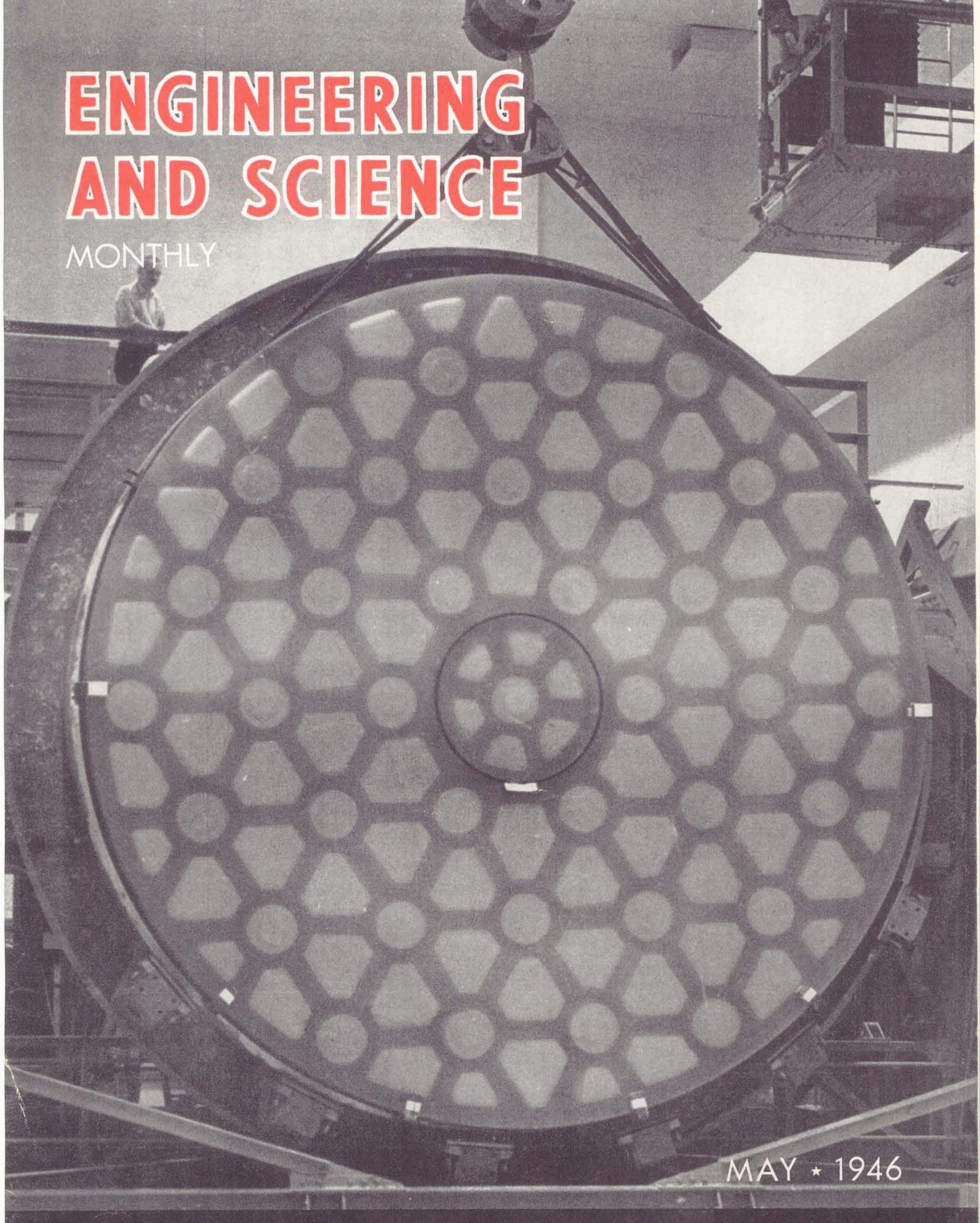
ENGINEERING AND SCIENCE

MONTHLY



MAY ★ 1946

PUBLISHED BY CALIFORNIA INSTITUTE OF TECHNOLOGY ALUMNI ASSOCIATION

BY-LINES

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Frederick C. Lindvall received his B.S. degree from the University of Illinois in 1924 and his Ph.D. in Electrical Engineering from California Institute of Technology in 1928. After two years with the General Electric Company at at Schenectady, he returned as an Instructor in Electrical Engineering at the Institute and later became Professor of Mechanical and Electrical Engineering. During the war he worked on rocket and underwater ordnance problems for a Caltech O.S.R.D. project. In September, 1945, he was appointed Chairman of the Division of Civil and Mechanical Engineering and Aeronautics.

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FRANK W. DAVIS

After graduating from California Institute of Technology in 1936, Frank W. Davis joined the U. S. Navy Reserve for flight training at Pensacola, Florida. Upon completion of that training he was commissioned as a regular officer in the U. S. Marine Corps. After serving three years in fighter and dive bomber squadrons, he joined Vultee Aircraft, Inc. (later to become Consolidated Vultee Aircraft Corporation) as a flight test engineer. Subsequently, he became engineering test pilot, chief of aerodynamics and flight test, and assistant chief development engineer.

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HORACE N. GILBERT

Professor Gilbert was graduated from the University of Washington with an A.B. degree in 1923. He received his M.B.A. at Harvard School of Business in 1926, remaining there to teach for three years. In 1929, Professor Gilbert joined the faculty of the California Institute of Technology, taking leave first in 1940 to return to Harvard as visiting lecturer in Industrial Mobilization, and again in 1942 to go to Wright Field as a civilian in the capacity of principal production supervisor. In March, 1945, Professor Gilbert returned to the Institute, but in May of that year he accepted a four-month appointment to the United States Strategic Bombing Survey in Europe.

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Cover Caption:

Work on the giant 200-inch Palomar telescope has now been resumed in the laboratories of C.I.T. Palomar Mountain, 125 miles distant from Pasadena by road, was the site selected from more than a dozen studied and investigated during a period of two years. In addition to the astrophysical laboratory, there will be dwellings for the astronomers and their families, smaller observatory housings for the three "pilot" Schmidt telescopes, Diesel-power facilities, a water system and fire protection, radio communication and an airplane landing field for handy commuting to Pasadena in the new star-studying community now nearing completion in San Diego County.

ENGINEERING AND SCIENCE
Monthly

The Truth Shall Make You Free

CONTENTS FOR MAY, 1946

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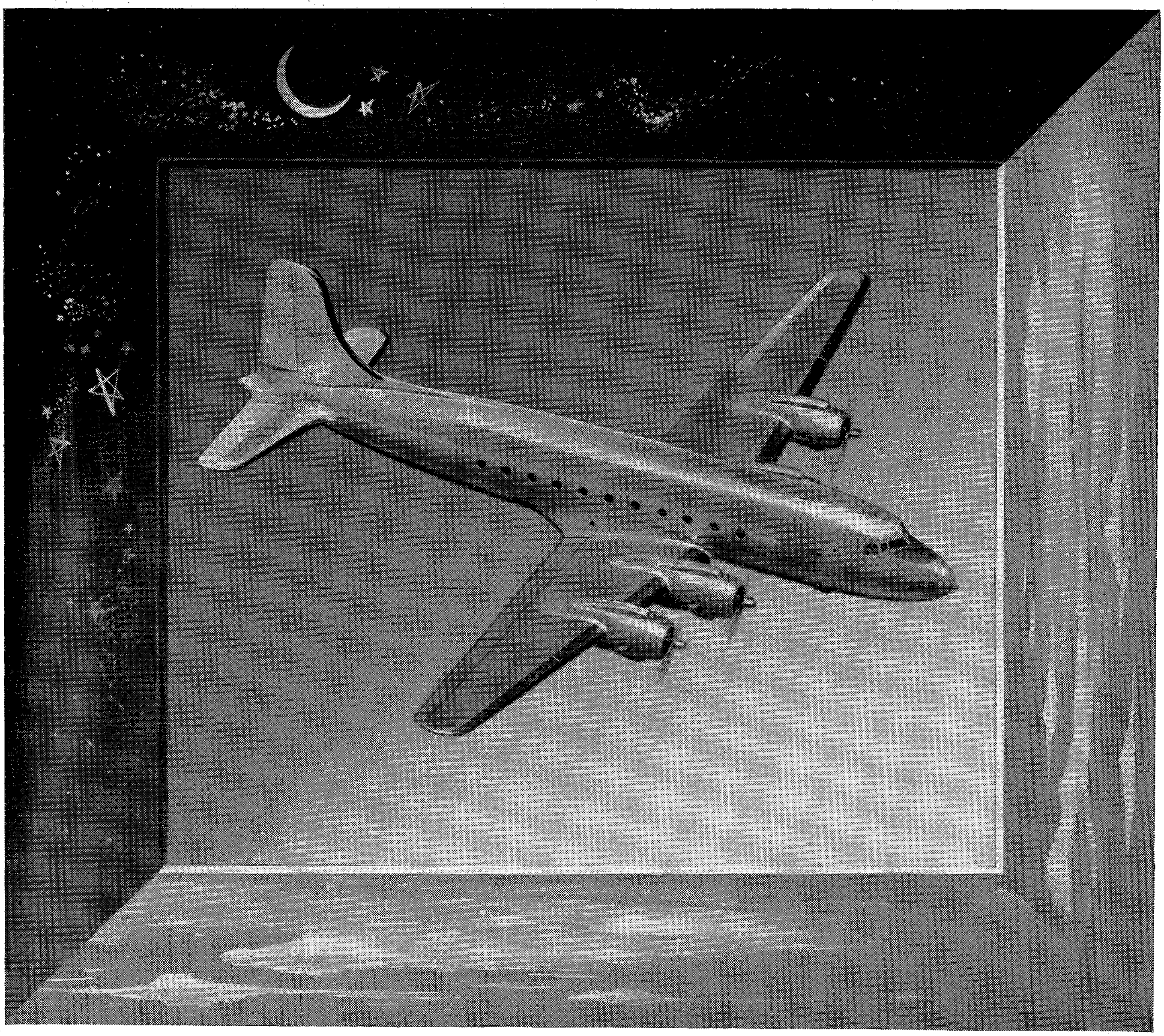
ENGINEERING AND SCIENCE MONTHLY

Edited at California Institute of Technology

ENGINEERING AND SCIENCE MONTHLY is published monthly on the 25th of each month by the Alumni Association California Institute of Technology, Inc., 1201 East California Street, Pasadena, California. Annual subscription $3.50; single copies 35 cents. Entered as second class matter at the Post Office at Pasadena, California, on September 6, 1939, under the Act of March 3, 1879.



ENGINEERING AND SCIENCE
Monthly

Vol. IX, No. 5 May 1946

NEW PRESIDENT OF C. I. T.

DR. LEE A. duBRIDGE

AT a meeting of the Institute faculty, May 13, 1946, James R. Page, chairman of the board of trustees, announced the election of Dr. Lee A. DuBridge, 45, to the presidency of the California Institute of Technology. Dr. DuBridge succeeds Dr. Robert A. Millikan, vice president of the board of trustees, whose retirement as president last August left the Institute without a head.

Mr. Page stated that the trustees were keenly aware of the educational problems and the increased responsibility that would face the Institute during the period of postwar readjustment in an era when science and technology will inevitably have a more profound and immediate effect on the life of the community and the nation. "Our institution and the whole southern California community are indeed fortunate," said Dr. Page, "that Dr. DuBridge is willing to assume the leadership of the California Institute of Technology. Dr. DuBridge is not only an internationally known scientist, but an experienced and successful administrator as well. His work as director of the Radiation Laboratory at the Massachusetts Institute of Technology, where he headed a large section of the great radar development, has amply demonstrated his capacities."

A native of Indiana, Dr. Dubridge was graduated from Cornell College, Iowa, in 1922, and continued training in his chosen field of physics at the University of Wisconsin, where he received the degree of Doctor of Philosophy in 1926. He is no stranger to the California scene or the California Institute of Technology. From 1926 to 1928 he pursued his researches in physics at the Institute as a Fellow of the National Research Council, having elected to come here in order to work with and under Dr. Millikan. In 1928 he went to Washington University in St. Louis as assistant professor of physics, later becoming associate professor.

In 1934 Dr. DuBridge was called to Rochester University as Harris Professor of Physics and chairman of the department. He also served as dean of the faculty from 1938 to 1942.

His outstanding reputation as a scientist and his proved administrative capacity led to his being chosen in November, 1940, to head the Radiation Laboratory then being established by the National Defense Research Committee at the Massachusetts Institute of Technology. He served as director of the laboratory, on leave of absence from the University of Rochester, until his return to the faculty of that institution on February 14, 1946.

The Radiation Laboratory was set up to develop radar for military purposes. The success of that work and the crucial part which radar played in winning the war are now a familiar story. The work of the laboratory played the decisive role in maintaining clear supremacy in radar over the enemy countries by difficult and intensive research and development, by crash procurement of apparatus, by personnel training and by assistance and advice at the front.

As director of the Radiation Laboratory, Dr. DuBridge supervised the work of 3,900 persons, and handled a budget of some $4,000,000 a month. Radar equipment developed directly by the laboratory went into production for the armed forces to the extent of two billion

(Continued on Page 13)

Engineering Research and the Colleges

By F. C. LINDVALL

ENGINEERING research is a term which is loosely applied to a wide variety of projects, ranging from mere acceptance testing of a manufactured gadget to very fundamental studies leading to new data, indistinguishable from work normally called "science". By definition, engineering consists of the application of known principles of science to specific problems or devices, with the result that engineering research frequently tends toward development work which is in a sense engineering design. In this type of development the function of engineering research is to eliminate, as far as possible, the "factors of ignorance" in the design.

The demands of modern industry and transportation have required machine designers to "sharpen their pencils". Higher operating speeds, greater pressures, economy of weight and cost, improved efficiencies, all have forced designers into intensive study of stresses, new materials, analyses of vibration and dynamic loading, and new manufacturing techniques. These more difficult specifications require of the designer a better comprehension of fundamental principles, particularly in the field of Applied Mechanics. New data must be found, and refined instrumentation must be developed, both for obtaining the necessary design information and for analyses of performance of test equipment.

OPPORTUNITIES

Industrial research is generally undertaken with the purpose of attaining specific objectives and particular developments, whereas the engineering colleges have many opportunities for fundamental research directed toward improvements adaptable by industry in general.

The gas turbine is an instructive example of engineering research and development. In principle and practical use the gas turbine is old. Its development as a complete working unit is a major industrial project that is not suitable for a college to undertake. However, the improvements which are needed for extensive acceptance of the turbine by industry today lie in the fields of combustion, heat transfer, materials, machine design, and fluid mechanics. An engineering college could make substantial contributions in any or all of these basic fields: through a better understanding of the combustion process with a variety of possible fuels, through heat transfer studies and modifications of the basic thermodynamic cycle, by metallurgical improvement in the materials of the turbine, by aerodynamic studies of the flow problems involved, and by mechanical design directed toward higher performance and reduced cost. Results useful not only to the turbine design, but to other applications as well, should accrue.

SCOPE OF ACTIVITIES

Research in the engineering colleges, however, is not confined to the advancement of scientific knowledge. It has a number of other important functions. In the training of college students for work in modern engineering, it is most desirable to maintain a creative environment: research work is a stimulus to the students as well as to the staff members, and for worthwhile graduate work it is a necessity. A good research program requires collaboration with other research groups, both academic and industrial, with a resultant influx of new ideas and inspiration. Moreover, on a particular campus research engineers will be in much closer touch with their faculty colleagues who are doing investigations in related fields of chemistry, physics, and mathematics, with the result that some of the unfortunate departmental isolation which has existed in the past will tend to disappear. As demonstrated by war project work, the line between physics and engineering is indefinite, if not non-existent. As future applications of nuclear energy are studied, the engineers working in this field will require more knowledge of atomic and nuclear physics, and the physicist in turn will need more engineering assistance in apparatus design and development.

In such applications as servo-control systems, the combination of electrical, mechanical, and hydraulic elements involves engineering in a broad sense, and the analysis of servo-systems, with the associated feedback amplifier theory, is precisely the type of advanced work in engineering study and research that colleges should provide.

LIMITATIONS OF RESEARCH

Colleges will advisedly restrict research to that best suited to their particular facilities in personnel and equipment, and the work to a large extent should be fundamental. Too often college laboratories become loaded with testing work of routine character which provides little in the way of new information or inspiration for the better students.

Whenever a college has laboratory equipment which is unique, such facilities should be made available to the community and to industry, as a service. In return, outside sponsorship should be encouraged for related basic engineering studies which may have no immediate application. For example, at the California Institute of Technology unusual facilities exist for the study of physical properties of materials under rapid loading. The directors of this laboratory were asked to undertake an extensive series of tests on specimens of a particular steel which had been subjected to various kinds of heat treatment. The proposal as presented involved only test work of routine nature; but as modified at the request of the Institute, the program was broadened into a research activity which should give not only the specific information on how the material behaves, but also on why.

SUPPORT

The lack of adequate support for engineering research in colleges has always been a serious limitation. Unfortunately, a good deal of the desirable work to be done requires test equipment and facilities which are expensive, as relative to apparatus necessary for good work in some of the basic sciences. Most college budgets can support only a limited amount of engineering research, so that outside support must be sought from industrial and governmental groups. This type of support automatically brings the collaboration with outside laboratories and application engineers which, as mentioned above, is one of the objectives of engineering research in colleges.

The impetus given to research by the war will be maintained to a considerable degree in both governmental and industrial activities. Not only will new problems arise in which the colleges can be effective as research

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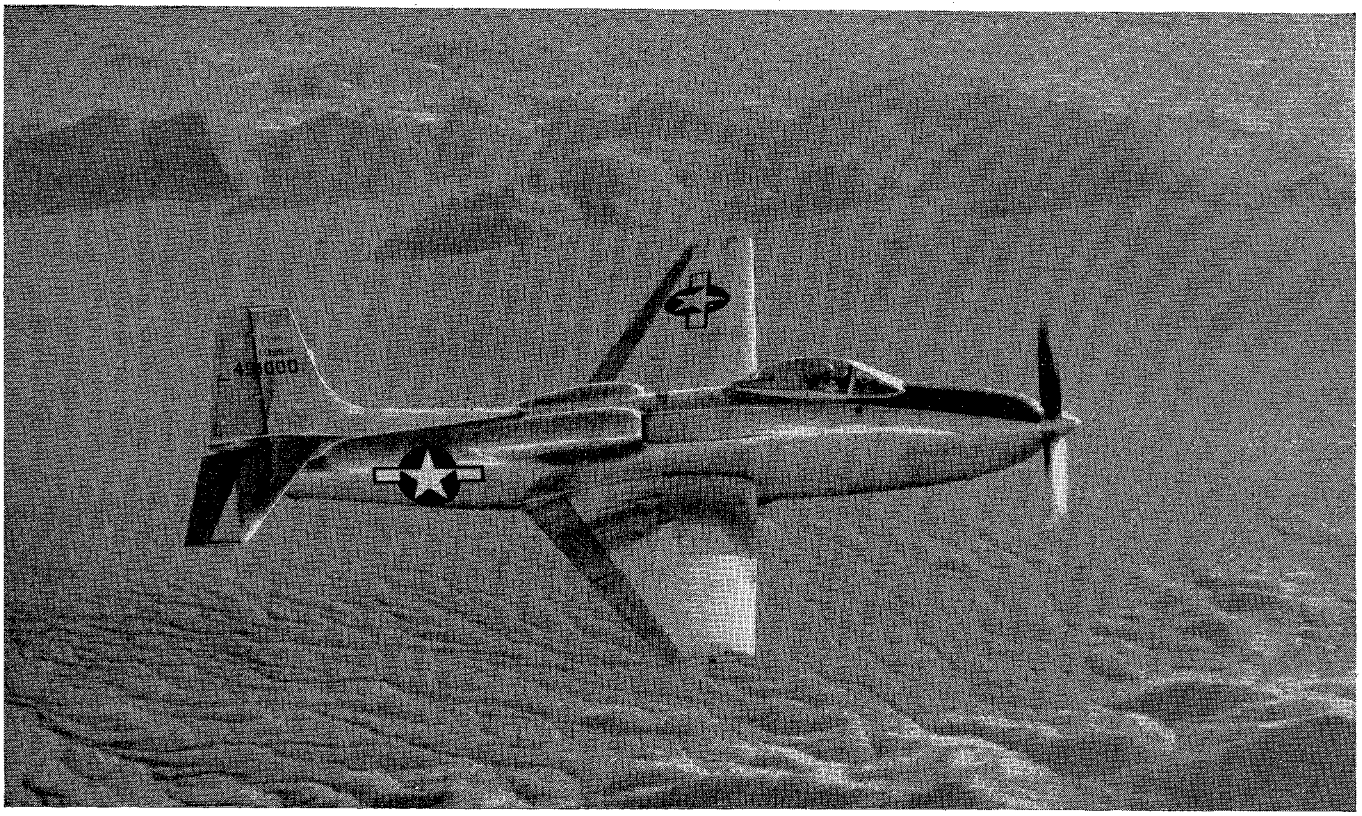


FIG. 1. The XP-81 shown above is the Army's latest fighter. Designed to escort B-29's on long range missions, it utilizes a gas turbine driving a propeller for cruising, plus a pure jet gas turbine for take-off and combat.

FLIGHT TEST

By FRANK W. DAVIS

THE purpose of this article is to present a brief, comprehensive picture of flight test activity. Better reading might be provided by describing the true flight test history of some particular airplane, but not until military restrictions are lifted can this be done.

My reason for wishing first to present a picture of the job of flight testing is that I believe no such picture to be now available and, furthermore, I feel that most of the articles appearing in popular periodicals have tended to build up in the mind of the reader an altogether false picture of the aims and methods of the flight testing profession.

The subject of flight testing covers a broad field. There are almost as many different types of testing as there are testing agencies. Each has its own particular objectives and requirements. For example, the National Advisory Committee for Aeronautics (NACA) maintains flight test groups who conduct tests for the purpose of studying new aerodynamic developments, correlating wind tunnel and flight test data, and also to meet the special requests for information made by the Army and Navy. They also maintain flight test groups to determine compliance of new airplanes with contract specifications, to test new equipment and new tactics, and to carry out a host of other jobs. The Civil Aeronautics Authority maintains flight test facilities for licensing aircraft, studying safety measures, etc. Some manufacturers of aircraft engines and equipment maintain flight test staffs for studying their special problems.

In addition to these, each of the aircraft manufacturing companies maintains its own flight test groups. The manufacturers' testing includes two general types: production testing and experimental testing.

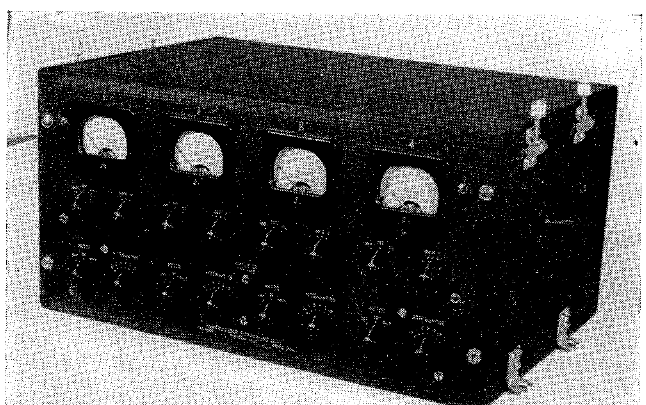


FIG. 2. Type I-106 amplifier.

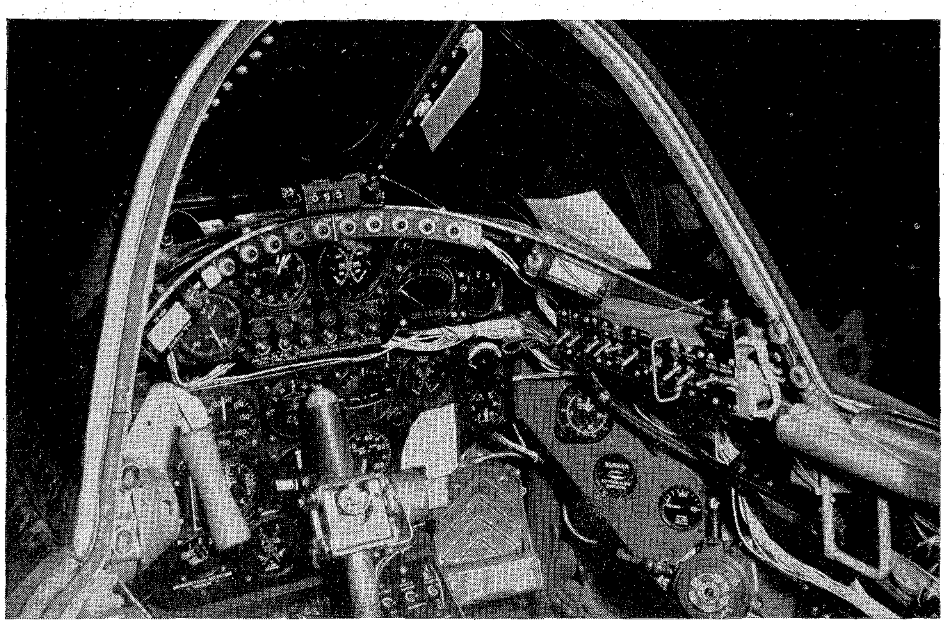


FIG. 3. Cockpit showing part of special instrumentation.

PRODUCTION TESTING

Production testing normally consists of flying for a specified length of time, each airplane which comes off the assembly line in order to make necessary checks and adjustments in preparation for turning the airplane over to the customer. The airplanes are usually flown in a normal manner through a carefully planned routine which includes a complete functional test of the airplane and its equipment.

In spite of mass production methods, changes sometimes occur in design, materials, or workmanship, which may alter flight charcteristics. With the tremendous expansion of production facilities, the introduction of new methods, and the wide use of sub-contracting and inexperienced personnel, it was not uncommon during the war to discover that an apparently small change which had been made in some plant to facilitate production had markedly affected the aerodynamic characteristics of the airplane. In cases where these things eluded the persons who might have foreseen the trouble, their manifestations contributed to keeping the lives of the production test crews from becoming too dull.

While production testing constitutes the major portion of the manufacturers' flight test hours, it is in the category of experimental flight testing that the bulk of engineering work lies. It is with experimental testing that the remainder of this discussion will deal.

EXPERIMENTAL TESTING

Before going into any of the details of experimental flight testing, it may be well to lay down the primary objectives of such a testing program. Normally, the first objective is to bring a new airplane to a state of development where production can safely be started, and where the prototype can be turned over to the customer for his approval. This requires a careful exploration of the limits of safety of the airplane as well as a determination of its normal flight characteristics, its performance, and the satisfactory functioning of its power plant and equipment. After production has started, changes in design are often found to be necessary or desirable. These, likewise, must be thoroughly tested and developed before they can be applied. The second objective of experimental testing is to increase the background of engineer-

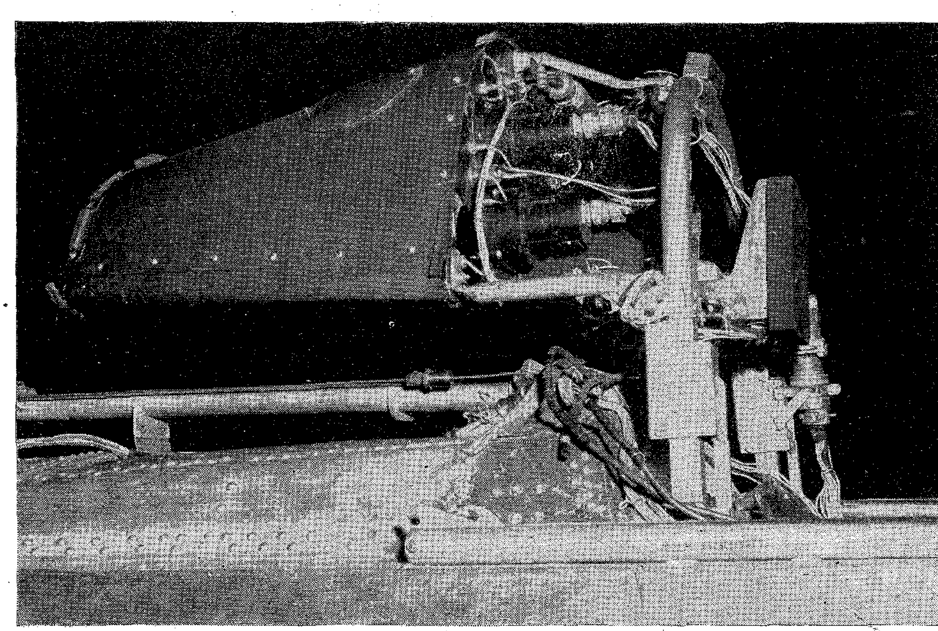


FIG. 4. Photo recorder for installation in canopy.

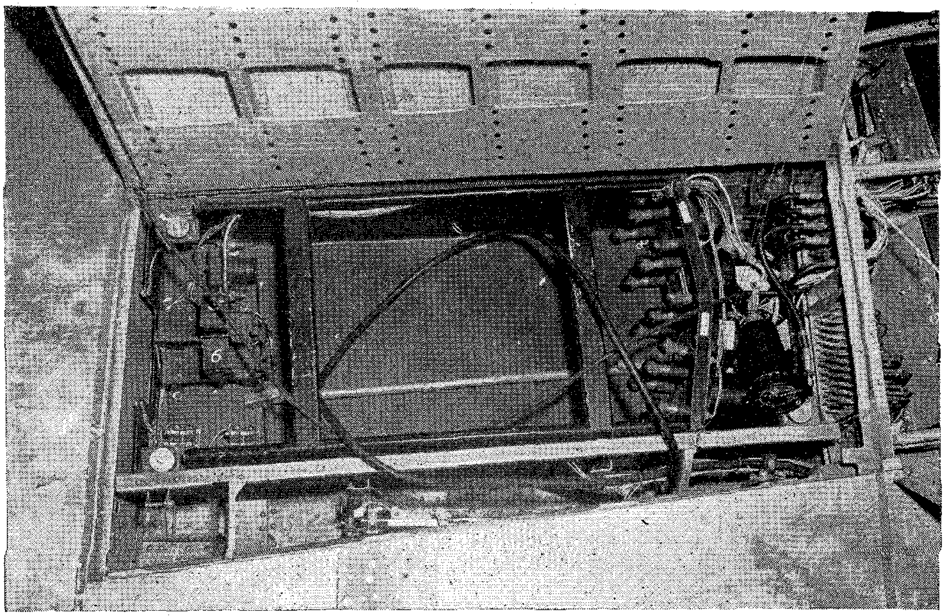


FIG. 5. Wing installation photo recorder.

ing knowledge by correlation of flight test results with calculations and the results of simulated tests, such as wind tunnel tests, static load tests, equipment tests, etc., in order to make future airplanes better.

The work of the flight test group begins long before an airplane is ready to fly. Even during the preliminary design stages, information concerning previous airplanes will be selected from the flight test files in order to help solve the design problems arising on a new airplane. What was particularly good about a former airplane? Why was it good? How can that feature be incorporated in the new one? What things have given trouble? How can similar trouble be avoided? These are questions which the flight test group should be able to answer.

Several months prior to the initial flight the work immediately connected with flight testing begins. By this time the airplane has begun to take shape. If it is a pursuit, for example, people are probably calling it the *XP* and are getting a little impatient to see it fly. Nevertheless, several months of hard work remain before there will be much daylight between the runway and the wheels. At this time it is necessary for the flight test group to crystallize its ideas and to outline a tentative test program which will tell what is to be tested, what things must be measured, and how they can be measured.

MEASUREMENTS

With any scientific test the problem of measurement is of high importance, as is also the problem of recording measurements. In the *XP* the problem is doubly complicated for several reasons. The airplane is almost completely filled with engine, guns, fuel, radio, and other equipment, and the few small spaces left are not necessarily accessible. The instruments used may be subject to changes in atmospheric temperature from 120 degrees F. to —60 degrees F. and to changes in atmospheric pressure from around 15 pounds per square inch to 3 pounds per square inch. They will be subjected to the vibration which is bound to result from hanging several thousand horsepower on a structure which is light enough to fly, and to an acceleration which may vary from —130 feet per second per second to 250 feet per second per second.

The problem of recording has the added complication that the only fellow available to operate and observe all

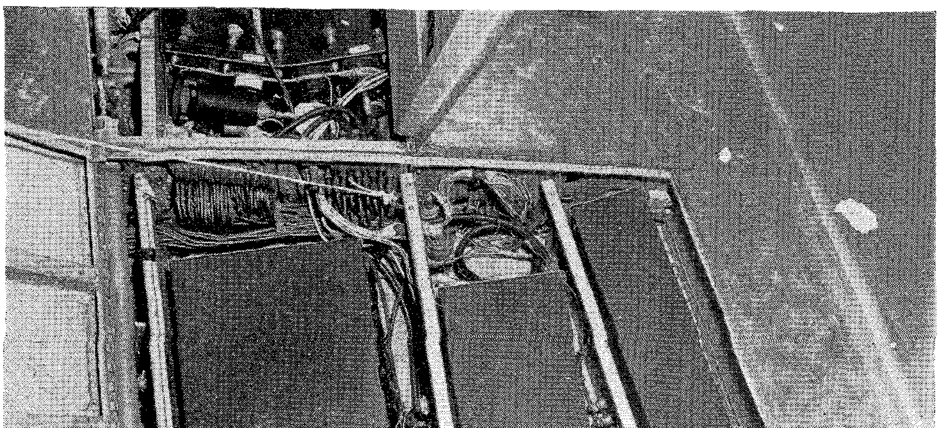


FIG. 6. Wing installation of oscillograph amplifiers.

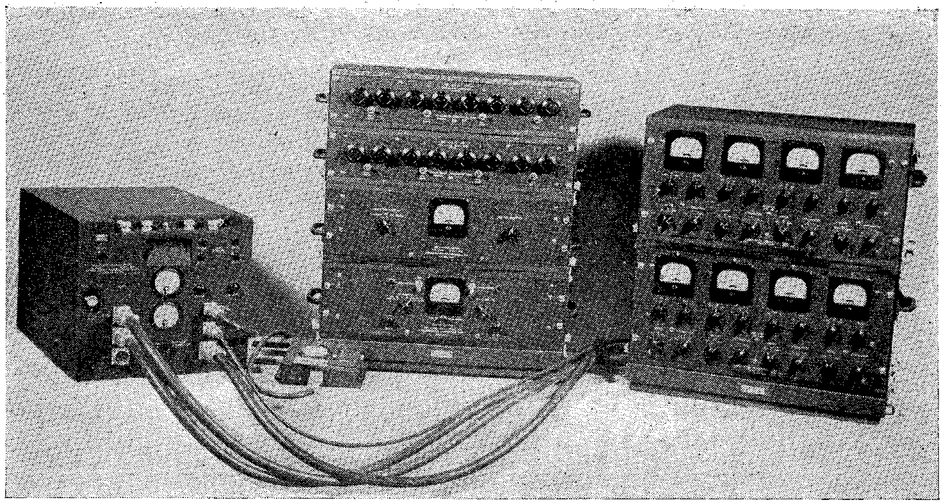


FIG. 7. Vibration and strain measuring equipments.

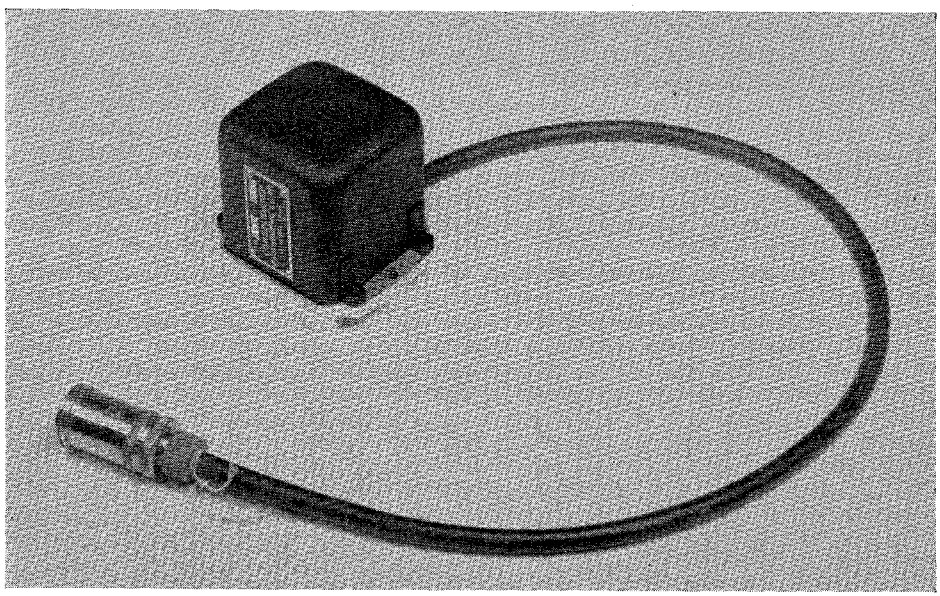


Fig. 8. Type 4-101 accelerometer.

of these instruments is the pilot who, even in the normal course of flying a modern pursuit, is not particularly famous for having nothing to do.

A glance at the items to be measured shows that the instruments can be grouped into relatively few types. Temperatures, pressures, angles, forces, time, and acceleration, constitute the bulk of instrumentation, plus some other special items, such as rate of fuel flow, stresses, and frequency and amplitude of vibration.

The temperature measurements serve partially to define the atmosphere in which the airplane is operating and to tell whether the engine is receiving the correct cooling, the cockpit the correct heating, etc. The greater part of temperature measurement in aircraft is done by thermocouples, and some very clever equipment has been developed for automatically recording the output of a large number of thermocouples.

The measurement of pressures serves further to define the atmosphere, and in addition is used to measure airplane speed, air flow through ducts and around the engine, and to deal with numerous other items such as oil and fuel pressure, engine power, etc. Pressure gages, either recording or direct reading, are preferred for aircraft work, but under carefully controlled circumstances manometers can be used to good advantage. Photographic methods of recording are usually employed.

The measurement of forces and angles is of itself not a difficult procedure, but the transfer of the measurement from, say, a wing tip to the cockpit or a recording instrument in an airplane is more difficult. The fact that the wing may deflect several inches, or even several feet, under load, rules out any transfer of measurement mechanically or by light beams. The method in most common use now for transferring angular measurements from the source to the place of reading or recording is that of the Selson or Autosyn transmitter. Forces are generally measured as spring deflections, which may be transmitted in the same manner as angles. Considerable work is being done with strain gages for force measurement, and the method holds much promise.

Acceleration is generally measured by its effect on a mass suspended by a spring.

Photographic recording is probably the most widely used method at the present time, but much work is being done along other lines, such as the recording on the ground of signals sent out by radio from the airplane's measuring instruments (telemetering). This process is probably the most promising development in the whole field. By its use it has been possible to record actual data occurring under the most violent flight conditions in airplanes, and even in rockets and projectiles. One of the main drawbacks to this equipment is the limited number of channels which can be broadcast simultaneously.

After the decisions have been reached as to what things are to be measured, and how, the construction and installation of the instrumentation are begun. Most of the work should be finished by the time the airplane is ready to fly. In the meantime considerable work will have been done in gathering information about the airplane, its power plant and equipment, and in formulating a complete program for the testing.

THE PROGRAM

The program will probably be laid out with the following objectives, in order of priority:

1. To correct any flight or power plant characteristics which would be dangerous to further flying.
2. To obtain a power plant installation which is safe to operate at maximum power.
3. To obtain sufficient performance information to evaluate the airplane's worth.

4. To determine accurately the flight characteristics and correct as many unsatisfactory items as practicable.
5. To make final power plant installation and performance checks after all changes have been completed.
6. To explore the absolute limits of safety in so far as diving speed and pullout severity are concerned.

Work toward the completion of this program starts with the initial flight and normally continues through several score flights.

One of the big problems of any scientific investigation is the elimination of uncontrollable variables from the experiments. The number of variables possible in an airplane is almost unlimited, and continuous and close cooperation is necessary between the pilot and the flight test engineers in order to reduce them to a minimum. At best, considerable detective work is necessary in order to track down the problems which arise. A fairly straightforward example of this type of sleuthing occurred a few years ago in connection with a serious vibration problem. The pilot was able to determine that there were two types of vibration superimposed on one another: first, a pitched vibration of high frequency which was a function of engine RPM, and, second, an unpitched vibration which was apparently a function of power. It was determined that the pitched vibration was caused by resonance of the propeller blades and engine. This was corrected by cutting a few inches off the end of the propeller, thereby changing its vibrational frequency. By use of a recording oscillograph and vibration pickups at several points on the plane it was found that the unpitched vibration was caused by the effect of the engine exhaust on the tail of the airplane. This was then eliminated by changing the shape of the exhaust outlet.

By far the greatest part of experimental flight testing is concerned with the solution of problems such as this, plus the determination of performance and the refinement of flight characteristics.

BETTER PLANES VERSUS HEADLINES

The so-called "heavy performance" has received much attention, because it lends itself to sensational presentation. The general public has been led to believe that the intrepid test pilot climbs into the prototype airplane, "gives it the gun", climbs immediately to the airplane's ceiling, comes screaming back down in a vertical dive, tries valiantly to pull the wings off, lands, lights a Camel, and turns the plane over to the Army.

Actually, nothing could be farther from the fact. Most of the pilots involved in experimental testing are relatively old-timers, who didn't get that way by the above procedure. Many of them are first-class engineers whose interest in flying is in making better airplanes and not headlines. Many have families and have no intention of collecting their insurance at an early age. And finally, most of them are acutely aware of the irreplaceable work and time which go into a prototype airplane.

Actually, the "heavy performance", such as the initial flight of a new prototype, the dives, pullouts, and spins, is approached with a tremendous amount of caution and patience. In every case the limits of safety are explored by progressing toward them in small steps, meanwhile keeping accurate records of all critical items possible, and using them, by extrapolation, to predict the results of each succeeding step before it is taken.

In the case of the initial flight, runs along the ground are made at successively increasing speeds up to take-off speed. During each of these runs the pilot "feels out" the various control characteristics of the airplane and endeavors to predict whether or not the airplane can be handled at a higher speed. This process may take several days or even several weeks, if airplane changes are necessary, before it is finally decided that full flight can be safely accomplished. Incidentally, this process is a telling test of a pilot's patience. Normally there is considerable pressure to fly the airplane as soon as possible. This comes from everyone interested, including the pilot, and the temptation is very great to say, "To hell with this fiddling, let's get the thing over with." However, in cases such as this, remembering the old adage helps a great deal: "There are Old Pilots, and there are Bold Pilots, but there are no Old Bold Pilots."

In the case of dives and pullouts where the airplane is being tested to the calculated limits of its strength, it is felt that radio recording and radio control will eventually replace the pilot. This would certainly be the economical way to do the job. It is sometimes hard for the civil or mechanical engineers to become reconciled to the fact that the airplane is stressed to yield at just above its maximum flight load, with no safety or ignorance factor. Such practice is absolutely necessary in the interest of lightness, but it means that failures sometimes occur which may very well produce disastrous results. Since a good engineering pilot represents a rather expensive and scarce piece of test equipment, it is felt that considerable saving can and will be accomplished by carrying out these tests initially in radio-controlled airplanes.

DEVELOPMENT AND APPROVAL

In this discussion, full justice has hardly been done the job of flight testing. It is actually the most interesting job in aviation. It is truly a rare privilege to be "the first by which the new is tried" when "the new" is a piece of equipment which represents the combined efforts of several hundred of the best engineers and artisans in the world.

Undoubtedly the perfect airplane will never be built, and as long as this is true the flight test crew should continue to have the first word in pointing the way for improvement and the last word in accepting each improvement.

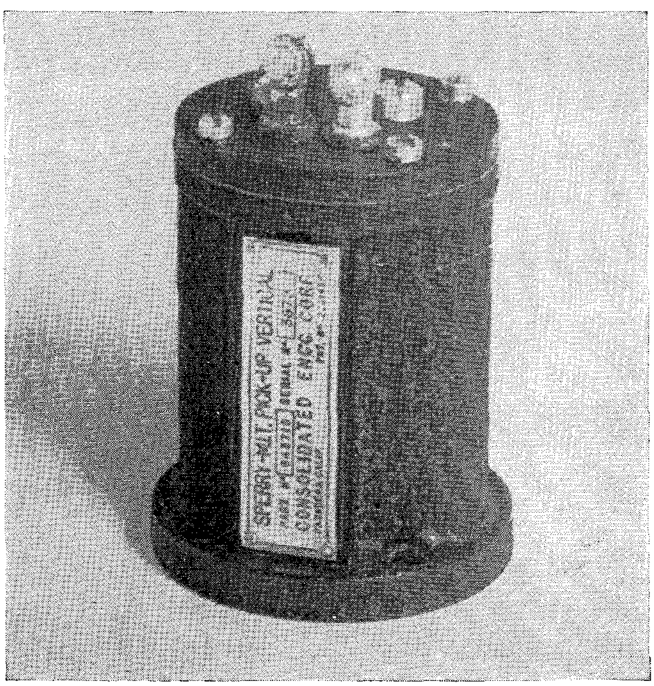


FIG. 9. Type 4-106 linear pickup.

The Air Offensive Against Germany

By HORACE N. GILBERT

WE now have a good idea of the effectiveness of Allied strategic bombing on German war industries and population centers. By field surveys in Germany, by interrogation of German industrial leaders and governmental officials, and by analysis of captured records and documents, it is possible to focus the brilliant light of hindsight on that large portion of our war effort. The findings are significant, not as a basis for criticism of the conduct of the war against Germany, but as a means of studying the way in which a modern industrial economy stands up under such attack.

As a summary observation, three facts stand out: 1) Allied bombing wreaked terrific physical damage on Germany, including its industrial targets; 2) Industrial production, especially of war goods, increased significantly during and immediately after our heaviest bombing attack; and 3) German industry eventually did collapse, but not until so late that the breakdown could well be attributed in large measure to the arrival of Allied troops. These conclusions are an urgent challenge to determine just what happened. The lessons are important, not only for purposes of historical reference, but because they throw light on our own problem of industrial planning in a world of nations that have not yet learned to live together in peace.

THE AIR OFFENSIVE AGAINST GERMANY

The Combined Bombing Offensive by the American and British Air Forces, planned soon after the 1940 blitz on Britain, was officially ordered by Churchill and Roosevelt at their conference at Casablanca in January, 1943. The offensive had two parts: the bombing of cities to reduce the will of the German people to continue the war, and the bombing of war industries to reduce Germany's ability to continue the war. This use of the air arm of the military services was known as "strategic" bombing; it was differentiated from "tactical" operations which covered fighter and bomber support of ground forces. The activities of the Eighth and the Fifteenth Air Forces, based in England and in the Mediterranean, respectively, were predominantly strategic; the Ninth Air Force, based first in England and later in France, was predominantly tactical.

The United States and Britain split the strategic bombing assignment between them. The A.A.F. undertook the precision bombing of German industry principally by day, and the R.A.F. undertook the area bombing of German urban centers by night. By the summer of 1943 enough of our four-motored bombers had been based in Britain to permit the beginning of heavy attacks. The raids rose gradually in size and in frequency; a wide assortment of targets was hit. The ratio of planes lost varied with types of targets; in the early months the A.A.F. refrained from concentrating against certain targets, such as synthetic oil, because it was not willing to take the heavy losses that would be suffered. In October, 1943, however, a heavy raid was made on the ball-bearing center of Schweinfurt; over 20 per cent of the planes were lost. Beginning on February 20, 1944, there were the famous five days of intensive concentration on bombing out fighter airplane production. By that time the range of our fighter escorts had been increased so that they could defend the bombers all the way to their targets and return.

A good deal of bombing was not strategic in the strict sense. Tremendous tonnages were dropped on the submarine pens along the French Coast, on airfields, and, later, on V-weapon launching sites. Field Marshal von Rundstedt stated to interrogators that the use of heavy bombers by the Allies in the St. Lo break-through was the most impressive use of such air power that he had ever seen. But before and after D-Day, both the American and British Air Forces placed principal emphasis on the bombing of German cities and war industries.

The apparent success of the Combined Bombing Offensive is attested by the wholesale ruin of practically all of Germany's larger cities, and by the heavy damage done to those industrial installations selected as targets. Our precision bombing proved not to be so very precise, but the Germans bear emphatic witness that targets marked for destruction eventually were destroyed.

THE GERMAN DEFENSE AGAINST STRATEGIC BOMBING

The Nazi high command, immediately it came into power in 1933, had undertaken to build and expand Germany's war industries. Because of obvious geographical factors, at least two policies were adopted relative to the possibility of bombing attacks against German industry: a deliberate expansion of heavy industry in central Germany to reduce the dependency of the nation's economy on the Ruhr district, and the adoption of the principle of local dispersal in the erection of new war plants, especially those to be used for aircraft manufacture. In accordance with this principle, no factory structure was to cover an area of more than 75,000 square feet; the airplane plants that were built were an aggregation of several separate structures sufficiently far apart to isolate bomb damage. Air raid shelters were provided for these new plants even before 1939. Most of the aircraft plants were highly integrated. The work characteristically was laid out to provide two production centers for each part or subassembly as insurance against a bomb hit. No blackout-type structures were built.

A second consideration which explains further the ability of German industry to maintain output in the face of Allied bombing was an installed over-capacity in many important industries. This permitted such industries to operate on a single shift, or at something less than full capacity, until the last year of the war. This situation was especially conspicuous in aircraft manufacturing capacity. Leaders of Germany's aircraft program estimated that the heavy February, 1944, raids on fighter plants destroyed 75 per cent of those facilities by 75 per cent, with a consequent 50 per cent reduction in scheduled output for a period of about two and a half months. But the rapid repair of the least damaged of those facilities, and the establishment of multiple shift operations, with incentive rations to workers who put in long hours, resulted in no loss of production the following month. The production of single engine fighters increased by 30 per cent in March, and by September, 1944, it had trebled.

The under-utilization of the full productive capacity of the German industrial economy in the first three years of the war is one of the astounding revelations that have come with the end of the war. An important aspect of this situation appears to be the arrogance of the Nazi leaders in assuming that they could conquer the world without an all-out effort. Hitler was convinced in October, 1940, that Britain was out of the war and it was a minor question as to when she would sue for peace. In October, 1941, he was similarly convinced, with his armies at the gates of Leningrad and of Moscow, that Russia was defeated. Even after Stalingrad, the key Nazi leaders were confident that they could trade space for time until the German armies could be re-equipped and reinforced. Hitler had supreme contempt for the United States; in spite of warnings from some of his subordinates, he took no notice of the great bombing offensive being mounted against Germany, until the latter half of 1943.

THE DISPERSAL OF GERMAN INDUSTRY

Before 1939, it has been noted, German war industries had been expanded with an eye to possible bombing attacks. During the war it became necessary to take further emergency steps in this direction. The pattern was first to disperse, then to concentrate underground, and at the end of the war great above-ground, bunker-type structures were being erected to house certain vital industries.

It is important to note the timing of this emergency action. Industry and government leaders estimated that Allied bombers would not have enough range to carry heavy loads into the central and eastern areas of Germany, and some officials, especially Hitler, were contemptuous of the effectiveness of the bombing offensive to be mounted from Britain. Late in 1941 Focke-Wulf decided to remove its aircraft manufacturing operations from Bremen because this city was within range of heavy bombers. It selected Marienburg in East Prussia, Posen in Poland, and Sorau and Cottbus, southeast of Berlin. The moderate amount of new construction that was carried out during the war was located in the strategic interior, including Czecho-Slovakia and Austria, partly for protection against bombing attacks and partly for more convenient location with reference to labor resources.

In the summer of 1942 responsible governmental agencies prepared plans for the emergency dispersal of certain war industries. An order was issued to disperse inventories of materials and supplies in warehouses within a few miles of the manufacturing plants. Steps were taken to have more than one source for all components. It is important to note, however, that no general order to disperse important war industries was issued until late in February, 1944. Prior to that time dispersal had been a spotty matter.

The morning after the great raid on Schweinfurt in October, 1943, Reichsmarshal Goering called an emergency meeting in Berlin. He began by asking in great anger why the ball-bearing industry had not been dispersed. He was quieted by being reminded of his promise that the Luftwaffe would protect the Fatherland against such air attacks. The incident reveals the status of critical industries as to dispersal at that late date. Emergency steps were taken immediately to disperse the ball-bearing industry, but it should be repeated that the general order was not issued until February, 1944.

When dispersal was ordered, it applied only to high priority war industries. The aircraft industry, which in the German classification system included anti-aircraft, and comprised between 40 and 45 per cent of German war industry, was most affected by the dispersal order. During March and April, 1944, 27 aircraft plants were dispersed to 329 scattered locations. The radius over which they were dispersed varied from a few to several hundred miles. The action was facilitated by the dispersal plan which had been prepared by the Air Ministry in 1942. It was made possible by the establishment of an emergency priority as to transportation services and as to the commandeering of plants. Manpower controls were already adequate to permit the mandatory transfer of workers, German as well as foreign, to the dispersal locations.

Dispersal seriously reduced the quality of targets for Allied bombing, and in this regard undoubtedly was successful. It brought on exceedingly great operating difficulties, however, and within a few months there was an insistent demand that facilities be provided underground which would permit re-concentration of operations. It was not too difficult to disperse machines, tools, and manpower, but the dilution of supervisory personnel required by dispersal presented an impossible situation. The maintenance of adequate inspection also became most difficult. A serious problem existed because of the inadequacy of transport facilities serving the dispersed locations. It has not been clear, in studying the dispersal of German war industry to avoid the consequences of Allied strategic bombing, whether the program was undertaken as a temporary expedient until underground facilities had been prepared, or was regarded as permanently feasible.

UNDERGROUND OPERATIONS

The first substantial underground operation was that set up in the tunnels near Nordhausen for the production of the V-2. The decision apparently was made in the fall of 1943, and production operations were removed there directly from the Army Artillery Park at Peenemunde, where the weapon had been developed. The V-1 had been put into production in conventional facilities at first, but during 1944 it, too, was moved into the Nordhausen tunnels. When the war ended, in addition to the V-weapons, a jet airplane power plant was being produced there.

It was not until the summer of 1944 that an all-out effort was made to put as much production underground as possible. Weapons with the highest priority were taken care of first. Following V-weapons came aircraft engines, especially for the fighter types. It was not practical to put the assembly of aircraft underground, but considerable progress was made with critical parts and components.

The Nordhausen tunnels, which afforded about 1,000,000 square feet of productive working space broken down into two long tunnels and about fifty cross tunnels, were built for the purpose and were reasonably satisfactory as a place in which to carry on manufacturing operations. There were four level entrances from the outside, temperature and humidity conditions were not bad, and the anhydrite formation was neither corrosive in its effect on machines nor did it release an undue amount of dust. Many of the other underground facilities, however, did not work out at all satisfactorily. Several salt mines were used. In few cases were the shaft entrances adequate for the circulation of workers, materials, and products; ventilation was difficult and the corrosive effect on machines was serious; draughts frequently were a problem. In no cases were operations completely integrated in these underground facilities. All were vulnerable as to their supplies of electric power and as to transport connection with suppliers and others upon which they were dependent.

FOREST PLANTS

Underground operations were not the only way in which protection from Allied bombing was sought, although quantitatively they were the most significant after simple dispersal proved unsatisfactory. Several concerns, Messerschmitt in particular, were successful with the operation of forest plants. These were small, narrow, wooden structures in dispersed clusters along the autobahns* in the same general district. They were cheap to erect, and working conditions were good. Not one was bombed. Fighter-type aircraft were small enough to use such restricted production space. Level stretches in the autobahn were used for testing and fly-away; this fact was detected by aerial reconnaissance, but not a single photograph located the hidden plants where production operations were being carried on.

Eleven great bunker-type plants had been planned, five had been started, and two at Kaufering and Muhldorf-am-Inn were approximately 50 per cent completed when the war ended. Each was to provide about a million square feet of production space, on several levels. They embodied the submarine pen idea: heavy reinforced concrete construction in the shape of a tortoise shell. A hill with the right dimensions was selected, it was covered with concrete, and then the earth was removed. A shortage of steel and the time factor explain the fact that these bomb-proof facilities were not completed before the end of the war.

THE RECORD OF GERMAN INDUSTRIAL OUTPUT

The rapid increase in production of airplanes, especially of the defensive fighter types, during and after the heaviest Allied bombing raids, has already been mentioned. This misfire of the expected cause and effect relationship is not surprising when it is realized that German industry had not yet been given an all-out assignment by Hitler, and national survival depended on the production of greatly increased quantities of weapons. The immediate answer to the great raids by Allied bombers was to put more defensive fighters into the air, and the accomplishment of this objective became an urgent national project. In spite of the great destruction done to aircraft production facilities during the February raids, and in spite of the disruption caused by emergency dispersal during March and April, the German aircraft industry increased its production of fighters in a remarkable fashion. If Allied Intelligence had not grossly underestimated German fighter plane production in the months before D-Day, one wonders if the invasion would have been carried out as scheduled.

Responsible German officials formed an emergency organization late in February, 1944, to meet the disastrous situation resulting from the heavy raids on airplane plants. It was called the "Jagerstab" (Fighter Staff), and combined the forces of the Air Ministry and the Armament Ministry (Speer). Otto Saur, one of Hitler's close associates, was made its Chief. His method principally was to give the aircraft program top priority, but he leaned heavily on terrorizing industrial managements. The Jagerstab did get results, and in August, 1944, it became a "Rustungstab" (Armaments Staff) with Saur at its head. The same techniques were employed to get greater production of tanks, ammunition, etc., as had been found successful with fighter aircraft.

*An "autobahn" is a road with double traffic lanes in each direction separated by a park strip.

The average production of various types of munitions in 1944, as compared with January-February, 1942, was as follows:

Tanks	5	times increase
Weapons	3	" "
Ammunition	3	" "
Aircraft	2½	" "
Tractors	2½	" "
Warships	1½	" "
Vehicles	1½	" "

The general index of munitions production reached its maximum in July, 1944, but it did not collapse until March, 1945.

Shortage of oil was the most serious single factor in the collapse of Germany. It did not become so acute as to affect military operations directly, however, until September, 1944. The loss of the Roumanian oil fields was a serious blow. The synthetic oil plants of Germany, it has been noted, were so well protected by anti-aircraft and fighter defenses that the Allied bombing forces at first could not afford to attack them because of the losses which would be incurred. Even after long-range fighter escorts had been provided these bombers, and the plants at Merseburg, Leuna, and other centers were attacked, Allied losses were heavy. German officials stated that had the bombing attacks on their synthetic oil industry been initiated a year earlier, the war would have been a year shorter.

CONCLUSION

The strategic bombing campaign, it can now be observed, overlooked the opportunity to paralyze German industry by attacking its electric generating installations. Allied Intelligence had accepted the theory that an elaborate grid system existed in Germany which could handle any emergency created by loss of, or damage to, an occasional generating plant. The capacity of the grid system proved to be very low in most cases; late in the war, when saturation bombing of German urban centers was carried out, more especially by the R.A.F., a good many sources of electrical power were put out of commission. The grid system was so inadequate that large sections of German industry had to be rationed on consumption of electricity.

Transportation targets occupied an important place in the Combined Bombing Offensive. Assessment of the damage done to these targets is made difficult by the fact that much, if not most, of the visible ruin done to bridges, equipment, terminals, and marshalling yards was the result of tactical operations in connection with the advance of the ground forces. Strategic bombing of transportation targets appears not to have been especially successful. Large groups of workers could be mobilized on short notice to repair damage done to marshalling yards. The Ardennes Offensive was mounted in December, 1944, by putting more than a thousand trains through some of the worst bombed marshalling yards. Civilian goods traffic was sacrificed.

This account gives a discouraging picture of the effectiveness of Allied strategic bombing. No question is raised as to the fact that tremendous tonnages of bombs were dropped on industrial and urban targets in Germany. The accuracy with which they were dropped could scarcely be described as "precision", but the German people were impressed by the fact that when a target was selected for destruction, sooner or later it was destroyed. What was lacking in accuracy was made up for in quantity.

The error made in ordering the Strategic Bombing Offensive was a fundamental one. Churchill and Roosevelt appear to have been incorrectly advised at Casablanca that the morale of the German people could be broken by bombing their cities, and that the ability of the German Army to resist could be materially reduced by bombing munitions plants. The two air forces did a remarkable job; the physical destruction wreaked was terrific. Nazi propaganda, however, was able to maintain the German will to resist in spite of great personal discomfort, and the Allies had not reckoned on the recuperative capacity of German industry.

Secondary criticisms of the Combined Bombing Offensive can be made, though they are mentioned with full appreciation of the fact that hindsight affords an unfair advantage: 1) Allied Intelligence failed at many points, especially as to industrial matters. 2) The types of bombs dropped and their fuses were not such as to cause maximum damage to the targets; the percentage of duds was high. 3) Undue emphasis was put upon tons dropped, regardless of their effectiveness.

Too much cannot be said in praise of the crews of the bombers and the pilots of their fighter escorts, and for the way in which they carried out their parts in the Combined Bombing Offensive. The airplanes themselves were highly satisfactory. Division Commanders worked out brilliant devices such as formation flying, to insure the return of as many as possible of the aircraft and their crews.

If strategic bombing was not as successful as expected in reducing the will and ability of Germany to resist, what did beat her? The answer appears to be this: As a by-product of strategic bombing the Allies secured air superiority; with air superiority it was possible to mount, execute, and carry through a successful invasion. The ground forces moved into Germany with air cover. The Luftwaffe had been beaten, and Germany's ground forces, acordingly, were at a great disadvantage. Germany was not beaten until Allied soldiers physically took over the occupation of Germany. The question that remains to be answered is: Could the Allies have secured air superiority over Germany in a more direct way than through the use of thousands of four-motored bombers, tens of thousands of lives, and billions of dollars?

NEW PRESIDENT

(Continued from Page 3)

dollars. In directing the work of the laboratory, Dr. DuBridge won the wholehearted cooperation and confidence of the scientists, the industrialists, and the armed forces. To the thousands engaged in the effort, his name is synonymous with intelligence, integrity, and modesty; and they bear witness that his attitude made this important war work a model of fellowship in effort.

Internationally known for his research work in nuclear physics, Dr. DuBridge supervised the construction and installation of an atom-smashing cyclotron at the University of Rochester in 1938. This seven-million volt apparatus produced in 1938 the highest energy proton beam which had been used up to that time.

Among the academic, professional, and scientific organizations of which Dr. DuBridge is a member are, the National Academy of Sciences, the American Physical Society (of which he is now vice-president), Sigma Xi, Phi Beta Kappa, the American Association for the Advancement of Science, the American Optical Society, the Institute of Radio Engineers, the American Association of Physics Teachers, and the American Association of University Professors. He is representative of the American Physical Society on the Physical Science Division of the National Research Council, and a member of the executive committee of the American Institute of Physics.

He has been a member of the editorial boards of the American Physics Teacher, the Physical Review, the Review of Scientific Instruments, and is consulting editor of the International Series in Physics. He has published many articles in scientific journals, and also two books, "Photoelectric Phenomena" (1932) and "New Theories of the Photoelectric Effect" (1935).

In 1925 Dr. DuBridge was married to Doris May Koht of Reinbeck, Iowa. They have two children, Barbara, 15, and Richard, 12.

It is expected that Dr. DuBridge will assume his new duties as president of the California Institute of Technology at the beginning of the next academic year, in September, 1946.

ENGINEERING

(Continued from Page 4)

laboratories, but also much work can be done in the "fine structure" of engineering, to borrow a term from spectroscopy—in details of analysis and performance which are no longer unimportant in modern, more refined engineering design. The colleges are in a favorable position in engineering research, since all phases of science are represented and may be made available for contribution to specific problems. With a proper balance between such research and teaching, the colleges can be even more effective in their primary responsibility—the training of engineers.

Fill in and send to:
News Editor, Engineering and Science Monthly
1201 East California Street, Pasadena 4, Calif.

Name________________ Class______

Home address________________

Information about myself (marriage, position, type of work, change of position or location, etc.)

Information about another alumnus

Name________________ Class______

REPRODUCTION OF PRINTS, DRAWINGS, AND PAINTINGS OF INTEREST IN THE HISTORY OF SCIENCE AND ENGINEERING

8. "Steam Locomotion as an Art Subject"

By E. C. WATSON

ONLY rarely have either great artists or great poets dealt with steam locomotion. This is perhaps understandable even though it is regrettable, for as the Scottish engineer says in Kipling's "M' Andrew's Hymn":

"Lord, send a man like Robbie Burns to sing the
Song o' Steam!
To match wi Scotia's noblest speech yon orchestra
sublime
Whaurto—uplifted like the Just—the tail-rods
mark the time.
The crank-throws give the double-bass, the feed-
pump sobs an' heaves,
An' now the main eccentrics start their quarrel on
the sheaves;
Her time, her own appointed time, the rocking
link-head bides,
Till—hear that note?—the rod's return whings
glimmerin, through the guides.
They're all awa! True beat, full power, the clangin'
chorus goes
Clear to the tunnel where they sit, my purrin'
dynamoes.
Interdependence absolute, foreseen, ordained,
decreed,
To work, Ye'll note, at any tilt an' every rate o'
speed.
Fra skylight-lift to furnace-bars, backed, bolted,
braced an' stayed.
An' singing like the Mornin' Stars for joy that they
are made;
While, out o' touch o' vanity, the sweatin' thrust-
block says:
'Not unto us the praise, or man—not unto us the

praise!'
Now, a' together, hear them lift their lesson—theirs an' mine:
'Law, Order, Duty an' Restraint, Obedience, Discipline!'
Mill, forge an' try-pit taught them that when roarin' they arose,
An' whiles I wonder if a soul was gied them wi' the blows."

In 1844, however, that master of light and color, J. M. W. Turner (1775-1851), was inspired by a scene on the Great Western Railway in England to paint a superb picture dedicated to steam and to speed. Although an old man at the time, Turner comprehended the dynamic poetry of a train in motion through a landscape simultaneously swept with rain and drenched with sunlight, and portrayed it upon a canvas that now hangs in the National Gallery in London.

While no other treatment of steam locomotion compares in artistic merit with Turner's "Rain, Steam and Speed", there do exist a few paintings of early trains which merit reproduction in a series of this kind because of their historical accuracy. Among these are some of the works of the American historical painter, Edward Lamson Henry (1841-1919).

To quote from the Dictionary of American Biography, "Henry's major interest was in the past life and customs of the United States, especially during the first half of the nineteenth century. He began soon after his return (from study in Paris under Suisse, Gleyre, and Courbet) to paint pictures which were accurate to the last chair and the most minute button. Owing in part to his attention to detail, his work was of greater historic than artistic merit . . . Primarily an illustrator in oils, he found an appreciative public in that vast majority which demands of a picture first of all that it tell a story."

Plate 1 reproduces Henry's painting of the first train operated in the state of New York. The locomotive portrayed, named the "De Witt Clinton", made its first trip in July, 1831, over the Mohawk and Hudson Railroad (now the New York Central). On August 9, it made the trip from Albany to Schenectady, a distance of seventeen miles, in less than one hour.

A painting of a railway scene of a somewhat later period (1837) by the same artist is reproduced in Plate 2. Unfortunately, a copy of Henry's better-known painting, "Railway Station—New England" is not available to the writer. Although not great art, Henry's paintings, because of "their rare sincerity and their quaintness," probably "will always be of interest and of value . . . and will throw an ever-penetrating light into our vanished customs and past social history".[1]

1. Lucia Fairchild Fuller, *Scribner's Magazine, 66,* 256 (1920).

C.I.T. NEWS

C.I.T. STARRED SCIENTISTS

In a recent letter to California Institute of Technology, Stephen S. Visher, professor of geography at the University of Indiana, enclosed a summary of the graduates of C.I.T. who have received stars in present and past editions of "American Men of Science".

Professor Visher's summary includes the following C.I.T. starred alumni. *In chemistry:* Joseph E. Mayer, '24, Kenneth S. Pitzer, '35. *In physics:* Carl D. Anderson, '27, Richard H. Crane, '30, J. W. M. DuMond, '16, Robley D. Evans, '28, Edwin M. McMillan, '28, William Shockley, '32.

The list also includes the following C.I.T. starred alumni in doctorates. *In astronomy:* O. C. Wilson, '34. *In chemistry:* L. O. Brockway, '33, R. G. Dickinson, '20, P. H. Emmett, '25, Sterling B. Hendricks, '26, Linus Pauling, '25, E. Bright Wilson, '33, Don M. Yost, '26. *In mathematics:* H. P. Robertson, '25. *In physics:* Carl D. Anderson, '30, I. S. Bowen, '26, R. M. Bozorth, '22, H. Richard Crane, '34, J. W. M. DuMond, '29, Robley D. Evans, '32, Charles C. Lauritsen, '29, A. C. G. Mitchell, '27, S. H. Neddermeyer, '35, H. Victor Neher, '31, L. N. Ridenour, '36, Robert B. Brode, '24. *In zoology:* Albert Tyler, '29.

Stars in "American Men of Science" indicate that in the opinion of his peers the starred scientist is distinguished for research. It implies either a large volume of good work or a considerable amount of original work. It does not imply that the work done by other scientists is not outstanding, but merely that it has not impressed the voters as being quite so worthy of approbation.

Professor Visher's letter also contained Table I reprinted from "Science", which is reproduced below. Column I gives the number of scientists first starred in 1933 to 1944, serving on the faculties of the universities which had three or more such scientists in 1944. Column II is the number of the members on the teaching staff on November 1, 1944. Column III is the number of scientists starred in 1933-1944 per 100 members of the 1944 teaching staff. It indicates that in this respect C.I.T. leads the field.

TABLE I

	I Starred Scientists 1933-1944	II Total Teaching Staff 1944	III Starred Scientists Per 100 Members of Staff
Brown	4	157	2.6
California	41	2,376	1.7
California Institute of Technology	20	140	14.3
Chicago	30	798	3.8
Columbia	36	2,488	1.4
Cornell	18	1,052	1.8
Duke	3	465	0.6
Harvard	50	1,775	2.8
Hopkins	16	765	2.1
Illinois	18	1,743	1.0
Indiana	7	467	1.5
Iowa	10	622	1.6
Iowa State	4	413	1.0
Massachusetts Institute of Technology	19	442	4.3
Michigan	30	820	3.7
Minnesota	18	836	2.1
North Carolina	6	311	2.0
Northwestern	12	1,330	0.9
Ohio	9	1,123	0.8
Pennsylvania	14	1,322	1.1
Penn. State	3	864	0.3
Princeton	26	220	10.2
Rochester	7	544	1.3
Rutgers	5	444	1.1
Stanford	22	645	3.4
Swarthmore	3	91	3.3
Virginia	6	270	2.2
Washington (St. L.)	6	468	1.3
Wisconsin	13	1,469	0.9
Yale	22	994	2.2

THE ANNUAL SEMINAR

ON April 29 at the Ninth Annual Alumni Seminar at C.I.T. two hundred and seventy-one Caltech alumni and guests heard reports of the work underway or completed at the Institute, and learned of some of the projects planned for the future.

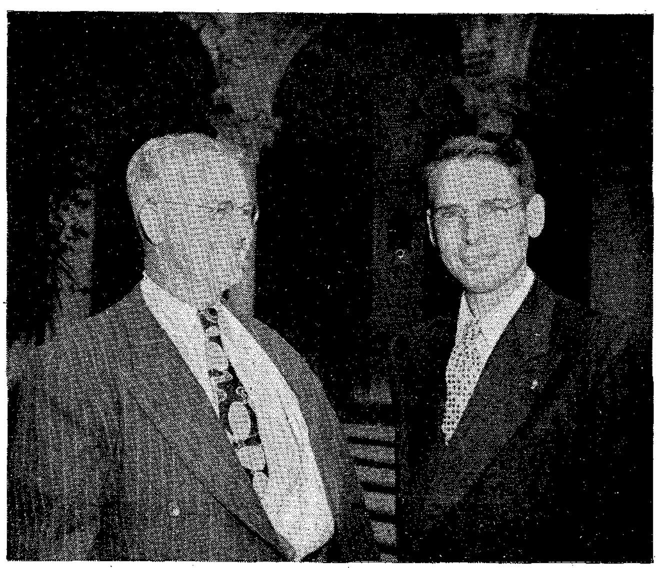
A program without a wasted moment featured the following events: A chapel service conducted by Dr. Max M. Morrison, pastor of Westminster Presbyterian Church, Pasadena, with music arranged by Mrs. Lucille Martin, Westminster director of music; a discussion by Dr. Martin Summerfield of C.I.T.'s Jet Propulsion Laboratory on the history of rockets for weapons for jet propulsion and for high altitude reserve; a report by Mr. Allen E. Puckett on the program of the Guggenheim Laboratory, with particular reference to the problems involved in flight at the speed of sound; a commentary by Dr. Wallace Sterling, Professor of History, on the world political situation; luncheon in the student houses; a talk by Dr. Frederick Lindvall, Professor of Mechanical and Electrical Enginering, on the methods of electrical analysis of mechanical problems; a survey by Dr. William E. Pickering, Associate Professor of Electrical Engineering, on the present status of radar and the application of radar to peacetime use; a discussion by Robert Gray, head of the department of Industrial Relations, on recent developments in his field of activity; and a talk by James R. Page, President of the Board of Trustees of the Institute on C.I.T.'s past achievements and future program.

One of the highlights of the Seminar was Mr. Puckett's forecast of air travel at speeds of 1,000 miles per hour. Discussing the difficulties encountered in overcoming the wall of resistance created by drag at speeds above our present maximums of 400 to 500 miles per hour, Mr. Puckett evaluated the designers' chances of reducing drag or increasing horsepower to surmount the problems of wind resistance and complex air flow prevalent at the speed of sound (760 miles per hour at sea level). Using slides and an able descriptive facility, Mr. Puckett drew a graphic picture of what might happen to a plane and pilot accelerating approximately 740 to 760 miles per hour. He stated that the baffled pilot might find, without using more power, that the speed of his plane had suddenly increased, not from 740 to 760 miles per hour, but from 740 to 1,000 miles per hour or more. Theoretically, drag may decrease when the speed of sound has been exceeded by a body in flight, said Mr. Puckett. He further predicted that aircraft speed in the future would not increase in small increments of five to ten miles per hour, but that speed gains would be tremendous once means are found to pass the critical point of resistance near the speed of sound. Mr. Puckett believes that the aerodynamicists will soon be able to perfect planes capable of flight at supersonic speed.

Another subject of special interest to the alumni was covered by Dr. Lindvall in his talk on electrical analyses of difficult problems of motion, vibration, and heat flow. Reviewing the existing possibilities of representing physical systems by electrical circuits, Dr. Lindvall enumerated some of the advantages of electrical calculation over mechanical calculation. The present use of suitable electrical units of inductance, resistance, and capacitance to represent physical elements of a given problem is relatively expensive and it takes a correspondingly longer time to obtain a dependable solution. In certain complex calculation, speed gains by use of electrical calculation might save days, weeks, or even years, of computation. Dr. Lindvall told of the work being done by Westinghouse, General Electric, and the Massachussets Institute of Technology, and of the electrical facilities available in their laboratories. At the present time no comparable equipment is in existence on the west coast, but it is Dr. Lindvall's hope that C.I.T. may acquire electronic computing devices which will provide equivalent facilities in California. Dr. Lindvall stated that the problem of financing the acquisition of equipment was now under consideration and that the alumni might be called upon to help determine to what extent western industry would need the services of this modern electronic computing device.

The alumni also listened to up-to-the-minute accounts on radar and rocket developments. Dr. William Pickering covered the history of radar from its inception and clarified both the basic principles of radar operation and the uses of the many types of radar in World War II. He concluded by outlining the application of radar in peacetime. Dr. Martin Summerfield stressed the important place rocket principles will have in industrial application and in pure scientific research.

Covering the important field of world affairs, Dr.



AT LEFT: Nicholas D'Arcy '28, and Kenneth Belknap '27, '47 and '46 Seminar chairmen, respectively. BELOW: Alumni luncheon at student house.

Sterling presented a helpful charting of the activities of the United Nations and of the Paris Peace Conference. The problems of labor and management were ably presented by Mr. Robert Gray. Mr. Gray's comments on securing employee understanding and cooperation, and on the current G.I. "on the job" training program, were received with interest evidenced by an active question and answer period which followed his talk.

Mr. James Page paid tribute to the achievements of Dr. Robert A. Millikan and of the Institute, and prophesied a creative future for C.I.T. exceeding the achievements of the past quarter of a century.

Special commendation on the success of the entire program is due Kenneth A. Belknap, '27, general chairman of the 1946 Seminar Board, and Nicholas D'Arcy, '29, assisting chairman. The alumni owe thanks also to the members of Ken Belknap's committee for their competent assistance in handling introductions, luncheon arrangements, registration, and the other arduous chores essential to the smooth functioning of a successful program. Ken's committee included: Ernest B. Hugg, '29, George Rice III, '31, Lupton A. Wilkinson, '38, Joseph J. Peterson, '37, Paul Hammond, '36, Harold Huston, '29, Harlan Asquith, '29, Edward Cornelison, '25, James H. Keeley, '31, Ira Bechtold, '30, Conrad Scullin, '29, and Charles Varney, '22.

DR. CORYELL WILL JOIN M.I.T. STAFF

DR. CHARLES D. CORYELL, who is distinguished for his work in the inorganic and physical chemistry of the isolation and identification of radioactive atoms, has been appointed professor of chemistry of Massachusetts Institute of Technology, according to Dr. Karl T. Compton, president of that Institute.

Dr. Coryell was a scholarship student at the California Institute of Technology from 1929 to 1932. During this three-year period he received the bachelor of science degree in chemistry and was awarded the California Institute of Technology Junior Travel Prize. In 1933 he enrolled for a year at the Technische Hochschule in Munich where he carried on special investigations on the fluorescence of acetone. Returning to C.I.T. for graduate work, Dr. Coryell received his degree of doctor of philosophy in physical-inorganic chemistry in 1935.

In 1938, Dr. Coryell joined the staff of the University of California at Los Angeles as an instructor in introductory chemistry, quantitative analysis, and physical chemistry; he was appointed assistant professor in 1940, and associate professor in 1944. In 1942 he was granted a leave-of-absence to lead a research staff working on the radiochemistry of the fission products in the chemistry division of the metallurgical laboratories at the University of Chicago.

Transferred to the newly opened Clinton laboratories at Oak Ridge, Tennessee, in 1943, Dr. Coryell was chief of a research section on radio-chemistry and fission products at the first industrial atomic power and plutonium production plant. This work involved intensive research in inorganic, physical, and analytical chemistry, especially that part known as radiochemistry, together with development work on high activity radiochemical separations and remote control operations. Upon completion of final reports for this project, Dr. Coryell will join the staff of the department of chemistry at the Massachusetts Institute of Technology in July.

INCREASE IN TUITION

AT a meeting held on April 1, 1946, the board of trustees of the California Institute voted to increase the annual tuition fee to $500.00, effective October 1, 1946, according to an announcement by James R. Page, chairman of the board.

The California Institute, like other non-tax supported colleges and universities, relies for a major fraction of its income on returns from invested endowments. This income has been reduced as interest and dividend rates have fallen, and still further reduction is expected. At the same time, the Institute is confronted with increased expenditures for salaries and wages, supplies and equipment, operation and maintenance. The decision to increase tuition was made as one, but only one, of the steps necessary to bring Institute income into line with Institute expenditure.

To aid students who have undue difficulty in meeting the cost of beginning or continuing their work at the Institute, there are available funds for loans and scholarships of which the trustees and faculty hope to make as liberal use as possible. It is hoped that no student who clearly belongs at the Institute will be prevented from attending because of financial need.

ATHLETICS

By H. Z. MUSSELMAN,
Director of Physical Education

A SQUAD of thirty-five enthusiastic men reported to Coach Mason Anderson for a six-week spring football practice session. This group will be enlarged later this season by men now engaged in other spring sports.

At present, only two lettermen from last year's squad —Don Hibbard, end, and Dennis Long, tackle—are available. However, several other men who, as members of the V-12 unit, made their letter on the 1945 team expect to be released from Service this summer and are planning to return to the Institute in the fall to complete their undergraduate work.

The fall term will not open until October 7, thus delaying the regular practice until that approximate date and necessarily curtailing the 1946 schedule. Opening the season with Occidental in the Rose Bowl on Friday evening, October 25, the Engineers on consecutive weeks will play Whittier, Redlands, Pomona, concluding their schedule with the newly-organized Pepperdine team.

MT. PALOMAR TELESCOPE

THE astrophysical observatory of California Institute of Technology, with a reflecting telescope one million times as powerful as the human eye, which can peer sextillion miles into space, and which does not vary from perfection more than one millionth of an inch, is nearing completion.

Construction work on the $6,000,000 Mt. Palomar reflecting telescope, financed by the Rockefeller General Education Board, was halted during the war years, but has now been resumed. The giant eye, originally cast in the Corning Glass Works, New York State, in 1929, will be ready for installation on the 6,500-foot mountain-top site fifty miles north of San Diego in the summer or fall of 1947. The 200-inch mirror disk, with a diameter and height of 137 feet each, will have four times the light-gathering power of the 100-inch telescope on nearby Mt. Wilson, presently the largest in existence.

PERSONALS

IT WILL be helpful if readers will send personal items concerning themselves and others to the Alumni Office. Great interest has been shown in these columns, but more information is required. Do not hesitate to send in facts about yourself, such as change of position or location, present job, technical accomplishments, etc. Please help.

—Editor.

1920

HARVEY W. HOUSE has moved his family to Pasadena from Oakland, California. Mr. House is conducting a research for the Pacific Coast Clay Products Institute in the laboratory of Gladding McBean Co.

1929

DR. KARL M. WOLFE has been working for the Aerojet Engineering Corporation and is presently supervisor of the research instrumentation group. He has been with Aerojet for about ten months.

MILTON SPERLING has been separated from the Navy and has returned to his previous employers, the Richfield Oil Corporation, in Los Angeles.

1930

NORMAN F. DOHERTY is in charge of the photochemicals department, Curtis Laboratories, Inc., Los Angeles, manufacturing Curtis color cameras, and printers and processing chemicals for paper prints in color.

HUGO KLEINBACH is employed at Technicolor Motion Picture Corporation, Los Angeles.

LIEUTENANT-COMMANDER HARRIS K. MAUZY, formerly with the Seabees, has returned to the bridge department of the State Division of Highways and is located in the Los Angeles office.

1931

WINTON C. KOCH is a cameraman at Technicolor Motion Picture Corporation, Los Angeles.

1933

LOUIS H. GOSS assumed duties on April 1 as city administrator of Monterey Park, California. Mr. Goss was formerly city engineer of Brawley, California.

BRUCE M. DACK announces the opening of an engineering office in Sacramento, California, which will serve the building industry of central and northern California.

PROFESSOR FRANCIS R. HUNTER is in the department of Animal Biology, University of Oklahoma, Norman, Oklahoma, having received his discharge from the Army Air Forces.

1934

DR. NORTON B. MOORE is now manager of research at the Aerojet Engineering Corporation, Azusa, California. He is directing research efforts on various types of jet propulsion devices.

MAJOR ALFRED I. SWITZER is serving with the General Engineer District as chief of the engineering division in Manila. Major Switzer has been in the Service for more than three years, a year of which was spent overseas. Prior to entering the Army, Major Switzer was an hydraulic engineer of Los Angeles Engineer District in Los Angeles.

LIEUTENANT-COMMANDER CARROL CRAIG is chief of the Ammunition Storage and Safety Unit of the Bureau of Ordnance and is stationed at Washington, D. C.

1935

JACK M. ROEHM has recently accepted a position as director of engineering with Buehler and Company in Chicago, Illinois. This company was formerly the Victor Research Laboratory Division of Victor Adding Machine Company. Prior to and during the war, Mr. Roehm worked for Carl L. Norden, Inc., designers and manufacturers of the Norden bombsight and automatic flight control equipment.

DICK JOHNS is back at the Institute as Assistant Professor in Geology.

1936

WALFRED E. SWANSON has resigned as engineer with the Sacramento Office of the U. S. Engineer Department and is now with the Gibbon and Reed Construction Company, Las Vegas, Nevada.

LIEUTENANT-COLONEL AL CREAL, USMC, after spending the past two years on a special assignment at Washington, D. C., stopped at the Institute enroute to Pearl Harbor where he will receive further orders in the Pacific.

1938

BLAINE A. DIXON, JR., has accepted a position with Columbia Steel Company at Torrance, California.

1940

DONALD E. LOEFFLER is on terminal leave from the Armed Forces. Don, a Captain in the Air Corps, served as a photographic officer with duty confined to the States.

JEROME KOHL was married on March 1 to Miss Freeke van Nouhuys of Berkeley, California. Jerome is employed as a senior engineer at the Avon Refinery of Tidewater Associated Oil Company, Associated, California.

LLOYD GOODMANSON, who is with Boeing in Seattle, Washington, spent a short vacation in southern California.

TOM HUDSPETH has accepted a position in the radio department of Hughes Aircraft in Culver City, California.

ROY E. MARQUARDT is project director heading the jet research program for the Navy being conducted on the campus of University of Southern California. Prior to his assignment to the Navy project, he taught at that university under the ESMWT program and for two years before was in charge of Navy research at the Northrop Aircraft Corporation. The Marquardt Aircraft Company, the engineer's private business, is currently manufacturing a 140 horsepower gas turbine under Army contract and is building jet motors.

DUMONT S. STAATZ, M.D., former Captain in the Medical Corps, was discharged from the Service last October and, with his father, is in private practice in Tacoma, Washington.

MORTIMER STAATZ is an Interpreter in the Second Marine Division, now stationed in Japan.

1941

WILLIAM H. WAGNER is now employed by Shell Oil Company as an engineer.

HOMER JACOBSON announces the arrival of a son, William, on March 7 at Yonkers, N. Y.

PHILIP BROOKS is the father of a son, Michael, born recently. Philip is Welfare and Recreation Officer at Yorktown. He expects to be released from Service in late spring.

LIEUTENANT CLAUD S. RUPERT, USNR, who has been stationed at Naval Research Laboratory, Washington, D. C., left in April for Pacific duty to witness atomic bomb tests at Bikini Atoll in the Marshall Islands.

LE ROY G. WAIGAND is on terminal leave which expires in June. Major Waigand served in England, France, Belgium, New Guinea, Leyte, and Luzon with the Corps of Engineers on construction of roads, cantonments, hospitals and depots. He is now living at 1200 South Second Street, Alhambra, California.

LARRY WIDDOES is enrolled at the University of Michigan graduate school and is living at Willow Village.

MERRITT EUSEY, JR., has accepted a position as a sales engineer in the Los Angeles branch office of the Minneapolis Honeywell Regulator Company.

1942

NEAL HORNE started to work in April as a mechanical engineer for Austin Company, contractors, in Los Angeles.

ROBERT DE VAULT is a project engineer for the jet propulsion research program being conducted by the Navy at the University of Southern California.

KENNETH H. BEERS is still in the Navy on board the U. S. S. *New Jersey* which is now at Long Beach, California. Ken has a new daughter, Carol Ann.

PAUL McKIBBEN, contrary to rumors, is home—safe.

LIEUTENANT (jg) RICHARD HEAD is attached to the Bureau of Aeronautics in the Navy Department at Washington, D. C.

LIEUTENANT (jg) WALTER P. MITCHEL who is stationed at the U. S. Navy Electronics Laboratory at San Diego, visited the Campus in March.

CARTER HUNT has accepted a position with Hiram Walker and Sons in Peoria, Illinois.

KENNETH URBACH has accepted a position with the Radio Frequency Laboratories Inc., Boonton, New Jersey, and started work in March.

1943

LIEUTENANT (jg) ROLAND SAYE has just returned from China where he was stationed six months at the Port Directors *Office in Tsingtao. Roland is on* inactive status and is now living in West Los Angeles, California.

LIEUTENANT (jg) DOUGLAS C. REID is at the Navy Yard Oil Burning School, Philadelphia, as an Instructor and hopes to be home in May.

L. B. EDELMAN is attached to the Bureau of Aeronautics in the Navy Department at Washington, D. C.

LIEUTENANT (jg) JACK D. STONE returned in March from Honolulu and enjoys terminal leave until the middle of May. Jack was married eighteen months ago to Suzanne Smith of Chicago, Illinois.

WAYNE BROWN accepted a position in the Engineering Department of Douglas Aircraft, Santa Monica, California.

ENSIGN BOB McLEAN is aboard the *new carrier, U.S.S. Princeton,* which visited Havana, Cuba, on a recent shake-down cruise.

LIEUTENANT (jg) CHAS. STRICKLAND will finish his post graduate work at Annapolis the latter part of March and will then be separated from Service.

1944

DAVID R. JONES is now separated from Service, having returned from the Naval Ordnance Laboratory, Washington, D. C. Dave is living in Beverly Hills, California.

SECOND LIEUTENANT AL SAPLIS, after receiving his commission in the Infantry, shipped out in October and disembarked at Okinawa. He is now in a transportation outfit charged with the operation of the Port of Naba.

LIEUTENANT (jg) DONALD KEATING, *an Executive Officer and Navigator* on LST 811, returned to the West Coast after 15 months overseas in the Pacific. His ship took part in the later phases of the liberation of the Philippines, the invasion of Okinawa and later the invasion of Ie Shima. Don has made three trips to Japan with the occupation forces and has covered nearly every island in the Pacific.

ENSIGN RONALD S. JOHNSON is back in civilian life and visited the Campus in March when on terminal leave. Ron was shore based in Manila as a deep-sea diver for two months, from where he just returned. Prior to overseas duty he was at N.T.S. (Salvage) in New York. Ron *was married in March, 1945, to Miss* Roberta Lamon of Beverly Hills, California.

ENSIGN ROBERT LAABS visited the Campus in March while on terminal leave. Bob returned from active duty on Guam and Okinawa where he was stationed with the 148th Pontoon Battalion. Bob was married one year ago in March to Miss Betty Jean Bryant of Hollywood, California.

ENSIGN HORACE HIGGINS is back on a civilian status and has secured a position in engineering design with B. H. Hadley Co., Pomona, California. Horace was stationed on a PC-1256 at Iwo Jima for six months, later going to Chichi Jima for one month. The ship was brought back to Charleston to be de-commissioned.

FRANCIS E. MacDONALD is employed by the Nelson Equipment Company, Los Angeles.

1945

R. V. KNOX, BOB JORDAN, DUANE McRUER, DON SWANSON, DOD DODDER, DAVE BANKS, HARRY BROUGH, FRED DAVIS, LOWELL PARODE, DON SWEET, GENE SCOTT, JOHN LYONS, JOE HOOK, DON DUNCAN, BOB TROUT and DICK SPRINGER held an Alumni Association dinner on St. Simon's Island, Georgia, recently. These men of 1945 are stationed at the Tactical Radar Training School on the island and expect sea duty soon with probably discharges in the fall.

ENSIGN BOB TROUT was transferred in March from St. Simon's Island Radar School to report to San Francisco for duty in the amphibious forces. Bob was married last November to Miss Alice Champion of West Los Angeles, California.

BERNARD RASOF was married on February 9 to Miss Beatrice Leplin of West Los Angeles. Bernard is teaching mathematics at the Institute and working for his doctorate.

ENSIGN BRUCE WERNIER came down *from San Francisco to southern California* and visited the Campus in March while his ship, LSM 450, was being overhauled.

ENSIGN WILLIAM (Bill) TILDEN visited his family in Los Angeles in March on a 15-day leave from Camp Endicott, Rhode Island. Bill is coming back to school in the fall for graduate work.

ENSIGN JOHN S. DAVIS is stationed on the U.S.S. *Iowa.*

ENSIGN NORMAN LEE is at Navy Frontier Base, Charleston, South Carolina, awaiting an assignment to another ship.