying MS

1942

Bebe, Mehmet F. Prof.
Callaway, William F.
Cunningham, Robert E.
Gayer, Martin R.
Go, Chong-Hu MS
Goldin, Robert MS
Grossberg, Allan L.
Levin, Daniel MS
MacKenzie, Robert E.
Martinez, Victor MS
Muratzade, Enver Prof.
Novitski, Edward PhD
O'Gorman, John M. MS
Sternberg, Joseph
Tovell, Walter M. MS
Yuan, Shao-Wen

1943

Angel, Edgar P. MS
Barnett, Paul R. MS
Beard, Dick Jr. MS
Bethel, Horace L. MS
Bradstreet, Sam Jr. MS
Bridgland, Edgar P. MS
Brown, Maurice W. MS
Brownson, Jackson MS
Bryant, Eschol A. MS
Burlington, William MS
Bushell, Redgnald D. MS
Carlson, Arthur V. MS
Chenery, Hollis B. MS
Colvin, James H. MS
Crosthwait, T. L. MS
Crow, Loren W. MS
Daniels, Glenn E. MS
Delancey, Charles MS
Edelman, Leonard B. MS
Enyert, Richard L. MS
Essick, John M. MS
Flavell, Edgar W.
Gaffney, Thomas A. MS
Garrison, William MS
Gayle, De Witt R. MS
Gould, Jack E. MS
Hamilton, William MS
Harless, Raymond MS
Hewson, Lawrence MS
Hillyard, Roy L. MS
Hilsenrod, Arthur MS
Jay, Lee A. MS
Johns, Robert R.
Jurisich, Peter L. MS
King, Edward G. MS
Kane, Richard F. MS
Koch, Robert H. MS
Kong, Robert W. MS
Lee, Edwin S., Jr. MS
Leeds, William L. MS
Levine, Robert P.
Ling, Shih-Sang MS
Lobban, William A. MS
Lockhart, Wm. H. MS
Lundquist, Roland MS
MacMillan, Andrew MS
Mampell, Klaus PhD
Mataya, Jack L. MS
McClendon, Elmo MS
McNeil, Raymond F. MS
Mixsell, Joseph W. MS
Moore, Paul R. MS
Mowery, Irl H. Jr. MS
Neuschwander, Leo MS
Nesley, William L. MS
Newton, Everett C. MS
O'Brien, Robert E. MS
Patterson, Charles MS
Patterson, Ernest MS
Pearson, John E. MS
Rambo, Lewis
Rhoades, Walter Jr. MS
Rivers, Nairn E. MS
Roberts, Fred B. MS
Rupert, J. Jr. MS
Sack, Harold J. MS
Sanders, Leslie D. MS
Scholz, Dan R. MS
Shannon, Leslie A. MS
Simpson, Raymond MS
Smitherman, Thos. MS
Stewart, John T. MS
Sweeney, William MS
Taylor, Howard E. MS
Tindle, Albert Jr. MS
Vicente, Ernesto MS
Walsh, Joseph R. MS
Washburn, Courtland MS
Weis, William T. MS
Wood, Jesse A. MS
Yung, Chiang H. MS

1944

Ahuza, Victor B. MS
Alpan, Rasit H.
Baronowski, John J. MS
Bell, William E. MS
Birlik, Ertugrul MS
Burch, Joseph E. MS
Burke, William G. MS
Chambers, Lester S. MS
Chang, Howard H. C.
Cox, Charles S.
Dameson, Louis G.
Day, Stanley S.
Debevoise, John M. MS
Estrada, Neuk S. MS
Geisberg, Ralph L. MS
Goldsmith, Edward A.
Hall, Arthur S. MS
Harrison, Charles P. MS
Heinz, John A.
Huggins, John C.
Johnson, Wm. M. MS
Kern, Jack C. Jr. MS
Labanauskas, Paul MS
Leenerts, Lester O. MS
Maier, Mark P. MS
Parker, Theodore B. MS
Riddell, Richard B. MS
Shults, Mayo G. MS
Smith, Philip B.
Stanford, Harry W. MS
Stein, Roberto L. MS
Sullivan, Richard MS
Sunalp, Halit MS
Taylor, Garland S.
Titzler, Henry N. MS
Trimble, William M.
Writt, John J. MS
Yik, George

1945

Ari, Victor A. MS
Bunze, Harry F. MS
Carlson, Harry Wm. MS
Jenkins, Robert P.
Knox, Robert V.
Krause, Jack D.
Leydon, John K. MS
Lien, Wallace A. MS
Magneson, Norman J.
Nesbitt, Mason W. MS
Pooler, Louis G. MS
Roberts, Wayne A.
Romney, Carl F.
Scarbrough, Alfred D.
Taylor, Edward C., Jr.
Werme, John V.
Wiedow, Carl P. MS

1946

Anderson, John B. MS
Barber, John H. MS
Brolin, Elmore G.
Brinkhause, Harvey H.
Bromley, E. Jr. MS
Burdg, Charles E.
Burger, Glenn W. MS
Conradt, Robert H.
Dyson, Jerome P.
Ellis, Douglas S.
Esner, David R.
Hoffman, Charles C. MS
KeYuan, Chen MS
Kronmiller, George MS
Lambertus, Harold MS
Lamson-Scribner, Frank
Lanni, Frank PhD
Larsen, Harold C. MS
Lewis, Frederick W. MS
Lowery, Robert H. MS
MacDonald Norman J.
McCann, Hal D.
Miller, Jack N. MS
Monteath, E. B. MS
Myers, Terrell C. MS
Nurre, Vincent W.
O'Meara, Donald J. MS
Pentney, Robert W. MS
Russell, Charles R. MS
Simmons, George F.
Smith, Harvey F. MS
Tung, Yu-Sin MS
Uberoi, Mahinder S. MS
Weitzenfield, Dan MS
Williams, Ralph C. MS

1947

Anderson, Reed M.
Atencio, Adolfo J. MS
Baer, Oliver A. MS
Dagnall, Brian D. MS
Das, Subodh C. MS
Clock, Raymond M. MS
de Witte, Leendert MS
Garrison, Edward MS
Huang, Ea-Qua MS
Hutcheson, Paul T. MS
King, Emmett T. Prof.
King, William R., Jr.
Leo, Fiorello R. MS
Lesko, James S. MS
Lundy, William P.
Lyon, George W.
Manning, Ordway T.
McClellan, Thomas MS
Monoukian, John MS
Powell, Orville Prof.
Rosell, Fred Jr. MS
Shackford, Robert MS
Smith, Alexander PhD
Vadhanapanich, Charoen
Veale, Joseph E. MS
Wellman, Alonzo Jr. MS

1948

Bloom, Justin L.
Blue, Douglas K. MS
Chapman, Curtis Jr. MS
Crawford, William MS
Doyle, George J. MS
Fay, Alfred P.
Garber, Max
Hall, Edward N. MS
Jenista, Charles Jr. MS
Lambert, Peter C.
MacLean, Douglas J.
McCollan, Albert E. MS
Metzler, David E.
Mitchell, Edward E.
Morehouse, Gilbert MS
Oberman, Carl R.
Parkinson, Geoffrey MS
Reed, Arthur W. MS
Schocken, Victor PhD
Slusher, John T. MS
Stein, Paul G. MS
Steward, Malcolm MS
Stewart, Robert S. MS
Swain, John S.
Swank, Robert K. MS
Tomlin, Raymond MS
Walters, James Jr. MS
Willmer, David B. MS
Winniford, Robert MS

1949

Barker, Edwin Jr. MS
Bauman, John Jr. MS
Brady, Franklyn H. MS
Buff, Frank P. PhD
Clancy, Albert Jr. Engr.
Cooper, Harold D. MS
Craighead, Emery MS
Crate, James H. ID
Darrow, Robert A.
Geldart, Lloyd Engr.
Hrebec, George M.
Hughes, Richard F. MS
Jacomini, Omar J. MS
Kashiwabara, Naomi
Krasin, Fred E.
Lamb, William Engr.
Linderman, Harold J.
Lipow, Myron
Love, Everett E. MS
Love, John R.
MacKinnon, Neil Engr.
McElligott, R. Engr.
Merrell, Richard L. MS
Mirza, Rafat MS
Petty, Charles C. MS
Rosner, Arnold S. MS
Shull, James R. MS

1950

Alexander, Joseph MS
Bryan, Wm. C. Engr.
Burket, Stanley C. PhD
Calhoun, William D.
Conly, James C. PhD
Craig, Roy P. MS
Crossley, Harry Engr.
Curtis, Robert N.
Garrison, James Jr. MS
Glaser, Donald A. PhD
Goodwyn, James C. MS
Gross, Frederick A. MS
Holmes, Geoffrey B. MS
Holmes, James R. MS
Honda, Shigeru I.
Leinbach, Fred Jr. MS
Lemaire, Henry PhD
Lerman, Leonard PhD
Li, Chung H. MS
Mansfield, James M.
McDaniel, Edward MS
McLaughlin, Jack PhD
McMillan, Robert MS
Montemezzi, Marco A.
Morgan, William T. MS
Ottestad, Jack B.
Roberts, Morton S. MS
Soldate, Albert M. PhD
Stewart, Dale F.
Stolovy, Alexander MS
Vivian, James A. MS
Whitehill, Norris D.

1951

Karlsson, Thorbjorn MS
Lafdjian, Jacob P. MS
Ostrander, Max Engr.

1952

Kennon, Richard
Lunday, Adrian C. MS
Robbins, Howard PhD
Robieux, Jean MS

CALTECH CALENDAR

January 1953

ALUMNI ACTIVITIES

January 15	Dinner Meeting, Lakewood Country Club
February 7	Dinner Dance
March	Dinner Meeting, Santa Monica area
April 11	Annual Seminar
June 10	Annual Dinner Meeting
June	Annual Family Picnic

ATHLETIC SCHEDULE

VARSITY BASKETBALL

- Jan. 10, 9:00 p.m. Whittier at Caltech
- Jan. 16, 8:15 p.m. Pomona at Pomona
- Jan. 17, 8:15 p.m. LaVerne at LaVerne
- Jan. 20, 4:30 p.m. Cal Poly at Caltech
- Jan. 24, 8:15 p.m. Redlands at Redlands
- Jan. 31, 8:15 p.m. Occidental at Caltech

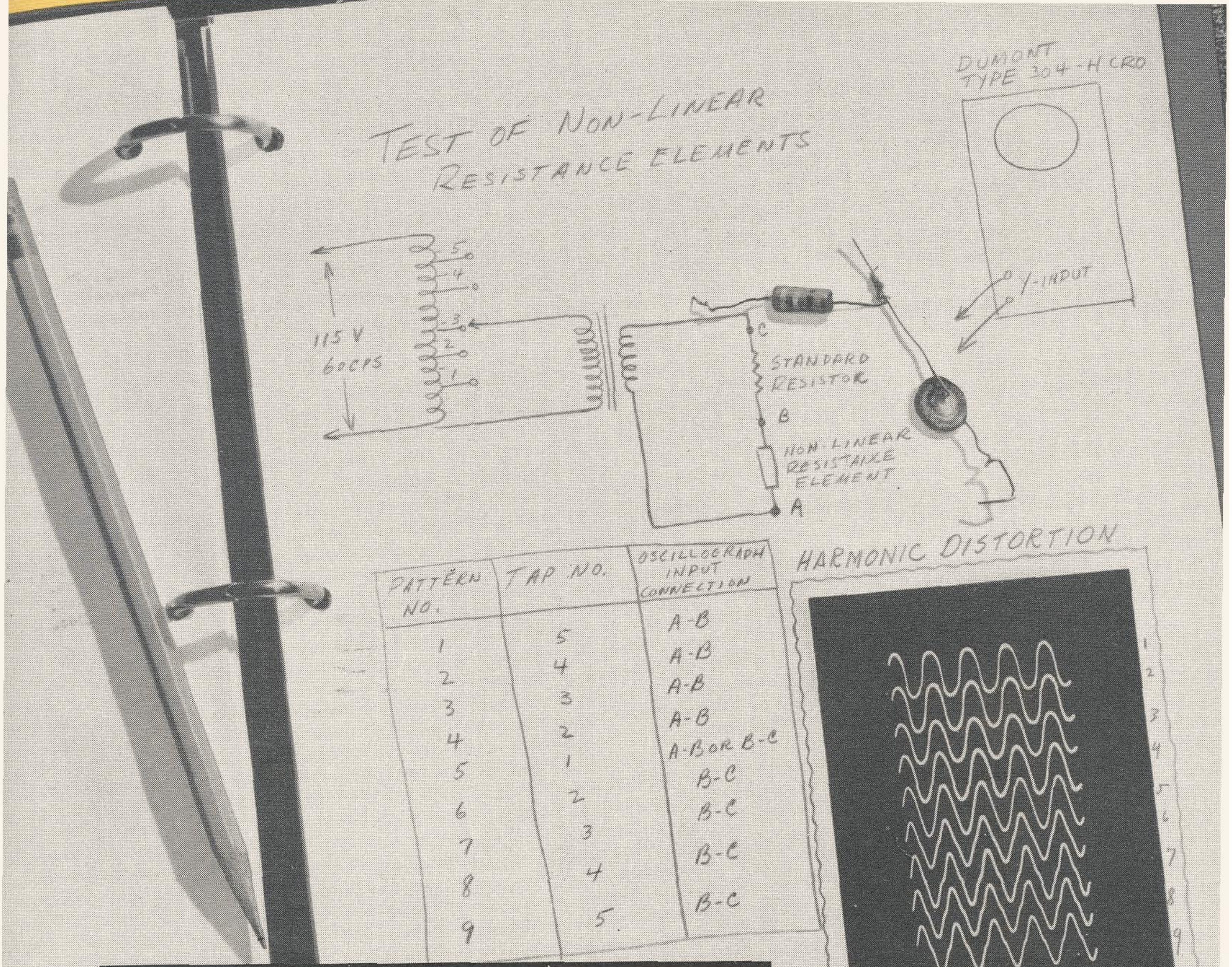
FROSH BASKETBALL

- Jan. 9, 9:00 p.m. Whittier at Oxy Gym
- Jan. 16, 6:45 p.m. Pomona at Pomona
- Jan. 17, 6:45 p.m. LaVerne JV at LaVerne
- Jan. 24, 6:45 p.m. Redlands at Redlands
- Jan. 31, 6:45 p.m. Occidental at Caltech

DEMONSTRATION LECTURES

Friday Evenings
7:30 p.m.—201 Bridge

- Jan 9 "The Age of the Earth," by Prof. Harrison Brown
- Jan. 16 "The Universities and and Industries of Italy" by Prof. F. C. Lindvall
- Jan. 23 "Gyroscopes" by Prof. Leverett Davis, Jr.
- Jan. 30 'High Voltage," by Prof. R. W. Sorensen (Demonstrations will be given in the High Potential Laboratory.)
- Feb. 6 "I. Theory of Lunar Crater Formation. II. A Motion Picture of the Planet Jupiter," by Prof. R. B. Leighton



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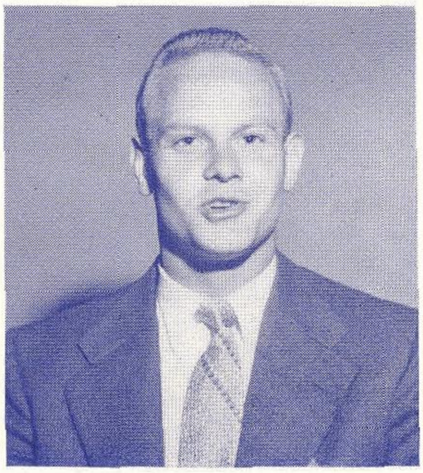
MY QUESTION TO THE G-E STUDENT INFORMATION PANEL:



"What qualities do I need for a successful career with a company like General Electric?"

... HARRY K. LEADER, Lafayette College, 1954

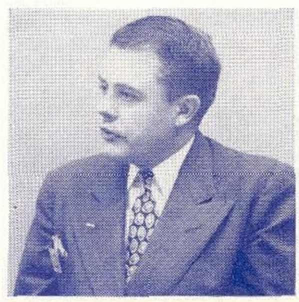
Two answers to this question, given at a student information meeting held in July, 1952, between G-E personnel and representative college students, are printed below. If you have a question you would like answered, or seek further information about General Electric, mail your request to College Editor, Dept. 221-6, General Electric Co., Schenectady, N. Y.

G. C. HOUSTON, *Manufacturing Services Division* . . . While this is a rather broad question, I am sure it is one of real importance to any young man starting out in industry and looking forward to a position of responsibility in any of our successful industrial enterprises.

The mere asking of this question indicates that the individual has a definite goal or objective. This is important since progress can be made only if we attempt to reach a well-defined objective—even though it may be modified to some extent in the light of later experience. In G.E. we are looking for young men who have not only determined their objective but who are ready to work for it—who accept responsibility and have ability to get things done—who work well with others—to be a part of the team.

This calls for other qualities essential to long range success. We look for the enthusiastic individual, one not easily discouraged, and who can inspire the confidence of his co-workers. We desire individuals who show imagination and good judgment—particularly the ability to look ahead and maintain perspective beyond the immediate situation. Finally, we cannot overlook the qualities of loyalty and dependability since these are important in steering the individual through periods of discouragement which occur in every career.

When you decide on your business affiliation, make sure you associate yourself with a company that is soundly managed, that has a good business future, and that is the kind of company you would like to be a part of for the long pull.



E. S. WILLIS, *Corporate Services Division* . . . A successful career with a company like General Electric is built on the same qualities that contribute to success in any endeavor. However, in G.E., there is additional opportunity to develop these qualities because of the wide variety of training sources and openings which are available.

Basic qualities needed for any successful career include an open mind, willingness to accept responsibility, persistence, adaptability, co-operativeness, and common sense intelligence. Others such as physical well-being, ability of expression, and sound inquisitiveness also go to make up a truly qualified individual.

Most important is the fact that General Electric offers a wealth of opportunity to develop special capabilities and talents. The broad selection of training courses, in any chosen field, gives you a chance to sharpen your basic training and abilities. By decentralizing operations into about 70 different businesses, there is opportunity to see—in comprehendable dimensions—the full operation of the business. It means, too, that senior managers and young employees are more closely associated—a real advantage for the young man on his way up.

Also, our business requires specialists as well as managers. Thus, there are equal chances for success for those who concentrate in particular fields such as research, design, accounting, and planning.

So set your cap for a goal. And capitalize on your native qualities, which fortunately are different with each of us.

You can put your confidence in—

GENERAL ELECTRIC