ENGINEERING | AND | SCIENCE

May 1964

Published at the California Institute of Technology

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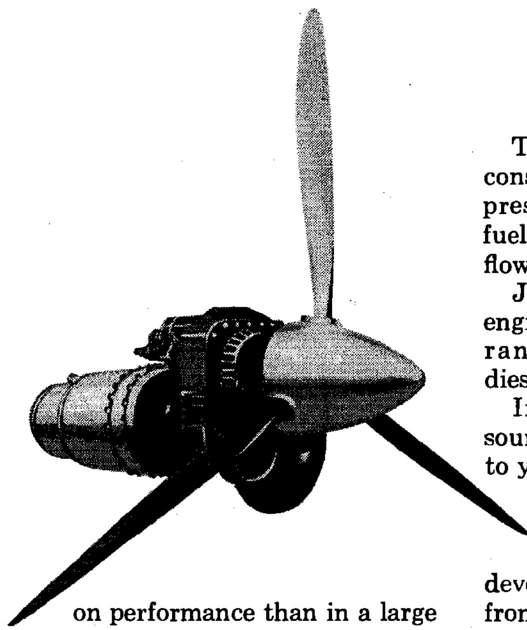

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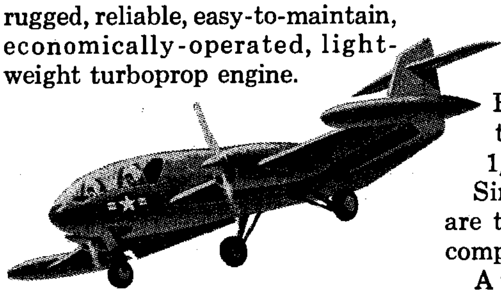

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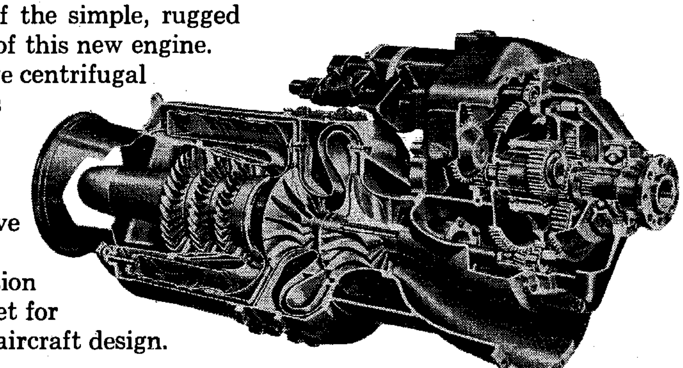

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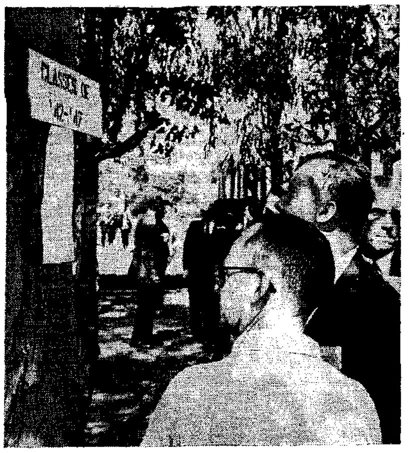
MAY 1964 VOLUME XXVII NUMBER 8



On Our Cover
Alumni take a coffee break at the 27th Annual Alumni Seminar held on the campus on May 2. Almost 1,500 alumni, wives, and guests attended the 1964 seminar, which featured 11 lectures, three exhibits, and an evening banquet. For more pictures and news of the seminar – page 16.

Alumni Survey
Alumni are featured on pages 7-11 of this issue as well, where the initial results of the 1963 alumni survey are discussed by John R. Weir, associate professor of psychology.

This is the first survey of Caltech alumni in 11 years – Dr. Weir having made his last survey in 1952. "Caltech's 1963 Alumni Survey," on page 7, is the first of a series of articles on the new survey. Some of the highlights in this first article concern the geographic origins of Caltech alumni, their education, major field of study, religious affiliations, age, and parents' educational background.

In *Engineering and Science* for June, Dr. Weir will give results on the political and cultural interests of Caltech graduates.

Further articles will deal with civic activities of alumni, achievements since college, occupational fields, income, and the present attitude of Caltech graduates toward Caltech and their education.

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Books

THE THEATRE OF DON JUAN
by Oscar Mandel

University of Nebraska Press..............*$10*

Reviewed by Harvey Eagleson, professor of English

Like the Oedipus, Electra-Orestes, and Faust legends, the Don Juan legend has been one of the great sources of inspiration for artists in every genre from literature and painting to music and ballet. In his new book Oscar Mandel, associate professor of English at Caltech, has done a great service for both the scholar and the general reader in bringing together the major theatrical works based on the legend, some of them hitherto not easily available. The book contains nine plays, two of them puppet plays and one the libretto for Mozart's *Don Giovanni*.

But the book is not just an anthology, a collection of pieces illustrating a certain theme. This is a book on the Don Juan legend and the pieces are integral parts of the general discussion. For that reason I found the book absorbing, as I would not have done if it had been merely a collection of plays about Don Juan – particularly, as Professor Mandel himself points out, since the plays on the whole are not very good ones, even the one by the great Molière. Mandel writes, "The fact must be faced: Don Juan as a type of man remains in the end more interesting than any of the plays, poems, or novels which gave him life."

But the legend itself is basically a good yarn and the various purposes to which it has been adapted during its life make interesting reading. Unlike the Oedipus and the Electra-Orestes legends whose beginnings are lost in time, we know by whom and when the Don Juan legend was invented. "The man who created Don Juan was a monk and dramatist of the first half of the seventeenth century, Gabriel Tellez, better known as Tirso de Molina, and considered today one of the four best playwrights of Spain's Golden Age. In 1630 a play entitled *El Burlador de Sevilla y convidado de piedra (The Jester of Seville and the Stone Guest)* appeared under his name in a collection of works by Lope de Vega 'and other authors' . . . No play of the Renaissance has so vast a progeny as this undated piece which its author, not even identified beyond all possibility of doubt, did not bother to include in his own collected works."

The myth created and established, Professor Mandel traces its various manifestations, its accretions of symbol or new significant meaning, down to our own day, using a collection of plays, as I have said before, as illustrative material interwoven in the test. "For the purpose of this collection, a Don Juan play is one which uses, adapts or alludes to the original legend . . . In eighteenth-century puppet plays Don Juan is not amorous; in nineteenth-century musical comedy he is an oaf; in the twentieth-century conceptions of Shaw and Frisch he distrusts and even dislikes women."

As Don Juan changed – he can scarcely be said to have developed – he represented first the "triumph of sensuality." Then, naturally, as he flouted some of the conventions of society, he easily became a symbol of revolt, politically, religiously. "Here Don Juan is an atheist; there a Christian. At one time he is a thinker; at another a fool . . . He can be a gentleman or a ruffian. And he may appear as hero, villain, or – often – as both . . . They are the attributes which give him his individual humanity while he pursues his symbolic career of pure sensuality."

Professor Mandel calls the present and third stage of Don Juan's evolution his Molecular stage "for ours might well be known as the Molecular age. The name points to the science which dominates our lives; to our habit of analyzing all things down to their indivisible minimum; to the dehumanization of life; to our sense of isolation and fragmentation; to the virtual abandonment of the idea of human progress; and to our small helplessness . . . The man in love is ripe for disappointment and failure. The scene darkens. Don Juan becomes modern . . . And here is by all odds the most important event in the dramatic life of Don Juan. *He ceases* to enjoy himself . . . what happened to Don Juan also happened in the fiber of our whole culture. The irrepressible child of the Renaissance, who seems to have enjoyed even the scene of his damnation . . . crumbles into a shabby and uneasy psychological case."

I hesitate to call this work a scholarly book, because the epithet is usually a polite euphemism for saying a book is filled with recondite information and is dull. This book is a scholarly work, but it is not dull. Scholars will find it on their own. What I wish to do is recommend it to to people who just like to read interesting books and haven't the remotest intention of ever writing an article or giving a lecture on the Don Juan legend.

MEMO | from the desk of **ARTHUR EHRLICH** Sales Manager

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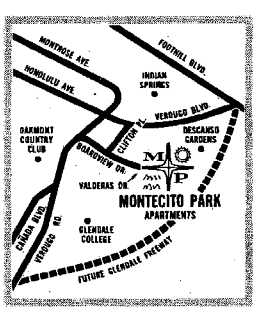

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ENGINEERING AND SCIENCE
May 1964, Volume XXVII, No. 8

CALTECH'S 1963 ALUMNI SURVEY

Initial results of the 1963 survey show some striking changes since the last survey of Caltech alumni in 1952. The first in a series of articles.

by John R. Weir

Caltech last studied its alumni by means of a questionnaire in 1952. In the 11 years that have elapsed since that survey was made, the total number of graduates has grown from approximately 6,000 to 9,000; the student body from about 1,000 to 1,300; the faculty from 343 to 515; Institute expenditures from $5,200,000 annually to $17,900,000; and Institute net assets from $50,000,000 to $124,000,000. These figures give some indication of the important changes that have taken place in the Institute since World War II.

As a consequence of these and other developments, our knowledge of Caltech alumni gained from the 1952 survey became obsolete. This led to the decision to conduct a new one. We expected the usual reaction to our lengthy lists of questions — and we got it. "Mail questionnaires are a pain in the neck!" was a fairly general comment by those completing their forms. Nevertheless, the information gained in the earlier survey was of such value to the Institute that it was decided to bring our information up to date even at the risk of imposing on the good nature of the alumni. We hope they will accept our thanks for the time and effort so many gave to help us learn more about our graduates. Perhaps this and the subsequent articles that will be published in *Engineering and Science* reporting the results of the survey will be of sufficient interest to repay them for their time and trouble.

In the 1952 survey, 67 percent of the 5,647 alumni for whom we had addresses returned completed questionnaires. Now, 11 years later, we have sent questionnaires to 8,051 alumni, and got a return of 61 percent. This lower response is somewhat puzzling in view of the fact that the 1952 questionnaire had to be returned with the alumnus's name attached to it (though it was later obliterated), while the 1963 form was completely anonymous.

In the latest survey we went to considerable labor and expense to maintain anonymity so the respondent would be encouraged to answer all questions fully. Each blank questionnaire was mailed with an Institute-addressed postcard containing the alumnus's name and address. Instructions were to mail this postcard separately, after the questionnaire had been completed and mailed. This card thus represented our only record of who had returned finished questionnaires and permitted us to send follow-up requests to those who had not responded. Since there was no identifying name on the questionnaire, the replies were as anonymous as possible on such a detailed questionnaire.

In the past we have often wished for more data on the relationships, if any, among grade-point average, extracurricular activities, and post-graduate achievement. We have attempted to gather these data in the present survey. Before the questionnaires were mailed out, the four-year grade-point average from the Registrar's records, and extracurricular activities from Alumni Office records were coded and entered on the back cover of his questionnaire for each Caltech BS graduate. In addition, all alumni were asked to recall as accurately as they could their undergraduate grade-point averages. From these figures we hope to determine the relationship between college grades and adult achievement, honors, income, and occupation.

The data in each of the 4,884 returned questionnaires were classified into 200 items and keypunched into four IBM cards; coding and punching requiring 1,493 man-hours. After a few dozen hours of computer programming, the punched card data were transcribed onto magnetic tape and fed into the IBM 7094 computer in the new Booth Computing Center, which produced 168,480 tabulations on 378 feet of paper – all in 16 minutes and 47 seconds. This represents only the most simple tabulations; the more complex ones are yet to come.

SURVEY RESULTS

Adequacy of the Sample

The first question to be answered in any study of this kind is whether the sample from which the conclusions are drawn is reasonably representative of the total population to which the conclusions will be applied. There are two important ways in which our sample of respondents can be compared with the total graduate population. These comparisons are by age and by first degree.

AGE OF ALUMNI

	% Survey Sample	*% All Graduates (estimated)*
Under 30	20	20
30-39	29	28
40-49	29	26
50-59	16	18
60 and over	6	8

The sampling bias of age is a very small one. The sample is a bit short in the older age ranges, undoubtedly due to death and a waning association with the environment of early years, but here the percentages are relatively small and should not have important biasing effects on the survey tabulations.

FIRST DEGREE

	Number	*% Survey Sample*	*Number*	*% All Graduates*
BS	3257	71	5259	59
MS	938	20	2578	29
Eng.	68	1	242	3
PhD	347	8	858	10

Such differences as appear in this comparison can undoubtedly be attributed to the tendency for higher degree-holders to think of themselves as alumni of the colleges from which they got their bachelors' degrees. Consequently, they would not be interested in participating in this survey. This would seem especially true for holders of the master's degree, who usually spent one, or at the most two years at the Institute. Again, we probably have a large response from the BS degree-holders because they spent four years at Caltech and are still interested in it.

These two biases pose no problems for the purposes of this survey. Since we want to draw conclusions about Caltech alumni who are most representative of our graduates, it is to our advantage to have data from as many undergraduates as possible. It is also to our advantage to have a smaller percentage of the very large number of MS-only holders among the alumni, so that they will not distort the results.

These two comparisons indicate that the sampling bias is small, and in a direction that permits us to draw valid and useful conclusions about the California Institute from an analysis of our survey sample.

Early Background

The new survey reveals some interesting and important trends in the size and location of the towns from which our alumni come. For example, in 1952, 39 percent of our graduates reported being raised in large cities; in 1963, this percentage has grown to 42. This is certainly not a large increase, and is probably a consequence of a general nationwide trend that has been going on for some time.

SIZE OF PLACE WHERE MOST OF PRECOLLEGE YEARS SPENT

	% in '63	*% in '52*
Farm	6	6
Small town	10	11
Small city	22	22
Medium city	20	22
Big city	15	14
Metropolis	27	25

Secondly, there is a shift in the part of the country in which our alumni grew up. In 1952, 56 percent reported they were raised in California; in 1963, this has dropped to 51 percent. At the same time, the proportion in '52 who said they were from the Midwest and the East totaled 20 percent, whereas in '63 this has grown to 26 percent.

Geographic Region Where Most of Precollege Years Spent

	% in '63	% in '52
California	51	56
West	11	11
Midwest	16	14
South	7	9
East	10	6
Foreign	5	4

Finally, those who report graduating from high schools in southern California dropped from 53 percent in 1952 to 43 percent in 1963. At the same time, the total percent of those graduating from high schools in the rest of the West, the Midwest and the East went from 37 percent in the 1952 survey to 47 percent in the 1963 survey.

Geographic Region of High School

	% in '63	% in '52
Southern California	43	53
Rest of West	22	17
Midwest	14	12
South	6	6
East	11	8
Foreign	4	4

A similar trend can be observed in the recent figures for the high school origins of Caltech freshmen. In recent years about 40 percent of our freshmen came from California high schools, 15 percent came from the rest of the West, and 45 percent came from east of the Rockies and foreign countries. It also seems likely that the relatively recent increase in the number of graduate students at the Institute will reinforce this trend, inasmuch as they have gone to even more widely scattered high schools than have the undergraduates.

This shift of our student body and alumni from local or regional sources toward being more representative of the nation as a whole suggests that in a relatively short time Caltech will no longer be a predominantly "California" or "Western" institution.

College Years

The alumni are more highly educated than they were in 1952. The proportion with a BS as their highest degree has dropped from 45 to 36 percent, while those with MS as highest degree have risen from 32 to 34 percent, and those with doctorates and engineering degrees from 23 to 30 percent. In fact, alumni are now about evenly divided: ⅓ Bachelors, ⅓ Masters, and ⅓ Doctors.

Highest Degree Earned

	% in '63	% in '52
BS from Caltech	36	45
MS from Caltech	24	26
MS, non-Caltech	10	6
Doctorate or Professional, Caltech	20	17
Doctorate or Prof., non-Caltech	10	6

The increase in the frequency of higher degrees is also evident when we look at the decade in which the degrees were granted. As the table below indicates, there is a fairly even distribution of BS's for each decade since 1930. However, there is a definite increase in more recent years in the percent of Master's degrees earned, and a most pronounced change in the proportion of those earning the doctorate.

Decades in Which Degrees Were Earned

	BS	*MS*	*PhD*
% 1910-1919	1		
% 1920-1929	9	2	2
% 1930-1939	20	14	13
% 1940-1949	32	30	16
% 1950-1959	30	37	46
% 1960-1962	8	16	23

They Are Young

The table above also affirms the relative youthfulness of our alumni. Almost all have received their degrees since 1930, while slightly more than half have received them since 1950. The greatest extreme is found in the column for the doctor's degree, where we see that over two-thirds of these degrees were earned after 1950. If the proportions for the 1960-1962 period hold through 1969, about half of all doctorates held by our alumni at that time will have been earned since 1960.

If we look at the age of our alumni rather than at the decade in which they received their degrees, we find further, but less dramatic, evidence of this youthfulness. The table below shows that half of our alumni are less than 40 years of age, and three-quarters are less than 50. At the same time, it is also evident that the alumni group is not as youthful as it was in the 1952 survey, when almost three-fourths were less than 40 years of age.

Age of Alumni

	% in '63	% in '52
Under 30	20	32
30 to 39 years	29	40
40 to 49 years	29	20
50 to 59 years	16	8 (50 and over)
60 and over	6	

These percentages are not as extreme as they were 11 years ago, and another decade will see our alumni the same age as other typical alumni groups, yet our alumni will remain relatively young when compared with age distributions for college graduates in the general population. This fact should be kept in mind later on, when we analyze the post-graduate achievement of various degree-holders and attempt to evaluate their accomplishments.

Undergraduate Major

MAJOR SUBJECT FOR BACHELOR'S DEGREE

	% in '63	% in '52
Aeronautics	2	
Astronomy & Astrophysics	*	1
Biology	2	2
Chemistry & Biochemistry	5	9
Chemical Eng. & Appl. Chem.	10	8
Civil Engineering	13	12
Electrical Engineering	23	20
Geology	3	5
Geophysics	1	
Mathematics	3	2
Mechanical Engineering	28	30
Physics & Applied Physics	10	11
Total in Engineering	63	62
Total in Science	34	38

*Less than ½ of one percent

There are a few small differences in the percentages in various majors between the '63 and '52 surveys, i.e., a decrease in chemistry and chemical engineering and an increase in electrical engineering. These changes are both small, and are not matched by any changes in recent years in the actual number of degrees awarded in these majors by the Institute. Therefore it seems reasonable to ascribe the differences in this table to sampling errors.

However, since the 1952 survey there have been important revisions of undergraduate curricula and course requirements in almost all divisions of the Institute. Subject matter formerly taught in graduate courses now appears at the undergraduate level; concepts from sophomore and junior courses now frequently are part of freshman courses. In addition, there has been a noticeable increase in the number of undergraduates selecting mathematics or science as their major and a decrease in the number selecting engineering. These changes are too recent to affect the results of this survey, but some idea of the probable future effect may be gained from the fact that while the survey indicates roughly two-thirds engineering and one-third science majors, the percentage of engineers within graduating senior classes in the last ten years has declined from 50 to 30 percent, and may go even lower.

Graduate Majors

MAJOR SUBJECT FOR HIGHEST ADVANCED DEGREE

	% in '63	% in '52
Aeronautics	10	18
Astronomy & Astrophysics	1	*
Biology	1	2
Chemistry & Biochemistry	11	10
Chemical Eng. & Appl. Chem.	5	5
Civil Engineering	6	7
Electrical Engineering	17	14
Geology	5	6
Geophysics	1	1
Mathematics	3	2
Mechanical Engineering	12	10
Physics & Applied Physics	14	12
Business Administration	3	2
Law	1	2
Medicine	1	1
Meteorology	3	5
Other	6	3
Total in Engineering	45	49
Total in Science	41	35
Total in Other	14	16

*Less than ½ of one percent

Among the graduate majors there is only one change from 1952 to 1963 that may not be due to sampling error. It is the drop in the percentage of alumni who hold degrees in aeronautics – from 18 to 10 percent. During World War II Caltech had a Navy V-12 training program that produced a great many graduates in aeronautics. Since 1947, when this program was discontinued, the production of aeronautics graduates has returned to prewar levels. Consequently, the total of aeronautics majors has not increased in volume to the same extent as other majors. Furthermore, at the time of the 1952 survey a large proportion of all aeronautics majors were V-12 graduates who, after the 11 years between surveys, probably no longer feel close to the Institute or sufficiently interested to participate in the survey.

The proportions of engineers and scientists among graduate degree-holders are more nearly equal than they are among undergraduates. The increase in the proportion of scientists and the decrease in the proportion of engineers is partially accounted for by the changes in the aeronautics major. It may also be due in part to a recent trend at the Institute toward the granting of more degrees in science and fewer in engineering. This change is paralleled at the undergraduate level. If the trend continues it may ultimately result in Caltech becoming an institute of pure and applied science, with a small proportion of majors in engineering pursuing a course of study quite similar to that of the science majors. The recent change in the name of the Engineering Division to Division of Engineering and Applied Science may be a portent of things to come.

Religious Affiliation

We found in the 1952 survey that our alumni were predominantly Protestant in their religious affiliation — much more so than U.S. college graduates in general. While this is still the case, there have been some small but interesting changes.

RELIGIOUS AFFILIATION

	% in '63	*% in '52*
Protestant	77	84
Catholic	8	7
Jewish	8	5
Other	7	4

The decrease in the percentage of Protestants and the increase in Catholics and Jews was evident in the 1952 survey when alumni under 30 were compared with those over 50. The percentages for the younger group were very similar to the '63 figures, which suggest a broadening base of religious affiliation among our alumni.

The foregoing figures on religious affiliation are derived from answers to the question: "Were you brought up as a . . . Protestant? . . . Catholic? . . . Jew? . . . Other?" They do not reveal the amount of active participation in religious affairs. When asked how frequently they go to church, a more definite attitude emerged. In 1952, 29 percent were active churchgoers. In 1963, this number had grown to 36 percent. At the same time, 50 percent of the '52 sample attended church rarely or not at all, while only 46 percent of the 1963 sample report nonattendance.

FREQUENCY OF CHURCH ATTENDANCE

	% in '63	*% in '52*
Now go to church every week	19	13
. . . pretty regularly	17	16
. . . a few times a year	18	21
. . . rarely	20	26
. . . not at all	26	24

While there is a slight increase in church attendance in the 1963 sample, Caltech alumni could hardly be called a churchgoing group, since almost half of them go rarely or not at all.

Parents' Education

Less than ten percent of all Americans who are old enough to have a college degree actually do have one. And so, on the average, one might expect this proportion to be true for the parents of college graduates. However, it is known that college graduates tend to encourage their offspring to attend college. Consequently, the percentage of parents of college graduates who also attended college is considerably more than ten percent.

Among Caltech alumni, almost half of the fathers and more than one-third of the mothers attended college. Over 50 percent of our alumni report that one or more parents attended college.

ALUMNI WHOSE PARENTS ATTENDED COLLEGE

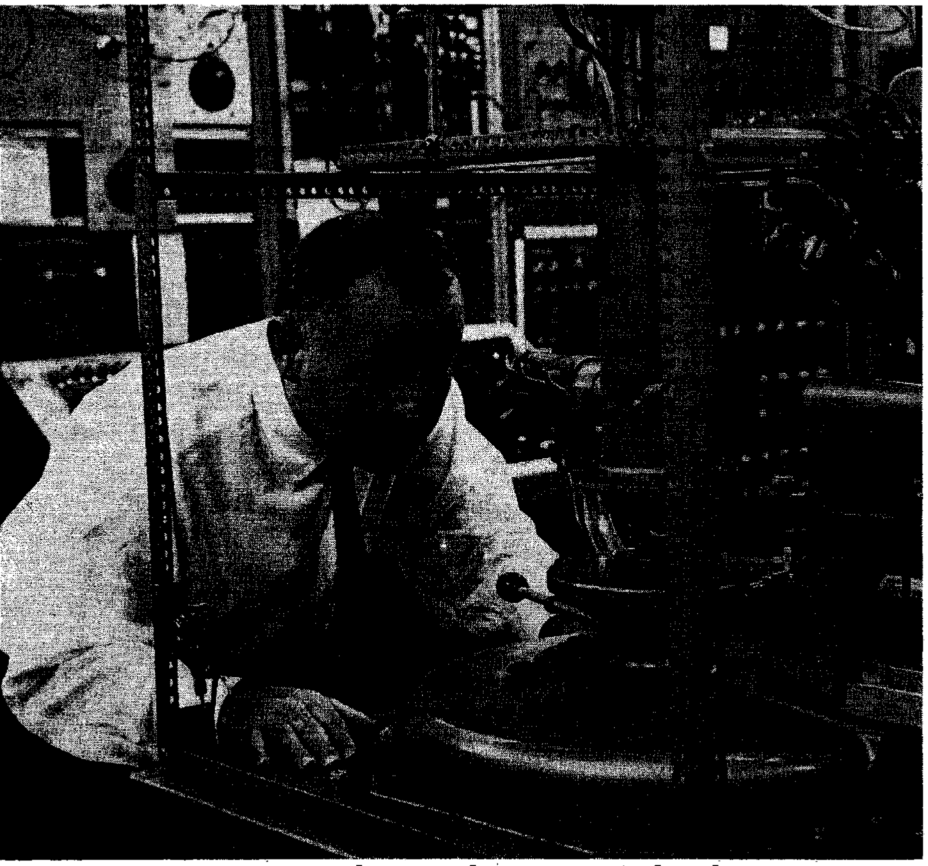
	% in '63	*% in '52*
Father attended college	45	43
Mother attended college	36	33

These percentages are higher than the national average, and indicate that Caltech alumni come from highly educated families. However, some other colleges have student bodies with a higher proportion of parents who attended college. For example, a recent cooperative study compared the parents' education of Caltech students with those of science majors in an Ivy League college. The percentage of fathers with only a high school education was 37 for Caltech, and 27 for the Ivy League college. Twenty-five percent of the Caltech fathers had attended graduate school, while 50 percent of the Ivy League college fathers had done so.

About the same proportions held for the mothers' education. Forty-five percent of the mothers of Caltech students had a high-school-or-less education, versus 29 percent for the Ivy League mothers. And, at the other extreme, only 8 percent of Caltech mothers attended graduate school while 17 percent of the Ivy League mothers had done so.

These differences in family educational background are probably due to several causes. Perhaps different social class position, a longer tradition of college attendance, and more entrenched intellectual values are more characteristic of an Ivy League student body than of Caltech's. But future articles on our survey results will show clearly that Caltech alumni are hard to beat when it comes to academic honors and other notable achievements in later years.

This is the first in a series of articles to appear in ENGINEERING AND SCIENCE *reporting the results of the survey of Caltech alumni made last year. The next issue will take a look at some of the political and cultural interests of our graduates.*



C. J. Pings studies optical properties of a liquid.

LIQUIDS — ORDERED CHAOS

The behavior of gases and solids is quite well known. Theories have been developed which make it possible to predict their behavior under different circumstances.

There are lots of theories about liquids, too. But none are completely successful. Scientists simply do not know why liquids flow, splash, and otherwise behave as they do.

At Caltech, Cornelius J. Pings, associate professor of chemical engineering, has been studying the fundamental behavior of liquids for the past eight years. This work is now being expanded under a new contract with the Air Force Office of Scientific Research. Additional support comes from the Office of Naval Research and the National Science Foundation.

Dr. Pings and his group are attempting to learn more about how atoms and molecules behave in the liquid state at various temperatures and pressures. This involves not only "looking at" atoms and molecules, but also studying the microscopic forces that lace them together in the informal, shifting way that is characteristic of liquids.

"Although the molecules of solids are arranged in orderly rows and those in gases in perfect disorder, the molecules in liquids comprise a moving interlocked mess — a sort of ordered chaos," Dr. Pings explains. "In liquids, each atom is affected by thousands of surrounding atoms whose positions in relation to each other are constantly changing."

This is one good example of a *many-body problem,* a name given to a number of current problems in physics involving the simultaneous interaction of a large number of particles, atoms, or molecules. The biggest digital computer in existence is not powerful enough to solve these problems by brute-force arithmetic. Although they are currently the focus of much activity by theoretical physicists and chemists, progress is slow, and a general solution to these many-body problems is not yet in sight.

A lack of a good working theory for the behavior of liquids has its frustrating and expensive consequences at the practical level. The modern-day engineer and scientist, for all of his knowledge of atoms and molecules, cannot make a straightforward prediction of the elementary properties of even the simplest liquids. Such things as densities, viscosities, and boiling points — needed for the design and intelligent operation of chemical plants, oil refineries, and liquid-fueled rockets — cannot be reliably estimated from theory and must usually be measured in the laboratory and pilot plant.

It is apparent also that continued lack of full understanding of the behavior of liquids in general, and solutions in particular, will stand as a barrier to full insight to many basic problems in physiology and medicine. Chemical kinetics in the liquid phase is currently at a stalemate, in contrast to the significant gains in gas-phase kinetics in the last decade.

Previous experimental studies have been made of the forces and configurations involved in liquids. However, much is still unknown and the theoretician is frequently stymied by lack of knowledge of what is actually going on at the molecular level in liquids and dense gases. Pings and his co-workers are interested in determining the behavior of very simple liquids at a wide variety of temperatures and pressures. The group hopes to obtain enough data to provide a sound framework for a comprehensive, over-all theory. The team is now enlarging its laboratory space to make observations of molecules and their forces in liquids with several techniques.

The first is x-ray diffraction. It enables investigators to measure the average number of neighboring atoms and the distance they sit from each other. A beam of x-rays is directed at the liquid being studied and the atoms in the fluid diffract the x-rays. The diffracted radiation is detected by scintillation counters. Mathematical analysis of the diffraction data yields direct information about the *average* configurations in the system of moving liquid molecules.

One set of completed experiments on liquid nitrogen has revealed that each nitrogen molecule on the average is surrounded by a "shell" of 15 neighboring molecules at a distance about 5 percent greater than the shell of nearest neighbors in the crystal lattice.

A current experiment on liquid argon will determine how these configurations change with the temperature and density of the fluid. Mr. S. E. Rodriguez has just completed a set of diffraction studies on liquid gallium for his PhD thesis. Gallium is a metallic element that looks like mercury, although it is less than half as dense. It normally freezes at 29.8°C. However, Rodriguez was successful in supercooling one specimen to 0°C for more than 30 hours while he determined its structure. Tentative conclusion: Unstable supercooled gallium is a normal liquid as far as its molecular-level configuration is concerned.

The second experimental technique is a study of the refractive index of the fluids. This is the measurement of how much a beam of light is bent as it stabs through a liquid. The amount of bending is indicative of the electrical environment in the immediate vicinity of a molecule in the liquid.

These measurements have been made on methane, carbon tetrafluoride, and argon. The argon measurements have been concentrated on the liquid up to 100 atmospheres, but have been included in some studies of both gaseous and solid argon. Of particular interest in this study is the Lorentz-Lorenz theory, which postulates a quite simple relationship between the dielectric constant (or refractive index) and the density of a substance.

The experimental work so far has indicated that the theory seems to be quite good for non-polar *gases, liquids,* and *solids*. This may be of some significance, since very few properties can be predicted for all three states of matter by a single theory or model.

The third experimental technique is ultrasonic absorption. Ultrasound pulses disturb the liquid slightly, causing its structure to change. The rate at which the liquid's forces pull its molecules back to their original position could apply to information that may lead to a theory of predicting viscosity and other transport properties.

Much of the investigation is concentrated at the critical region of a liquid, the borderline region between liquid and gas. Theoreticians still have no satisfactory explanation for the very strange behavior of a fluid at its critical state. It is known that very large clumps form in liquids in this region. The clumps often are so large that they cause light to scatter. In some instances an otherwise colorless liquid looks brown from the scattering.

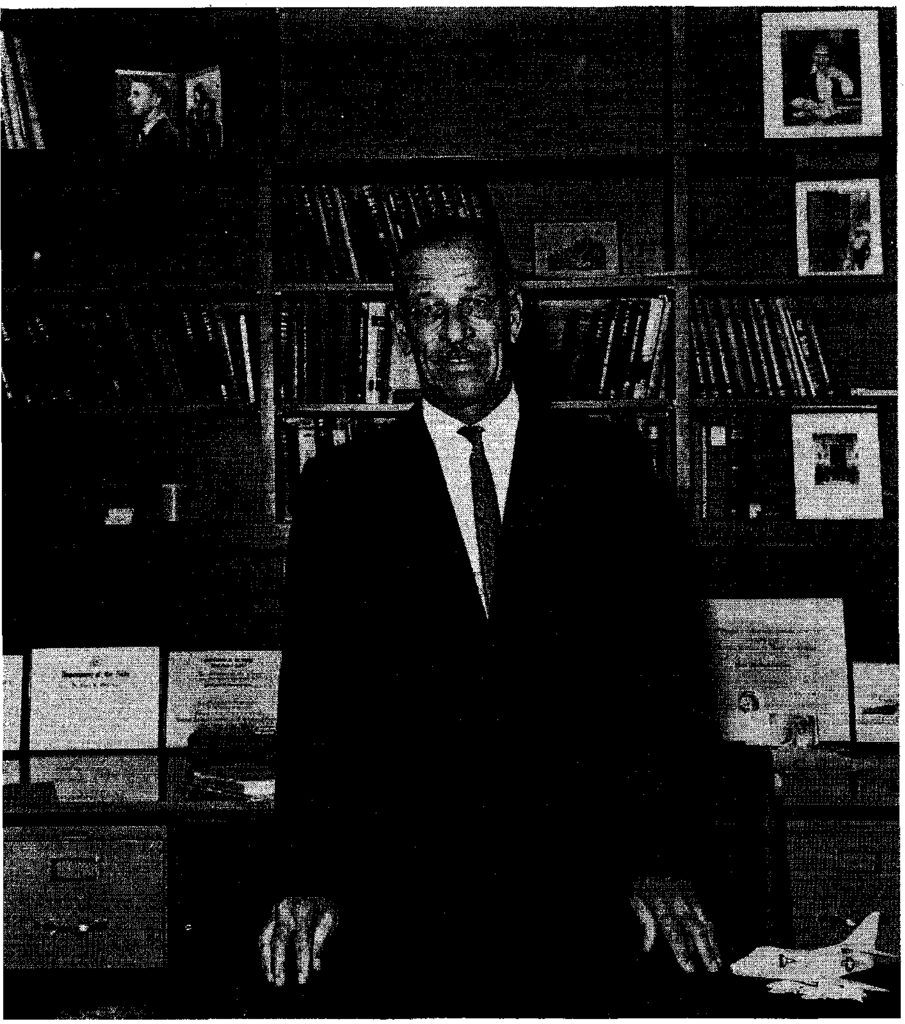
There is considerable theoretical and practical interest in this region. Practically, there is much interest in the fact that heat capacity and thermal conductivity increase as much as ten times. The thermal conductivity properties suggest that liquids in the critical state may provide a very effective heat transfer medium for boilers and chemical processing equipment, and the heat capacity properties may be useful for heat control, as a sort of heat buffer.

On the theoretical side, the critical region seems to be sort of a promised land for the theoretician interested in many-body problems. A key to the critical region might very well also turn the lock of the whole liquid state problem. Two international meetings will be held in the next 12 months on experimental and theoretical problems of the critical state.

Liquids currently under investigation by the Pings group are all relatively simple; they include mercury, carbon tetrafluoride, gallium, nitrogen, and argon. Some substances, such as argon and nitrogen, require cooling down to temperatures of minus 310 degrees F. before they will liquefy.

At present, water is too complex a liquid to investigate. One of its complicating factors is the presence of the unusual hydrogen bond forces between the molecules, resulting in very peculiar behavior.

"I think we will wait a few years," says Dr. Pings, "before we tackle anything as complicated as water."



The Month at Caltech

Clark B. Millikan, NAS Member

Clark B. Millikan, professor of aeronautics and director of Caltech's Graduate Aeronautical Laboratories, was elected a member of the National Academy of Sciences at its annual meeting held on April 28 in Washington, D.C. Election to the Academy, one of the highest scientific honors in the nation, is in recognition of outstanding achievement in scientific research, and membership is limited to 500 American citizens and 50 foreign associates. With 32 members, Caltech has the highest percentage of members of any university faculty.

Dr. Millikan's major investigations have been in the fields of airplane aerodynamics, fluid mechanics, wind tunnel design and operation, and guided missiles.

He was graduated from Yale University in 1924 and received his PhD in physics and mathematics at Caltech in 1928. He joined the Caltech faculty the same year, became full professor of aeronautics in 1940, and in 1949 was appointed director of the Guggenheim Aeronautical Laboratory. His title was changed in 1961 to director of the Graduate Aeronautical Laboratories. He was a member of the Executive Committee of the Institute from 1945 to 1947, and has been chairman of the Institute's Jet Propulsion Laboratory Committee since 1949.

Dr. Millikan is an honorary fellow of the American Institute of Aeronautics, of which organization he was president in 1937, and is a fellow of the Royal Aeronautical Society of Great Britain, the American Academy of Arts and Sciences, and the American Physical Society.

Dr. Millikan received the King's Medal for Service in the Cause of Freedom in 1948 from the British Government, and the United States Medal for Merit in 1949. He is a member of the Air Force Scientific Advisory Board, and also the Scientific Advisory Committee of the Army Ballistic Research Laboratory. He serves as a director of the Aerojet-General Corporation and the National Engineering Science Company.

Dr. Millikan is the son of the late Robert A. Millikan, who was chief administrative officer of Caltech from 1921 to 1945.

Kimber Genetics Medal

Max Delbruck, professor of biology, received the Kimber Genetics Medal for 1964 from the National Academy of Sciences at its annual meeting in Washington, D.C., last month. The award was given "for his decisive role in the contributions of biology, chemistry, and physics to the understanding of the essential molecular characteristics common to all known living systems, from the smallest viruses to man himself."

A native of Berlin, Germany, Dr. Delbruck began his studies on the genetic aspects of virus infection in 1938 while a fellow at Caltech, and his discoveries are credited with making possible important research by laboratories throughout the world. He has been a member of the Caltech faculty since 1947.

Arthur Noble Award

Arnold O. Beckman, chairman of the Institute's Board of Trustees, received the City of Pasadena's Arthur Noble Award on May 11 for "a real and lasting contribution to the well-being and beauty of our community" for the new Caltech Beckman Auditorium which he donated to the Institute. He was the 36th recipient of the award which was established in 1924 by Arthur Noble for promotion of civic beauty, pride, and culture. Master of ceremonies for the invitational gathering of Caltech Associates, city and civic leaders, members and friends of Caltech, was Dr. Simon Ramo, president of the Caltech Institute Associates.

The ceremony was held in the new auditorium. President DuBridge gave a slide lecture on "Caltech – Yesterday, Today, and Tomorrow," and the Caltech Glee Club opened the ceremony.

Humanities Grant

Caltech's humanities division has received a grant of $500,000 for research from Old Dominion Foundation of New York. The grant will establish an endowment fund whose annual income will provide paid periods of leave for members of the humanities faculty, for study at other institutions or libraries, here and abroad.

"The endowment meets a very special need at Caltech," says President DuBridge. "Our humanities division is devoted primarily to teaching; but the best teachers in the humanities, as in other fields, are as a rule deeply committed to scholarly research. To attract and hold such teachers we must encourage and reward research, and that is exactly what Old Dominion Foundation is helping us to do."

Old Dominion Foundation was established in 1941 by Paul Mellon of Upperville, Virginia. Areas in which it has been particularly interested include the humanities and liberal education, the arts, mental health, and conservation. Its grants to date total approximately $65 million.

Arnold O. Beckman, receives the City of Pasadena's Arthur Noble award from Mayor Floyd Gwinn (left) and Lathrop K. Leishman, (right) chairman of the selection committee.

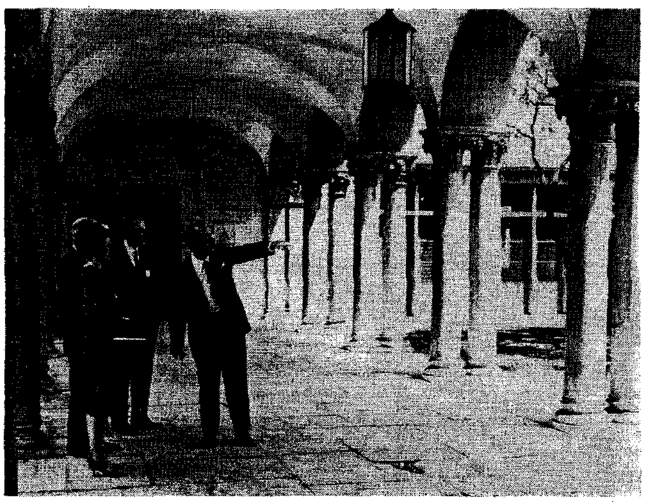
Caltech was a pioneer in emphasizing the importance of the humanities in technical education. As early as 1921 it established the requirement that at least twenty-five percent of every undergraduate's classroom time be spent in the study of English, history, philosophy, economics, and languages.

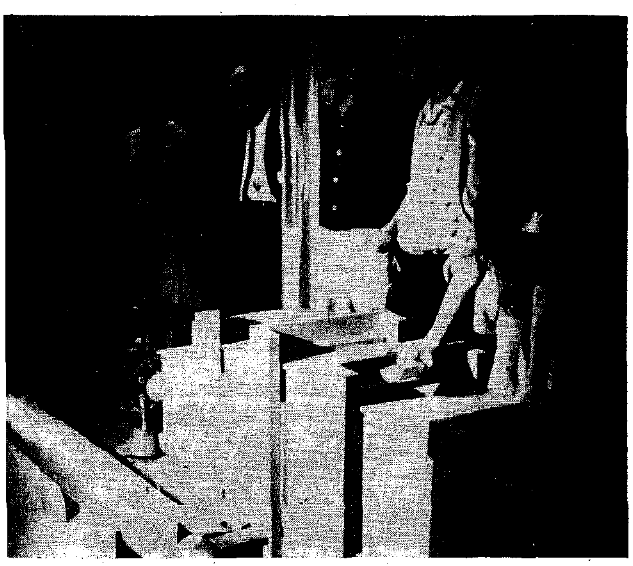
Commencement

Caltech's 70th annual commencement on June 12 will be held on the Beckman Auditorium Mall. Henry T. Heald, president of the Ford Foundation, will deliver the commencement address.

CALTECH'S 27th ANNUAL ALUMNI SEMINAR

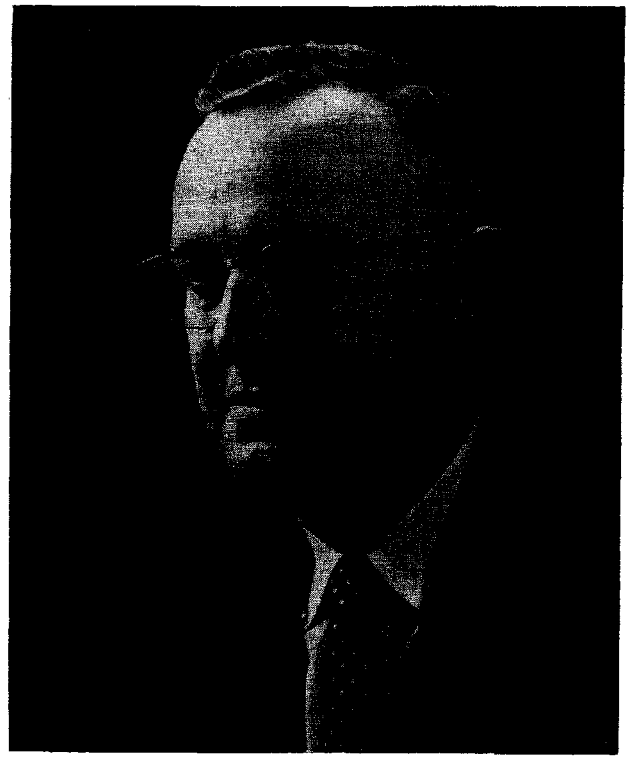
Almost 1,500 alumni, wives, and guests came to the Caltech campus on May 2 for the 1964 Alumni Seminar, which featured a series of lectures and exhibits, and an evening banquet. President DuBridge gave a special talk on "Science in Space" in Beckman Auditorium. Exhibits included tranquil and torrential flows in the new 130-foot tilting flume, dynamic tests of structures, and the linear accelerator. At the evening banquet held at the Huntington-Sheraton Hotel, Mrs. Georgiana Hardy, president of the Los Angeles City Board of Education, spoke on "The Little Red Schoolhouse Still Haunts Us."





CARL NIEMANN

1909 - 1964



Carl G. Niemann, one of the nation's leading organic chemists, and a member of the Caltech faculty for 27 years, died of a heart attack on April 29 in Philadelphia. He was 55.

Dr. Niemann and his wife, Mary, were en route to Europe for a vacation. He had been attending the annual meeting of the National Academy of Sciences in Washington, where he presided over a session of the Academy's chemistry section, of which he was chairman.

Born in St. Louis, Carl Niemann was graduated from the University of Wisconsin and received his PhD in biochemistry there in 1934. He was a research associate at the University of Wisconsin in 1934-35, a fellow of the General Education Board at the Rockefeller Institute for Medical Research in 1936-37, an assistant in chemistry at the Rockefeller Institute in 1936-37, and a Rockefeller Foundation Fellow at the University College Hospital Medical School in London in 1937-38. He joined the Caltech faculty in 1937 and became a full professor in 1945.

Dr. Niemann made outstanding advances in the understanding of enzymes, which control the biochemical activities in living cells. Most recently, he had been working on limitations in the specificity of enzymes. He also did significant work on the chemistry of amino acids, peptides, carbohydrates, and lipids.

He had served as chairman of the Caltech faculty and was chairman of the graduate committee of the division of chemistry and chemical engineering.

He was also a consultant of E. I. DuPont de Nemours Co. and of the Smith, Kline and French pharmaceutical company.

He was elected to the National Academy of Sciences in 1952. He was a member of the American Chemical Society, the American Society of Biological Chemists, Sigma Xi, and the British Chemical Society. He was a fellow of the American Academy of Arts and Sciences and of the New York Academy of Science.

A memorial service was held in Dabney Hall on May 12, with eulogies delivered by President DuBridge and by John D. Roberts, chairman of the division of chemistry and chemical engineering.

"Carl Niemann was in many ways the ideal academic scientist," said Dr. Roberts. "He was quietly but tenaciously independent. He knew that to be successfully independent involved being responsible and, in every commitment he took on, he was always completely responsible . . .

"The essence of the Niemann approach to science and life was scholarship and effectiveness. Clearly, one has to be effective to fulfill so many responsibilities and yet produce over 260 carefully written research papers. He conducted himself at all times with a characteristic of calm dignity; he was a tireless and never frantic worker. The less efficient and less effective of us could only marvel at how he worked day after day with his office door wide open. He always had a cheerful welcome to anyone wishing to consult with him, but as soon as the business at hand was over, one sensed he was completely politely beginning to think about the next phrase of the unfinished manuscript before him . . .

"Carl Niemann was a scholar and a scientist of the first rank. He was devoted to the principles of both academic freedom and academic responsibility. He pressed himself on no one, but he gave unstintingly to those who sought his help. His legacy is a corps of superbly trained and loyal students, a deeper understanding of the chemistry of life, and the many results of his efforts to make a better Division and a better Institute.

"He was taken from us and his family at the very height of his career, just before the start of a European vacation. We and his many other friends will not soon forget the way in which he enriched our lives and our profession."

INTRODUCTION TO MODEST MORPHOLOGY

by John D. Strong

Modern technology is constantly faced with problems for which it is of transcendent importance to get timely solutions. Many of these problems are so complex that they cannot be solved by conventional methods, but the Morphological Research Method developed by Fritz Zwicky, Caltech professor of astrophysics, provides formal procedures suitable to the solution of such problems. These procedures have much in common with those used informally and intuitively by our scientific giants — especially Faraday and Mendéléeff. In their application, however, Zwicky's procedures have the new feature of explicit formality, so that they can be consciously practiced.

Zwicky's morphology arranges the progress toward the solution of a problem into four phases:

1. Formulation of the problem
2. Analysis of the problem
3. Synthesis of valid solutions
4. Judgment of these solutions

The real inner purpose of separating and formally arranging these phases, and of formally arranging the application of talents to them, is to *remove restrictions* which would otherwise preclude optimum solutions. A completely rigorous and full response to these four phases, as it applies to almost any technical problem, requires the devoted application of several competent scientists for a matter of years. As in an imperfect practice of the Christian Ethic, which can be practiced rigorously and fully only by saints, there is merit in an imperfect, or less than rigorous and full application of the morphological method.

A problem must be a strategic one to be worthy of the extensive effort of giants. In contrast, I describe the applications of "modest morphology" to problems of experimental physics, particularly instrument design, and, specifically, problems whose solution is subject to severely modifying, prescribed restrictions.

The prescribed restrictions relate to the fact that our problems come under established, defined programs with fixed budgets and definite performance dates. We apply morphology to the many small, unanticipated, ancillary problems that come up in our research. Most of them could be solved by straightforward engineering; only occasionally one requires invention. These tactical problems, however, must be solved for so-and-so-much money, and within such-and-such a time limit. Also, we work under many other restrictions. It is a mistake to complain, for all of these restrictions are a proper condition on our work. Fortunately, they do not preclude the restricted use of Zwicky's morphological method.

This restricted application is most effectively applied by a properly indoctrinated group, working together. And it is part of the indoctrination for members of the group to learn that the formality of the method may appear, at first, to be an unnecessary distraction. They will soon learn, however, that the distraction is worthwhile because, in the end, by practicing modest morphology they will require less time to meet their goals, and they will achieve their goals more effectively and enjoy more personal satisfaction.

Here, then, are the four phases of modest morphology as we practice it.

Phase I. The Problem. I have often visited groups, busy at research, that have not formulated an explicit definition of their problem. Such a definition is important.

Phase II. The Analysis of the Problem. The purpose of the second phase, analysis, is to enumerate and organize *all* the parameters that are pertinent to valid solutions of the problem.

In our modest practice we state our problem, list the *main* parameters and begin forthwith to synthesize solutions. We take the parameters as being either obvious to all concerned, or we develop the parameters more formally as we go, by feedback from the various solutions that come up. Thus, in our less formal practices we are fluid, the parameters being changed as we progress. Even the definition of the problem may be changed by the synthesis of solutions for it.

Phase III. Synthesis of Solutions. In an extensive morphology it is necessary to make every possible combination of the parameters, and thus to derive *all* of the valid solutions. In our restricted practice of morphology there is a tacit understanding that we must get at least two valid solutions. The second solution is often more satisfactory in elegance, in cost, or in time of realization than the first, even when the first was completely adequate. The first solutions, as in the example I give later, may be conventional ones, widely practiced. And in the rare case when no improvement is made over an adequate first solution, a confidence factor is obtained, from getting a second, that is worth the trouble it costs.

Combinations of parameters frequently produce inventions. The law defines invention as an act of the creative imagination lying beyond that which is possible to the mind of those who are simply skilled in the art. A creative combination of parameters is referred to in the law as the so-called "flash of genius." Inventions arrived at by the practice of the morphological approach are sometimes, but usually not, of this sporadic flash type; they ordinarily come from the deliberate application of the imagination to the parameters analyzed. *The fact that "inventions" can be deliberately induced is a main value of the morphological approach.* Zwicky's morphology teaches the "secret" of sparking this induction.

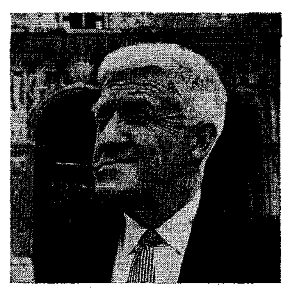
Invention (the discovery of a hidden valid solution) is not inhibited when one follows the rule that, during the synthesis phase, it is only proper to pass judgment as to whether or not combinations form valid solutions. It is improper to judge these combinations initially on any other basis. If this rule is obeyed, garnering valid solutions to a problem becomes straightforward.

One can best understand the compromises of modest morphology, as contrasted with the uncompromising thoroughness and rigidity of Zwicky's teaching, by extending our analogy to the Christian Ethic. Like a man who acts like a Christian on Sundays but is "practical" during the week, we apply the commandment to get *all* the valid solutions, each without prejudice, only as far as we can afford to within the frame of our restrictions. It is our practice to sustain the morphological attack until we get two or more valid solutions to a problem, or until we have made a sincere try for a second solution.

In modest morphology the valid rule that certain spontaneous, premature evaluations of valid solutions must be suppressed until *all* the valid solutions (or at least two, in our case) are garnered is all but impossible to adhere to. It is difficult to follow this rule because one must suppress much impulsive judgment; each successive solution, or invention, as it is garnered, will be spontaneously judged "good" or "bad." For example, a particular solution may be impulsively and prematurely judged "bad" because it requires materials for reduction to practice that are not available, or it requires skills that are not attainable, or it involves expense that is unsupportable. During the synthesis stage, only the judgment that a solution is a valid one, or not, is proper.

And yet, after the climate of modest morphology has matured in a group, these spontaneous, premature evaluations of "good" and "bad" are gracefully handled; and they serve a valuable function.

In a properly indoctrinated group, if a solution is valid, but is spontaneously declared by anyone in the group to be "bad," then the inventor will be



John D. Strong has been professor of experimental physics and director of the Laboratory of Astrophysics and Physical Meteorology at Johns Hopkins University since 1945. He is recognized today as one of the world's greatest optical scientists.

A graduate of the University of Kansas, he got his PhD from the University of Michigan in 1930, and came to Caltech as a research fellow. He was in charge of the research and development work which resulted in the optical systems of the Palomar Observatory. In 1937 he became assistant professor of physics and astrophysics here.

While at Caltech, Dr. Strong evolved the first practical technique for evaporating aluminum directly to mirrors, now a standard practice. At Johns Hopkins, his interest in infrared spectroscopy has led to a unique and highly specialized design of ruling engines for diffraction gratings, and further, to the application of experimental physics to meteorology and astrophysics.

The morphological method which Dr. Strong discusses in the accompanying article is nothing more than an orderly way of looking at things. Its aim is to achieve a schematic perspective over all of the possible solutions of a given large-scale program. The method was developed by Fritz Zwicky – professor of astrophysics at Caltech, and staff member of the Mount Wilson and Palomar Observatories – with whom John Strong worked while he was on the Caltech faculty.

especially proud of it. Or he may secretly have judged it "bad" himself, and he will be proud of having suppressed his prejudice. He will admonish his critics for their prejudice — and then look for some "good," knowing that "bad" solutions are valuable for the following reasons:

1) Some "bad" solutions actually produce results which "good" ones do not, and thus may amplify or alter the statement of the problem.
2) A "bad" solution may induce a "good" one.
3) Two "bad" solutions may combine to produce a "good" one.
4) A "bad" solution may point out the need for more analysis.

Phase IV. The Judgment. The choice of the particular solution that is to be reduced to practice, and tested, from among all those that have evolved, can now properly be made with open consideration of values which have heretofore been suppressed, such as available materials, attainable skills, supportable cost, achievable deadlines.

Since our practices fall far short of the ideal, how, then, is our modest morphology different from standard engineering practice in which alternate solutions or alternate designs are also evolved? The main difference lies in our attitude about, and treatment of, "bad" solutions. Experience has taught us their value. We seek them out and treat them with respect.

Many examples of the application of modest morphology are not as crisp and black-and-white as my exposition might imply. In many instances the fruit of this application, like all good solutions, seems, in retrospect, to be trivial and obvious.

Our experience in the design of a dividing head for a new diffraction grating ruling engine will illustrate the value of modest morphology.

Man's most powerful tool

Albert Ingalls, in an article on ruling engines in *Scientific American* for June 1952, states that it is no exaggeration to say that the splitting of light into its colors by means of spectrographs is man's most powerful tool for investigating the universe. Astronomers use spectrographs to study the stars, physicists to probe the atom, chemists to identify molecules, biologists to explore living substances, food processors to test food, detectives to analyse blood stains.

A prism may be used to sort out the colors of the light, but modern spectrographs require the use of the much more powerful diffraction grating.

The ruling of diffraction gratings is an art that has been practiced for more than 80 years by American physicists — notably, in the beginning, H. A. Rowland, J. A. Anderson, and R. W. Wood at The Johns Hopkins University, and A. A. Michelson at the University of Chicago.

Nowadays, a diffraction grating is made in a thin uniform aluminum film deposited on a polished plane or concave spherical glass surface. Several tens of thousands of grooves of a specified profile (or shape) must be embossed (or ruled) in it by the diamond tool of a ruling engine. The power of the grating depends not only on the precision of shape of the plane or spherical surface, but also on having the embossed grooves straight and parallel to one another, and equidistant — all within a small fraction of the wavelength of the light which we wish to analyse with the grating.

Two basic approaches

The generation of precise shapes can be achieved, in principle, by two basic approaches — either by a *construction procedure* that is inherently adapted to generate the desired surface automatically; or by a *correction procedure* that eliminates local imperfections after they are revealed by a suitable test.

I can illustrate and contrast these procedures by describing the construction of a concave polished grating blank. Two similar pieces of glass are rubbed together with an abrasive between them. This rubbing produces mating spherical surfaces (one converse and the other concave) automatically. Subsequently, after polish, the concave surface may not be precise enough for a grating blank. But it can be made precise by "figuring" — that is, by local polishing, guided optically by the Foucault knife-edge test. This is a correction procedure.

As far as the ruling of optical gratings is concerned, the problems of procurement of spherical and flat blanks have been fairly well solved during the past 60 years. Actually, it seems that the ancient Egyptians knew and used the sophisticated and inherently precise procedure of lapping three surfaces together to make them flat. But there are other instances where inherently automatic procedures may be used in the construction of a ruling engine.

By the application of modest morphology we developed a new method whereby we made a straight rod for our ruling engine. It was made straight to a millionth of an inch by an automatic, inherently

THE BELL TELEPHONE COMPANIES SALUTE: ERNIE SELZER

Five assignments in less than two years would indicate Ernie Selzer (B.S., 1961) is a man on the move at Pacific Telephone. He is presently a senior engineer working on the design of a worldwide data system for a large customer in the Los Angeles district.

Men with technical and scientific backgrounds are needed to understand the new concepts and growing complexities of communications. Ernie has been involved in engineering toll switching equipment, data transmission lines, and the design of private switching systems.

Ernie has made rapid strides to earn a reputation as a competent, versatile engineer. He has proved his abilities on every assignment and has gained the personal satisfaction and recognition that go with a job well done.

Ernie Selzer, like many young engineers, is impatient to make things happen for his company and himself. There are few places where such restlessness is more welcomed or rewarded than in the fast-growing telephone business.

BELL TELEPHONE COMPANIES

precise, procedure. I mention this application here only as introduction to another equally effective automatic procedure that we developed, and that I shall use to illustrate the application of modest morphology.

The morphologist, when doing total research, is not only interested in how to produce straight lines, flats, spherical surfaces, and so on, by one or the other of the intrinsically accurate methods, or by one or the other of the methods of successive approximations; he will actually want to know the totality of mechanical, optical, electrical, or chemical methods that there are, by which he could produce the required geometrical figures. The importance of such knowledge of all the possible methods is evident when it is realized that the best method of producing straight grooves on a grating blank may not at all be the best method to achieve straightness in other cases where it is vital — as for the seven-mile-long rocket test sleigh track at the Holloman Air Force Base at Alamogordo, N. M., or the two-mile-long linear particle accelerator at Stanford University. Failure to choose the best method of producing a straight line may in some cases actually result in losses of millions of dollars.

Two main difficult problems

In the development of a ruling engine there have been two main difficult problems: one is the problem of shaping of the grooves, for blazed gratings; and the other is the control of the diamond's motion, to get straight and accurately spaced parallel grooves.

The first problem requires a suitable metal film into which to form the grooves, and skill in adjustment of a precisely shaped diamond ruling edge. My own introduction of aluminum films, when I was at Caltech, provided the suitable film, and the skillful adaptations of the ancient art of cutting and polishing diamonds provided the tool.

As to the latter problem, after we had developed new methods of generating, mounting, and using precision lead screws for our ruling engine, to produce proper spacing of the grooves, we needed means to accurately control the positions of the screws. For instance, in order to accurately effect the shift of 69 millionths of an inch from one groove ruling stroke to the next, we needed to rotate our lead screw (of 40 threads per inch) accurately by increments of angle of one degree of arc.

In the prior art, two methods were commonly practiced to get such incremental rotations. One method was to mount the wheel of a worm gear combination on the screw and turn its associated worm, repetitively. The other method was to use a dividing head — a wheel with, say, 360 triangular-shaped teeth around its rim. Then an associated pawl engaged a tooth of the head to locate the angular position of the head. The wheel might thus be rotated, repetitively, one tooth of angle at a time, and then held in each position by the pawl.

Following our policy for such cases we set ourselves the task of adding at least one new method to the prior art, before we would select a plan for execution. But all of the new methods that we garnered, when later judged, proved to suffer an intolerable accumulation of errors. In contrast, the dividing head or worm wheel with an integral number of teeth around its circumference is free of accumulated error.

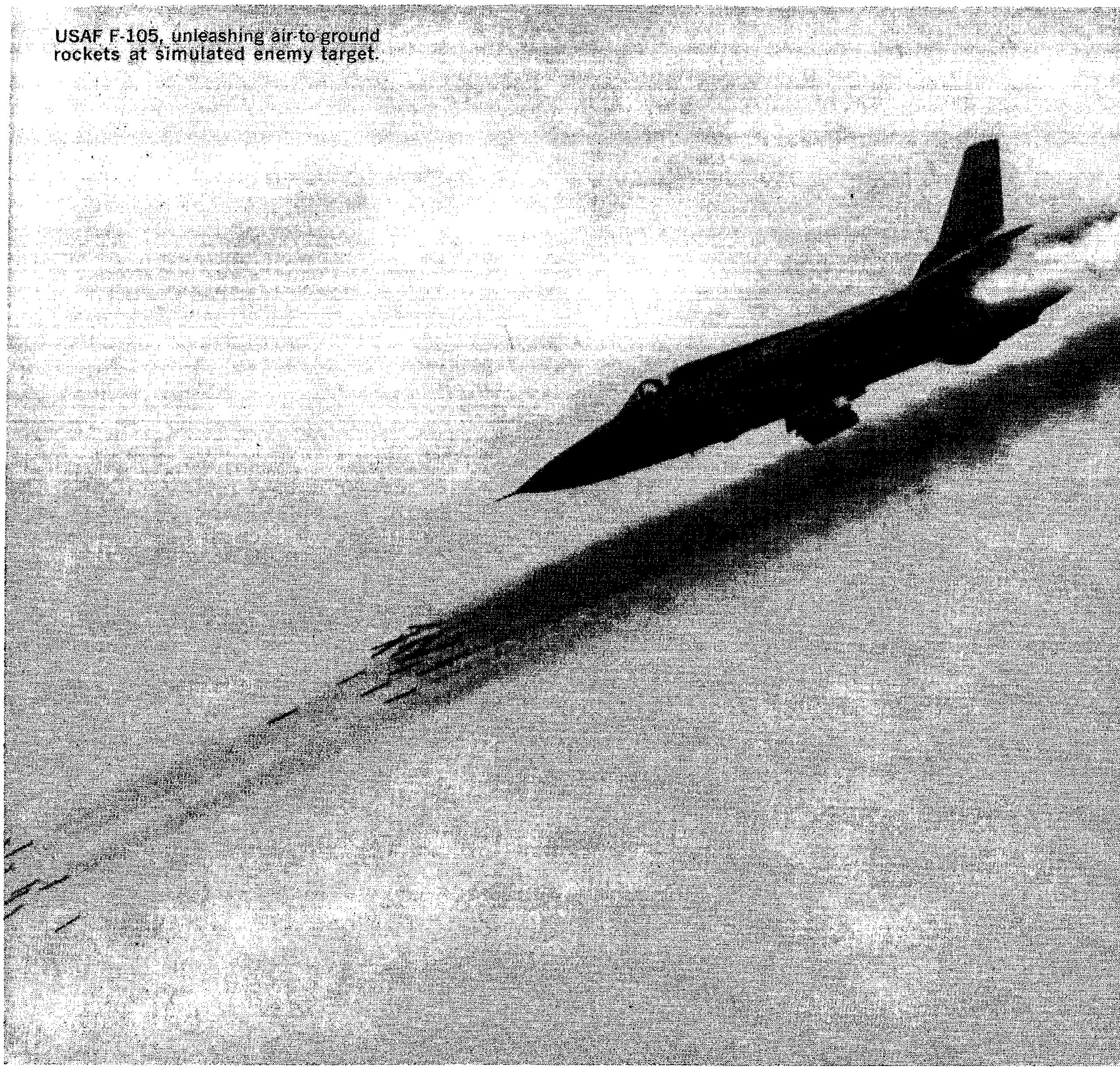
New methods

We therefore elected to use a dividing head and moved on to the problem of finding new methods of doing this.

In connection with the application of modest morphology to this new problem, we began to look for methods to mount, and to use, the dividing head that would provide equal incremental rotations irrespective of its faulty construction. This was our definition of the problem.

Proceeding to find at least one new solution to add to the commonly practiced methods, first we considered angular positioning the dividing head with not one pawl but with a pair of pawls symmetrically disposed at opposite sides of the head's circumference. They were to be spring-mounted. It is well known by surveyors, and others, that by reading a precise transit circle twice, at points separated by 180°, and averaging these readings, one gets an angle value that is free of such errors as arise if it is mounted off-center. We considered achieving this effect automatically by means of the two spring-mounted pawls. This adaptation of an old trick provided a new valid solution to the first half of our problem; and it led us to realize that we could also average out, or ignore, the individual tooth errors of an imperfectly made wheel if we used 180 pairs of such spring-mounted pawls. And this "obvious" elaboration provided a new valid solution for both halves of our problem.

Going on from there, in consideration of various means by which we could use 360 spring-mounted pawls, such as opening up and closing them like


USAF F-105, unleashing air-to-ground rockets at simulated enemy target.

the opening and closing of the petals of a flower, we came upon the terminal idea, which was to use the 360 spring-mounted pawls as 360 laps, and by this means generate a perfect dividing head.

The 360 laps were to take the form of short springs of steel, of triangular cross section. They were to be mounted for this purpose by fitting and fastening them in the teeth of a second dividing head. I call the dividing head that was intended to be perfected, the "work." I call the second head the "tool." We machined these two dividing heads so they were alike and as precise as possible.

The 360 steel springs of the "tool," when bent in slightly, and charged with a suitable abrasive compound, act as laps when they are lowered into the teeth of the "work." Consider any one of them as it rubs its way into contact with first one tooth, and then the adjacent one of the work, and so on. As this occurs, the other 359 springs will position the work, which is floated freely on an oil film. And, even if the 360th lap is not perfectly located where it should be, considering the other 359, it will, on its own favored side, still lap away more or less from any misplaced tooth in the work, according to the error of location of that tooth. Thus the teeth are all shifted, by lapping, into the positions that will yield greater uniformity of spacing. The result is that, as the lapping progresses, the teeth of the work are rapidly made free of error. And since we use hydraulic devices to control the stroke of the tool, automatically (that is, to raise the wheel with its laps, rotate it 1° between each stroke and lower it onto the floating work) this improvement of uniformity in location of the teeth, intrinsically precise, progresses automatically.

After 50 hours of unattended lapping, we found that the errors of our first wheel were reduced by an order of magnitude. Radial and tangential starting errors of a tenth of a thousandth of an inch, and a minute of arc, became, after lapping, final errors of only one or two hundredths of a thousandth of an inch, and a second of arc or two. Although this was more than adequately precise for us, there is no reason the process will not continue to far greater precision (without any exercise of skill) in instances where such greater precision will be required.

This example is typical of our experience. I doubt if we would have come upon this practical new method that perfects a dividing head without any exercise of skill if we had not applied the principles of modest morphology, or at least we would not have marched straight to it, as we did.

One of the most important tasks before us, for the future, is the construction of large transparent gratings which will cover the whole aperture of wide angle telescopes.

Fritz Zwicky, (who, with the late Professor R. W. Wood, of Johns Hopkins University, many years ago assembled the first mosaic grating for the 18-inch Palomar Schmidt telescope) thinks that the 48-inch Schmidt telescope, equipped with an efficient full-aperture transparent grating, would be more effective than all other telescopes, as far as the discovery of new celestial objects is concerned. It also would make possible the wholesale spectral analysis of millions of stars and galaxies as faint as 1/100,000, the brightness of the faintest naked-eye stars. The solution of the problems involved in the construction of such large transparent gratings, with funds that can be properly made available, again calls for the use of the morphological method. In this case, in fact, the morphological method may even be indispensable.

Alumni News

Board Elections

In accordance with Section 5.02 of the By-Laws, the Secretary, having received no further nominations, cast a unanimous ballot at the Board of Directors meeting on April 28, 1964, for the following:

President – Patrick J. Fazio, BS53Ge	(1 year)
Vice Pres. – David L. Hanna, BS52ME	(1 year)
Secretary – Donald S. Clark BS29ME, MS30ME, PhD34ME	(1 year)
Treasurer – John R. Fee, BS51CE	(1 year)
Director – James L. Adams, BS55ME	(2 years)
Director – Sidney K. Gally, BS41EE	(2 years)
Director – John L. Mason, BS47ACh, MS48ChE, PhD50ChE	(2 years)
Director – John T. McGraw, BS38ME	(2 years)

These officers and directors will begin their terms of office following the Annual Meeting, June 10, 1964. The continuing members of the Board are:

Director – Wm. H. Corcoran, BS41ACh, MS42ChE, PhD48ChE	(1 year)
Director – Richard P. Schuster, Jr., BS46EE, BS49ACh	(1 year)
Director – Herbert M. Worcester, BS40ME	(1 year)
Immed. Past Pres. – Peter V. H. Serrell BS36ME, MS39ME	(1 year)

Annual Alumni Meeting

Allen E. Puckett, vice president of the Hughes Aircraft Company, will be the speaker at the Annual Alumni Meeting to be held at the Rodger Young Auditorium in Los Angeles on June 10. The subject of his speech will be "A Look Ahead in Defense and Space Industries."

Dr. Puckett received his PhD from Caltech in 1949, and then became head of the aerodynamics department of the Hughes Guided Missile Laboratory. Now, besides being vice president, he serves as director of the Aerospace Engineering Division of Hughes. He is currently vice chairman of the Defense Science Board, one of the members of the working group of the Defense Advisory Council, and a consultant to the President's Science Advisory Committee.

The annual meeting will also feature a reunion of the classes of 1914, 1919, 1924, 1929, 1934, 1939, 1944, 1949, 1954, and 1959, and President DuBridge will give a report to the alumni. Cocktails will be served at 5:45 and dinner at 6:30 p.m.

CALIFORNIA INSTITUTE OF TECHNOLOGY — INTER-OFFICE MEMO.

To: D. Hanna & R. Nance FROM: D. S. Clark DATE: 5-6-64

SUBJECT: Alumni Fund - May Issue E & S

What would you suggest for this month's issue? We have $79,000 from 1500 alumni. Only $21,000 to go.

Don - what more can we say? We just mailed a reminder notice to all non-donors on 4-30. Dave

Let's concentrate on the 6900 who haven't given yet -

Personals

1935

ROBERT J. HALLANGER (contrary to a report which appeared in Personals, April 1964), is now vice president of Brown and Caldwell, consulting engineers, with offices located in San Francisco, San Marino, and Seattle. He was formerly director of engineering at the Fibreboard Paper Products Corporation in San Francisco.

1952

JOHN C. THOMPSON, MS, is now vice president of the Peerless Manufacturing Company in Dallas, Texas. He has been with the company for 16 years, most recently serving as sales manager and assistant general manager.

1953

LESTER D. EARNEST has been appointed associate head of the national system planning department at the Mitre Corporation in Washington, D.C. He was formerly assistant to the technical director of the defense communications agency at Mitre. The Earnests live in Fairfax, Va., with their three children.

1957

DONALD C. FORSTER, MS, PhD '60, manager of the electron device research department of the Hughes Research Laboratories in Malibu, Calif., was named the outstanding young electrical engineer for 1963 by Eta Kappa Nu, the national electrical engineering society. The award was given on March 23 at the annual convention of the Institute of Electrical and Electronic Engineers in New York City, for research activities and accomplishments in "low noise and microwave tubes and millimeter wave power sources."

JAMES D. ACORD, guidance and control project engineer for the Mariner 1964 Mars mission at JPL, shares a $1,000 award with Howard C. Vivian, JPL engineering specialist, for "outstanding contributions to space science technology." The award was given by the National Aeronautics and Space Administration for the invention, by the two men, of a space vehicle attitude control system employed on Ranger and Mariner flights.

MATTHEW S. MESELSON, PhD, will become professor of biology at Harvard University on July 1. He has been at Harvard since 1960.

1962

ROBERT KOH was killed in an automobile collision on the outskirts of Boston on March 12. He was 22.

Bob was born in China and came to the U.S. when he was two years old. In 1958 he graduated from Tarentum High School in Pennsylvania as valedictorian of his class and president of the student council. He came to Caltech on a full scholarship and served as ASCIT president in 1961-62 and also as the first president of Page House. He won three honor keys for student activities and graduated as a mechanical engineer.

At Harvard, Bob was in the top 5% of his class and was one of 28 members of his class chosen for The Century Club on the basis of intellectual and leadership ability. Bob was to have been married in June, after receiving his MS, to Miss Hsuan-i-Chiu, a student nurse at Simmons College in Boston. For their honeymoon, they had planned to go to Antigua, Guatemala, where he was one of five men chosen for a fellowship to set up a Harvard program at the University of Guatemala.

A Memorial Fund has been set up in Bob's name which will be used for the purchase of books for the Baker Library at Harvard. Contributions may be sent to Asst. Dean Richard Chapin, Morgan Hall, Harvard Business School, Boston 63, Mass.

PLACEMENT ASSISTANCE TO CALTECH ALUMNI

There are two ways in which the Placement Service may be of assistance to you:

(1) To help you seek new employment or a change of employment.

(2) To inform you when outstanding opportunities arise.

This service is provided to Alumni by the Institute. A fee or charge is not involved.

If you wish to avail yourself of this service, fill in and mail the following form:

To: Caltech Alumni Placement Service
California Institute of Technology
Pasadena, California 91109

Please send me:

☐ An Application for Placement Assistance

☐ A form to report my field and operation so that I may be notified of any outstanding opportunities.

Name .... Degree (s) ....

Address .... Year (s) ....

....

CALTECH CALENDAR

ALUMNI EVENTS

June 10
Annual Alumni Meeting

FRIDAY EVENING DEMONSTRATION LECTURES

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

May 22
The Fertilization of Eggs
—Albert Tyler

May 29
Radio Galaxies
—Alan T. Moffet

ALUMNI ASSOCIATION OFFICERS AND DIRECTORS

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Peter V. H. Serrell, '36

SECRETARY
Donald S. Clark, '29

VICE PRESIDENT
Patrick J. Fazio, '53

TREASURER
John R. Fee, '51

Robert Boykin, '34
Wm. H. Corcoran, '41
David L. Hanna, '52
Wm. L. Holladay, '24
G. Russell Nance, '36
Richard W. Powell, '40
Richard P. Schuster, Jr., '46
H. M. Worcester, Jr., '40

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Electronic Energy Conversion Corp.
342 Madison Ave., Now York 17, N.Y.

Vice-President — Bruno H. Pilorz, '44
75 Echo Lane, Larchmont, N.Y.

Secretary-Treasurer — Harry J. Moore, '48
590 Madison Ave., New York, N.Y.

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21 Seven Oaks Rd., N. Billerica, Mass.

Vice-President — Thomas C. Stockebrand, '53
10 Bulkely Rd., Littleton, Mass.

Secretary-Treasurer — Charles K. Daniels, '59
8 Cutler Farm Rd., Lexington, Mass.

WASHINGTON, D.C. CHAPTER

Chairman — Willard M. Hanger, '43
4720 Sedgwick St., N.W., Washington, D.C.

CHICAGO CHAPTER

President — Laurence H. Nobles, '49
Dept. of Geology, Northwestern Univ., Evanston, Ill.

Vice-President — Philip E. Smith, '39
Eastman Kodak Co., 1712 Prairie Ave., Chicago, Ill.

SAN FRANCISCO CHAPTER

President — Edwin P. Schlinger, '52
G.E. Vallecitos Atomic Lab., Pleasanton, Calif.

Vice-President — Dallas L. Peck, '51
U.S. Geological Survey, Menlo Park, Calif.

Secretary-Treasurer — Thomas G. Taussig, '55
Lawrence Radiation Lab., Univ. of Calif., Berkeley, Calif.

Meetings: 15th Floor, Engineers' Club, 206 Sansome St., San Francisco
Informal luncheons every Thursday at 11:45 A.M.
Contact Mr. Farrar, EX 9-5277, on Thursday morning for reservations.

SACRAMENTO CHAPTER

President — Dudley E. Bennett, '47
4535 Marble Way, Carmichael, Calif.

Vice-President — Harris K. Mauzy, '30
2551 Carson Way, Sacramento 21, Calif.

Secretary-Treasurer — William D. Pyle, '49
3920 Dunster Way, Sacramento, Calif. 95825

Meetings: University Club, 1319 "K" St.
Luncheon first Friday of each month at noon.
Visiting alumni cordially invited—no reservation.

Advancement in a Big Company: How it Works

An Interview with General Electric's C. K. Rieger, Vice President and Group Executive, Electric Utility Group

C. K. Rieger

■ Charles K. Rieger joined General Electric's Technical Marketing Program after earning a BSEE at the University of Missouri in 1936. Following sales engineering assignments in motor, defense and home laundry operations, he became manager of the Heating Device and Fan Division in 1947. Other Consumer-industry management positions followed. In 1953 he was elected a vice president, one of the youngest men ever named a Company officer. Mr. Rieger became Vice President, Marketing Services in 1959 and was appointed to his present position in 1961. He is responsible for all the operations of some six divisions composed of 23 product operations oriented primarily toward the Electric Utility market.

Q. How can I be sure of getting the recognition I feel I'm capable of earning in a big company like G.E.?

A. We learned long ago we couldn't afford to let capable people get lost. That was one of the reasons why G.E. was decentralized into more than a hundred autonomous operating departments. These operations develop, engineer, manufacture and market products much as if they were independent companies. Since each department is responsible for its own success, each man's share of authority and responsibility is pinpointed. Believe me, outstanding performance is recognized, and rewarded.

Q. Can you tell me what the "promotional ladder" is at General Electric?

A. We regard each man individually. Whether you join us on a training program or are placed in a specific position opening, you'll first have to prove your ability to handle a job. Once you've done that, you'll be given more responsibility, more difficult projects—work that's important to the success of your organization and your personal development. Your ability will create a "promotional ladder" of your own.

Q. Will my development be confined to whatever department I start in?

A. Not at all! Here's where "big company" scope works to broaden your career outlook. Industry, and General Electric particularly, is constantly changing — adapting to market the fruits of research, reorganizing to maintain proper alignment with our customers, creating new operations to handle large projects. All this represents opportunity beyond the limits of any single department.

Q. Yes, but just how often do these opportunities arise?

A. To give you some idea, 25 percent of G-E's gross sales last year came from products that were unknown only five or ten years ago. These new products range from electric tooth brushes and silicone rubber compounds to atomic reactors and interplanetary space probes. This changing Company needs men with ambition and energy and talent who aren't afraid of a big job—who welcome the challenge of helping to start new businesses like these. Demonstrate your ability—whether to handle complex technical problems or to manage people, and you won't have long to wait for opportunities to fit your needs.

Q. How does General Electric help me prepare myself for advancement opportunity?

A. Programs in Engineering, Manufacturing or Technical Marketing give you valuable on-the-job training. We have Company-conducted courses to improve your professional ability no matter where you begin. Under Tuition Refund or Advanced Degree Programs you can continue your formal education. Throughout your career with General Electric you'll receive frequent appraisals to help your self-development. Your advancement will be largely up to you.

FOR MORE INFORMATION on careers for engineers and scientists at General Electric, write Personalized Career Planning, General Electric, Section 699-11, Schenectady, N. Y. 12305

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