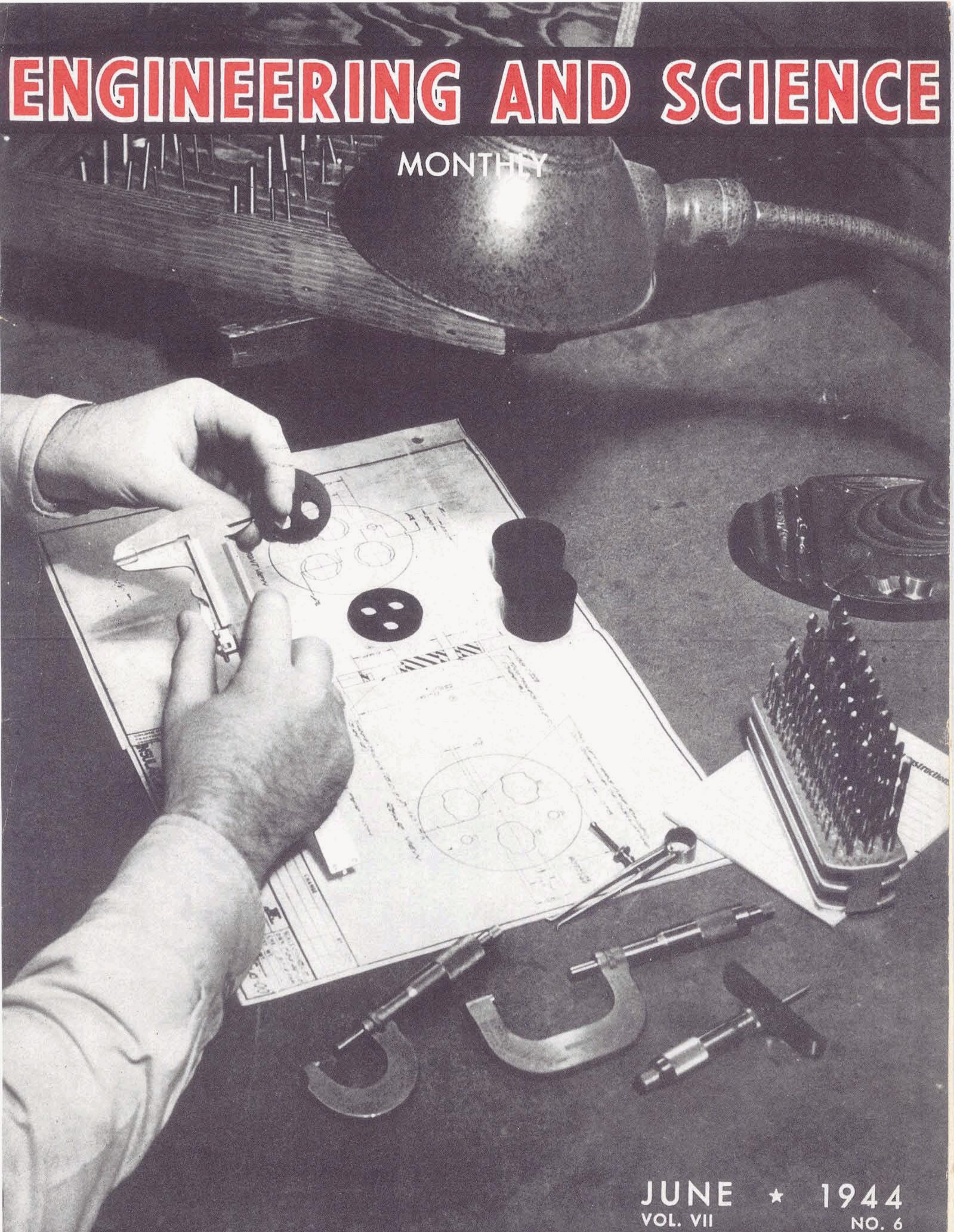
ENGINEERING AND SCIENCE

MONTHLY



JUNE ★ 1944
VOL. VII NO. 6

PUBLISHED BY CALIFORNIA INSTITUTE OF TECHNOLOGY ALUMNI ASSOCIATION

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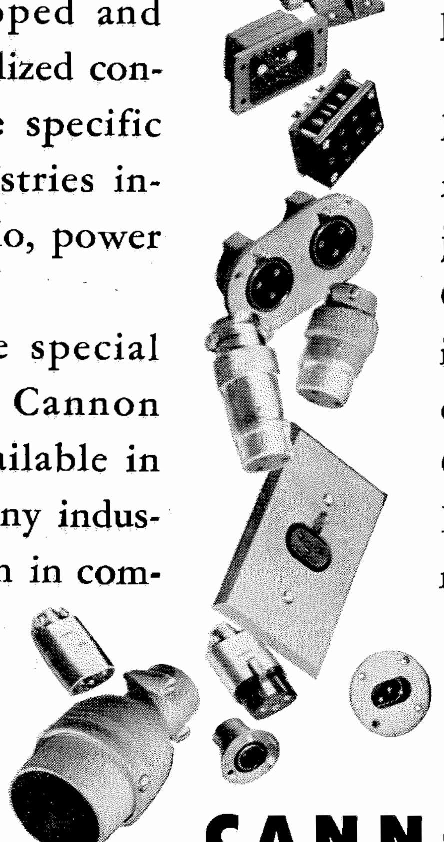

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BY-LINES

FRANK CLAYTON

Mr. Clayton, chief plant engineer at the Fort Worth division of the Consolidated Vultee Aircraft Corporation, received his B.S. degree in electrical engineering from Caltech in 1925. He was with General Electric Company until 1933, and has worked on various projects, including the 50 to 60 cycle frequency change in Los Angeles and the illumination of the Golden Gate International Exposition.

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CHARLES S. BARRETT

Dr. Barrett, associate professor at Carnegie Tech in Pittsburgh, is active in research in physical metallurgy. He has published numerous technical articles on the applications of X-rays, gamma rays, and electrons to metallurgical problems and is the author of a text and reference book on the structure of metals. He is active in the technical societies devoted to physics and metallurgy.

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PAUL D. V. MANNING

Dr. Manning, vice president in charge of research of International Minerals and Chemical Corporation, Chicago, received his M.S. degree from Caltech in 1917 and his Ph.D. degree in chemical engineering from Columbia in 1927. He has been responsible for the development of a new process for the production of magnesium metal from langbeinite ore in New Mexico and from Texas dolomite.

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DAVID WELCH

Mr. Welch received his A.B. degree in mechanical engineering from Stanford in 1941 and his professional degree in industrial design from the Institute in 1943. He had some business experience in the industrial design field and is now employed as instructor in the engineering drafting department of the Institute.

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ENGINEERING AND SCIENCE MONTHLY is published monthly on the 25th of each month by the Alumni Association, Inc., California Institute of Technology, 1201 East California Street, Pasadena, California. Annual subscription $2.50; 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

The Truth Shall Make You Free

CONTENTS FOR JUNE, 1944

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ENGINEERING AND SCIENCE MONTHLY

Edited at California Institute of Technology

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COVER ILLUSTRATION

Constant inspection of parts and assemblies as well as frequent checkup of machines and methods are the best assurance of performance in actual use of the many vital circuit connectors in modern aircraft. The photograph on the cover was made in an inspection office of the Cannon Electric Development Company, makers of these connectors.

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ENGINEERING AND SCIENCE
Monthly

Vol. VII, No. 6 June, 1944

The Month in Focus

INCREASE of production facilities since the beginning of the war has been tremendous. These facilities of course have not been limited to manufacturing but have included equipment and plants for the production of raw materials which are utilized in construction and manufacture. Everyone is conscious of the effort devoted to the expansion in the production of steel, aluminum, magnesium, and other materials.

Production of Magnesium

The growth of the magnesium industry is particularly interesting, and has given rise to much discussion of whether or not the construction of facilities for the production of magnesium has been overdone. The annual capacity of all magnesium metal plants in the country for 1943 was approximately 580,000,000 lbs., and in February of that year it was estimated that the annual requirement for this metal for aircraft purposes and for alloying with aluminum would be about 170,000,000 lbs. Whether or not this capacity is being or will be fully utilized will not be discussed here. That is a broad and general question of economics. However, this issue of *Engineering and Science* carries an excellent article by Dr. Paul D. V. Manning on magnesium and its production. Another chapter of the magnesium story, pertaining to the development and improvement of alloys, is yet to be written. However, before that story can be told, more research must be done. This will be an exceedingly interesting development to follow for there are some inherent difficulties related to the structure of magesium, and until these problems are solved the widespread engineering use of this interesting metal and its alloys may be subject to question.

The Electron Microscope

In the field of scientific instruments, the electron microscope has recently created wide interest. Its relative newness does not permit a statement of its ultimate range of usefulness. Dr. Charles S. Barrett presents, in this issue, a clear picture of the essential features and some of the uses of the electron microscope. Although several illustrations of its use are presented, the reader will also realize that there are certain limitations to the application of this instrument. At present it is not possible to interpret all that is seen in a photograph made on the electron microscope. The instrument is another tool which physics has made available to other fields of science and through which it may be possible to obtain a fuller knowledge of the properties of engineering materials.

Aircraft Plant Engineering

The vast amount of effort associated with constructing and equipping a large aircraft plant is presented by Frank Clayton in his article on the Fort Worth Plant of Consolidated Vultee. The coordination required in an undertaking of such magnitude requiring speed was remarkable and the project illustrates the combined use of the many branches of engineering involved in such an enterprise.

Is Engineering a Profession?

In discussing the ramifications of engineering, one frequently hears the plea that engineers should be designated as a professional group. There have been frequent attempts to place the engineer in a category comparable to that of the physician or lawyer. It is difficult, however, for engineers to form a unity because of the extensive scope covered by their various fields. This fact was presented by Herbert J. Gilkey in the March, 1944, issue of the "Journal of Engineering Education": "To be at all comparable in scope to engineering, medicine would have to embrace everything from the delivery of a baby to the disposal of a carcass, from the manufacture of drugs and instruments to the performance of a tonsillectomy on a giraffe." Engineering is not a unit since it comprises many diversified activities including electrical, mechanical, civil and chemical engineering. Engineers with a degree of common interest may belong to the technical society representing that field; but membership in one organization is not sufficient, for the individual engineer has interests in other societies covering overlapping fields. This diversification of interest is probably the principal deterrent to unity. For instance, one civil engineer may be concerned with construction, incorporating an interest in the properties of construction materials and the influence which various methods of utilizing these materials has on the strength of the structure. He is further concerned with the methods of testing component parts of the structures and must assist in the establishment of codes for construction in order

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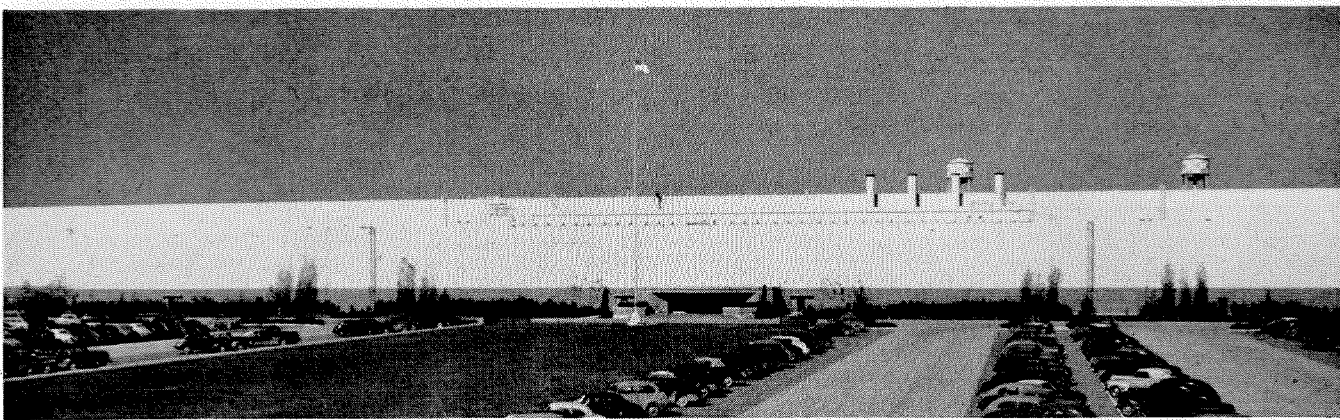


FIG. 1—Main entrance to administration building, showing stacks above boiler house and assembly building in background.

Controlled Conditions in the WORLD'S LARGEST WINDOWLESS FACTORY

BY FRANK CLAYTON

WHEN it was announced early in 1941 that the United States would start on a program aimed at the construction of 500 heavy bombardment airplanes a month, the first reaction of members of the aircraft industry, particularly engineers engaged in plant design, was to translate this quantity into terms of new factories and to speculate on their size and locations. Based on the production then being realized, it appeared that six to eight new plants would be required, each as large as the Consolidated Aircraft San Diego plant or the Boeing plant at Seattle.

SELECTION OF SITES

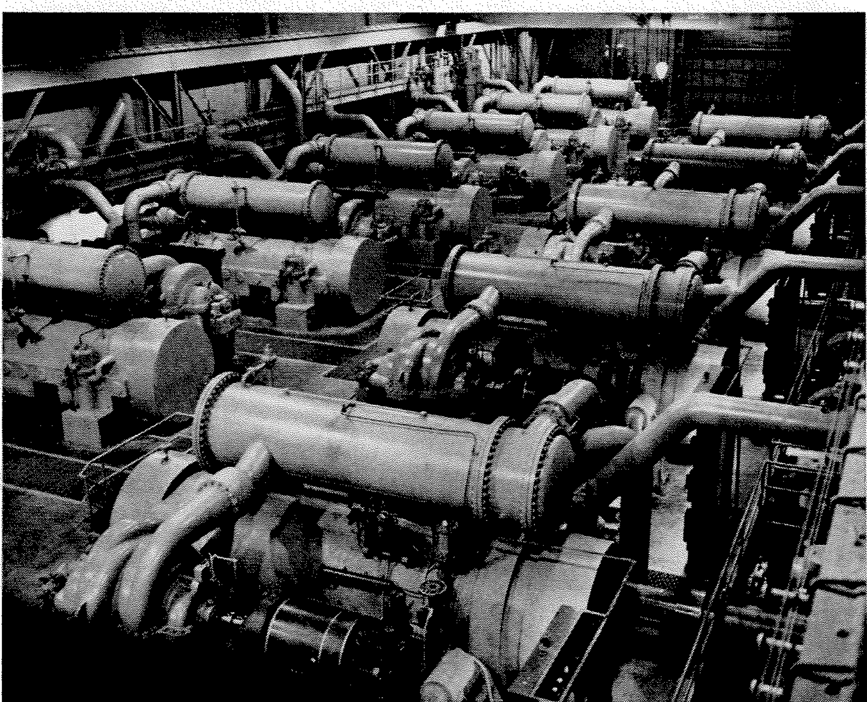
In selecting sites for the new plants, primary consideration was given to the following factors:

1. Protection.
2. Weather.
3. Labor supply.
4. Terrain.
5. Utilities.

Consideration of the first factor precluded location of the new plants near the Pacific or Atlantic coasts, although the Douglas Long Beach plant was then under construction. In general, the new plants were all located in the Middle West or South.

The second consideration, weather, while important for flying and testing, has become less and less a factor in manufacturing as air conditioning has come into wider use.

While the needs of war industries in general have caused large movements of labor all over the country, often doubling the population of communities, for example San Diego and Fort Worth, it is desirable and generally necessary to locate any new large factory near an adequate supply of labor. This assures at least manpower enough to get started, and a fairly large com-



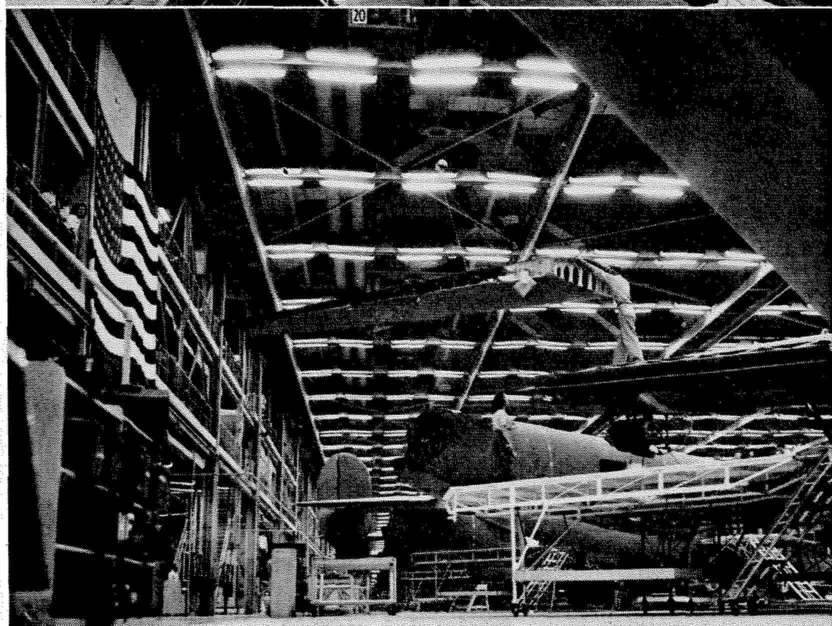
AT LEFT:

FIG. 2—Turbine deck showing eleven of the twelve refrigeration units. Refrigerant condensers are at the top, evaporators under them, and steam condensers and circulating pumps at lower level under the deck.

AT RIGHT:

FIG. 3—General view of final assembly line showing high bay lighting installation.

FIG. 4—Assembly area showing monorail crane, lighting system and, above trusses, ventilating air distribution.



munity usually has more capacity than a small one to absorb additional population or at least accommodate it while new facilities are being acquired.

Consideration of terrain is very important, since every large aircraft plant must have an adjacent, suitable air field. Realizing the vast training program necessary to utilize the expanded production, and the limited approaches and available space at most air terminals, most of the new plant projects included new air fields. At Fort Worth the field is operated by and shared with the Air Training Command. It is important, especially for flight testing, to have not only runways of adequate length but an unobstructed surrounding terrain, preferably one where there is reasonable chance to set a plane down in an emergency without completely wrecking it or losing the crew.

Like most manufacturing plants, aircraft factories require adequate utilities. A reliable source of satisfactory fuel is essential for heating, heat treating, process work, generating process steam, etc. Electric power is essential for lighting, ventilation, process purposes, and for operating productive machinery. Adequate quantities of pure water are needed for a variety of purposes ranging from drinking and sanitation to chemical baths, air conditioning and watering the lawn. Not of least importance in a factory employing thousands of workers is an adequate sewage disposal system.

Based on the above considerations, a survey had been made the previous year for a suitable site for a new Consolidated Aircraft plant, with Fort Worth as the favored location, but other considerations dictated its location in San Diego, where it is now known as Plant Two. The groundwork having been thus laid, Fort Worth was soon chosen as the site for a new heavy bomber plant to be owned by the U. S. Army and operated by Consolidated Aircraft Corporation. Since the merger with Vultee, this is known as Consolidated Vultee Aircraft Corporation, Fort Worth Division, and the plant itself as Government-owned Aircraft Plant No. 4.

PRODUCTION PLAN

The original production plan involved three plants to be operated by three different companies. At the same time Fort Worth was selected for a plant to be operated by Consolidated, Tulsa, Oklahoma, was chosen for a duplicate plant to be operated by Douglas. Both plants were to assemble B-24 airplanes from parts and components to be manufactured in a new plant to be operated by Ford Motor Company and located at Willow Run near Detroit.

As the plants were constructed, it became apparent that the Fort Worth plant would be ready for production long before any parts could be obtained from Willow Run, so early in 1942 it was decided to add a parts manufacturing plant at Fort Worth. This, combined with the original assembly plant and subsequent expansions, some still in progress, constitutes the largest factory of its kind in the world.

Starting out by assembling planes from parts shipped from San Diego, the first completed B-24 was turned out in April, 1942, 100 days ahead of schedule. In the meantime, parts manufacturing was started in the original assembly building, and considerable production was accomplished before the first set of components was received from Willow Run. Later, these came in on schedule, and the originally designed capacity of the assembly plant has been exceeded while at the same time an even greater quantity of completely Fort Worth built planes has been turned out.

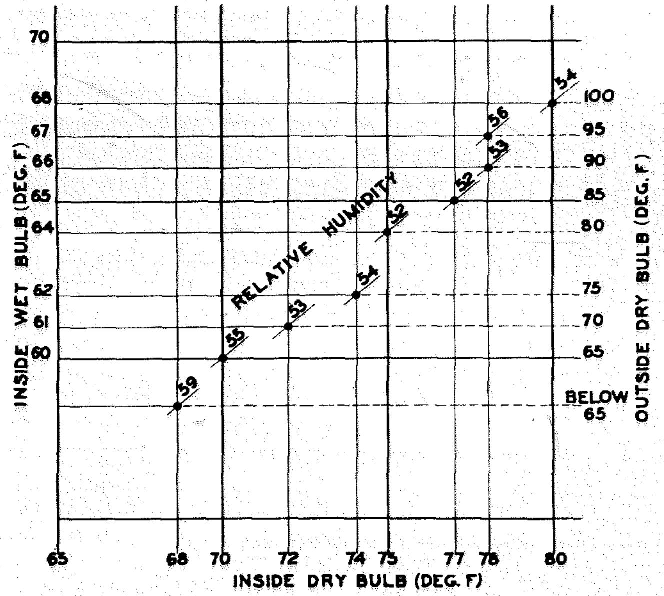


FIG. 5—Chart showing actual inside conditions held in factory areas at various outside temperatures. High relative humidity is possible without condensation due to wall insulation and construction.

ENGINEERING

In order to divide the burden as well as obtain the benefits of the experience of all three organizations, engineering of the various phases of the program was divided between them. Thus, Ford and Douglas worked on tooling and production, Ford actually building final assembly fixtures for all three plants, while Consolidated took over the plant engineering and machine tool procurement programs for both the Fort Worth and Tulsa plants.

These plants, owned by the U. S. Army, were designed and built by the Austin Company under contracts with the U. S. Engineers. Consolidated Aircraft Corporation was given a contract for consulting services and acted as consulting engineers on the design and construction of these plants.

For reasons of economy and speed, and due to their original duplicate designed functions, the Fort Worth and Tulsa plants were made identical as to size, shape, structural design and plant facilities. They differed only in orientation and utility services. Thus, it was possible to use the same structural, electrical and mechanical engineering and most of the plans for both plants. It was also possible to combine purchases of equipment for both. When the lighting fixtures and air-cooled distribution transformers were purchased in this manner, they constituted the largest orders, respectively, for either type of equipment in the history of the electrical business.

DESIGN CRITERIA

In line with the first factor in selection of a suitable site, one of the first criteria to be decided upon was that these plants were to be of "blackout" construction. This meant that they were to be operable day and night at full capacity without any possibility of light showing outside, especially from above. Actually, for convenience, safety and plant protection, both fence- and floodlights are liberally used but all are extinguishable from a single "blackout" switch located at the police supervisory desk.

The "blackout" feature obviously requires that all work be carried on under artificial light, and that mechanical ventilation and air conditioning be provided. Inasmuch as the course of the war has largely eliminated the need for "blackout" protection, it is a moot question today whether the original aim was really protection or the setting up of criteria requiring air conditioning. It is highly doubtful if, under conditions of critical material shortages, air conditioning would have been approved if the design of the plant had not made it a necessity.

Dimensional criteria were determined from the experience of Consolidated gained in the manufacture of B-24 airplanes as well as large flying boats at San Diego. Plans for moving assembly lines had already been conceived, and it was decided to incorporate this method in the new plants. Extensive studies were also made of other new plants such as the Vega plant at Burbank, Consolidated parts plant at San Diego, then under construction, and the Douglas Long Beach and North American Dallas plants, both air-conditioned and of "blackout" construction.

A comprehensive study of weather conditions in this vicinity covering a period of years was made, and on this basis the following criteria for air conditioning were determined:

Maximum summer conditions:
Outdoors—100° F. dry bulb.
78° F. wet bulb.
Indoors—80° F. dry bulb.
67° F. wet bulb.
Relative humidity in plant—52% to 56%.

Minimum winter conditions:
Outdoors— 0° F. dry bulb.
Indoors—65° F. dry bulb.
Relative humidity in plant—40% to 59%.
Control to be ± 1° F. within any zone, with 5° maximum variation throughout the plant.

Illumination design has been based on a maintained lighting intensity of 35 foot-candlepower at the working plane with maximum horizontal and upward components.

AIR CONDITIONING SYSTEM

From the assumed population of the plant, building dimensions and orientation, as well as lighting and productive machinery and equipment loads, it was determined that the capacity of the refrigeration system should be approximately 12,000 tons (7,000 tons in the original assembly plant design, and 5,000 tons for the added parts plant). With this capacity the thermal transmission of walls and roof was as follows:

Walls.................065 B.T.U. per hour per square foot
Roof...................07 B.T.U. per hour per square foot

These values have been realized through use of a unique construction of steel paneling combined with approximately four-inch thickness of fiber glass wool. By exposing the inner surface of the fiber glass, a very good acoustic condition in the plant has been achieved.

The volume of air circulated is equal to approximately 1.4 changes per hour based on total cubic content of the buildings, with 25 per cent to 100 per cent fresh air depending on outside conditions. This appears to be a slow rate of circulation, until it is realized that most occupancy is in the first 12 feet above the floor, whereas the average height of the roof is 55 feet. Actual circulating fan capacity in the assembly and parts manufacturing buildings alone is in excess of 2,600,000 cubic feet per minute.

The problem of air distribution was complicated by the requirement that all air-supply outlets as well as returns be located 40 feet above the floor so as to clear the monorail crane system secured to the lower chord of the roof trusses and covering the entire building area.

To accomplish this, and as a result of competitive designs tested under simulated conditions, double-purpose outlets were chosen which automatically change from diffusing characteristics when handling cool air on the "summer cycle" to concentrated downward distribution when handling warm air on the "winter cycle."

Temperatures in various zones are controlled by double range thermostats of pneumatic type, remote-controlled from the boiler room. Indoor and outdoor temperatures may be read and adjustments made, when and if necessary, anywhere in the plant from the master control panel.

Humidity control, while not as complete as in the conventional washed-air-reheat cycle system, is reasonably satisfactory and the operating cost is considerably lower. The range of relative humidity specified under "design criteria" is based on what the system is capable of and falls within a very desirable portion of the comfort zone as shown on standard psychometric charts, modified for the degree of air movement existing.

All fans in the main factory buildings are located on decks above the lower chord of the roof trusses and are connected by catwalks. Each deck has two fans averaging 40,000 cubic feet per minute each, driven by 30 and 40 horsepower motors. Cooling is by finned coil units through which is circulated chilled water from the central refrigeration system. Spray pumps and per cent of fresh air admitted, controllable from the boiler room, afford control of humidity, and self-cleaning oil type filters clean both the fresh and recirculated air. Air control is effected by means of pneumatically operated fresh air, recirculated air, face and bypass dampers. Minimum fresh air settings are determined largely by the need to supply exhaust air for spray booths, heat treat vent hoods, etc., amounting to over 300,000 cubic feet per minute. Excess exhaust air is discharged through automatically-controlled relief dampers which form a natural restriction, with the result that the buildings are carried at a positive static pressure of approximately one-quarter inch. This tends to exclude outside air when doors are opened.

Except for pedestrians, entrance and exit are via electrically-operated vertical lift doors varying in size from 20 feet wide and 15 feet high to 200 feet wide and 40 feet high. These admit the largest trucks, railroad cars, etc., and provide for removal of completed planes. To decrease exchange of air when large doors are opened, a series of high-velocity nozzles is provided above each, automatically controlled to emit a curtain of warm or cool air, as the case may be, across the door opening whenever it is operated. At the same time all relief dampers automatically close, tending to cause an outward flow of air.

Heating in the original assembly building is by warm water circulated through the same piping system used for cooling, and steam boosters for use when temporary heating is needed, as on a cool morning during weather when the general system is on the summer or cooling cycle. In the parts manufacturing building steam heat is utilized. Because of the distance from the central heating plant and the limitation of heat-exchanger capacity, it was found most economical to use high-pressure steam. This is advantageous also because of the demand for process steam throughout the parts manufacturing area.

The central heating and refrigerating plant consists of four steam generators each rated 100,000 pounds per hour at 225 pounds per square inch and no superheat. These are gas fired with automatic-combustion control and with fuel-oil standby. Steam is distributed to the assembly building and other buildings in the plant at 50 pounds per square inch for booster coils and process purposes, and at 125 pounds per square inch to the parts manufacturing building for both heating and process. Balanced type pressure reducing valves are used in both cases. All boiler auxiliaries, such as feed water pumps and forced and induced draft fans, are turbine driven.

Boiler feed water treatment consists of a lime soda ash filtering and treating unit operating on 10 pounds per square inch back pressure. Provision is made for feeding either filtered city water or raw lake water to the unit.

Warm water for assembly building heating is obtained by surface condenser-type heat exchangers, circulating water at approximately 90 degrees Fahrenheit.

Chilled water, varying from 47 degrees Fahrenheit to 59 degrees Fahrenheit as required, is cooled by means of 12 turbine driven centrifugal type compressors, utilizing freon F-11 as refrigerant. Eleven of these machines are rated 1,090 tons and one 550 tons, giving 12,540 tons total capacity of the plant. In practice, one machine is normally held in reserve at any one time, even in hottest weather. Steam consumption is approximately 15,000 pounds per hour at full capacity on each of the large machines. Refrigerant and steam condensers both use condenser water circulated from and to the nearby lake through a closed system. Approximately two gallons per minute per ton of condenser water is required which, together with other raw water needs, is circulated by means of five synchronous motor-driven pumps with a combined capacity of approximately 30,000 gallons per minute located in a pump house at the lake about three-quarters mile from the plant. This pump house also contains electric- and diesel-engine-driven fire pumps for the plant fire-protection system. Summer water temperature of the lake is approximately 85 degrees Fahrenheit.

Chilled water is circulated to all fan locations through a closed system by means of seven 300 horsepower induction motor driven centrifugal pumps, three of which are also used to circulate heating water in the assembly building.

LIGHTING SYSTEM

The lighting requirements of a "controlled-conditions" plant are not essentially different from those of any plant operating more than one shift, except that the requirement of continuous operation means more frequent lamp replacements and greater maintenance. In selecting a lighting system, however, the total wattage is very important, not only from an energy cost standpoint but because of added load on the air conditioning system, which results in both investment and operating costs several times as great as any difference in cost of energy.

In order to obtain 35 foot-candlepower maintained minimum intensity at floor level from sources 40 feet high, the normal method had been to use relatively narnow distribution type reflectors with either incandescent, high-intensity mercury, or a combination of these two types of lamps. A few installations had been made of type *F* fluorescent lamps. The various systems analyzed for this plant, and their relative factors for comparison, are shown in Table No. I. (1—lowest to 5—highest cost).

TABLE I

Type of Lamp	*Installed First Cost*	*Operating Cost**	*Color Factor*	*Maintenance Cost*	*Light Distribution*
Incandescent	1	5	3	5	3
High-Intensity Mercury	3	1	5	3	5
Incand.-Mercury Comb.	2	4	4	4	4
Type F Fluorescent (40W lamp)	5	3	1	2	2
Type "RF" Fluorescent	4	2	2	1	1

*Including air conditioning.

The desire for high lighting intensity on the vertical plane indicated the use of wide angle distribution, even at 40-foot mounting height. This and other factors indicated in Table No. I led to the selection of type *RF*-industrial white 85-watt lamps, mostly in two-lamp wide-angle porcelain-enameled steel reflectors. These are installed in double rows bracketed from the main trusses which are on 25-foot centers. Individual fixtures in each row are on approximately eight-foot centers. Figuring 200 watts per fixture, including losses in the ballast, results in 1.92 watts per square foot of floor area. With the wide-angle distribution, over 700 fixtures contribute measurably to the light at any point. Also, and contrary to conventional illumination calculation, the intensity is very little different on a working plane at floor level or 15 feet above the floor as, for instance, on top of a wing or fuselage.

In order to increase the upward component in assembly areas, a white cement finish on the floor has been provided. This gives an upward intensity of approximately 12 foot-candlepower even under the wing of a plane, eliminating the need for auxiliary lighting on the final assembly line except inside the fuselage. The average life of type *RF* lamps has been found to be 4,000 hours, after which time all lamps in a given area are changed and reflectors cleaned. Later additions, as well as a large area under the parts manufacturing building mezzanine, utilize type *F* 100-watt lamps as the manufacture of type *RF* fixtures was stopped by W.P.B. during construction of the parts plant.

All factory lighting, except auxiliary and extension lights, is operated on 254 volts from the 254/440Y-volt, three-phase, four-wire distribution system. It is controlled by magnetically-operated latched-in contactors, usually of 100-ampere capacity, with individual circuit protection by means of cartridge fuses on the load sides. Push buttons are provided for operation from the floor without necessity of dropping circuit wiring for this purpose. This design has resulted in the use of no wire larger than No. 12 A.W.G. in any lighting circuits, and with maximum voltage drop of three per cent from transformers to fixtures.

EMERGENCY SYSTEM

Emergency lighting, absolutely necessary in a "blackout" plant, is provided by means of incandescent lights to give approximately one-eighth foot-candlepower intensity in general areas and one-fourth foot-candlepower on stairways, in passageways and at exits. A separate 2400-volt emergency feeder extends throughout the plant, normally energized from the main substation, and from a 500-kilowatt steam turbine-generator set which automatically starts upon failure of power. Individual areas are fed from small air-cooled transformers and magnetic throw-over switches which act upon failure of regular power supply in any individual area. In case of a power outage, the generator set will start, attain full speed and the first circuit close in approximately 11 seconds. There are three circuits, the other two closing a few seconds later. Emergency power from this system is also provided to operate enough outside flood- and fence-lights for safe evacuation and plant protection, as well as time clocks and the factory whistles.

ELECTRICAL DISTRIBUTION

The power capacity of the electric utility system in this territory, while ample to carry the plant, is relatively limited, especially as to summer demand due to very heavy air-conditioning loading. This was a large factor in deciding on steam-driven refrigeration. The plant service is from a switching station inserted in a 60-kilovolt network loop, and located approximately six miles from the main Fort Worth generating station which has a capacity of 50,500 kilowatts. In the opposite direction the loop is of limited capacity, but arrangement was made through the Federal Power Commission to have the two Possum Kingdom Dam generators, of 12,500 kilowatts each, carried on the line as a spinning reserve during those hours they would not normally operate.

The plant is served by two 10,000 kilovolt-ampere substations, 60—2.4/4.16-Y kilovolt, 60-cycle, three-phase. One of these serves the original assembly plant and the other, the parts plant. During the first year of operation over 50 outages occurred, mostly due to atmospheric disturbances on the west or weak loop of the network. A calculating board study of the system was made at Massachusetts Institute of Technology which indicated that with the west line open the entire plant load of approximately 16,000 kilowatts could be carried from the east, or Fort Worth side, with satisfactory voltage; but if the east line opened, the voltage drop would not only be excessive but the total load could not be carried at all. The study indicated that with the installation of 8500 kilovolt amperes of capacitors at the substations, the west line would carry approximately 12,000 kilowatts. In an emergency this is accomplished by cutting off the air-conditioning machinery with the exception of fans, enabling the factory to maintain full production.

As a result of the study, automatic circuit breakers were installed at the switching station, set to open either line separately in the event of a fault, and the capacitors were installed in the substations on the 4160-volt bus. It is now necessary to cut off half the capacitors during light load periods to prevent over voltage and corresponding short life of the incandescent lights in the plant.

Switching of 4160 volt power is done by means of remote controlled electrically operated metal clad outdoor switchgear. In general, each breaker controls a feeder handling two 600 kilovolt amperes, 4160—254/440-Y, three-phase, air-cooled transformers mounted on platforms in the building trusses approximately 45 feet above the floor. Primaries are protected by gang operated oil fuse cutouts. The 4160-volt distribution systems in both assembly and parts manufacturing buildings are radial type. A solidly grounded neutral is carried throughout the plant.

Power distribution is at 254/440-Y volts, grounded neutral, and is of two types. In the assembly building, because of both its great length and relatively light loading per unit of area, a straight radial system is used. Distribution is through a dead front switchboard at each transformer equipped with main air circuit breaker and fused circuit switches ranging from 30 to 400-ampere capacity. In the parts manufacturing building, where load density is greater and spacing closer, a secondary network is used, consisting of 1000-ampere plug-in bus arranged in two 550-ampere circuits each. Thus, at any cross section of the building, four 500-ampere circuits are available. Switchgear at each transformer consists of a main air circuit breaker, four network air circuit breakers and network protection relays. This has been of great convenience in that heavy machinery is frequently moved, and all loads are readily taken care of.

In addition to power distribution to individual loads, plug-in bus duct is widely used in machine tool areas. Also, 440-volt arctite receptacles are installed throughout the plant for plugging in arc welders, rectifiers, hydraulic test stands, etc.

Power for hand tools, extension lamps and other 120-

(Continued on Page 18)

THE *Electron* MICROSCOPE

BY CHARLES S. BARRETT

THE development of the electron microscope is the most important advance in the field of microscopy in many years. It opens to view for the first time the world of things at a size of a millionth of an inch. Bacteriology, biology, chemistry and metallurgy have profited from the use of this instrument during the very few years it has been available and much more may be expected of it in the future. An attempt will be made in this article to touch upon its applications to various fields of research, but the writer himself is engaged in metallurgical research and therefore will speak of that field in greater detail.

THE INSTRUMENT

The current commercial model of the electron microscope, manufactured by the Radio Corporation of America, is truly imposing. (See *Fig. 1.*) It stands about seven feet high and, together with its auxiliary vacuum pumps and work benches, requires a room of moderate size. It is in reality a large vacuum tube containing an incandescent lamp filament that throws off electrons when heated, a source of high voltage electricity to speed the electrons down through the instrument, and a series of wire-wound magnets to bring the electrons into focus on the viewing screen and on the photographic plate. There are 53 radio tubes in it, which are fitted compactly on panels that fold down from the back of the instrument. The numerous electrical circuits and radio tubes are necessitated by the requirement that the electrical currents through some of the windings be held constant to one part in 25,000, while the voltage in the city electric lines supplying the microscopes may vary by one part in 25. The mechanical details of the device are also intricate, for they must provide for movement of the specimen and of the photographic plate inside the vacuum chamber without disturbing the high vacuum. There are more than 50 joints that must be made and maintained vacuum tight. Quite naturally, the adjustment and maintenance problems are much more numerous and varied with this instrument than with ordinary microscopes.

An instrument so complex in construction and so time-consuming in operation should give in return some results far superior to those from an ordinary light microscope, and this it does. It is a sort of "supermicroscope," with a power to magnify small particles and details of objects that is far beyond that of conventional microscopes. It has been said that the electron microscope can enlarge a human hair to the size of a giant redwood tree, or a particle of metal powder so fine as to be barely visible to the size of a room. While statements like these can be justified, the degree of magnification that can be obtained is not the important aspect of the problem. Even a child's movie projector can produce enlargements of this size, if the screen is moved to a sufficient distance from the lantern.

The importance of the electron microscope lies, rather, in the amount of detail that can be seen in the final enlargement—the sharpness of the image. Some of the accompanying reproductions of pictures taken with the electron microscope and with the conventional type microscope illustrate the fact that, at the same magnification, much more can be seen in the electron micrograph than in the light micrograph. In fact, the details that can be seen in the photographs from the electron microscope range down to a tenth and even to a hundredth the size of the smallest details that can be seen with the ordinary light microscope. Particles can be photographed that are only 10 to 15 atoms in diameter. This great increase in power (resolving power, as the microscopist calls it) could only be obtained in a light microscope by a reduction in the wave length of the light to a hundredth of the actual wave length of visible light. This is impossible with light, but in the electron microscope it is accomplished, in effect, by substituting for light a stream of

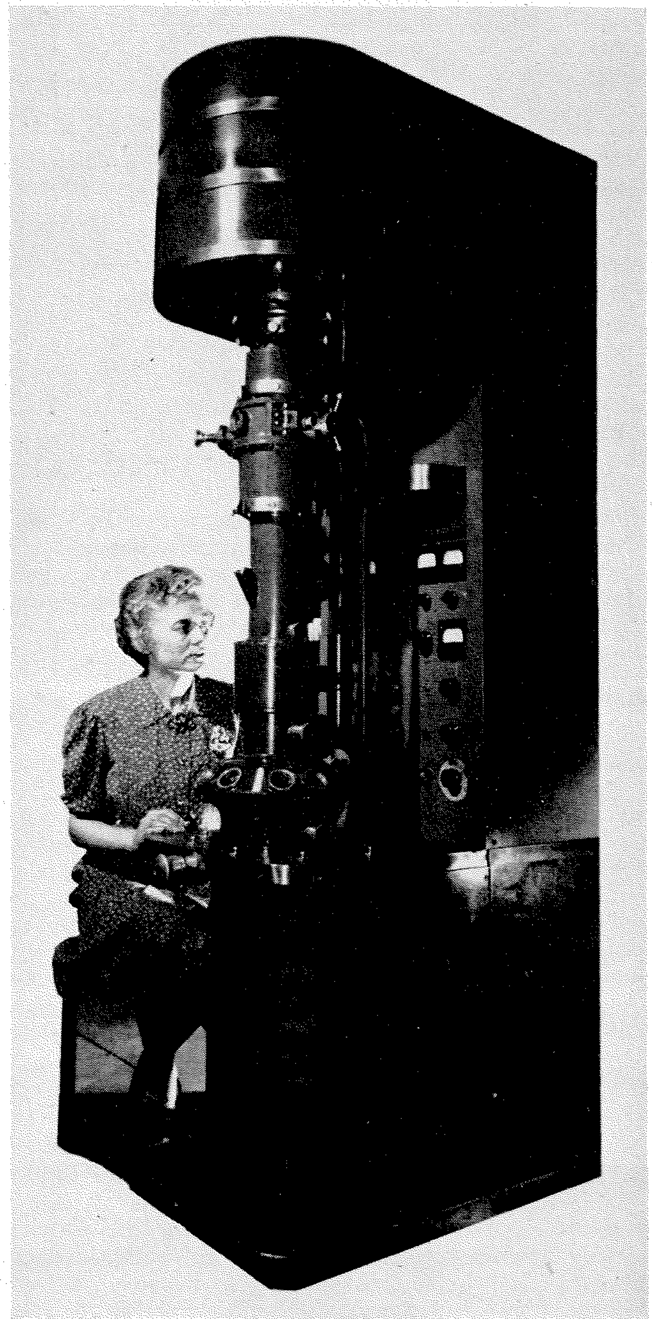


FIG. 1—The electron microscope.

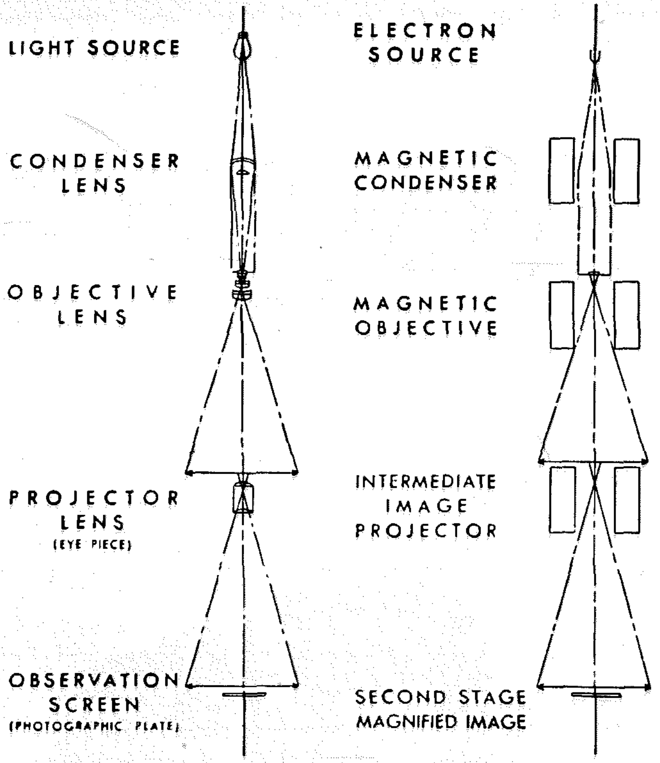


FIG. 2—The sequence of lenses in a high-power microscope is duplicated in an electron microscope.

electrons that act in the way that a beam of light of this short wave length would act. The electrons are directed by electric and magnetic means so that they are focussed as a beam of light is focussed by a lens. (See *Fig. 2.*)

The substitution of a beam of electrons for a beam of light shortens the wave length much more than a hundredfold, and if one could make full use of the principle that the resolving power increases proportionately, one might imagine that the electron microscope would permit us to see individual atoms. At the present time, however, this is not possible, and it seems likely that several factors will prevent it even if additional improvements in the apparatus are made.

It is sometimes practicable to magnify the linear dimensions of objects 100,000 times by using an electron microscope, but usually it is better to use magnifications of 5,000, 10,000 or 20,000, for it is seldom that the detail can be increased by using magnifications beyond these figures. The entire field of view at a magnification of 100,000 diameters is not large enough to show the whole of one red blood cell, or of an average-sized particle of airborne dust 0.002 millimeters in diameter. It is understandable, therefore, why it is often best to increase the field of view by reducing the magnification to about 2,000 diameters when exposing the negative and then to enlarge the negative in the dark room when making prints of it.

OPERATION

The electron microscope is operated by inserting a sample in the vacuum chamber and adjusting it in the beam of electrons. The enlarged image is brought into view and focussed on the viewing screen, which is about the size of one's hand, by turning knobs much as one tunes a radio receiver. Increasing the current through the final lens causes the image to grow from a pinpoint until it covers the entire screen, and at the same time the image rotates about its center. If the sample is powdered material, dust, colloidal particles or bacteria, the image will be a greatly enlarged shadow of these. The electrons seldom actually penetrate the particles themselves, for only particles that are less than one or two hundred atoms in thickness are transparent to the electrons; all larger particles are opaque and merely cast shadows on the viewing screen. Unfortunately, the image is in black and white and lacks the color that is such a striking and valuable attribute of an image in an ordinary microscope, but it is nevertheless excellent for measuring the size and shape of the particles or for disclosing their surface contours. It is possible to take two pictures of the same particles in such a way that they can be viewed in a stereoscope. When one looks at a pair of stereoscopic pictures the sense of depth they convey makes it easy to imagine one is in a micro-world full of strange objects.

APPLICATIONS

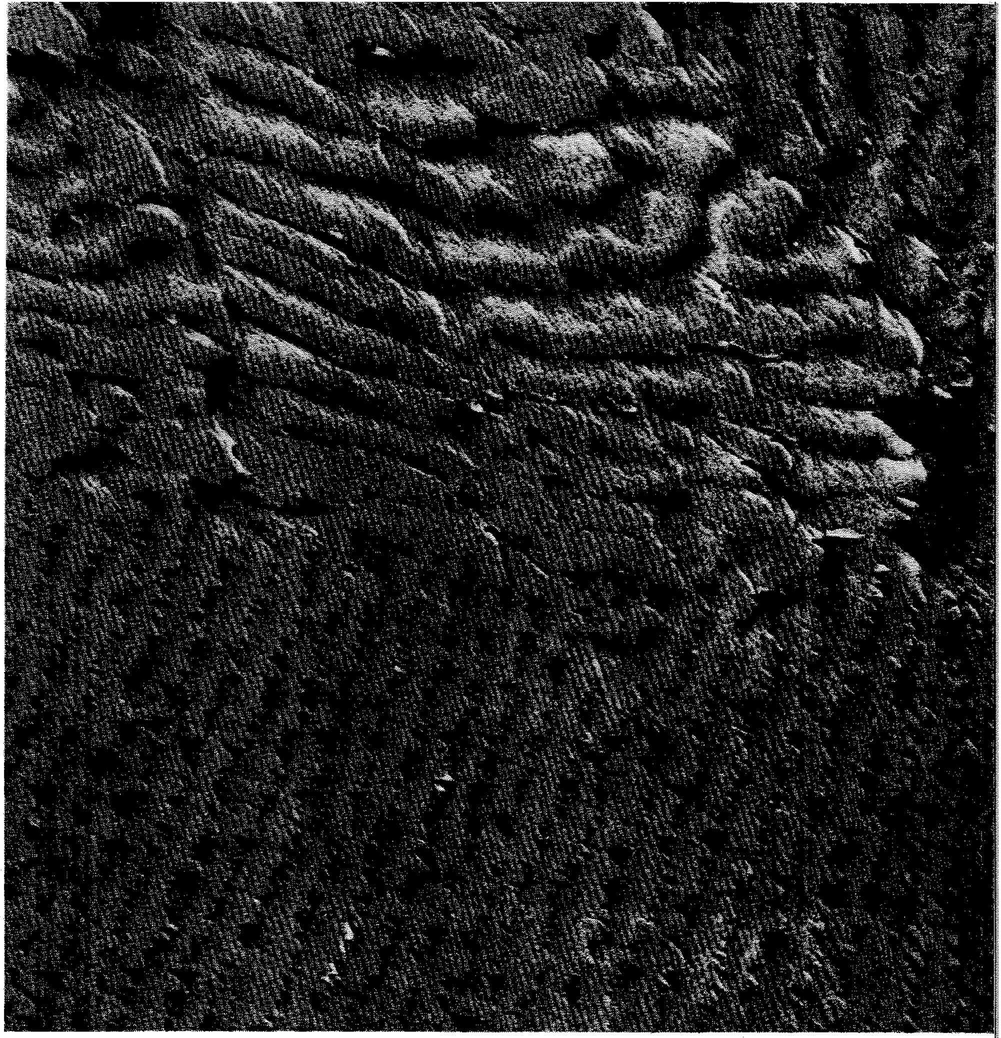
In the fields of bacteriology, biology, and chemistry, many discoveries have been made and many structures seen for the first time with the electron microscope. The study of viruses has progressed rapidly with the new instrument, for practically all of the viruses are too small to be observed directly by any other means. Their exact shape and size can now be measured, as well as their tendency to clump together. The manner in which drugs attack the viruses can be studied, as well as the way viruses are attacked by antibodies that are generated in the body. When bacteria are magnified to the size of cigarettes it becomes possible to view the much smaller organisms known as bacteriophage that attach themselves to the bacteria and bring about their destruction. One type of bacteriophage, which consists of tadpole-shaped bodies each having a head and a tail, has proved to be quickly destroyed by sound waves and by ultraviolet light. The long thread-like arms by which the bacteria move, called flagella, are now readily photographed, and protective outer shells have been found on several varieties of bacteria, including typhoid bacilli, streptococci and pneumococci.

One or two examples from the chemical field may be cited. Very fine grained carbon has many commercial

FIG. 3—Cubic particles of magnesium oxide enlarged 20,000 diameters.

AT RIGHT

FIG. 4—Pearlite in steel. A lamellar arrangement of iron and brittle iron carbide. The magnification is 20,000 diameters.



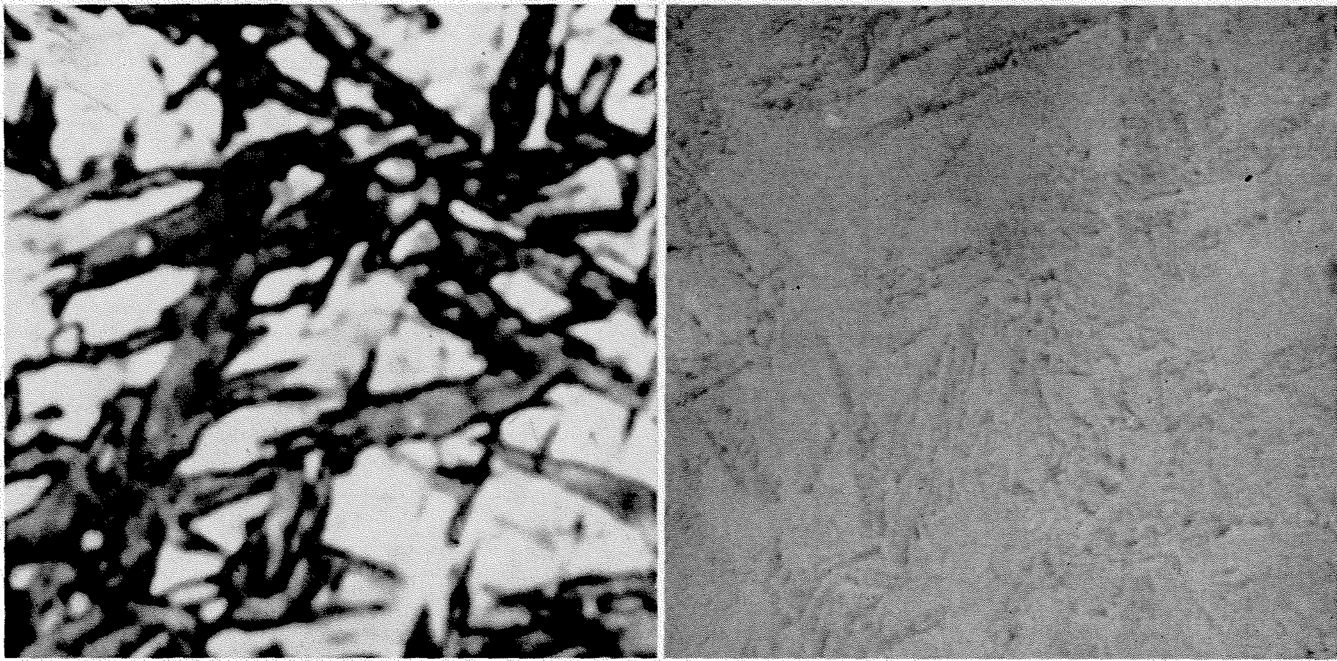
uses; it colors inks and plastics, reinforces rubber and improves its physical properties, serves as a lubricant, and is employed in the radio industry. The size and shape of the particles of colloidal carbon can be investigated very easily in the microscope, which makes it an important means for the manufacturer to inspect and control his carbon production processes. Similar applications are common in the field of paint manufacture, where the size of the particles of pigment and the way in which they cluster are of great industrial importance. The appearance of magnesium oxide particles (see *Fig. 3*) has been found to be closely related to properties of the oxide that are of importance in industrial chemistry. A bright future for electron microscopy exists in the study of high polymers, where some preliminary successes have been reported in the determination of molecular weights of polymers.

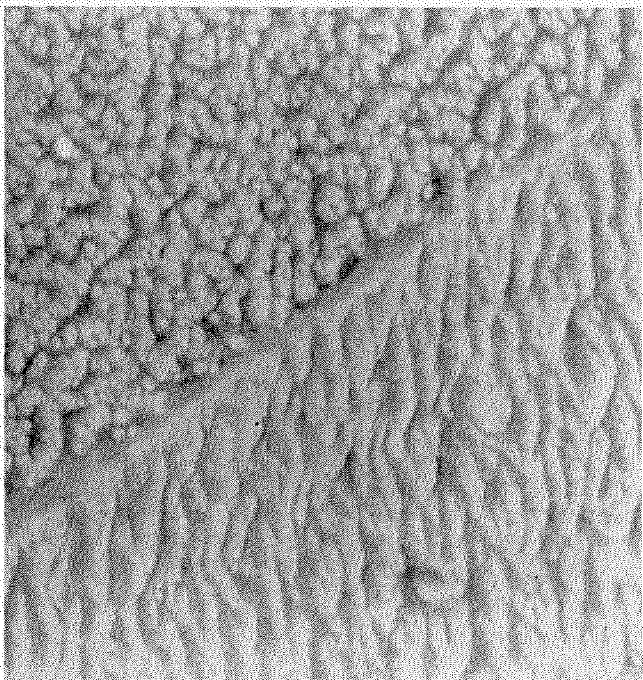
The instrument in the Metals Research Laboratory of Carnegie Institute of Technology is one of the few devoted to research in physical metallurgy. It is a real handicap to the metallurgist that he cannot look at metal specimens directly in this instrument. The electrons have so little penetrative power that they cannot pass through the thinnest metal sheet. The structure that is developed on the surface of a thick piece of metal after careful polishing and etching can be photographed easily with an optical microscope, but to make a photograph with the electron microscope it is necessary to prepare a replica of the surface thin enough to transmit electrons. One way to accomplish this is to paint the metal surface with a dilute varnish and strip off the film of varnish after it has dried. When the conditions are carefully controlled, the resultant film, transparent to the electrons, duplicates the markings seen on the surface of the metal. While this is one of the simplest techniques available, it has not given results as satisfactory as some others. A method that has been tried on the Carnegie Tech microscope recently with considerable success is being developed by metallurgists at The Aluminum Company of America. In this method, a thin oxide layer is formed on the surface of the metal (usually aluminum or an aluminum alloy in this case) and the metal is then dissolved by chemicals. The residual film serves as a replica of the surface undulations and also traps within it various particles that originally existed within the metal.

REPLICAS

The most effective of the present methods makes use of a replica that is made from a previously prepared replica—the electrons pass through a film that is two steps removed from the metal surface that is being studied. The procedure for the double replica technique is briefly as follows: A specimen is polished, etched, and examined for suitability under the optical microscope. When it passes this inspection it is mounted in a press and a thermoplastic material (polystyrene) is molded into the prepared surface. This is accomplished by applying a pressure of 3,000 pounds per square inch and a temperature of 150°C. After cooling, the plastic molding is separated from the metal and mounted in an evacuated bell-jar, where a thin layer of silica (SiO_2) is deposited upon it by evaporating a piece of quartz in a small electric furnace. When a layer 200 or 300 atoms thick has been deposited, the molding is placed in a liquid (ethyl bromide) that dissolves the plastic and leaves the thin silica film swimming in the solvent. The almost invisible film is then caught on a fine wire mesh and transferred to the microscope, where its variations in thickness provide a replica of the details on the surface of the metal specimen.

Such a series of operations naturally provides many opportunities for trouble, and the preparation is often spoiled before it reaches the final stage. The final picture may present difficulties, too, for it may be full of details that are totally unfamiliar to the metallurgist. He is faced with the questions, "Are they real or spurious? If they are spurious, how can they be avoided? If they are real, what do they mean?" Each specimen becomes





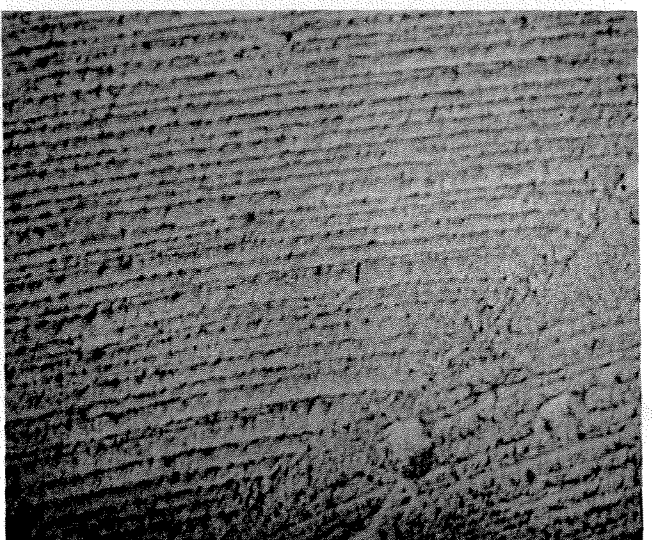


FIG. 5—(Two views at top) Hardened steel as viewed with the optical microscope (on the left) and the electron microscope (on the right) at the same magnification, 4000 diameters. Dark, roughened areas are martensite crystals.

FIG. 6—(Center, left) The surface of copper after etching. A boundary between two different crystals is shown at 10,000 diameters.

FIG. 7—(Lower, left) Markings on metal surface caused by severe deformation. The movement of layers over each other produces a stepped surface. The magnification is 15,000 diameters.

a challenge and leads to an "adventure" of some kind. After surviving a series of such adventures one realizes how the microscopist felt in the early days of the optical microscope, when he, too, saw structures never seen before, which were sometimes difficult to interpret. The correct pictures and the correct interpretations of them were gradually developed by the combined experience of many observers who used many lines of indirect evidence, and the same evolution will undoubtedly take place in this new microscopy. There are frequent exchanges of information on techniques and results among electron microscopists—in fact, in typical American fashion, a technical society has been organized for electron microscopists and various symposia have been held.

STRUCTURE OF METALS

Many of the 1500 or more photographs that have been made on the microscope at Carnegie Institute of Technology are of steel in one or another of its structural modifications, an appropriate interest for a laboratory located in Pittsburgh. Pearlite is the name given to one common structure in steel (the name originating from the mother-of-pearl appearance of the etched surface). As *Fig. 4* shows, pearlite consists of alternate dark and light lamella, which are layers of iron and iron carbide. The layers of this picture are too closely spaced to be seen clearly on a light microscope.

The structure of steel that is heat treated to great hardness is illustrated by the pair of micrographs shown in *Fig. 5*, one made with the electron microscope and the other with the optical microscope. Dark boat-shaped

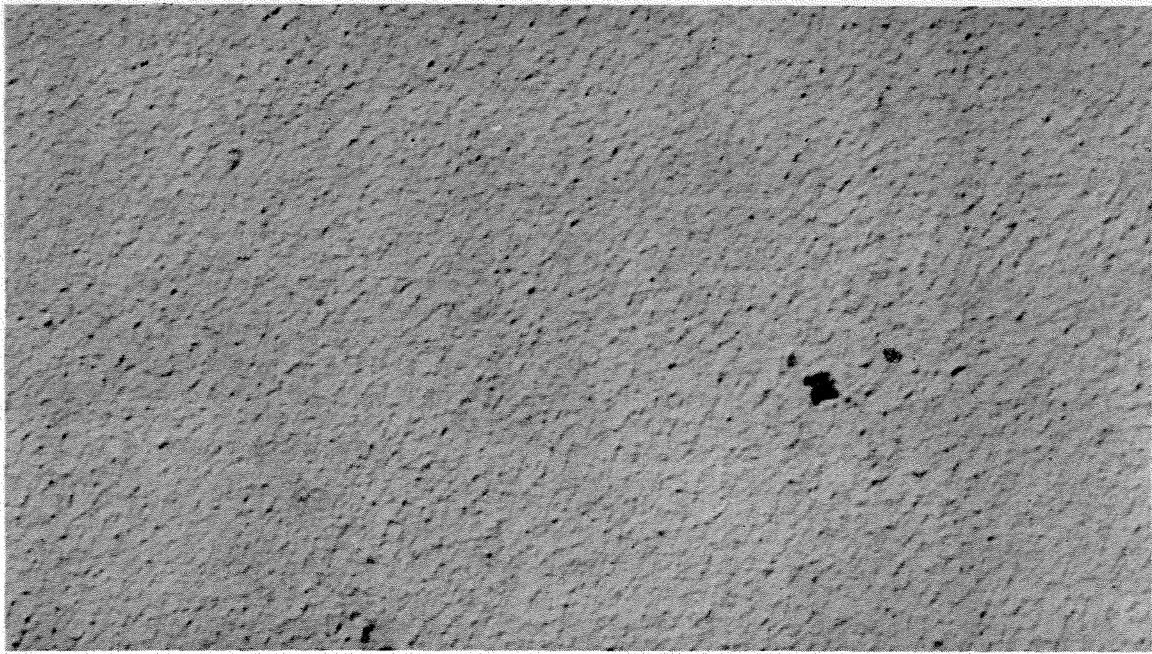


FIG. 8—Hardened Monel metal at a magnification of 20,000. The black specks are precipitated crystals 50 to 100 atoms in diameter, causing the hardening.

markings of the optical picture resolve into pitted areas on the electron picture. These pits are the individual points of attack of the acid that has etched the surface, and they mark out the crystals of the constituent known as martensite, which produces the hardness.

Pictures often resemble aerial photographs and sometimes give a remarkable appearance of depth or perspective. The photograph of etched copper reproduced in *Fig. 6* is an example of this. Why acids carve the surface of a metal into such complex but systematic patterns and what the patterns mean with regard to the internal structure of a crystal are questions that will require much more research to answer.

The markings on the surface of a metal that has been compressed or stretched are of great scientific interest, for they reveal the mechanism of plastic flow in metals. Some bands and lines can be seen on a deformed metal with the unaided eye, but a great many more appear if a low power microscope is used. The number increases so rapidly with higher magnifications that one wonders whether there are still others that could be made visible with electron pictures, and whether the lines that appear to be single lines at ordinary magnifications might not be resolved into bundles of closely spaced lines when the new microscope is employed. The photomicrograph in *Fig. 7* does show, indeed, parallel "slip lines" too closely spaced to be seen clearly with the earlier types of microscope. The lines are caused by the movement of layers of the crystals over one another much like the displacement of cards in a deck, a movement that leaves the surface crossed by a series of steps about a millionth of an inch apart. But the belief that these lines might be made up of still more closely spaced lines seems to be unfounded; in all electron microscope pictures that have been made thus far the lines occur as individuals. Physical metallurgists are giving much thought to the semi-regularity in the spacings of the slip lines, so apparent in the accompanying reproduction, for when the spacings are understood we shall be much nearer a full understanding of the strength of metals.

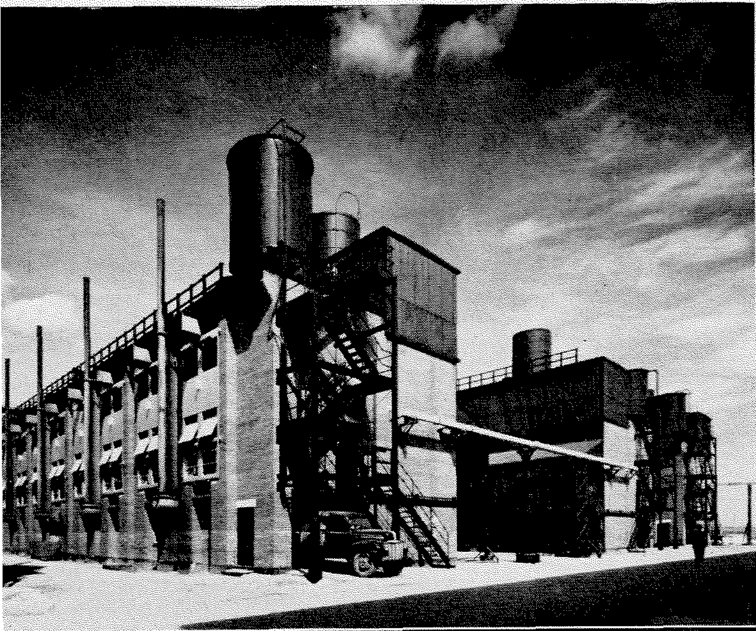
Fig. 8 shows the structure of Monel metal, a stainless alloy of both industrial and household uses. It is one of a class of important alloys that can be hardened by a heat treatment that consists of heating to an appropriate temperature, quenching in water, and finally "aging" at another temperature, lower than the first. The purpose of these treatments is to provide a supersaturated condition in the metal that tends to relieve itself by precipitating a galaxy of small new crystals throughout the body of the metal. Metallurgists had concluded from indirect evidence that this precipitation during the aging treatment actually occurs, but they were unable to see the precipitated crystals in this alloy after the hardening treatment. This was a tailor-made task for the new microscope, which was easily able to resolve the individual particles and to show their size and distribution. There are a great many other age-hardening alloys that provide similar opportunities for the new instrument to supplement the old, to reveal fine precipitated particles not yet seen, and to yield new information on the complex structural changes accompanying hardening.

OTHER DEVELOPMENTS

While there is much interest in electron microscopes, not many metallurgical laboratories have installed this equipment. A director of research must think several times before buying an instrument that costs about three times as much as the best optical microscope and also requires more skill and more time to operate. Consequently there is much interest in the development of a portable model that will be simpler and will cost but little more than a high power optical microscope. Both the R.C.A. Laboratories and the General Electric Company are now developing such models.

A recent improvement of the current model that is being installed on many instruments is an attachment that permits a chemical analysis to be made of the collection of minute particles viewed on the screen. The analysis is made by means of the diffraction of electrons from crystalline material in the sample, making use of the principle that every crystalline substance has its own characteristic manner of diffracting a stream of electrons. A pattern of concentric rings is produced that serves as a

(Continued on Page 18)



MAGNESIUM

SOURCE

IT is axiomatic that man develops for his use those things which are easy to produce and are most plentiful. As his mental capacities have increased, difficult projects have become easier to develop. This is the story of magnesium.

There are only two structurally important metallic elements in the earth's crust more plentiful than magnesium. These are aluminum and iron. The only other metals more plentiful are calcium, sodium and potassium.

Magnesium is chemically one of the most reactive metals. It is never found as a metal but always combined with other elements, including oxygen, chlorine and combinations of these and other elements. Its reactivity is the reason why this very plentiful element has not been produced as a metal earlier in civilized history, and is also responsible for certain erroneous ideas which tend to limit its commercial use today.

In nature, magnesium is found in many forms. The most important of these, with the average content of the element, are listed in Table No. I.

All of these sources are to be found in the United States, most of them in large quantities. At the present time, all of these materials can be used for the production of magnesium. Five of them are being used either directly or indirectly.

In the relation between sources, distribution of raw materials and processes for production, magnesium stands unique among all metals in world mineral history. It is more universally distributed throughout the whole world than any other metal—its presence in sea water has taken care of that. And even in the present somewhat embryonic state of the development of the industry, magnesium can be produced more cheaply from the widely disseminated and dilute sources such as dolomite and sea water, in spite of the fact that it is

AT LEFT:

FIG. 1—(Upper) Magnesium cells at Defense Plant Corporation's plant at Austin, Texas, operated by International Minerals and Chemical Corporation. The plant produces this lightest of all structural metals from dolomite by the Dow process. The current used for refining the metal is carried through and between cell buildings by a series of bus bars, some of which can be seen in the right foreground. The cell buildings are brick and steel framework and have superstructure covered by asbestos-protected metal.

FIG. 2—(Middle) Dolomite, which serves as the basic ingredient for production of magnesium at Texas plant, is received, crushed and burned as it goes from right to left through the facilities shown here. Note the length of the rotary lime kiln which extends from the base of the crushers to the reinforced structure on the left.

FIG. 3—(Lower) The facilities for converting dolomite into metallic magnesium at the new Texas plant are being used in the open wherever possible. Where character of operations has made it necessary, certain areas of the multi-story reinforced concrete structure have been enclosed with siding of corrugated asbestos.

Metal of the Future

BY PAUL D. V. MANNING

TABLE I

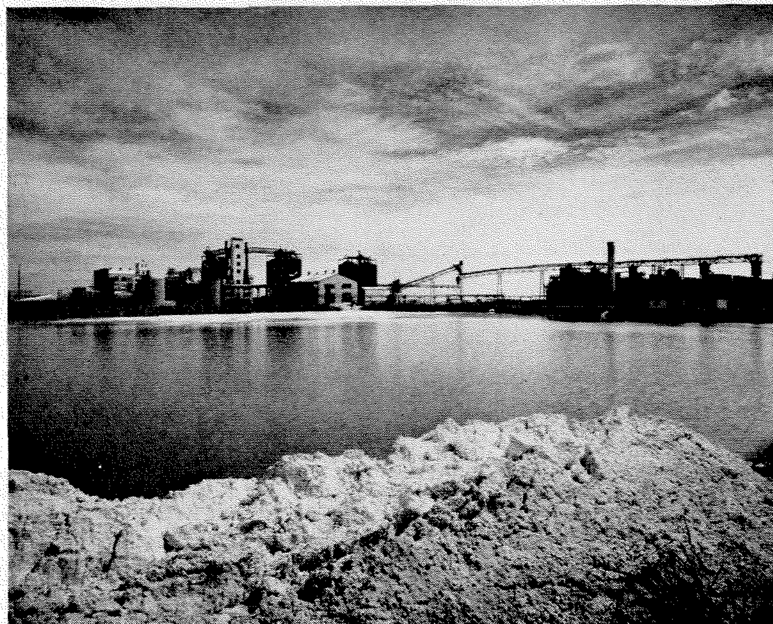
Source	Average Per Cent of Magnesium
Dolomite	13.8
Serpentine	25.9
Olivine	28.4
Magnesite	28.7
Brucite	41.6
Langbeinite	11.6
Sea water	.13

present in sea water in the most dilute form in which it is found. About 200,000 gallons of sea water are required to produce one ton of metal. This circumstance is completely novel in the history of metals, having never been met with before. Keep this in mind while we consider one other phenomenon.

In the industrial development of the world, man has always taken the most concentrated deposits of minerals, converted them to his use, and then by his own and natural processes, allowed them to return to the universe in such extremely dilute forms as to make it doubtful that the same metal will ever be recovered. In other words, the normal cycle has been to take the most concentrated form available, purify and use it, and then to allow it to return to nature. As an example, iron is produced from the richest ore deposits, and made into useful objects which immediately begin to rust away, the ultimate process being to deconcentrate an ore to the point where it is scattered beyond use.

But magnesium, after only a few years of commercial production, is being produced from the most dilute form in which it is found in nature, a source which is also the most widespread throughout the world. The development of the magnesium industry is the most outstanding illustration of how an industry should grow.

Here we have a metal produced from a source widespread throughout the world, a source that is inexhaustible, right at the start of the development of its usefulness. True, its properties are not all that we would set up if we were to plan our ideal metal, but such an ideal exists in no other metal. But as we learn how to handle magnesium, alloying it with other metals to produce the physical and chemical properties we want, and as we



AT RIGHT:

FIG. 4—(Upper) Looking across a waste disposal pond toward the new shelf dryers (center) and magnesium cell buildings (right) at the new magnesium plant in Texas.

FIG. 5—(Middle) This 100-foot Dorr tank, which functions as a magnesium hydrate thickener, is covered by a wooden roof with a single center support and timber trusses extending from it to the reinforced concrete rim of the tank.

FIG. 6—(Lower) Magnesium chloride cell feed produced from dolomite is distributed from shelf dryers to the cell buildings by means of an overhead conveyor which feeds directly into large bins located above the end of each cell block. The unit shown in the extreme right absorbs and treats the hydrochloric acid derived from the electrolytic refining process.

continue to improve the processes by which it is made, we may expect magnesium to play a part in human life not heretofore found for any other metal.

EARLY DEVELOPMENTS

Sir Humphry Davy first made the metal, in 1808, using potassium vapor. This process of course has not been used outside of the experimental laboratory. Magnesium metal remained a chemical curiosity for almost 50 years, until 1857, when small scale production was begun in France. Seven years later a small plant began operation in England, and about the same time its manufacture was initiated in the United States. Almost the entire production went for flashlight purposes. In this country the manufacture was discontinued in 1892. All of these initial operations were of no importance and it may be said that the industry remained undeveloped until 1896, when the Germans began making the metal on a larger scale, passing an electric current through molten magnesium chloride, a by-product from their operation of the Stassfurt potash and magnesium deposits.

Although the larger proportion of the world's magnesium metal is still produced in a manner that does not differ essentially from the German process, practically the entire credit for the progress of the industry in the United States is due to Dr. Herbert Dow, his associates, and the organization they developed. Dr. Dow noted that the salt brines from wells near Midland, Michigan, contained magnesium chloride and his painstaking work resulted in the commercial production of magnesium.

The story of the industry resulting from this work is one of the most interesting in the history of American enterprise. Established in 1890, the Dow Chemical Company has grown to one of the major chemical producers in the United States, with net sales of nearly $47,000,000 in 1941. It may be said that this entire development grew out of Dr. Dow's effort to produce magnesium metal from the Michigan brines.

In 1915, the price of the metal was $5 per pound. United States production in 1918, the final year of the first World War, totaled 142 tons. By 1925, this figure had dropped to 122 tons but the price had been reduced to $1 per pound.

Although the total production in 1941 was about 17,000,000 pounds, such great progress has been made by the cooperative efforts of those now constituting the producing industry that when present installed capacity is realized, the total annual production in this country should exceed 500,000,000 pounds, an increase of about 30 times the 1941 production.

PRODUCTION PROCESSES

All of the processes in use may be classified into three general methods. Most of the production is accomplished by means of the action of an electric current on melted magnesium chloride. The chloride is decomposed to form melted metallic magnesium and chlorine gas. The former is cast into pigs. The latter is used to produce additional magnesium chloride, using as a raw material, dolomite, sea water, or magnesite. This process is used in the plants operated by the Dow Chemical Company, International Minerals & Chemical Corporation, Diamond Alkali Company, Mathieson Alkali Works and Basic Magnesium.

A second process, depending for its operations on the reduction of magnesium oxide by carbon, was developed by Fritz Hansgirg in Austria. In this process, carbon and magnesium oxide, the latter produced in its American adaptation from dolomite and sea water, are heated together in an electric furnace. There results a gas mixture of carbon monoxide and magnesium vapor. This is shock cooled, that is, cooled so rapidly that the magnesium is condensed to fine particles of dust before the reaction can reverse to again give carbon and magnesium oxide dusts, which would result if the cooling were carried on more slowly. This cooling was accomplished by refrigerated hydrogen in the original Hansgirg process, but at Permanente, California, where the American modification is in use, the furnace gases are chilled by injection of natural gas, which, after separation of the condensed magnesium powder, is used as fuel.

In a process devised by Dr. H. A. Doerner of the Pullman, Washington, Station of the U. S. Bureau of Mines, the shock cooling is accomplished by the injection of an oil spray which vaporizes and chills the magnesium vapor.

Magnesium dust produced in the Hansgirg process is quite pyrophoric and must be handled carefully. It is distilled into crystals, which are then melted and cast in pigs.

Another process is being operated on a relatively small scale. This process has been used in principle with different reducing agents in France and elsewhere before the war. It consists essentially in heating magnesium oxide with reducing agent in a vacuum retort, at one end of which is a condenser. In the United States, the reducing agent used is ferrosilicon, calcined dolomite providing the magnesium oxide. The magnesium vapor solidifies on the condenser as magnesium crystals. It is removed by opening the retort. The retort of usual size produces about 70 pounds of metal in eight hours.

Although the Dow Chemical Company is the first commercial producer to start with sea water and make magnesium metal by carrying out the process entirely in one establishment, sea water has been used in this country for many years to produce magnesium hydroxide on a large scale by Marine Magnesium Products Corporation, operating on the shores of San Francisco Bay. Starting several years later, the California Chemical Corporation, now owned by Westvaco Chlorine Products, continuously produced artificial dead burned magnesite from bitterns resulting from the solar evaporation of sea water in the production of salt near San Francisco.

In these two processes, as in the Dow sea water operations, magnesium hydroxide is precipitated from sea water by adding burned lime to it. Both the Westvaco and Dow plants use oyster shells shoveled from marine deposits in bays as a raw material for making the lime. The process developed and used by Marine Magnesium Products Corporation uses a good grade of lime and produces a quite pure magnesium hydroxide.

Working in England, H. H. Chesny, formerly with the Marine Magnesium Products, utilized burned dolomite and sea water to precipitate magnesium hydroxide, this process having the advantage that the magnesium oxide in the burned dolomite adds to that made from the soluble magnesium salts in the sea water. A very good grade of magnesium hydroxide is produced, and in England this process was used to produce magnesium hydroxide, which was sold as a raw material used in making metallic magnesium some time prior to the Dow sea water operations.

The Chesny process is now in use in this country on the Atlantic Coast, producing magnesium oxide for refractories. On the Pacific Coast, magnesium hydroxide lately has been produced from sea water and dolomite, as a raw material for the Kaiser magnesium operations.

International Minerals and Chemical Corporation has developed a new process which is in successful commercial operation in Texas, utilizing dolomite for making magnesium hydroxide. The primary chlorine requirements for production of the magnesium chloride from this magnesium hydroxide are produced from langbeinite and potassium muriate, mined and processed near Carlsbad, New Mexico. The complex saline brines produced in the Carlsbad potash operations are purified and used to make carnallite, which is then used to make magnesium chloride.

Both the Mathieson Alkali and the Diamond Alkali processes use dolomite, the primary chlorine being obtained from calcium chloride, resulting as a by-product from the manufacture of soda ash by the ammonia-soda (Solvay) process.

Basic Magnesium raw material is obtained as magnesite from the Nevada deposits, the primary chlorine being produced by electrolytic cells.

It will be seen from the above that magnesium oxide in some form is the one primary raw material for all magnesium production in this country, with the exception of part of that produced by the Dow Chemical Company from the Michigan brines.

PROPERTIES, COMPARISON, USES

Magnesium is a silvery appearing metal. It is both malleable and ductile and so light that a cubic foot of it weighs only 109 pounds. On an equal volume basis, it weighs only two-thirds as much as aluminum, one-fifth the weight of nickel, and one-fourth the weight of copper. It is interesting to compare the selling price of magnesium with that of some of the more common metals on several different bases of weight, mol and volume. These figures are given in Table No. II using the present prices. The term "mol" expresses the figures giving weight and cost in ratio of the molecular weights.

These figures are rather startling to those who have thought magnesium an expensive metal. Observe that on the basis of cost per cubic foot, magnesium is more expensive than iron only—cheaper than aluminum and about one-third as costly as copper, while zinc, a metal used for galvanizing steel sheet, wire, etc., sells for nearly 15 times the price of magnesium!

What then needs to be done to get magnesium into the common uses of the metal field? First, we must develop alloys that are stronger and have the physical properties needed to meet the required service conditions. This work has really only just begun.

Metals now commonly alloyed with magnesium include aluminum, manganese, cadmium, zinc and tin. Just as in the early days of the development of steels, no steel could be made that would withstand the pressures required to permit the use of our present high-powered propellant powders in guns or to meet the conditions imposed by our modern internal combustion engines, so we may confidently expect that magnesium alloys will be developed that will give us the strengths required without losing the advantages of light weight. Twenty years ago who would have expected to have steel with a tensile strength of 190,000 pounds per square inch? Ten years ago we could not make a fusion weld of magnesium. We have all of these things and more today.

Magnesium and its alloys machine well, are ductile, malleable, can be cast in sand, permanent molds or die cast, can be extruded and rolled as well as hammer and die forged. A number of the alloys respond well to heat treatment.

A recently-developed simple process permits a satisfactory fusion welding even of thin magnesium sheets without the use of a flux. In this method, which is an invention of engineers of Northrup Aircraft, Inc., and the Dow Chemical Company, a tungsten electrode is used with a direct current electric arc, the current passing

TABLE II

Metal	*Molecular Weight*	*Pounds per Cubic Foot*	*Cost per Pound*	*Cost per Mol*	*Cost per Cubic Foot*
Iron	56	450	$ 0.01	$ 0.56	$ 4.50
Copper	64	556	.12	7.68	66.72
Tin	119	456	.52	61.88	273.12
Zinc	65	443	.75	48.75	332.25
Magnesium	24	109	.205	4.92	22.35
Aluminum	27	165	.15	4.05	24.75

TABLE III

Metal	*Weight per Mile of No. 10 Wire (lbs.)*	*Base Cost of metal alone per mile of No. 10 Wire*	*Relative Electrical Conductivity Silver = 10*
Iron	134.0	$ 1.34	1.62
Copper	165.9	19.90	9.55
Tin	136.0	70.80	1.42
Zinc	132.0	99.20	2.53
Magnesium	32.5	6.67	3.62
Aluminum	49.1	7.38	6.18
Nickel	157.1	55.10	2.35
Lead	211.5	137.10	0.74
Silver	195.3	1093.88	10.0

between the magnesium and the electrode. At the same time helium gas pours from the electrode holder, completely blanketing the work and the electrode itself. The equipment is even more simple than that required for the atomic hydrogen welding process in use in welding steel. Helium is inert to magnesium. Its use prevents oxidation and, since no flux is required, the resulting weld is no more subject to corrosion than is the purest metal.

In addition, the use of helium tends to prevent overheating of the metal because of the high specific heat of the gas. For average medium work, 200 cubic feet of helium will give about 35 hours of welding.

In the second place, as an aid in speeding the development of the magnesium industry, we may list the possibility of alloys with lower electrical resistance. Table No. III gives the relative electrical conductivities of several of the common metals in terms of that of silver, which is given as 10.

A magnesium wire measuring twice the circular mils of a given copper wire will have only one-third more resistance than that of the copper wire. It will weigh only 39 per cent as much and the cost of the metal alone would be about 33 per cent less at present prices. As yet we are not ready for high tension transmission lines and bus bars of magnesium alloys. There are several problems to be solved. But there is an eventual possibility of these developments. Aluminum has already been used for both purposes.

Third in the list of major developments required to increase the scope of usefulness of magnesium is the improvement of its resistance to corrosion. Progress along this line is being made by alloying and by protective coatings. Magnesium, unlike aluminum, is highly resistant to alkalies but not to acids or to salts of acids. This explains its corrosion by salt water. However, other metals present in magnesium alloys change the action of many corrosive substances. Protective coatings applied either as by pickling, in which the metal itself plays a part, or as a lacquer or paint are becoming increasingly efficient and it is to be expected that continued progress in these lines will make it possible to use magnesium in places not now feasible.

Pure magnesium metal, while it loses its shine in air, does not otherwise corrode unless salt or acids are present.

The fourth requisite in the magnesium program is the education of the prospective magnesium user to overcome his fears of magnesium fires. Many years ago both gasoline and kerosene were thought to be so dangerous that neither would ever be commonly used. Today the inflammability of gasoline has been greatly increased and yet it plays a very important part throughout the entire daily lives of all of us. Dangerous? Yes, but only under certain conditions and certainly not when one knows how to handle it.

Most people do not realize that in every magnesium incendiary bomb is some thermite, a mixture of aluminum powder and iron rust. This mixture is first ignited and it is this that sets fire to the magnesium. Magnesium will burn but only if heated to 1,250 degrees Fahrenheit in the presence of air or an oxidizing material.

As to the fields where magnesium may be expected to make its first showing after the war, the following appear most worthwhile considering:

Lightweight household appliances, vacuum cleaners, sewing machines, refrigerators, furniture, folding tables, washing machines, ironers, dish washers and driers, clothes driers, ventilating and other fans, small motors, can all be made of greater usefulness with magnesium. Window shades, screens and frames for the windows themselves are possibilities.

In the field of transportation, by airplane, by automobile and by train, magnesium undoubtedly will fill a tremendous demand. Its use in airplane construction is increasing, and the per cent of the total weight of the plane that is magnesium continues to increase in present manufacturing practice. The advantages in airplane, rail and ship transportation obtained by use of light metals and alloys are quite obvious.

In the field of automobile manufacture, with continued high gasoline taxes it seems quite probable that the need for higher gasoline mileage to guarantee economical transportation will require lightweight cars.

In commenting on various possible uses for magnesium, Dr. Colin G. Fink suggests the use of magnesium for coins. Speaking of magnesium instead of copper pennies, Dr. Fink says, "There are approximately 1,000,000,000 copper pennies in circulation equivalent to 6,600,000 pounds of copper. The peacetime production cost of copper is six cents per pound as against about 14.5 cents for magnesium. For the same sized coin, the magnesium penny weighs but one-fifth the weight of the copper penny. In other words, 1,320,000 pounds of magnesium pennies at a base cost of $191,400 would replace 6,600,000 pounds of copper pennies at a base cost of $396,000. There is only enough copper in the world to last industry 40 years as against 10,000 years for magnesium."

In considering the possible future uses for magnesium and light metal alloys, it is difficult to find applications in which they cannot serve.

The Electron Microscope

(Continued from Page 13)

positive means of identifying the material. The microscope combined with the diffraction attachment becomes a research tool that is particularly advantageous for pigments, dusts, and various chemical preparations. Its usefulness in varied fields of research may lead in the future to an instrument in which individual particles only 50 atoms or so in diameter can be singled out of a sample of powder, photographed and then identified by "Submicroscopic chemical analysis," either by the diffraction method or by an analysis of the velocity of the electrons that emerge from the particle.

Windowless Factory

(Continued from Page 8)

volt equipment is supplied through 50 kilovolt-ampere, 440-120/208 volt, three-phase, air-cooled transformers installed at regular intervals throughout the plant. In general, each serves three multibreaker panel boards from which current is extended by conduit or through the underfloor duct system which is extended throughout most factory areas. Balance is maintained as closely as possible between phases.

CONCLUSION

To evaluate a "controlled conditions" plant properly in relation to traditional factory construction requires exhaustive analysis beyond the scope of this article. Certain advantages, however, are obvious. First, product quality and uniformity have a better chance of being maintained at a high level. Second, and especially in a severe climate, employee comfort and efficiency are greatly improved. Third, inaccuracies due to expansion and contraction can be held to a minimum. This is very important as assemblies of light metals get larger and larger, and for accurate machining of large light structures. Fourth, corrosion from both atmospheric conditions and handling is reduced.

The only serious disadvantage which has become apparent is that of increased investment and operating cost. This is a disadvantage only when full production is not maintained. In this respect it may be compared with a high-production special machine tool versus a less expensive but more common type.

For mass production, the special tool and the "controlled conditions" factory both have an outstanding place in the future of industrial development.

The Month in Focus

(Continued from Page 3)

that the public may be assured of safety. Another civil engineer may be concerned with the construction of channels, involving a knowledge of hydraulics as well as features of construction. Such differences may be cited in other branches of engineering. Thus it is apparent that the complete unification of engineers into a single professional group is difficult and that there are major barriers to the realization of this ideal. Some fields of engineering have been legally professionalized by several states in requiring licensing of those who wish to practice publicly. It is probable that more extensive developments will take place along these lines which will place the various fields of engineering on a professional basis in the eyes of the public.

Those who read "Mechanical Engineering" may have noted in the May issue the article by Hans Ernst on "High-Speed Milling with Negative Rake Angles." These developments originating on the Pacific Coast have led to greatly increased rates of production in milling operations. In this work, carbide-tipped cutters have been and are being operated at cutting speeds in excess of 500 feet per minute and with unusually high feeds. Some of the advantages obtained with these methods are higher production, improved finish, and less distortion of work due to heat. Naturally, these developments present many problems which require research to establish the soundest procedures. As a part of a program of studying milling operations under these new conditions, California Institute of Technology is conducting certain studies which will be interesting to watch. In his article in "Mechanical Engineering," Hans Ernst presents some interesting data in this connection.

CERAMIC STREET LAMP REFLECTOR

By DAVID WELCH

REDESIGN CONSIDERATIONS

ONE type of product which offers excellent possibilities for redesigning in ceramics is the opaque light reflector usually made from porcelain-enameled steel. If ceramics are to be substituted for metal, an application must be found where the reflector is not subjected to sudden shocks and continued handling. The street lamp reflector suggests itself as a logical application, partly because glass refractors have long been used in this type of lighting without excessive breakage, and partly because a great deal of attention was being given to black-out lighting restrictions when this problem was first considered. It was interesting to observe in a number of blacked-out areas where the light sources had been partially covered and the degree of illumination materially reduced, that actual visibility seemed to have improved. This observation suggests that a reflector designed to replace the existing residential street lighting unit and to comply with black-out regulations might even give better lighting conditions than before. In addition to functional improvements in the reflector itself, the initial cost and maintenance cost must compare favorably with those of existing competitive reflectors to insure a good postwar market.

Before the actual design work was started considerable research was done on the general subject of street and highway illumination to get a broader view and a better understanding of the problems involved. A number of sources listed in the "Industrial Arts Index" and the "Reader's Guide" were investigated. General Electric and Westinghouse publications, bulletins on black-out lighting, catalogues, and the "Patent Gazette" all provided interesting information on the subject. Finally the Society of Illuminating Engineers and the Los Angeles Bureau of Power and Light were consulted. With the general aspects of street lighting investigated, the next step was to collect data on residential street lighting. A brief investigation showed that very little advancement had been made in this particular branch of public lighting. The Pasadena Light and Power Department supplied information concerning the local potential market for this type of reflector and prices on competitive reflectors.

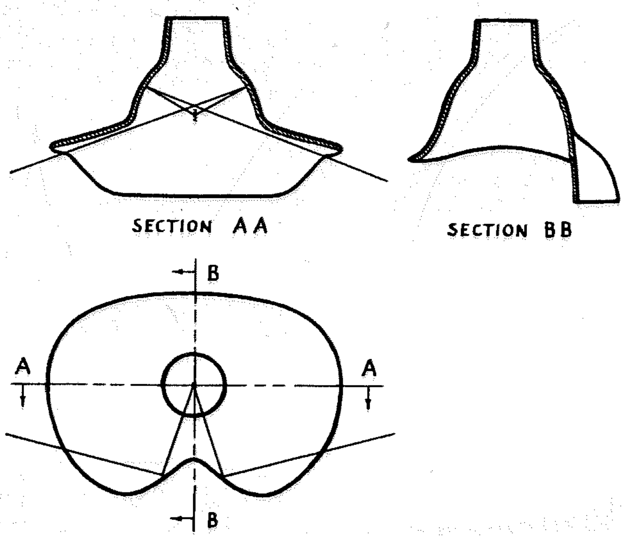


FIG. 1—Ray diagram illustrating the redirection of light to areas of weakest illumination.

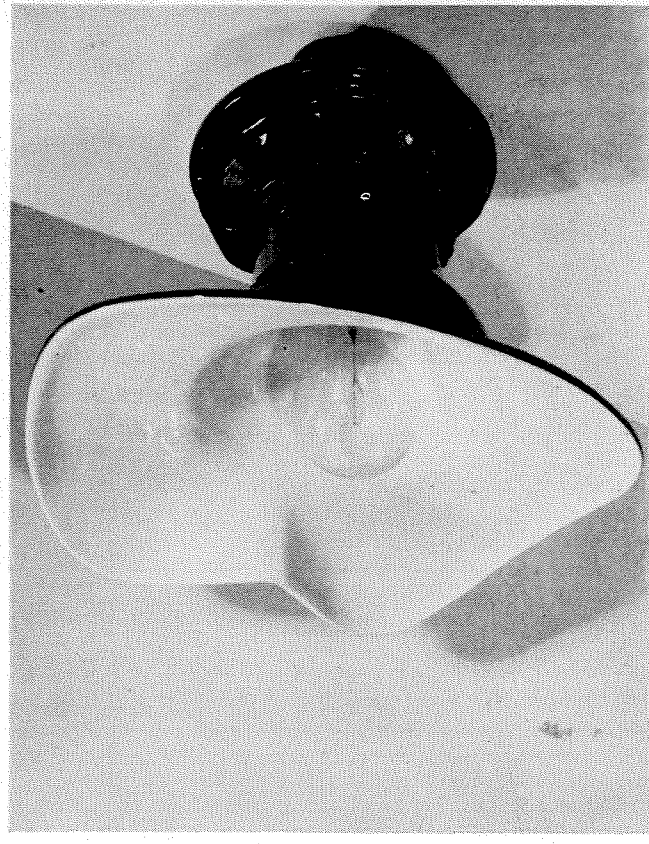


FIG. 2—Ceramic street light reflector.

The design of any new ceramic product requires that the designer have a working knowledge of the material and various processes used in the production of ceramic ware. Glazed ceramics present certain advantages as a material for light reflectors, such as excellent light-reflecting characteristics, resistance to weathering, and cheapness. On the other hand the low shock resistance of ceramics is a disadvantage.

A study of specific conditions affecting visibility along lighted thoroughfares, considering both the driver of a moving vehicle and the pedestrian, has shown that the elimination of intensely bright spots and the production of a more uniform distribution of light are the most important aspects to be considered in improving the visibility. In the past the degree or intensity of illumination has been determined for the most part by economic factors. Recommended intensity levels for better visibility under fixed conditions have been raised as lamp efficiencies have increased and the cost of electric power decreased. Exposed light sources or other bright spots are most detrimental to good visibility because they offer such a powerful contrast to dimly lighted surrounding objects that perception in the vicinity becomes very difficult. By eliminating these bright spots the visibility can be greatly increased at even lower levels of illumination. Data on present residential street-lighting practice were obtained through the assistance of the Bureau of Light and Power and samples of standard lamps, sockets, adapter bases and reflectors were secured.

LIGHT DISTRIBUTION

The radial wave reflectors used in the past have been designed to distribute light in a circular pattern. The reflector bowl tends to concentrate the rays in a small area below the reflector, instead of redirecting them up and down the thoroughfare, and there is no provision made for shielding house windows from direct rays. The lamp bulbs themselves are exposed to varying degrees, depending on the size of bulb and type of reflector. This presents a series of bright spots down the thoroughfare which counteracts some of the benefits gained through better illumination by offering such intense contrast with the surroundings that actual visibility is decreased. Emphasis in the design of the radial wave reflector seems to have been placed on obtaining an apparently efficient illumination curve with little consideration of visibility or of uniformly distributing the light up and down the street.

This analysis has led to several obvious improvements which should be incorporated into a new design. The light ordinarily directed downward by the bowl of the reflector and that ordinarily passing into house windows directly behind the lamp should be redirected up and down the road. The cut-off angles on the reflector should cut off direct rays from the filament at a greater angle with the horizontal and a backdrop should be provided to redirect those rays which would ordinarily shine into adjacent house windows. The preliminary designing was begun at this stage with the general objective of redirecting upward rays from the lamp filament and rays which would ordinarily shine into windows of adjacent houses out to areas where the illumination is weakest.

THE DESIGN

Rough sketches were made through various sections of the reflector to help develop the general form. A clay model was then made as an aid in visualizing the transitions between sections and the form as a whole. As a rough approximation of the reflector the model was now considered in relation to the manufacturing process. A slip casting in a one piece mold with a small amount of hand finishing was the obvious method for producing the reflector. As the reflector consisted of two halves which were mirror images of each other and whose axial plane was perpendicular to the thoroughfare, an accurate model had to be made and production molds taken off this.

With the general form of the reflector determined, a full scale drawing was next made, showing several sections through the center. First a full-scale section drawing was made of the standard base adapter into which the neck of the reflector must fit. Then the removable lamp socket and lamp were drawn in position and the position of the filament carefully located. The neck of the reflector was designed to fit the standard clamp adapters in the base and to distribute the stress over as large an area as possible. The neck of the reflector was tapered out from the base to the bowl of the reflector so as to provide sufficient clearance around the bulb for the tongs used by repair men in replacing bulbs. The shape of the reflecting surfaces was determined graphically, using the center of the filament as the light source. The bowl of the reflector was designed as illustrated in *Fig. No. 1*, to redirect the upward rays to areas between adjacent lamps on the street where the light intensity is weakest, instead of directing these rays straight down. The backdrop and aprons were developed in a similar manner with the same objective of redirecting as much light as possible to distant points, again illustrated in *Fig. No. 1*. Additional means of more efficiently distributing the light, such as by louvres in the neck of the reflector and a reflecting surface directly under the bulb, were considered, but eliminated because of production costs and difficulties in servicing.

PRODUCTION AND TRIAL

The working drawings were submitted to a manufacturer of ceramic products and discussed in regard to production and costs. Materials and glazes were suggested and slight revisions were made on the neck of the reflector to eliminate as much hand trimming as possible. A drawing was next made to shrink scale for the mold shop. From this drawing a plaster model was made and then a one piece mold was cast around the model. In the finished mold the first piece was slip cast. A pottery body was used, because of its low cost and relatively high shock resistance. After trimming and drying, the piece was fired and glazed. Clear glaze was used on the reflecting surfaces and green glaze to match the adapter was used on the outside. The reflection characteristics of the less expensive clear glaze over the light cream pottery body compared so favorably with a white glaze that it was finally selected for the inside surface.

The finished reflector was mounted in a standard base adapter, provided with a standard bulb, and given a check test in the photometric laboratory. Distribution curves showed too great a concentration of rays directly below the reflector, dictating a slight modification of the reflecting surfaces. The suggested revisions were sent to the mold shop, where the original model was altered to the new specifications. A new mold was cast around the revised model and several reflectors were cast. These were fired, glazed, and tested again. A sample unit was installed by the Pasadena Light and Power Department (see *Fig. No. 2*). Initial tests have indicated a great improvement in the general light distribution and visibility in the vicinity of the reflector as compared with that of comparable standard reflectors now in use.

C. I. T. NEWS

A CAMPUS TALE

By R. W. SORENSEN

THREE inducements caused me to answer, way back in 1910, a request from Cal Tech, then Throop Polytechnic Institute, that I consider joining its staff as the Electrical Engineering faculty. These were Dr. George E. Hale, as a member of the Board of Trustees, Dr. James A. B. Scherer, as President of the Institute, and the declared college policy of making the humanities, as they are taught at C.I.T., a large part of the entire four-year undergraduate curricula. Reminiscences concerning these arguments were brought to the fore a short time ago, when during some of my east coast rovings, I had dinner with a group of Cal Tech alumni in Washington, D.C. The group was small and the meeting took on the nature of an old-acquaintance get-together for a few of the many C.I.T. graduates who are now in Washington. Each one who partook of the excellent steak dinner was stimulated to the point of contributing some tale relating to the good old days when he was a student on the campus at 1201 East California Street. When my turn came, I told the tale of how Cal Tech got James A. B. Scherer for its president. Those present seemed keenly interested so I venture to tell the same tale to all alumni who read these pages, hoping that at least those who were students and knew Dr. Scherer during his presidency will find the tale as interesting as did those who heard it at our Washington meeting.

My first knowledge of Throop and Dr. Scherer was obtained when I considered joining the faculty being formed at the time Throop Hall, the first building on the present campus, was opened. Naturally, not knowing Dr. Scherer, I endeavored to learn something of his biography and discovered immediately that before going to Pasadena he had been president of Newbury College in

South Carolina. A contact with some of my friends in Pittsfield, Massachusetts, where I then lived, who had come there from South Carolina, brought forth from them very high praise for Dr. Scherer and comments of surprise when they learned that he had gone to Southern California.

Soon after I went to Pasadena and became acquainted with Dr. Scherer. I asked him how he became interested in Throop Polytechnic Institute and received from him information as follows:

He had conceived, as president of Newbury College, the idea that its curricula should include engineering subjects properly arranged with the liberal arts courses in such a way as to produce men of culture capable of doing engineering work. Knowing of the interest that Andrew Carnegie had in colleges of the type he had in mind, he decided to pay Mr. Carnegie, who at that time was in Scotland, a visit for the purpose of trying to interest him in helping finance his Newbury College Program.

Dr. Hale, who was well known to Mr. Carnegie because of the contracts he had as Director of the Carnegie Solar Observatory in Pasadena, also paid a visit at the same time to Andrew Carnegie in Scotland to discuss observatory matters and no doubt to also talk to him about his new interest of developing on the Pacific Coast the technical college which is now California Institute of Technology. In making these visits, and I think while crossing the ocean on the same boat, Scherer and Hale became acquainted. That acquaintance seemingly resulted in a discussion of their common educational interests which developed into the formation of a firm friendship and a request by Hale to Scherer that he accept the presidency of Throop Polytechnic Institute, the offer of course, as shown by future developments, being accepted.

As we closed the conversation which gave me the above information, Dr. Scherer showed me a leather-bound note book on the cover of which, in gold letters, were the words, "The First Half Million." I never saw inside the book but the seed planted therein by Dr. Scherer, Mr. Flemming, Dr. Norman Bridge, and other members of the Board of Trustees must have all been good seed that fell on good ground as evidenced by present-day activities.

One of the casualties of World War I was Cal Tech's president. When Dr. Scherer was called as a "Dollar a Year Man" to be one of the nation's Paul Reveres, he responded to a degree which threw him into ill health and forced his retirement as president but he never lost interest in the college and his faculty. Always, whenever we met he made inquiry about the progress of the college and the welfare of those who served with him during the first decade of college life on the present campus.

SPRING SPORTS

By HAROLD Z. MUSSELMAN
Director of Physical Education

AS this article is written, we are about halfway through our Spring Sports schedule in track, baseball, tennis and golf.

Coach Dr. Floyd Hanes' track athletes have been more than holding their own against the stiffest competition. To date they have won two and lost two dual meets, won the southern California relays, and placed third behind U.S.C. and U.C.L.A. in the A.A.U. meet.

Gathering eight first places and the relay, Tech emerged with an 82½-48½ victory over the combined southern California junior colleges in the opening dual meet. Clean sweeps were made in the discus, javelin and 2-mile.

In the southern California college relays, the engineers dominated the college division, scoring 56 points, followed by Oxy with 25¼ and Redlands 18. In the relay events, the Beavers captured the distance medley, 4-man 880, and open mile, while placing second in the novice 4-man mile and the shuttle hurdles. Tech men also won the open 100, shot, discus and high jump, while four second places were gained in the open events.

In the major dual meets, Cal Tech bowed to U.C.L.A. 72-59 and to U.S.C. 74-57. In each of these meets, the Beavers won only five events, but placed two men in nine events and copped the relay.

The Tech team placed a close third in the Southern Pacific A.A.U. meet which featured the cream of civilian and service athletes in southern California. Tom Carter placed second in both the 100 and 220. Gill Kuhns grabbed a second spot in the 440, while Bernie Wagner and Stan Barnes took second and fourth in the half. In the relays, the Beavers finished in second spot just behind U.S.C. in the mile, and placed third in the 4-man 880.

Capturing the relay by inches in a photo finish, Tech nosed out Oxy 67⅓ to 63⅔ to annex the mythical Southern California Conference track championship. Of the nine first places won by Tech, two established new school records. Don Tillman with a heave of 47 feet three inches broke the shot put record of 47 feet, three-eighths inches established by Bill Shuler in 1932, while Folk Skoog's 1932 record of 1:58.7 in the half dropped when Bernie Wagner toured the two laps in 1:58.4.

The baseball team is having difficulty in getting started. Opening the league season with an 8-5 win over Pepperdine, successive games were dropped to U.C.L.A. 20-1, Oxy 3-2 and U.S.C. 9-4. After the U.C.L.A. rout, a revised lineup played the best game to date against Oxy. However, inexperience and a multitude of errors are a severe handicap to the team. The teams in the league appear rather evenly matched, and most of the games have been close. At present U.S.C., U.C.L.A. and Redlands are tied for first place in the league standings.

As U.S.C., U.C.L.A. and Cal Tech are the only schools with teams in tennis and golf, our contests in these sports are rather limited. In tennis, the Beavers dropped matches to U.S.C. 8-1, 6-3 and to U.C.L.A. 7-2. Stan Clark, playing first singles, has proved the class of the collegiate players in southern California by winning all his matches. The golf team appears to be headed for an undefeated season, having defeated U.C.L.A. 16½-10½ and U.S.C. 19-6.

NEW YORK CHAPTER MEETINGS

WITH many of the members of the New York Chapter working long hours, traveling out of town, etc., it has not been easy to get together, but in spite of the difficulties, they have had three successful meetings.

On Saturday night, April 22, a group of about 35, including several ladies, held a dinner meeting at the Hotel Holley. Dr. Sorensen and Dr. Houston spoke briefly regarding their current activities, and of Institute affairs.

The main feature of the evening was an address by Dr. Ray Untereiner who is on leave of absence from the California Institute and now associated with the National Association of Manufacturers as economic adviser. He presented an inspiring picture of what could be accomplished by combining a huge potential postwar market with our tremendous manufacturing capacity to bring about a degree of prosperity and a standard of living beyond anything this country has ever known. All of this can be realized, he said, but only if definite advance preparations are made and favorable conditions are provided to insure confidence and incentive on the part of both labor and industry, and all other components of the consuming and investing public as well.

Dr. Untereiner pointed out that in contrast with the situation in the last war, manufacturing industries in general are now fully awake to the absolute necessity for postwar planning, and have already made substantial progress including actual appropriations for specific reconversion or peacetime projects. Furthermore, industry, recognizing the benefits of a free competition, is determined that monopoly shall have no place in the postwar setup. Likewise industry is now thoroughly converted to a liberal view toward labor and social security problems.

The address was followed by an instructive and enjoyable period of questions, answers, and discussion.

The first meeting of the year was held on November 19 where the chapter was entertained, following dinner at the Hotel Holley, by sound color movies showing the story of the production of petroleum products and the construction, operation, and maintenance of pipe lines, featuring particularly the "Big Inch" line of the War Emergency Pipe Lines, Inc.

The second meeting was held on January 26, at which time Dr. Sorensen described the latest setup and activities at the Institute.

The last meeting will probably be held in June. The president for the year has been Harry P. St. Clair, '20.

ANNUAL ALUMNI SEMINAR

THE Seventh Annual Seminar of the Alumni Association was held on the campus Sunday, April 16, with an attendance of 130. The success of the event was due largely to the efforts of Leonard L. Snyder, '27, and the members of his Seminar Board.

The morning session was opened by chapel conducted by Paul Ackerman, Y.M.C.A. secretary on the campus. The Reverend George A. Warmer, pastor of the Methodist Church, gave an inspiring address.

Professor Clark B. Millikan spoke on the topic, "The Activities of the Aeronautics Department in Cooperation with the Airplane Industry." This was followed by a discussion, "Unions and the Engineer," by Professor Robert D. Gray who presented the legal aspects, and by Professor Franklin Thomas who described the bargaining units that have been created by the American Society of Civil Engineers.

At 12:00 the group gathered at the Athenaeum for luncheon. Ernst Maag, president of the Alumni Association, introduced several guests, including Rear Admiral Ralston S. Holmes and Lieutenant Commander E. W. Mantel. James R. Page, president of the Board of Trustees, gave a broad view of Institute affairs, and Harry J. Bauer, a member of the Board of Trustees, spoke on "The Southern California Power Problem." John E. Michelmore, '26, sang several selections, accompanied on the piano by Paul E. Noll, '25. The luncheon period was closed by the group singing the alma mater song.

Professor Brighouse, who has been secured to give a course in psychology at the Institute, spoke on the subject, "New Frontiers of the Mind." The Seventh Annual Seminar was then closed at 3:00 with a few remarks by Dr. William B. Munro.

PERSONALS

1913

R. W. PARKINSON, who for some time has been chief engineer of the Caribbean Petroleum Company located at Maracaibo, Venezuela, has been located in New York for several months as American representative of that company. He recently returned from a three months tour of several South American countries.

1918

CORLISS A. BERCAW has been appointed to the position of assistant general manager of the Elliott Company's Springfield, Ohio, division. He was a naval ensign and aviator in World War I, and joined Westinghouse as an engineer after his discharge from service, becoming a special representative of the Diesel engine division. He was associated with the Baldwin Locomotive Works as sales manager of Diesel locomotives and later as production manager of the Diesel engine division before joining the Elliott Company. He is married and has two children.

1919

PAUL A. SCHERER is chief of the engineering and transition office, national Defense Research Council of the Office of Scientific Research and Development in Washington.

1921

CHARLES F. QUIRMBACH was appointed assistant electrical engineer of the Pacific Railway Company, Los Angeles, in March.

1922

F. L. HOPPER is with the Western Electric Company, Electrical Research Products Division, and has returned recently to Hollywood after six weeks in New York in connection with a project for the National Defense Research Council.

GERALD G. SPENCER is still assistant superintendent of the Fred C. Nelles School for Boys at Whittier. He is in charge of business management and engineering, a training program for delinquent boys.

1924

LIEUTENANT COLONEL EDWARD LOWNES is in charge of all Army construction in British Columbia, with headquarters in Prince Rupert.

1925

OSCAR S. LARABEE is now stationed at the Office of the Chief Engineer, General Headquarters, Australia. He is in charge of camouflage for that theater of operations and finds it extremely interesting work.

1926

MAJOR ARTHUR B. ALLYNE has been assigned at the Edgewood Arsenal, Md., as an executive officer of the Inspection Division, Office of Chief, Chemical Warfare Service. He travels around the country a great deal of the time on materiel surveys and inspections.

STANLEY C. VAN DYKE is the new president of the Pasadena Chamber of Commerce. He is a distributor for the Tidewater Associated Oil Company.

LIEUTENANT COLONEL STUART L. SEYMOUR was promoted recently from the rank of major in the Coast Artillery. He held a reserve commission as captain in that service and went on active duty at Camp Callan in April, 1941, being transferred to Camp Haan in the summer of 1942. He was line coach of the Caltech football team from 1930 to 1940.

1927

C. KENYON WELLS is division engineer in the Long Beach Water Department. He is married and has two sons, 7 and 11 years old.

DR. HALLAM E. MENDENHALL, of Summit, N. J., has been appointed manufacturing engineer by the Kearny Works of Western Electric Company. He will have charge of engineers assigned to the manufacture of vacuum tubes. For the past 10 years he has been engaged in electronics research and vacuum tube development at the Bell Telephone Laboratories in New York.

1928

NICHOLAS D'ARCY left the E. M. Smith Company recently and is now employed by the Carter Company.

MAJOR ED JOUJON-ROCHE is temporarily stationed at Camp Santa Anita.

1929

LIEUTENANT COLONEL ALLEN W. DUNN is now director of training on the staff of Brigadier General L. W. Miller at Camp Sutton, N. C.

WILLIAM LITTEL BERRY has been promoted from major to lieutenant colonel.

1930

LIEUTENANT J. H. MacDONALD, U.S.N.R., is attached to degaussing, San Pedro, Calif. He is married and has two children.

H. H. DEARDORFF has returned to his duties as resident engineer for the State Division of Highways at San Francisco after a few months work on a Navy project at the Institute.

1931

LIEUTENANT (j.g.) LARRY FERGUSON contracted a tropical disease while on convoy duty in the Caribbean area, and convalesced at the Boston Naval Hospital. He is now again on active duty.

1932

WILLIAM H SAYLOR is employed at the California Institute of Technology. He is the father of a son, Richard Clarke Saylor, born May 30, 1943.

1933

JOHN D. MENDENHALL has been administrative engineer of the Birmingham Modification Center for several months.

1935

JACKSON EDWARDS and Patricia Burr were married in November, 1942. He is chief engineer for Air Associates, Inc.

ROBERT M. STANLEY, chief test pilot of the Bell Aircraft Corporation in Buffalo, New York, was the first in America to fly the new jet-propelled airplane. The May 6 issue of Saturday Evening Post carried an interview with Mr. Stanley describing the flight.

1936

LOYAL NELSON is engaged at present in petroleum exploration in the capacity of petroleum geologist for the Texas Company.

EVERETT B. HENDERSON is an aerodynamicist with Lockheed Aircraft Corporation.

CAPTAIN WASSON W. NESTLER is still located in Florida as assistant to the Signal Officer of the Third Fighter Command. His primary concern is the supervision of operation and maintenance of V.H.F. Airborne radio equipment, as well as training of maintenance personnel and communications officers.

LIEUTENANT HUBERT A. ARNOLD, U.S.N.R., was teaching in Radio Materiel School, Treasure Island, for a year, but is now teaching in Radar School at Harvard University.

MAJOR ALBERT CREAL returned recently from 27 months in the Pacific and has been transferred to Washington, D.C. He is with the U.S.M.C.

1937

MAJOR PETER HINES WYCKOFF is with the Air Service Command, U.S. Army, Patterson Field, Ohio.

1938

WILLIAM BONELL and Miss Blanche Richardson were married on March 31.

JAMES W. VAN HORN is a second lieutenant in the U.S. Army Signal Corps somewhere in North Africa.

1939

C. HOWARD CRAFT has been working as a research chemist for Menasco Manufacturing Company, Burbank. In the near future he expects to assume a position as experimental metallurgist for the same company. He has two sons, James, 3, and Richard, 4 months.

LIEUTENANT (j.g.) WILLIAM LAWSON is with the Naval Ordnance Department, Navy Yard, Mare Island, Calif.

WALTER B. POWELL and Miss Marilyn Huddy, of Pasadena, have announced their engagement.

R. A. FISHER has been with General Electric Company at Lynn, but recently returned to Los Angeles where he is employed in the meters department of Airesearch Manufacturing Company.

1940

JONAS EWING HITE is now a first lieutenant in the infantry, and has been in the Pacific area since May, 1941, where he has seen considerable action.

LIEUTENANT JEAN B. STEVENS visited the campus in April after having returned recently from a year of active duty in the South Pacific.

ENSIGN WILLIAM A. SPOONER has been overseas since the first of the year. He has met Tech men from time to time in the various places he has been.

1941

CLIFFORD TRUESDELL is the father of a son born February 7.

LAWRENCE WIDDOES has been in the Navy since 1942. He was attached to the Naval Torpedo Station, Keyport, Wash., in the production of torpedoes, but has been shifted temporarily to the Naval Air Station, Whidby Island, Wash., in connection with the development of the aircraft torpedo.

FREDERICK W. THIELE is working on a war project at the Institute.

ROBERT H. EHRKE has been employed as a meteorologist with American Air Lines, La Guardia Field, New York City, and was awarded second prize in the annual Air Transportation Association contest sponsored to stimulate research in flight operations. He was married during the past year.

CAPTAIN CHARLES HIGHT is overseas with the Strategic Balkan Services.

C. VICTOR STURDEVANT and Miss Julia Shaver of Pasadena have announced their engagement. Mr. Sturdevant is engaged in research work in the engineering division of Douglas Aircraft Co., Inc.

1942

GORDON K. WOODS is marine engineer of Richmond Shipyard Number 3 of Kaiser Company, Inc. He and his wife are living in Berkeley, where she is completing her work for a master's degree.

LIEUTENANT WILLIAM C. JOHNSTON is attending the Flight Engineers School for the Army's new B-29 bomber and expects to be flying on the ship soon. He is the father of a son, William C. Johnston, Jr., born August 12.

WILLIAM D. BLUMENTHAL is a radio operator attached to the 13th Bomber Command somewhere in the Pacific.

LIEUTENANT (j.g.) PAUL VEENHUYZEN was married to Miss Virginia Gleitsman in Riverside on March 5.

LIEUTENANT OTHNEIL HORNE is with the A.A.F. at Geneva, Nebr.

LIEUTENANT (j.g.) JACK L. ALFORD, U.S.N.R., and Miss Edith Elizabeth Humann were married in March and are making their home in San Diego. Lieutenant Alford had returned recently from active duty in the Pacific.

TOM ELLIOTT has been promoted from the rank of ensign to that of lieutenant junior grade.

JOHN MILES is now working on a project at the M.I.T. Radiation Laboratory.

LIEUTENANT (j.g.) BILL MENARD, now in England, is the father of twins, Evelyn and William.

LIEUTENANT (j.g.) WARREN A. HALL is with the War Production Department, Navy Yard, Mare Island.

GEORGE MEYER was recently promoted from ensign to lieutenant junior grade.

1943

FOREST CLINGAN is with the Navy Ordnance Mine Detail 22 in the Pacific.

DEXTER HAYMOND was commissioned a second lieutenant in the Signal Corps at Officer Candidate School graduation exercises in April. He completed the new four-month course instead of the previous three-month training, spending the added month in the field learning various methods of signal communication.

ENSIGN DOUGLAS C. REID is overseas.

LIEUTENANT R. M. SCHOFIELD, ex-'43, is with the Army Air Corps in Clovis, N.M., stationed at an operational training unit.

ENSIGN GLEN BRACKEN is attached to the Inspection of Naval Materiel Office in Los Angeles.

ENSIGN STANLEY A. DUNN, U.S.N.R., and Miss Elizabeth Myer of Cambridge were married at Memorial Chapel, Harvard University, recently. Mrs. Dunn returned to Vassar College to finish the spring term. They will then live in Cambridge until Ensign Dunn completes his training course at the Massachusetts Institute of Technology.

ENSIGN DAVE ARNOLD is with the Ordnance Department, Navy Yard, Mare Island, Calif.

1944

CARL O. MATTINSON is with the Chemical Warfare Service Development Laboratory of the Massachusetts Institute of Technology.

FRANK W. LEHAN and Miss Nellie Mae Miller were married in February. Mr. Lehan is with the U. S. Army Signal Corps.