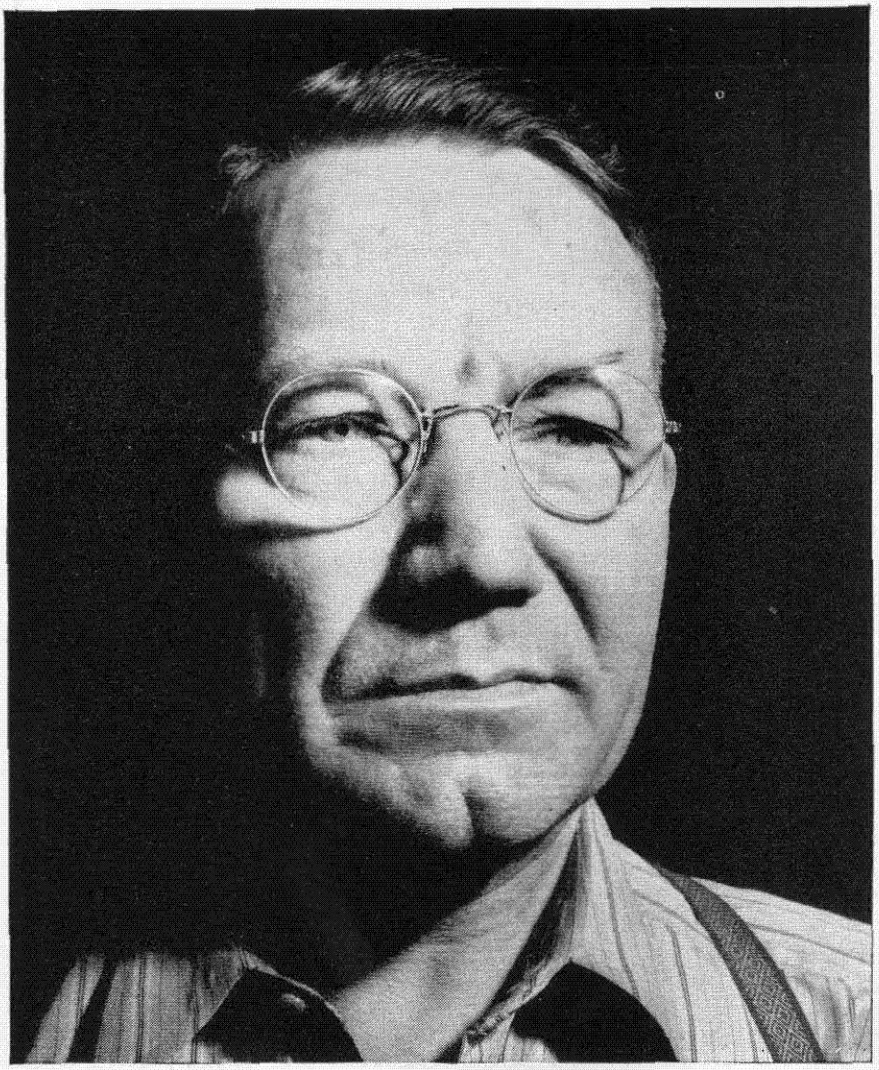
ALUMNI REVIEW

CALIFORNIA INSTITUTE OF TECHNOLOGY

Vol. 5 No. 3

April, 1942



VETERAN

HE IS independent and proud, yet democratic and friendly. He is the envy of the rest of the world, and its hope. He is generous and tolerant and peace-loving—and withal the most powerful man in the world. He is the American workman.

His hands, accustomed to the feel of wrench and lever and gauge, may never have held a gun; his mind, trained to think in terms of tolerances as fine as 1/10,000 of an inch, may never have wrestled with a problem of military strategy; and yet he is the veteran of a thousand campaigns.

His campaigns began in the laboratories, and his prowess was proved in the test pits of American industry. His battles were waged on the factory floor and in the field. His victories have helped to make the citizens of the United States the most fortunate people in the world, and the U. S. the greatest nation on earth.

In the plants of the General Electric Company, working with General Electric scientists and engineers, this man, the American workman, has made giant generators to light whole cities, X-ray tubes to penetrate the mysteries of human flesh and metal castings, radio and television apparatus to project man's voice and image through space over the mysterious waves of the ether.

Today, in the gravest hour of world history, he is engaged in the greatest campaign of all. But there is serenity and confidence in his face, and the experience of a thousand campaigns behind him. He is sure of his own abilities, certain of his country's future. General Electric Company, Schenectady, N. Y.

GENERAL ELECTRIC

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ALUMNI REVIEW

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STAFF

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EDITORIAL

The national emergency having put more and more claim on your Editor's time, we have deemed it expedient to appoint two Tech seniors, John Rubel and John Miles, as Associate Editors of the Review. The appointment of these two men has been accompanied by many other changes in the publication procedure. All correspondence and copy is now handled by the Alumni office at the Institute, and much of the copy, including all the personals and many of the news articles, is written directly in the office. For this purpose, and for stenographic work, a stenographer has been hired on a part-time basis, the rest of her time being devoted to employment work.

The noticeable increase in size of this issue is due largely to the enterprising nature of our business manager, David Hill, who has been quite successful in convincing advertisers what potential markets lie dormant in our alumni. However, we still need more news about alumni, and that depends on you fellows who are reading the Review. May we urge you to send any and all news about yourself and alumni friends to the Alumni Review, in care of the Alumni Office at Tech.

THE DEADLINE for entries to appear in the June issue will be May 25.

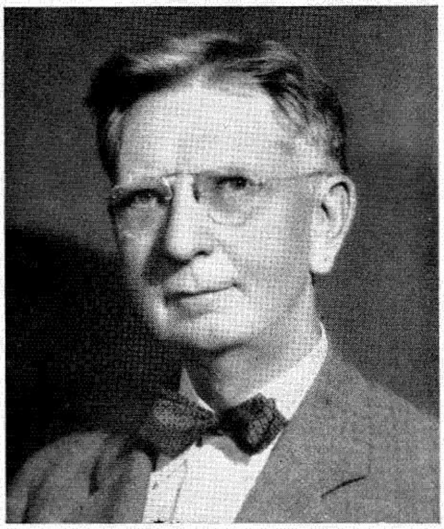
The following is the official statement regarding the widely publicized explosion which occurred on the Tech campus Friday, March 27. "A few minutes after 9 this morning, there was an explosion in the Kellogg Radiation Laboratory on the California Institute campus. This laboratory is in an area of the campus restricted in view of the work being carried on there. The explosion would appear to have been caused by an industrial accident in the powder vault of that building. The possibility of sabotage seems to be definitely ruled out.

Deceased:
Raymond L. Robey (an Institute employe) age 22.

Injured:
S. C. Snowden (graduate student) — second degree burns on face, hands, neck, and chest, but it is expected that he will recover completely.
Eleanor B. Speer (secretary, age 30) cuts, mainly on hands, not serious.
Frank F. Crandell (an Institute employe: age 33) not serious.

The following three are all employes of the telephone company, who happened to be engaged in some installation work nearby:
Charles Cummings—fractured leg.
Alfred Harris—very minor lacerations and cuts.
R. Pierce—hospitalized, but not seriously injured."

CONTRIBUTORS



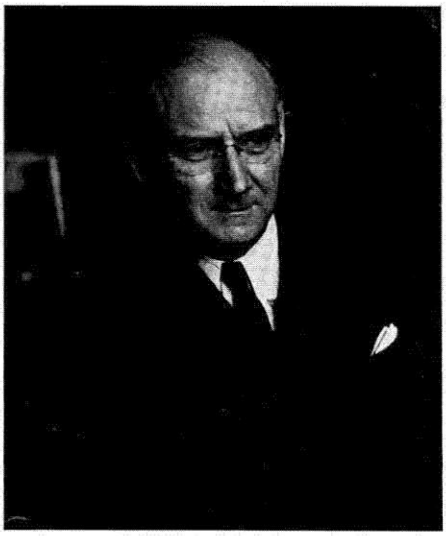
PROF. J. A. ANDERSON

John August Anderson received his B.S. from Valparaiso University in 1900 and took his Ph.D. at Johns Hopkins University in 1907. From 1908 to 1915 he was an Associate Professor of Astronomy at Johns Hopkins. Since 1916 he has been a member of the staff of the Mount Wilson Observatory of the Carnegie Institute of Washington. In 1928, by special arrangement with the Carnegie Institution, Dr. Anderson came to Tech to assume the responsibilities of a Research Associate in Astrophysics and to serve as an Executive Officer of the Observatory Council. He is now in charge of the 200 inch mirror to be used in the new Palomar Observatory.

PROF. WILLIAM V. HOUSTON

William V. Houston received his B.A. from Ohio State University in 1920, his M.S. from the University of Chicago

in 1922, and returned to Ohio State to receive his Ph.D. in 1925 to 1927 he was National Research Fellow at Caltech and in 1927-28 was a Foreign Fellow of the John Simon Guggenheim Foundation. Since 1931 he has been a professor in the Physics department at Tech and, in the absence of Professor Tolman, now acts as Dean of the Graduate School. At the present time Professor Houston is in Washington with the National Defense Research Council and will probably remain there for the duration of the war.



PROF. FRANKLIN THOMAS

Franklin Thomas graduated from the University of Iowa in 1908 with the degree of B.E. and received the degree of Civil Engineer in 1913. He has also been associated with McGill University in Montreal and the University of Michigan. From 1909 to 1910 Professor Thomas was Construction Foreman for the Mines Power Company in Cobalt, Ontario, while from 1912 to 1913 he acted in the capacity of Designer for the Alabama Power Company in Birmingham. In 1913 he joined the staff of the Institute and is now Head of the Civil Engineering department. Since that time he has also been with the U. S. Reclamation Service and has served as Vice-Chairman of Board of Directors, City of Pasadent, Vice-Chairman of the Board of Directors for the Metropolitan Water District, and as a Director of the American Society of Civil Engineers.

Alumni Seminar

Sunday, April 12

DR. J. NORTON WILSON

J. Norton Wilson received his B.A. from the University of British Columbia in 1934 and his M.A. in 1936. He then came to Caltech and obtained his Ph.D. in 1939. Since that time he has served as a Research Fellow and Instructor in Applied Chemistry at the Institute.

NEWS SHORTS

CALTECH GEARED TO WARTIMES DEMANDS

The California Institute faculty has decided the Institute could most effectively do its part in supplying the present need for trained men by devoting the summer to special courses designed to answer pressing war needs, and by continuing the regular curriculum on a three term basis.

The regular enrollment of the Institute necessarily is limited. This means that the number of engineers and scientists graduated each year is relatively small. Accelerating the program by adding a fourth regular term in the summer would, of course, hasten the time when these men would receive their degrees, but the number involved would be small compared to the number who are needed.

Special summer courses, however, can take men who already have some background in engineering or science, and by short, intensive courses, equip them to fill the particular needs of government services and defense industries. This will produce a far larger volume of trained men, and at the same time it will permit the Institute staff to continue its ever increasing program of research and development of the instrumentalities of war.

THE PRESENT STATUS OF OUR RUBBER SUPPLY

By DR. J. NORTON WILSON

The following article reviews, in a concise and semi-technical manner, the present status of the nation's rubber supply. Particular emphasis is placed on the preparation and properties of synthetic rubber; however, the situation is also adequately covered with respect to natural rubber, reclaimed rubber, and guayle rubber. Figures afe given covering production of the various rubbers from 1939 through 1942 (est.), relative costs, and a comprehensive chart comparing all important properties.

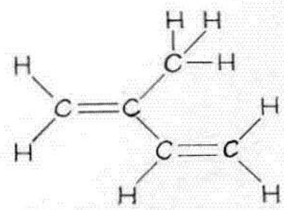
This country's consumption of rubber in times of peace amounts to about six hundred thousand tons of raw rubber a year, distributed roughly as follows:

Truck and bus casings and tubes	38%
Passenger car casings and tubes	34%
Industrial goods	12%
Other purposes	16%

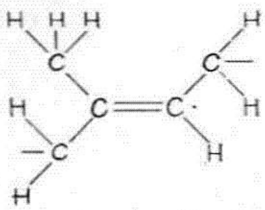
In 1941 the stimulus of increased production and apprehension over future supplies of raw rubber increased consumption by about thirty percent. Now our imports of raw rubber have been almost completely cut off. Rubber is needed to maintain transportation facilities and for many other purposes: tires for army cars, planes, and mobile artillery, for tank treads, engine mountings, shock pads, for conveyor belts, electrical insulation, flexible hoses, and for many other purposes. Where is it to come from?

The immediate demands of the war production program are being met from the stock pile of approximately six hundred thousand tons which had been accumulated by the end of 1941 by the government in cooperation with the rubber industry, and by curtailment, as every one of us knows, of civilian rubber consumption. The next most important source of rubber for the immediate future is the rubber reclaiming industry. About two hundred and seventy thousand tons of rubber were reclaimed in 1941 for the purpose of mixing with raw rubber in the manufacture of tires, etc., and it has been estimated that a maximum of perhaps five hundred thousand tons could be reclaimed annually in this country if processing equipment were available. The reclaiming process, which involves heating and agitation with concentrated alkali, is a relatively drastic one, however, and the quality of the rubber for many purposes is reduced with each reclaiming. There is consequently an evident limit to reclamation as a means of eking out our rubber supplies. A third possibility, the development of plantations of rubber trees and of guayule shrubs in this hemisphere, is of limited immediate value because of the time required to propagate the plants and to bring them to maturity. A program to develop such sources of natural rubber will be of value in a few years and is being developed. There is a fourth possible source, however, namely rubber made synthetically from raw material available in abundance in this country, and it is this source which is expected to fill the needs of the near future. It was announced by Jesse Jones on January 12, 1942, that the Federal Government would foster an immediate rapid expansion of our infant synthetic rubber industry. It is expected that about four hundred million dollars will be required for construction of new plants, and it is hoped that by the end of 1943 a productive capacity of four hundred thousand tons of rubber per year will be attained.

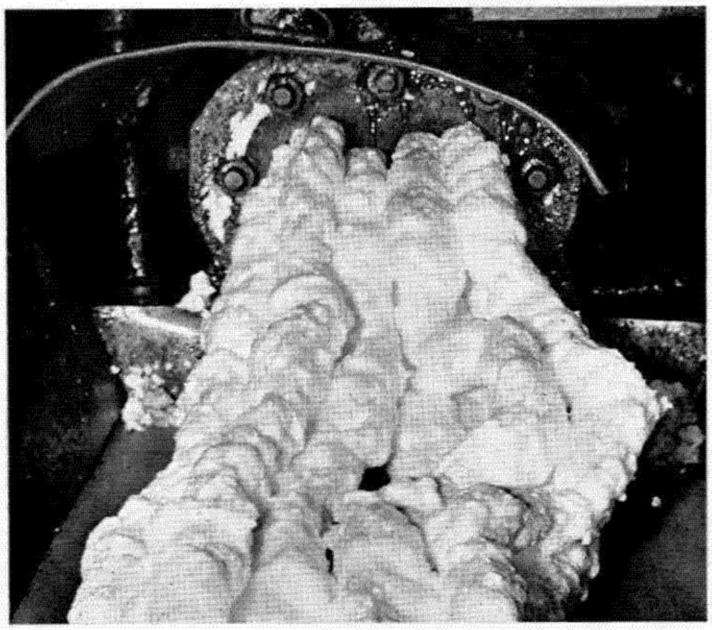
The history of synthetic rubber extends back to about 1880, when it was discovered that isoprene, a hydrocarbon with the formula C_5H_8, which can be obtained by destructive distillation of raw natural rubber, would form masses of rubberlike material on exposure to sunlight or to certain catalysts. The structure of isoprene is—



The process by which rubber is formed from isoprene may be represented as involving the opening of the double bonds at the ends of the molecule with the simultaneous formation of a double bond between the central carbon atoms, and free bonds on the end carbon atoms, thus:



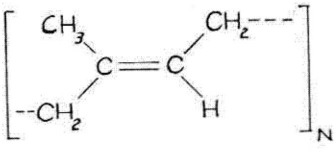
These active C_5H_8 units can then link together by means of the free bonds on the terminal carbon atoms and form long



Courtesy of Journal of Industrial Engineering Chemistry.
Courtesy of Standard Oil Company of New Jersey.

Polybutene at one stage in the manufacturing operation.

chains in which the unit C_5H_8 is repeated many times. This process is known as linear polymerization, and the product is a linear polymer. Raw rubber is believed to be formed in nature by essentially this process; the chains of polyisoprene present are of variable length; the number of isoprene units per chain ranges up into the thousands. The structure of natural rubber may accordingly be represented as—

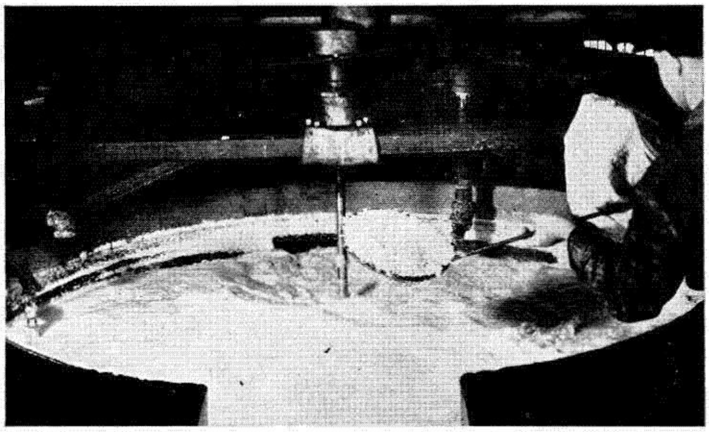


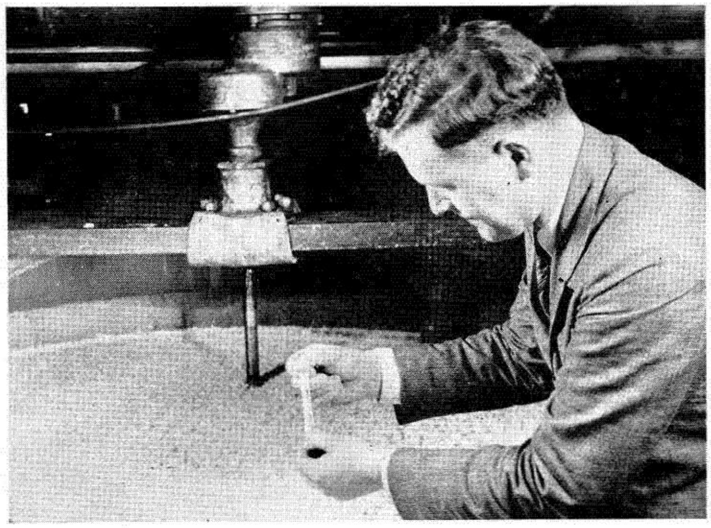
where N is a large number whose value varies from one chain to another.

The familiar elastic properties of natural rubber are due to the fact that these chains are flexible; they can bend by a process in which groups connected by a single bond rotate about that bond. In a piece of raw rubber most of the chains tend to be coiled rather than extended as straight as possible. When an attempt is made to stretch the rubber, the coiled chains may slip past one another, in which case the rubber is peranently deformed. The process occurs with natural rubber at temperatures not very far above room temperature; the rubber is then said to be plastic. Over a small range of temperature the chains in raw rubber instead of slipping past one another uncoil to some extend under an applied stress which is not too great, but are eager to return to their initial configuration when the stress is removed. Under these circumstances the rubber manifests its familiar and useful elastic properties.

The double bonds which still remain in polyisoprene are the most reactive parts of the molecule and are important for two reasons. In the process of vulcanization sulfur reacts with the double bonds and this reaction is believed to result in the formation of cross-links between the chains which tend to prevent the chains from slipping past one another. At any rate the result of vulcanization is to increase the tensile strength and the range of temperature over which rubber shows its useful elastic properties. Articles made of unvulcanized rubber are relatively useless; they become brittle in cold weather and plastic and tacky in warm wather. If vulcanization is carried far enough with a large enough proportion of sulfur, the chains are so firmly bound together that the rubber becomes hard and relatively inextensible. The double bonds in polyisoprene are also the points at which the molecule is attacked by oxygen. Reaction with oxygen has results similar to those obtained by reaction with sulfur; the familiar embrittlement and cracking resulting from atmospheric deterioration of rubber is principally the result of attack by oxygen.

Besides being subject to attack by oxygen and other chemicals which react with the double bonds in polyisoprene, rubber is also subject to attack by solvents such as benzene, gasoline, petroleum oils, etc. The relatively small molecules of solvent are attracted to the polyisoprene chains by van der Waals forces, just as the chains are attracted to each other. If the attraction between solvent molecules and isoprene chain is greater than the attraction between the chains themselves,





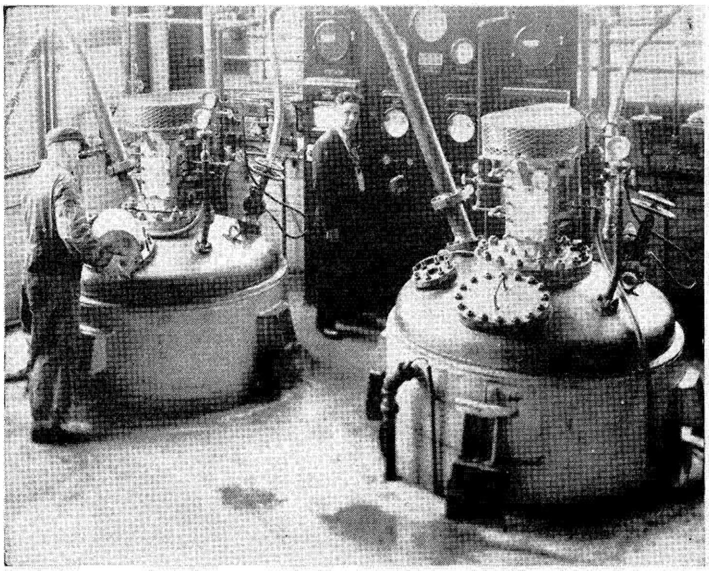
Courtesy of Chemical and Metallurgical Engineering.

Vat of a solution of raw rubber after it has been coagulated showing close-up of a strainer full of curd-like particles. Curd rises to the top of the solution after the washing process.

solvent molecules squeeze in between the chains and cause the rubber to swell and become soft. Certain solvents when present in excess may even dissolve part or all of the rubber. The susceptibility to attack by solvents is decreased but not removed by vulcanization.

The most obvious course to follow in attempting to make synthetic rubber would be to make isoprene synthetically and to attempt to polymerize the isoprene to yield a product similar to natural rubber. Some synthetic rubber has been made this way in the past, but this method is not now of commercial importance because isoprene is relatively difficult and expensive to prepare, and its polymerization is relatively difficult to control. Modern methods for making synthetic rubber involve the synthesis of compounds which can be cheaply obtained from abundant raw materials and are capable of forming flexible linear polymers similar to polyisoprene. No synthetic rubber has been prepared so far which is quite the equal of natural rubber in flexibility and rebound, but several varieties of synthetic rubber are superior to natural rubber in their resistance to attack by oxygen and other chemicals and to swelling by certain solvents.

It should be remarked that natural rubber, before it is made into useful articles such as tires and conveyor belts, is mixed or compounded with a variety of substances; sulfur for vulcanization, carbon black and other finely divided solids to increase resistance to abrasion, plasticizers to decrease brittleness at low temperatures, and other materials which, though

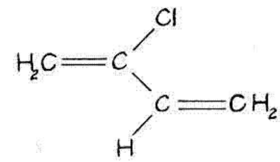


Courtesy of Chemical and Metallurgical Engineering.

Butadiene and other ingredients which go into the production of synthetic rubber are polymerized in large steel vessels in which they are agitated and emulsified in a soap solution under pressure.

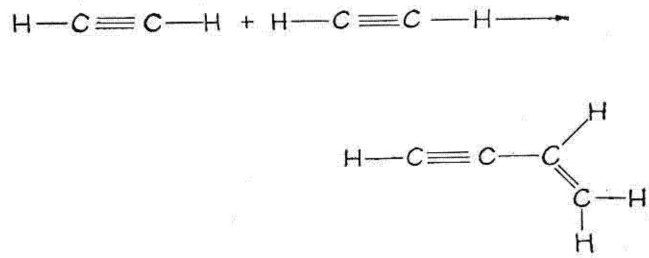
present in small quantity, are extremely important; i.e. accelerators to speed up the vulcanization reaction and enable its closer control, and antioxidants to delay deterioration by oxygen. The proper kinds and proportions of these substances, the proper methods for incorporating them with the rubber, and the duration of and conditions in the final heating process in which vulcanization or curing is carried out—in a word, the ways in which all the operating variables must be controlled to produce a product of the desired properties—have been discovered empirically as the result of multitudinous experiments. For each type of synthetic rubber a similar program of time-consuming experimentation is required before optimum conditions for utilization of the rubber can be established. The use of synthetics is further complicated by the effect of variations in the conditions under which the raw materials are polymerized. Fortunately a considerable amount of experimental information is already available as a result of investigations carried out by the chemical and rubber industries in adapting synthetic rubber to special applications for which its superiority in certain properties enabled it to compete, in spite of higher price, with natural rubber.

One of the first rubbers to become of commercial importance in this country was Neoprene, announced by duPont in 1932. Neoprene is a polymer of 2 chloro 1, 3 butadiene, whose structure is—

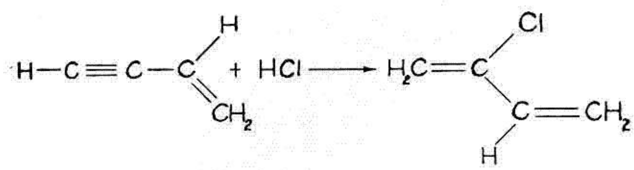


It will be noticed that this structure is identical with that of isoprene except for the replacement of the CH_3 group by a chlorine atom.

The raw materials for neoprene are coke, lime, and hydrochloric acid. Coke and lime are heated in an electric furnace to produce calcium carbide which will react with water to produce acetylene. By means of a suitable catalyst acetylene is made to react with itself to produce vinyl acetylene, a gas.



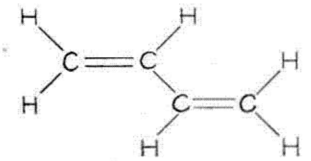
This gas is swept rapidly through a mixture of hydrochloric acid and a cuprous chloride catalyst to produce chloroprene—



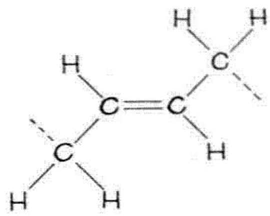
which polymerizes, under the influence of air as a catalyst, to produce a tough jelly, the so-called alpha polymer. The material may be stabilized in this form by the addition of diphenylguanidine and can then be compounded with other materials just as natural rubber can. The vulcanizing process can be carried out without sulfur, simply by heating with suitable catalysts, such as zinc chloride, aniline, or naphylamine.

Several types of Neoprene rubber are produced. They are similar to natural rubber in mechanical properties, but excell natural rubber in resistance to oxidation and to chemical attack generally. They are much more resistant than natural rubber to swelling and dispersion by petroleum oils, though they are subject to swelling and solution in aromatic hydrocarbons such as benzene. Neoprene is satisfactory for many purposes for which ordinary rubber is not, for example, for gasoline lines and tanks. The price quoted in August, 1941, for Neoprene GN was sixty-five cents a pound as compared to twenty-three cents a pound for raw natural rubber. Yes, it is suitable for tire treads.

The principal products of the new production program will, however, be of the Buna type. This type derives its name from butadiene and the symbol for sodium, Na. The reaction on which this name is based is the sodium-catalyzed polymerization of butadiene:



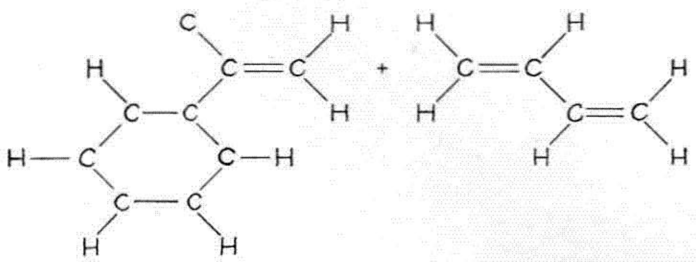
to produce long chains which are repetitions of the unit.



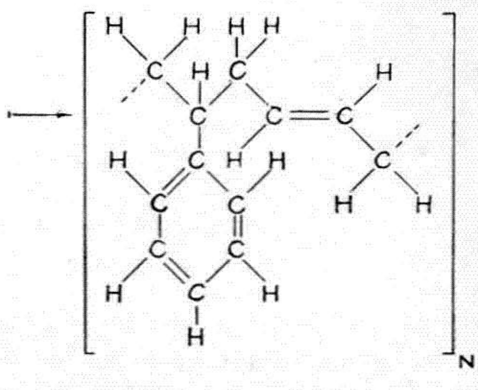
This structure occurs in the synthetic rubber known as Buna 85.

It has been found that a product of better mechanical properties and better resistance to solvents is obtained by polymerizing a mixture of butadiene and another unsaturated compound to produce linear copolymers in which the units which make up the chain are derived from both compounds.

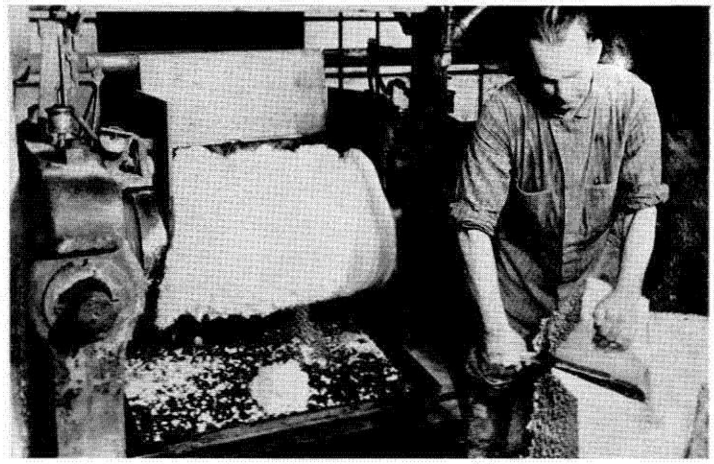
Thus the synthetic rubber known as Buna S is made by the catalytic polymerization of butadiene and styrene, according to a reaction which may be represented as follows:



Styrene **Butadiene**



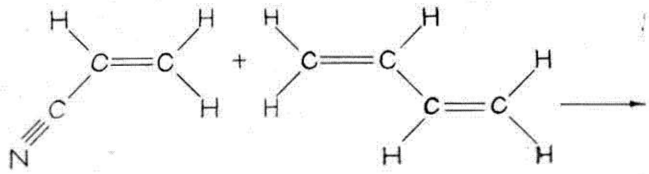
Buna S



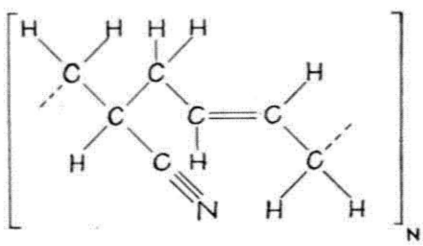
Courtesy of Chemical and Metallurgical Engineering.

Chunks of rubber, cut from the block in the foreground, are placed on a washmill where moisture is extracted and it is sheeted into thin sheets.

Likewise, the synthetic rubber known as Buna N, or Perbunan, is a copolymer of butadiene and acrylonitrile, prepared according to the reaction—



Acrylonitril



Perbunan

It is estimated that perhaps seventy per cent of the synthetic rubber program will be devoted to the production of the Buna copolymers. Under such names as Ameripol, Hycar, and Chemigum, this type of synthetic rubber has been on the American market for some time, and has been used for the production of conveyor belts, hose, gaskets, machinery mounts, and oil-resistant insulation. The Buna rubbers can be compounded and vulcanized in essentially the same way as natural rubber by the use of machinery of the type at present available in the rubber industry, though the details of the compounding procedure must be varied to fit the properties of the polymer being processed. One difficulty is that uncured Buna rubber is considerably stiffer and harder to work in the compounding mill than is natural rubber, and tends to overheat during compounding. If care is not used in the compounding,

(Continued on page 16)

PROGRESS REPORT — THE 200-INCH MIRROR

By PROF. J. A. ANDERSON

This article reviews briefly the history of the 200-inch mirror to date, and relates in some detail the problem of gravitational astigmatism. Sveral additional interesting problems are set forth.

The 200-inch mirror disk was cast at the Corning Glass Works in March, 1935, and arrived at Pasadena in April, 1936. The structure of the disk is indicated by the oblique photograph reproduced in Figure 1, showing the back and rim, and the diagram, Figure 2, showing a section along the line *AA* of Figure 1. In general it may be described as a continuous glass front supported by a system of glass ribs, so designed that when a concave curve is cut in the front surface (shown by the dashed line in Figure 2), the thickness of the glass shall be nearly the same everywhere. This construction was chosen in order to reduce the 'temperature inertia'* of the disk as a whole to a low value. It also makes it possible to bring the point of support of each supporting lever closer to the center of gravity of the weight to be supported. For this purpose there are 36 circular openings in the rib system to accommodate the same number of supporting levers. Figure 3 shows one of the supporting units which is 'double-acting'; that is, it takes the place of both the ordinary back and edge supports.

The work of shaping this disk into a finished mirror is not essentially different from that required for a smaller mirror familiar to all amateur telescope makers. Front and back must be ground flat and parallel to each other, and the edge ground to the form of a reasonably good circular cylinder. In addition, the 200-inch required that the 36 circular openings for the supporting levers be ground internally to very definite dimensions. An important difference arises from the great size and weight of the 200-inch; namely, that machinery is called for at every turn—and rather heavy and slow moving machinery at that.

For the rough shaping a half-sized tool of cast iron was prepared. Its weight was about seven tons. It was made thick enough to be used first as a flat grinder and later on to be turned convex for roughing out the concave curve of the mirror. All other tools, including one of full size, were built up of thin sheet-steel plates welded together. These are much lighter than cast tools of the same size and they have also been found to be superior in rigidity. The working surfaces of these tools are covered with glass blocks which are used uncovered for grinding and covered with pitch substitute for polishing. The weight of the full-sized tool (shown on the floor to the left in Figure 4) is about five tons.

In order to grind the back surface to a tolerably good plane, it was necessary to fill up the openings between the ribs. Little wooden tables were made and fitted into these openings in such a way that the tops of the tables lacked about 2″ of being flush with the ribs. Plaster of Paris was then used to complete the filling. Only in this way was it possible to grind the surface to a true plane. This done, the cavities were cleaned of plaster and tables and the disk turned over in preparation for the next step, which was to grind the face plane and parallel to the back.

Normally, this should have required a relatively short time, but actually it took many months, chiefly for the following reason: Corning had a considerable flood in 1935 while this disk was in the annealing oven. Water covered the floor of the room where the annealing was in progress to such a depth that it was necessary to shut off the current for about three days. A temperature drop of rather large amount was the result, but as soon as conditions permitted the temperature was slowly brought up to its normal value and held there constant for a time. Then the regular program of slow cooling was resumed. When, in late October, 1935, the disk was examined, it was found quite successfully annealed, but there were some bad-looking fractures in the front surface. The immediate cause of these fractures was clear, for a couple of the chrome-iron I-beams of the cover had sagged enough to become partly imbedded in the hot glass and, as the cooling proceeded, strains due to the differential expansion of iron and glass did the trick. One has a feeling that this would not have happened if there had been no interruption in the cooling, but, of course, this can now never be known with full certainty.

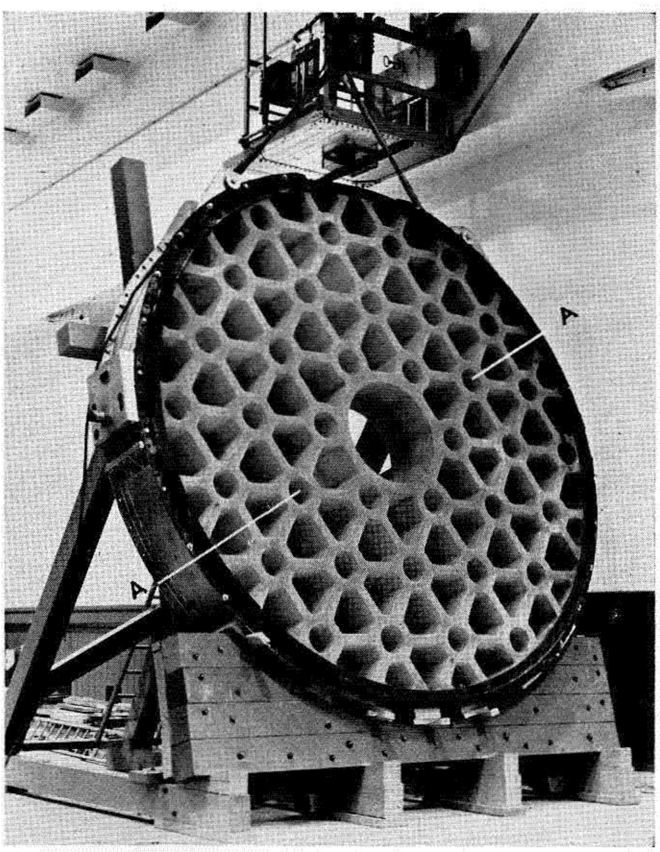


Figure 1: **Back of the big disk.**

1 "Temperature inertia" is a convenient term to indicate the length of time required for the temperature to reach equilibrium with the surroundings.

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The obvious thing to do was done; namely, to remove the fractures by sand blast and so find out whether sufficient thickness of glass remained to make a good mirror. The deepest excavation made in the sandblasting was over 5″ deep but it was near the center of the disk, so it would still be possible to grind the concave curve and have a glass thickness of 4″ left. If the disk had come out as planned, this thickness could readily have been 6″ or a little more, which might have been an advantage if rigidity alone is considered. A thickness of 4″ is, however, slightly better from the point of view of low temperature inertia, since all the ribs have about this thickness.

It was decided that, instead of merely making the front surface into a true plane, the extra 2″ of glass should be ground off before establishing the plane and making the disk parallel. This 2″ of glass represented a weight of 2½ tons and used up five tons of coarse Carborundum. Later on, another 2½ tons of glass would have to be removed in cutting the concave curve.

Grinding the edge was the next operation. This was done face down, with the face of the mirror raised some 8″ above the turntable by inserting suitable timbers. The grinding was done with a rotating hollow cylinder of Carborundum fed with water and Carborundum powder. The 40″ central hole was ground to size in this same set-up.

The next step was grinding the 36 cylindrical holes designed to admit the supporting levers. The axes of these cylinders should be perpendicular to the parallel planes of the front and back already established, and, in addition, their spacing should be adjusted to form a regular geometrical pattern. A special 'pocket-grinder' had been prepared, carrying at its lower end a cast-iron hollow cylinder about 11″ outside diameter. The rotating shaft carrying this cylinder could be given a slow motion in a circle having a radius variable slowly and accurately from nothing up to whatever the size required for the finished 'pocket'.

The 36 pockets lie on five concentric circles, six on each circle except the fourth one (counting out from the center), which has 12. On circles 1, 2, 3, and 5 they are 60 degrees apart, while on the fourth circle they are spaced in six pairs 60 degrees apart, the members of a pair being separated by an angle a little less than 22 degrees. The whole operation of grinding these pockets was completed in about three months.

Next the turntable of the grinding machine was covered with two layers of 1″ sponge rubber and the mirror placed face-up on this bedding. In order to insure as uniform a support as possible the compression of each sheet of sponge rubber was carefully measured under a fixed load, and only those pieces whose compression was within a narrow range of being the same were applied to the table.

The glass plug to fill up the 40″ hole in the center of the mirror had been ground cylindrical to a suitable diameter, and

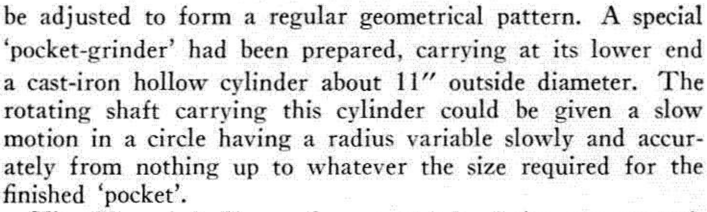
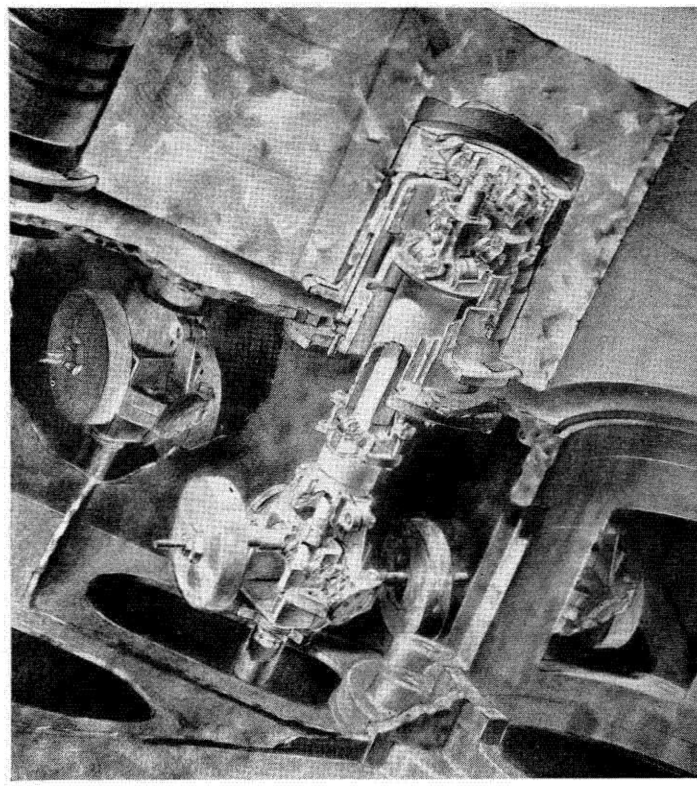


Figure 2: **Sections along line *AA* in Figure 1, *p,p* are openings for supporting units. In the casting ,thickness at *a,a* was 6″, at *b,b* 9¾″. In finished mirror (lower dashed line) thickness is approximately 4″. Over all thickness at edge is 24″. Finished weight, nearly 30,000 pounds.**



Drawing by R. W. Porter.

Figure 3: **Lever mirror support.**

it had to be inserted and fixed in place in such a way that, when the mirror is finished, it can be easily removed without any danger of harming the figure of the mirror. As the plug weighs about 1400 pounds, this did not look too easy. It was accomplished as follows: A wooden lifting clamp was applied to the upper half of the plug, leaving the lower ribbed section of about 15″ projecting below the clamp. A cake of ice about a foot thick was placed on the table in the center of the hole. By means of the crane it was then possible to rest the plug on the cake of ice. The clamp was removed and the ice melted, thus lowering the plug gently into its proper position, after which it was fixed in place by means of plaster of Paris and water-proof cement.

Before cutting the curve the support system was installed. This operation took approximately eight months. In preparation for it the weight to be carried by each of the 36 units had been calculated on the basis of careful measurements on the disk itself. Each support pocket was taken as the center of a hexagonal section of the disk. The hexagons around the central hole (Circle No. 1) and those adjoining the outer edge (Circle No. 5) are not complete, which fact complicated the calculations only slightly. The calculations furnished the weight to be carried by each unit and also located the center of gravity of each arbitrary section of the disk, thus giving the necessary data for each counterweight and for locating the internal points of application of the supporting force. Each support (Figure 3) was carefully adjusted and tested on a weight equal to that which it was intended to carry before it was attached to the mirror and its cell. Provision was made for temporarily disconnecting all the supports when work was in progress with large tools. They were, however, connected properly when an optical test was to be made.

The curve was roughed out with cast-iron tools of about one third size, and brought to approximately correct form by means of the half-sized tool already mentioned, after which

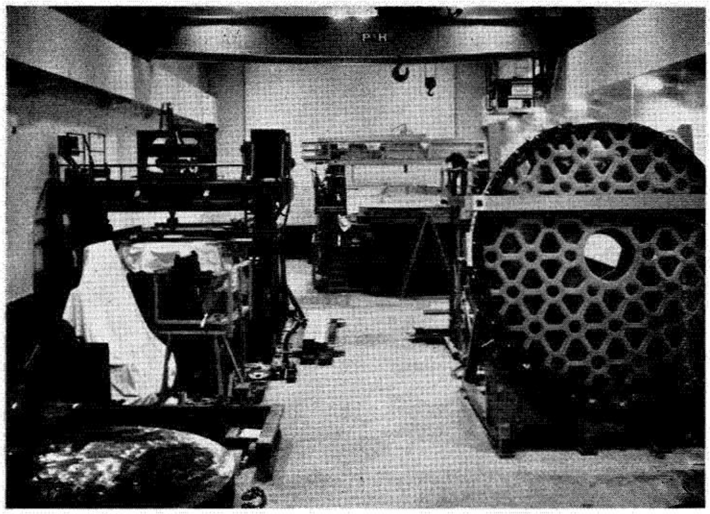


Fig. 4: **Five-ton full-sized steel tool.**

the glass-coated full-sized tool and the finer grades of Carborundum and emery finished the grinding. Measurements of curvature were made with a 36″ spherometer. Next, the full-sized tool was changed to a polishing tool, as already explained, and the surface brought to a nearly full polish. It was found that the full-sized tool used up rouge at the rate of some 50 pounds per hour, mostly by simply splashing it over the edge, hence subsequent polishing and figuring was done with smaller tools—106″ and down to about 12″.

Optical tests of the 200″ mirror were at first made with the mirror tipped up so its optic axis was horizontal, using therefore only the one component of the supporting levers. Later on, tests were made with the axis pointing about 4° above the horizon, so that both components of supporting force would be in action. In the later stages of figuring the mirror was made to rest on the supporting system while polishing was in progress.

The first optical test of the mirror, in September, 1938, revealed a fair spherical surface with some zonal and other errors, the chief of which was astigmatism. Measurement of the latter showed that the radius of curvature of a vertical plane was a millimeter or so shorter than that of a horizontal section. Rotation of the mirror about its axis in the testing position showed that the astigmatism did not rotate with it—in other words the radius of curvature in the vertical plane remained shorter in all positions of the mirror.

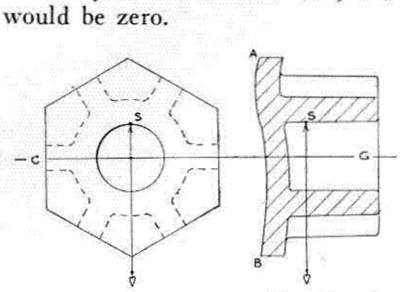
More refined measures revealed another surprising fact—namely, that at times the vertical astigmatism would have slightly different values in two orientations 180° apart. Running down the cause of this behavior required considerable time after it had been demonstrated to our satisfaction that the phenomena were real and not simply errors of measurement. A linear astigmatism of the order of 0.05″, with a not very smooth mirror surface where errors of measurement would average 0.01″ or 0.02″, does not seem so very bad—and the 180° effect of about 0.01″ might very well be considered accidental—as it was in fact until continued improvement in the figure reduced errors of setting to a few thousands of an inch. Anyway, both of these effects which had been noted in the early tests turned out to be real and correctable, though it must be confessed that it took a year or more to discover their nature and cause.

The cause of the vertical astigmatism lies in the structure of the mirror itself, combined, of course, with the method of internal support. Suppose the mirror is tipped up so that its axis is horizontal. Its weight then is carried by the 36 levers whose points of contact are in the rib structure and something like four or five inches behind the continuous front of the mirror. Let us think of one of the hexagons (Figure 5), into which we divided the mirror in the previous discussion, as made up of two parts: first, the solid front curved plate and second, the ribs. The front plate is about twice as stiff in a vertical plane as the rib system is.

If now the support point were located at the center of gravity (actually, on the axis of the 'pocket'), the half of our unit below the center of gravity would be in tension, so that it would stretch; while the part above would be in compression. Also, the deformation of the ribbed part would be twice as great as that of the solid front. If the undeformed front surface were a plane, it would, under this deformation, become slightly S-shaped vertically; that is, the upper-half would be slightly convex, the lower slightly concave. Since, instead of a plane, we have a spherical surface in the undeformed condition, the deformed condition will consist in the addition of a very weak convex cylinder to the upper half and a similar concave cylinder to the lower half of the unit. Taking now the whole mirror, each of the 36 parts would be similarly deformed, but there would be no general deformation of the surface as a whole.

Return now to the actual case. See Figure 5. The supporting point is on the upper surface of the 'pocket', which lies some 6″ or 6½″ above the center of gravity. The part *A* that becomes convex is therefore 6″ shorter than the lower part near *B*, which becomes concave. So we may say that, on the whole, the unit is concave; and when we now add up the 36 parts we find, in addition to the local deformation of each unit, a general (net) vertical concavity of the whole surface, which is what has been observed. The diagrams of Figure 5 will perhaps aid in understanding this. The local deformations of each unit are of course present, but they are so very much smaller than the net deformation that, provided the latter is small, the former will be too small to be observed.

If, in Figure 5, the support *S* could be located on line *CG*, curve *AB* would be symmetrical about *CG*, and the net curvature of *AB* would be zero.



Drawing by R. W. Porter.

Figure 5: **Theoretical hexagon.**

Clearly the effect just discussed will be absent, or have zero value, when the axis of the mirror is vertical. As the mirror axis is tilted toward the horizon, the effect will vary as the sine of the zenith distance. To correct it, a system of 12 gravity-operated 'squeeze levers' were applied, acting on the outer edge of the disk near the back, which, when the axis of the mirror is horizontal, act so as to correct the error. Since their effect also varies as the sine of the zenith distance, the compensation will be correct in all positions of the axis.

The second phenomonen mentioned above—that is, vertical astigmatism in two orientations 180° apart—is caused by a maladjustment of the supporting levers, and, like the one just discussed, is absent when the mirror faces the zenith. Let us again consider the mirror tipped up, with axis horizontal, and assume that the supporting levers such as *S*, Figure 6, in the upper half are on the average so adjusted that their supporting points are somewhat in front of the center of gravity sur-

(Continued on page 20)

THE ELECTRON MICROSCOPE

By PROF. WILLIAM V. HOUSTON

Starting from the fundamental principle of the ordinary microscope, Dr. Houston has developed the theory underlying the electron microscope in a simple, logical, and concise fashion. Applications and limitations encountered with both types of instruments are described.

To many people the microscope is the symbol of science. It is a popular symbol and it is an appropriate symbol, in spite of the fact that many physicists, chemists and engineers that claim membership in the ranks of science may never have learned to use it.

Science is based upon the analysis of matter or phenomena into parts. The objective for twenty-five centuries has been the discovery and description of "ultimate" parts. The Greeks called them atoms, and although atom has a somewhat different significance today, science is still looking for some sort of an ultimate constituent of matter.

The miscroscope was the first tool by means of which a real study could be made of objects too small to be seen with the naked eye. From its crude beginning some 300 years ago it has been developed into an instrument that is a credit to the inventive skill and analytical ability of those that have worked on it. The modern optical microscope is an instrument that approaches the "theoretical limit" of its performance.

An optical miscroscope is not of much use in the study of objects smaller than about 1/100,000 of an inch, but that has not stopped such investigation. Atoms and molecules are a thousand times smaller than the smallest object that can be seen in a microscope, and yet they have been extensively studied. Electrons and protons are still tremendously smaller than these, and yet they also have been intensively investigated and a great deal is known about them. These investigations have been by indirect methods. A great variety of experiments has been carefully studied to give the properties of the atoms, molecules, electrons, protons, etc., that are regarded as the constituents of matter. This type of work is a glorified puzzle. The conclusions hinge on the careful fitting together of a vast number of clues, sometimes apparently contradictory clues; and there is always the logical possibility that a newly discovered fact may seriously upset some of the conclusions.

In spite of the perfection of the optical miscroscope, and the success of the indirect method on very small particles, there is a range of sizes in which neither of them can be effectively applied. The indirect method has not been sufficient in the study of particles larger than molecules, and the optical microscope cannot reveal much about a particle unless it contains a very large number of molecules. This unknown region contains the particles studied by the colloid chemist by indirect means, and it contains the objects to which the biologist wishes to attribute much behavior that cannot be understood in terms of the visible parts of cells. It is one of the attractive frontiers of science that has recently been penetrated by means of the electron miscroscope.

The limitation on the performance of a microscope is set by its resolving power. This is its ability to distinguish, and to separate, two points on the object. Although a popular description of a microscope is often given in terms of its magnification, such a description is not always significant. It is of no value to produce a very large image if the outlines are blurred and the details are lost. In fact, magnification can always be produced. A simple method is simply to use one microscope to examine the image produced by another. The resultant magnification would then be the product of the magnifications of the two instruments, and might be very large. Whether this process would produce a sharp final image in which more detail can be seen than in the first depends on the two resolving powers.

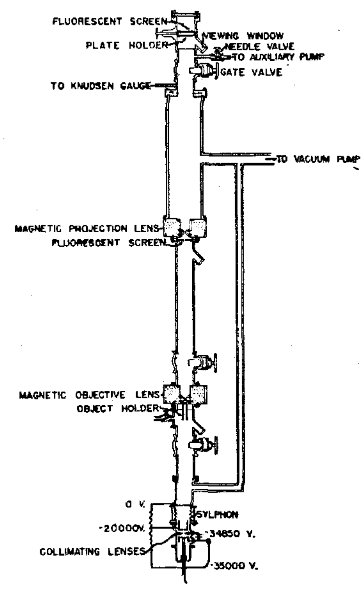


Fig. 1: **Outline Sketch of Dr. Houston's Electron Microscope in the Norman Bridge Laboratory.**

The resolving power of an optical system depends on a variety of things. The first may be said to be the precision of manufacture. If the lenses are poorly made, the resolving power will be poor. There are other limitations, however, that are more difficult to remove. These are associated with the fact that light of different colors is refracted differently by lenses, and the fact that simple lenses do not produce perfect images. These difficulties, caused by chromatic and spherical aberration, can be reduced in importance by careful design and the use of lens combinations. In fact, the skill of lens designers and manufacturers is such that the lens errors are now a negligible factor in limiting the performance of the best optical microscopes.

There still remains, however, a fundamental limit set by the nature of light itself. The simple theories of optical instruments are based on geometrical optics, in which light rays are used as idealizations of the paths along which the light travels. To get an exact theory it is necessary to take into account the wave properties of the light, and to calculate the amplitude of the waves at various points in the field. Such a calculation shows that the most perfect lens system can never separate, or "resolve", two points on the object that are closer together than about half a wave-length of the light used. For visible light this means that the resolving power is limited to about 1/100,000 of an inch. Details much smaller than this cannot be revealed by an optical microscope working with visible light, no matter how excellently it is designed and constructed.

The obvious solution to this difficulty is the use of shorter wavelengths, and microscopes have been constructed that use ultraviolet light. But the gain in this way is small, because light of less than about half the wavelength of visible light is absorbed by air and there is great difficulty in constructing the proper lenses, as glass is opaque to ultraviolet light. For many years people have dreamed of a microscope using X-rays, but as yet no very practical method of focussing them has been devised, and it has remained for the development of the field of electron optics to point the way to a significant improvement in resolving power.

The term "electron optics" arose after it was discovered that electrons and light have more similar properties than was at first realiezd. It had been known for a long time that electrons travel in straight lines when uninfluenced by any outside force and that they travel in curved paths through electric and magnetic fields. These paths correspond entirely to the light rays in ordinary geometrical optics, and by suitable design of the electric and magnetic fields the electrons can be brought to a focus similar to that of the light rays. Here is sufficient basis for a geometrical electron optics, and a basis for the construction of microscopes using electrons instead of light. But the analogy goes farther. Not only is there a geometric electron optics but the detailed study of the electron motion requires the solution of a wave problem. To know the details of electronic behavior one must take the wave properties into account and, as in the optical case, this sets a limit to the resolving power that can be attained with an electron microscope. Fortunately, the electrons have a very short wavelength and a wavelength that depends upon the velocity. The equation is $l = h/mv$, where l is the wavelength in centimeters, m is the mass in grams, and v is the velocity of the electrons in cm/sec. h is known as Planck's constant and has a value of about 6.6×10^{-27}. The mass of an electron is about 9×10^{-28} grams. Hence $l = 7.3/v$ but v is a large quantity. It is almost impossible to handle electrons whose velocity is much less than 10^8 cm per sec. so that l is pratically always a thousand times smaller than the wavelength of visible light.

Another way to express the wavelength of an electron is in terms of the potential difference used to produce its velocity. This leads to $l = (12/\sqrt{v}) \times 10^{-8}$ where v is the potential difference in volts. This shows that the wavelength can be made almost as small as desired by increasing the potential difference used to accelerate them. In any case, with potential differences of several thousand volts the wavelengths are very small.

After the recognition of the essential similarity between electron optics and ordinary optics, the problem was to devise an apparatus that would control the electrons in the same way that the lenses of an optical miscroscope control the light.

The problem has been solved in a number of ways that are very similar to each other. The drawing gives an outline sketch of the apparatus built in the Norman Bridge Laboratory. The ordinary microscope requires a source of light and the electron microscope requires a source of electrons. In the instrument shown this is a hot filament. An ordinary microscope uses a condensing lens or mirror to concentrate the light on the object. In the electron micrscope this purpose is served by a series of electrodes maintained at suitable potentials. These produce such an electric field that the electrons are caused to move in paths that bring them to a focus on the object to be examined.

One of the major problems in microscopy is the proper preparation and mounting of the object. When these are small and transparent, they can be placed on a glass slide through which visible light passes easily. However, electrons will not penetrate a piece of glass, and some other support must be used. A common solution of the problem makes use of a very thin film of collodion. The electrons pass through this, not because of any particular transparency to electrons that it exhibits, but merely because it is thin. The stopping power for electrons depends essentially on the number of grams per square cm of film. Collodion is convenient because it can be made into very thin films by allowing a solution of it to spread out on the surface of water.

Fig. 2: **A shot of Optical Rouge taken with the instrument of Fig. 1 Magnification: 16,500 diameters.**

(Continued on page 15)

EDUCATION FOR VICTORY

By PROF. FRANKLIN THOMAS

The Engineering, Science, and Management Defense Training Program at Caltech is briefly reviewed in the following. A complete list of courses now being offered is given. Professor Thomas goes on to explain the faculty decision against an accellerated under graduate program during the summer months and the elimination of this year's spring vacation.

Photo by O. K. Harter.

Fig. 1: **ESMDT Welding Class in action at C.I.T.**

One of the less spectacular but nevertheless highly useful aspects of converting the resources of the nation to a war production basis has been the training program in the engineering and science fields to meet emergency needs. In this program, the California Institute of Technology has participated on an extensive basis, particularly with reference to the fields in which it is specially fitted in both personnel and facilities.

In the early period of the defense program, the deficiencies of the nation in ships and aircraft were particularly recognized. With the rapid expansion of production facilities in these directions it was recognized that competent engineers and supervisors for those activities in the required number could only be achieved through the adaptation of persons with fundamental engineering or scientific training to the special applications of these principles to meet the new demands.

In July of 1940, shortly after Hitler had over-run the Low Countries and reached the English Channel, a group of engineering educators was assembled by Dr. John W. Studebaker, the Commissioner of the U. S. Office of Education, and the pattern of the training program which has subsequently proved so effective was evolved and a Congressional appropriation was secured to inaugurate the Engineering Defense Training courses. For administrative purposes the country is divided into twenty-two geographical regions. Professor Robert L. Daugherty is Regional Adviser for the region including southern California, Arizona, New Mexico and western Texas. This program has expanded under the Engineering, Science and Management Defense Training Program until there are now 140 institutions conducting these courses with a total enrollment to date during the current fiscal year exceeding 250,000. The corresponding figure for the Institute alone approximates 3000. This number represents both those courses which have been completed and those which are now in progress, but the number currently enrolled in courses conducted by the Institute is approximately 1500.

In addition to the E.S.M.D.T. program, both the Army and the Navy have arranged independently for the training of men in specialized fields of service. During the last two college years there have been groups of meteorology cadets detailed to the Institute for a nine months period of training. These cadets periodically represented 120 selected college graduates from engineering or science courses, who upon completion of their training period were commissioned as 2nd Lieutenants in the Army, Ensigns in the Navy, and Civil Service appointees with the Weather Bureau. The third such group is now under way. Accommodation for such enlargement of the number of students in Meteorology was provided by the utilization of much of the space in the Mudd Laboratory of the Geological Sciences.

Special training courses have students representing three general types. The numerically larger group is that in which the students are nearly all employed in the local industries and are taking advantage of the courses to improve their qualifications or to adapt themselves to some new type of employment more directly related to the war production needs. Both during the academic year and during the summer vacation there are groups of Army and Navy officers detailed to the Institute for special training as represented by courses arranged to meet their requirements and given as part of the E.S.M.D.T. plan. Representing the latter group is a class of Field Artillery Officers, which during the past few months has been occupied with a course in Military Meteorology, supervised by Dr. Th. von Karman. During the summer of 1941 and in prospect for the summer of 1942, there was a three months course in Aeronautical Engineering for newly commissioned Naval Ensigns who had just completed undergraduate courses in Engineering or Physics. The third group to be accommodated during the summer of 1941 was composed of civilians who were in a position to put in full time for the three month period. One group was enrolled in Production Engineering, another was enrolled in an introductory course in Electronic Circuits and Apparatus. The course in Aeronautical Engineering also included some civilians.

The following list of courses which have been offered or are in progress for the current year, represent a wide scope of specialized interest:—

Aircraft Production Illustration
Aircraft Power Plant Installation Design
Engineering Mathematics (Higher)
Fundamentals of Engineering Mechanics and Mathematics
Production Engineering

Introductory Electronics
Electronic Circuits and Apparatus
Elementary Radio
Theory and Science of Electric Welding, I.
Theory and Science of Electric Welding, II
Die Design and Press Work
Elementary Naval Architecture
Materials and Metallography Laboratory
Engineering Materials (Metallic) comprising sections in
- Materials and Processes
- Physical Metallurgy
- Metallography Laboratory
- Spectro-Chemical Analysis Laboratory

Basic Electric Circuits & Machinery
Military Meteorology
Aeronautical Engineering
Introductory Industrial X-Ray Technique
Aircraft Descriptive Geometry
Aircraft Detail Design
Aircraft Fitting Analysis
Production Engineering comprising sections in
- Industrial Relations for Supervisory Personnel (3 sections)
- Industrial Management
- Time Study
- Methods Improvement through Motion Study
- Cost Analysis and Control
- Tool Planning
- Wage and Salary Determination and Job Analysis
- Production Control
- Selection and Placement of Personnel
- Techniques of Training Personnel
- Quality Control
- Plant Layout and Materials Handling
- Advanced Tool Planning
- Introduction to Aerodynamics
- Electrical Machinery
- Ultra-High Frequency Technique
- Theory & Art of Resistance Welding
- Aircraft Production Design
- Strength of Materials
- Advanced Die Design
- Highway Engineering
- Engineering Materials (Metallic)
- Aerial Bombardment Protection
- Introductory Industrial X-Ray Technique
- Elementary Jig & Fixture Laboratory
- Advanced Jig & Fixture Laboratory
- Tool Engineering
- Theory of Aircraft Instrumentation
- Technical Drafting for Engineers
- Surveying Instruments and Procedure, II.
- Plane Table Topography
- Fundamentals of Radio
- Production of Strategic & Essential Minerals
- Marine Engineering, III.
- Radio Engineering
- Technical Report Writing
- Theory & Technique of Optical Testing Methods
- Identification of Industrial Materials
- Applied Geophysics
- Radio at Ultra-High Frequency

The faculty and the administration of the Institute during recent weeks have given a great deal of study to the question as to whether the Institute would more effectively serve the national interest by adopting an accelerated program for its regular activities or maintain approximately a normal academic year and utilize the facilities of the Institute during the summer for special emergency training. At a faculty meeting on March 6, 1942, when the question was specifically considered, it was the judgment of the faculty that none of the usefulness of the Institute would be lost if the summer were to be used for special work and there would thereby be avoided many complications which would result from attempting to coordinate classes which would be running out-of-phase with each other and many acute financial problems of students.

Photo by O. K. Harter.

Fig. 2: **Evening class in the EE Lab.**

As indications developed of the desire of the Army and the Navy to assign newly commissioned officers to the Institute for special courses during the summer and, somewhat earlier than the Institute's usual closing date, the faculty also voted to gain a week by eliminating the spring vacation and advancing the date of Commencement to June 5th. These large classes of young officers involve the use of the student houses and the training which is desired for these men can be provided by the especially qualified staff of the Institute and its corresponding equipment. There is an urgent demand for the production of the type of men trained by the Institute's regular courses, but this urgency must be weighed in the balance with the emergency nature of the training required by special groups. Furthermore, there is every indication that nearly all the undergraduate students will have opportunity to be usefully and lucratively employed during the coming summer in connection with war projects.

In addition to the large groups of officers and other men detailed here by the government for full-time courses during the summer, the Institute expects to offer both full-time and night courses for civilians to the limit of its capacity. Some of these classes may involve radical departures from the male student tradition of the Institute. Requests are being made by the aircraft and other industries that the diminishing number of young men available for drafting jobs be replenished by men above the age of 35 and also by women.

At present the greatest urgency for large numbers of people to be trained exists in the field of radio. The application of this radio training is for communications of all types and services and also for the more advanced and highly specialized application of ultra-high frequency detection technique.

EDUCATION FOR VICTORY

The many instances which could be cited of benefits which have resulted from these Defense Training Courses are impressive. Many students have thus been able to enter in very useful and advantageous capacities industries with which they had had no previous experience or connection. Some very significant developments with widespread effects through large industries have evolved from the participation of various supervisors in industry in these courses as instructors. The time and effort which has been so sincerely applied to these courses by the many students enrolled have represented very definite and productive contributions to the national welfare.

ELECTRON MICROSCOPE

(Continued from page 12)

The same situation arises when the electrons come to the object. The number of electrons transmitted at a given point depends on the thickness in terms of grams per square cm. For that reason most electron microscope pictures appear to be shadows. The electrons pass around the object but penetrate it to only a very slight degree. Only when the thickness of object varies over a small range and is such as to permit some transmission of electrons at all points, can a gradation of blackness be produced in the image.

The light that passes through the object in an ordinary microscope must be brought to a focus to give the image. In the same way, the electrons that pass through the object must be focussed to produce the image. The objective lens produces an image with a magnification of almost 100 at the focus of the projection lens. This projection lens again focuses the electrons into a further enlarged second image at the photographic plate. These lenses are magnetic lenses that consist of a coil of wire surrounded by a steel armor. The armor has a small opening in it so that the lines of force bulge out into the electron path over only a very short distance. In this distance the focussing takes place. The focal length of such a lens depends on the current passing through it so that the process of getting correct positions of object and photographic plate is replaced by a simple adjustment of the current.

Much of the complication of an electron microscope is due to the fact that fairly high voltages must be used for accelerating the electrons, and that the whole electron path must be in a high vacuum. The vacuum must be so good that the electrons make no collisions during the whole distance of some six feet from the filament to the photographic plate. This requires continuous pumping with high speed pumps as well as arrangements of valves by means of which the object and the photographic plates can be inserted and removed.

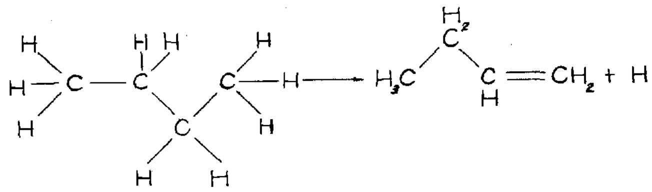
The voltages used vary from a few thousand to over a hundred thousand. A high voltage produces fast electrons that will penetrate a greater thickness of matter, but lower voltages show a better contrast in the image. Above all it is necessary to hold the voltage constant within a few volts. For this purpose, fairly elaborate voltage regulators must be used, and this is one of the major problems of construction.

The electron microscopes of today are only in the beginning of their development, and they are far from realizing the theoretically attainable resolving power. This makes it an attractive field of study for the engineer and physicist, while the field of study opened up by its applications promises to close the gap between the visible and the molecular ranges of size.

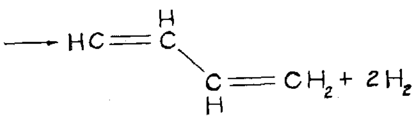
(Continued from page 7)

the rubber gets hot enough to become partially depolymerized, and must be discarded. This is one of the principal problems with which the tire companies attempting to use synthetics in tires have had to contend. Buna tires have been in use in Germany for several years and have been successfully made in this country; in fact early in 1941 tires made of synthetic rubber of the Buna type were being produced by one company at the rate of 500 to 1000 a week. It is said that passenger-car tire treads which are at least equal and perhaps superior in durability to those made from natural rubber can already be made from Buna type synthetics, and the possible improvements which may result from variations in processing techniques, and in the proportion of butadiene in the copolymers have not yet been fully explored.

The butadiene required can be prepared in a variety of ways, but the most likely sources are butane from natural gas and butene from the gaseous products of cracking processes in petroleum refineries. The reaction involved is essentially the removal of hydrogen at high temperatures under the influence of a catalyst.



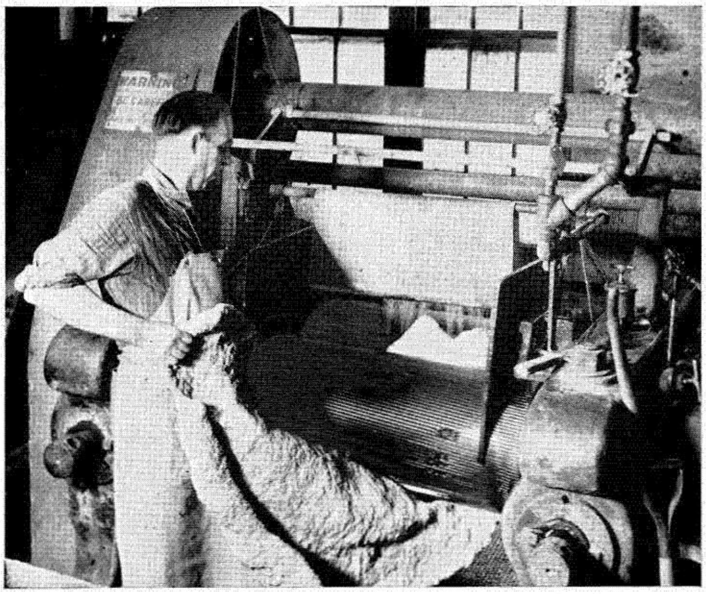
Butane **Butene**



Butadiene

A mixture of products is obtained from which the butadiene can be extracted and purified. The operations are of a type with which the refiners of petroleum and the manufacturers of synthetic organic chemicals are familiar, and the supply of raw material for butadiene production is enormous. Styrene can be separated from the products obtained by cracking selected petroleum fractions or can be made from ethylene (a by-product of petroleum refining) and benzene by catalytic operations at high temperatures. The acrylonitrile can be made from ethylene, chlorine, water and sodium cyanide, or from acetylene and hydrocyanic acid. Considerable expansion in the facilities for making these compounds in reasonably pure form will be required for the production of synthetic rubber on a large scale, and this expansion is in progress.

The preparation of the Buna copolymer itself is carried out by emulsifying butadiene and either styrene or acrylonitrile with water containing a suitable catalyst and agitating the mixture under suitable conditions of temperature and pressure. The reaction conditions must be closely controlled. The polymer separates out as a sort of synthetic latex, a creamy suspension of small particles of the polymer in the water. This latex can be coagulated by the addition of acids and processed like natural rubber.

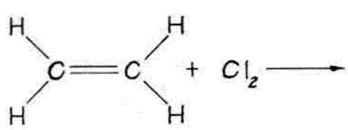


Courtesy of Chemical and Metallurgical Engineering.

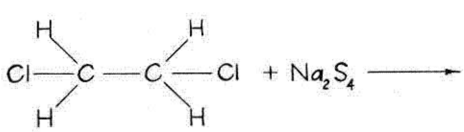
Mill man cutting a sheet of rubber so as to remove it from the wash mill.

It is estimated that when the methods for large scale processing have been stabilized Buna copolymer rubber can be made for perhaps thirty cents a pound, perhaps for as little as twenty cents. The cost of producing natural rubber in the far East in normal times ranges up to ten cents a pound, and the selling price of natural rubber in New York in recent years has ranged from three to twenty-seven cents a pound.

In addition to the Neoprenes and the Bunas there is a variety of synthetic rubber-like materials which are not so suitable as all-purpose substitutes for natural rubber, but are so superior to natural rubber for special purposes that even in normal times they compete successfully with natural rubber. For example there are the thiokols, made from unsaturated hydrocarbons, chlorine, and sodium sulfide according to reactions like the following:

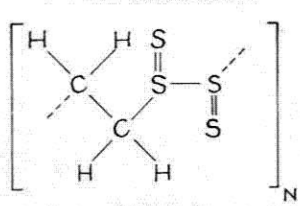


Ethylene Chlorine



Ethylene Dichloride

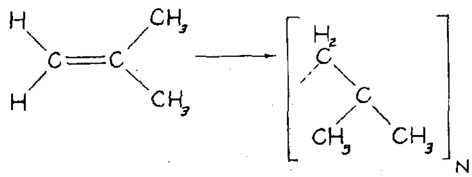
Sodium Tetrasulfide.



Thiokol

This type of rubber can be produced relatively cheaply and rapidly, is resistant to oxidation and to attack by many solvents, and is much less permeable to gases than is natural rubber.

Another type of synthetic rubber is obtained by polymerizing hydrocarbons containing a single double bond. Thus Vistanex is produced from isobutene obtained from petroleum:



Isobutene   Vistanex

The unit which recurs in this polymer contains no double bonds; hence the rubber cannot be vulcanized, but is more resistant to chemical attack than is natural rubber. A relatively recent development is Standard Oil's Butyl rubber, in which hydrocarbons containing a single double bond, such as isobutene, are copolymerized with a small proportion of hydrocarbons like butadiene, so that the resulting polymer contains occasional double bonds which permit vulcanization. The material after vulcanization should be highly resistant to oxidation and to chemical attack in general. Butyl rubber has interesting possibilities as a material for tire manufacture. It can be produced entirely from petroleum or natural gas, and the manufacturing operations are said to be relatively simple.

Still another synthetic rubber is prepared by polymerizing vinyl chloride; the group which recurs in this polymer is:

$$-CH_2-\overset{\displaystyle H}{\underset{\displaystyle Cl}{\overset{|}{\underset{|}{C}}}}-$$

The long chains in this material attract one another so strongly that the pure polymer is an amorphous white powder with little apparent resemblance to rubber. By the incorporation of about thirty per cent of an appropriate plasticizer, i.e., a non voltaile liquid, such as tricresyl phosphate, the relative motion of the chains is lubricated, so to speak, and a somewhat plastic rubber is obtained. Plasticized polyvinyl chloride is marketed in this country under the name of Koroseal, and finds many special applications in industry where its long flexing life and its high resistance to the attack of sunlight, oxygen, water and some oils make it superior to natural rubber.

Within each class of synthetic rubbers which we have mentioned great variations in the physical properties of the product can be obtained by variations in processing.

The contemplated intense development of the synthetic rubber industry may make available a great variety of types of

REMEMBER THE ALUMNI SEMINAR

rubber which are specifically adopted to duties which at present natural rubber has to be coaxed into doing. Apparently no synthetic rubber has yet been developed which is the equal of good natural rubber in all its mechanical properties, but rapid improvement is still going on. At any rate, there seems to be no good reason why we shouldn't be able to get enough rubber, natural, reclaimed, or synthetic, to run our war.

The following tables may be of interest in providing a condensed comparison of the properties of various types of rubber, and of the development of productive capacity in this country.

Prices Quoted for Rubber, August 1941. (per pound)

Natural	$0.23	Thikol F	$0.45
Neoprene GN	0.65	Vistanex	0.45
Buna S	0.60	Koroseal	0.60 (approx)
Buna N / Perbunan	0.70	Hycar	0.70

U. S. Production of Synthetic Rubber (long tons)

	Neoprene	Buna	Polysulfide (Thiokols)	Butyl	Koroseal
1939	1,750		500		
1940	2,500	60	700		
1941	6,300	4,000	1,400		?
1942 (estd.)	19,000	70,000*	?	5,000	18,000

*Very tentative and probably quite unreliable estimates of the productive *capacity* to be attained at the end of this year.

Comparisons of the Properties of Various Types of Vulcanized Rubber *as produced in July*, 1941

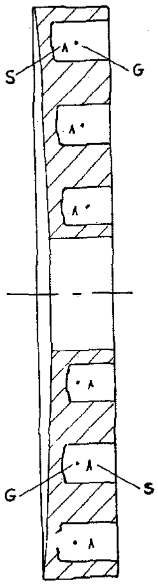
Courtesy of Chemical and Metallurgical Engineering.

E—Excellent, G—Good, F—Fair, P—Poor

	Natural Rubber	Neoprene	Thiokol	Koroseal	Bena N Perbunan	Buna S Ameripol (Oil Resistant Type.)
Resistance to tear and abrasion	E	G	P	E	E	E
Adhesion to Metals	E	E	F	F	E	E
Resistance to Ozone	P	E	E	E	F	F
Resistance to Acids and Alkalies	G	G	G	G	G	G
Resistance to Gas Diffusion	F	G	E	E	G	G
Elasticity and Rebound	E	G	P	F	G	F
Resistance to Corona Cracking	P	E	E	E	P	P
Flame Resistance	P	G	P	E	P	P
Resistance to Flex Cracking	G	G	F	E	G	G
Resistance to Flow	E	G-F	P	F-P	E	E
Freedom from Odor	G	F	P	E	F	F
Resistance to Swelling						
By aromatic Solvents	P	P	P	Shrinks	P	F
By lacquer Solvents	P	P	G	Shrinks	P	F
By gasoline or mineral oil	P	G	E	Shrinks	G-E	E
Stretchability Range	E	G	F	F	G	G
Resistance to checking in Sunlight	F	E	E	E	F	G

(Continued from page 10)

face in the mirror, while those of the lower half are misplaced in the opposite direction. Reference to the same figure will make it clear that, in the assumed position, the radius of curvature in the vertical plane will be lengthened, while if the mirror is rotated 180°, the radius will be shortened by the same amount. Here the remedy is obvious.

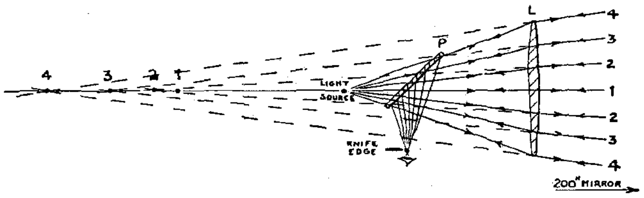


Drawing by R. W. Porter.

Fig. 6: **Cause of astigmatism.**

In order to test for astigmatism when the mirror faces the zenith, the arrangement shown in Figure 7 was employed. The light source and the knife-edge are, as usual, near *CC.* The plane mirrors *MM,* at 45°, are 8″ in diameter. By rotating the large mirror the zone indicated by the dashed line may be tested for astigmatism. By adjusting the counterweights of the 'lifting component' of the supporting levers, any observed small astigmatism may be removed.

The work of making the mirror surface a satisfactory sphere having a radius of curvature of 1335.7″ was completed in August, 1941. Parabolizing by alternate fine grinding and polishing was started August 30, and is now very nearly completed 'in the rough'; meaning thereby that the radii of zones



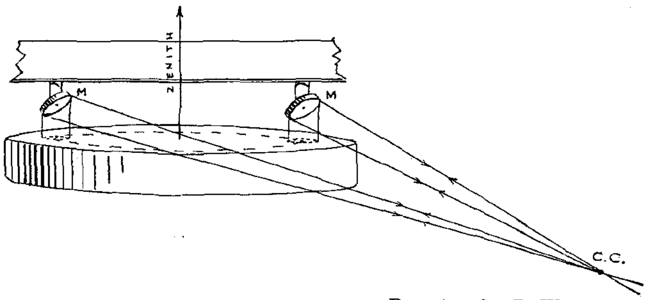
Drawing by R. W. Porter.

Fig. 7: **The method for testing by zones for astigmatism.**

are very close to the calculated values. The long work of smoothing and final figuring still remains to be done.

Testing will be done near the center of curvature, using a method worked out by Dr. F. E. Ross and the author. The method is new as far as we are aware; however, it would not surprise us if it should prove to be 'old as the hills'—for no complete search of the literature has so far been made. The method is shown in Figure 8. The lens *L* is so designed that, when the light source is placed at a point between its focus and the lens, the spherical aberration at its virtual conjugate focus is such that the conjugate focal points for different zones of the lens coincide with the 'centers of curvature' of the corresponding zones of the paraboloid. The light source is shown on the axis. To the right of the lens the rays travel along the normals to the paraboloid, whence they are returned along the normals and would converge to the source—but, by the aid of the half-silvered plate *P*, the returning light is brought to the knife-edge as shown. The source and knife-edge may be interchanged.

The author wishes to express his deep appreciation of the assistance given him by Russell W. Porter in the preparation of this article.



Drawing by R. W. Porter.

Fig. 8: **Testing method to be used in the final figuring.**

BOOK REVIEW

ADMIRAL OF THE OCEAN SEA

A Life of Christopher Columbus.

By Samuel Eliot Morison

(Boston, 1942). $3.50.

By William B. Munro

Edward S. Harkness Professor of History and Government

No one in American history has stirred up more controversy than the Genoese navigator who was designated as "Admiral of the Ocean Sea" and sent on his westward way by the sovereigns of Spain in 1492. By some he has been exalted as the most courageous and brilliant navigator of all time, one whose dogged perseverance in the face of monumental difficulties brought a new world into the orbit of human knowledge. By others he has been pilloried as a quixotic adventurer who stumbled upon a piece of good fortune and then stole the glory that belonged to other men. Professor Morison has undertaken to find out, by a new and interesting method, just what kind of navigator Columbus was. Himself a good historian and an equally good yachtsman he went over to Spain, chartered a sailing vessel, took a small crew aboard, and crossed the ocean to the Caribbean, checking up on Columbus along the way. With a copy of the Genoese navigator's *Journal* in hand he then trailed the route among the islands and to the mainland, visiting and identifying every coast and harbor that Columbus saw during his four voyages.

The results are interesting and significant. For one thing Professor Morison has established beyond question the fact that Columbus was an uncommonly expert navigator, knew where he was going and knew how to get there. He arrived exactly where he expected to be, so far as his own calculations of latitude and longitude were concerned; but what he found were the West Indies instead of the East Indies. This was because he figured the rotund earth to be a great deal smaller in circumference than it was. From the explorations of Marco Polo in Asia there were data from which Columbus could roughly estimate the distance eastward from Spain to Cipangu (Japan). He was convinced that this stretch covered a good deal more than half way around the globe, which left only seven or eight hundred leagues intervening westward. In this he was badly astray; but if his mathematics had been correct he probably never would have started.

It has often been said that the invention of the astrolabe by the Arabs made possible the first voyage to America. Columbus, as a matter of fact, did not use the astrolabe to determine his positions. He was a dead-reckoning navigator, but a mighty good one as Professor Morison proves. Occasionally Columbus took a shot at the altitude of a star to verify his figures, but the results were valueless. He was so inexpert in identifying the constellations that on more than one occasion he mistook other stars for Polaris. But when it came to reckonings from log and compass he was as good as the best. He also knew where to find the trade winds and how to use them. Not infrequently, when conditions were good, his caravels scurried along at six or seven knots per hour.

Some historians have suspected that the *Journal* which Columbus kept was faked, — written up after he returned home to prove that he knew where he was when he didn't. Professor Morison disposes of such yarns conclusively. Columbus had his failings, no doubt, but dishonesty was not one of them. He was vain and to a degree self-seeking, with an undue interest in titles and honors. He was not always a good disciplinarian and his followers sometimes got out of hand. He let them treat the natives badly, although it can fairly be said that had it not been for him the treatment would have been a good deal worse.

The book is a fine combination of sound history and nautical narrative.* It will appeal strongly to those who like the sea and know how a ship can be handled in fair weather or foul. No reader who belongs in that category will fail to marvel at the consummate skill with which this Admiral of the Ocean Sea, with only the most primitive instruments of navigation, plotted his course, kept his three ships together, brought them safely to new shores, and went confidently coursing around the uncharted Caribbean. His descriptions of landmarks on the various islands were so accurate that Dr. Morison was able to depend on them in negotiating a fairway between the reefs.

So here, in a word, is a narrative of the most significant sea exploit in all history by an author who is at once an eminent historian, a skillful navigator under sail, and a writer of good literature. It goes without saying that such a book is considerably out of the ordinary and represents an original approach to the problems and achievements of the first great figure in American history. One cannot too highly praise the quality of the author's style, his power of vivid description, his frequent flashes of humor —even his facility in the effective use of contemporary American slang. A lover of the sea, and all that is therein, Dr. Morison succeeds in transmitting to his readers much of the thrill that he felt as his own barkentine ploughed along the route of the Great Admiral toward the setting sun.

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* It is issued in both two-volume and a one-volume edition. The latter omits the extensive footnoets and most of two rather technical chapters.

. . . . OF INTEREST

CHEMISTS VIE WITH NATURE

Providing America at war with ample rubber will be a race between Mother Nature and the chemical industry, with the latter rated as having the best chance. Dr. F. W. Went, distinguished Caltech professor of plant physiology, told the Sigma Xi meeting held at the Atheneum March 11, that the chance of finding a new "miracle plant" that will produce rubber is slight.

He revealed that there is seed available for planting of 70,000 acres of Guayule, the desert rubber plant, which will produce 500 pounds of rubber per acre a year after four years, the period of maturity. However, an acre, at the end of the first year, should produce approximately 200 pounds.

Dr. Went visualized a production of 10,000 tons of Guayule rubber a year during the early stages, compared to normal American consumption of 600,000 tons.

With plant sources limited, Dr. Went expressed the belief that the chemical industry will come to the rescue with synthetic rubbers. This will be especially true if costs can be reduced.

As for Brazil, the scientist declared that rubber there is in maximum production. He disclosed that the Russians have developed a rubber plant that yields 350 to 500 pounds per acre a year.

The reason he discouraged the idea of discovering a new miracle rubber producing plant is that the earth has been pretty well combed for all available sources. If anyone announces discovery of a new rubber plant of value it can be tabbed as a brainstorm, Dr. Went concluded.

CALTECH RESEARCHERS DEVELOP METHOD OF IMMUNIZATION SERUMS

Production of immunization serums in a test tube is the amazing and far-reaching feat that has been accomplished quietly at Caltech, it was revealed early in March for the first time. The news already has been hailed by medical men as one of the more outstanding new developments in recent years.

The discovery opens up the possibility of a new method of the medical profession's fight against disease. Formerly it has been necessary to secure immunization serums from animals.

The Caltech investigators have not yet carried their experiments far enough to find out whether or not it will be possible to prepare solutions in the laboratory for practical use, but work along these lines is underway. However, those engaged in the work are optimistic about this practical outlook.

Those working on this project have been Dr. Linus Pauling of Caltech, Dr. Dan H. Campbell, noted University of Chicago professor, Dr. David Pressman, research fellow in immunochemistry, and Mr. Stanley M. Swingle, teaching fellow in chemistry.

Excerpts from Caltech's official announcement of the vital research follows:

"It has been known for many years that the body is able to protect itself against disease, and that artificial protection against disease by vaccination or immunization can also be achieved. Until very recently the machanism of this protection against disease has not been understood in any detail.

"During the past two years, however," the Caltech men "have not only obtained experimental information which provides support of a detailed theory of the mechanism of immunization, but have even succeeded in making in the laboratory substances, called antibodies, which are responsible for protection against disease and which hitherto have been made only in the animal body.

"The picture . . . formed as to the mechanism of protection against disease is the following one:

"There are produced in the animal body certain large molecules, called serum globulin, which are present in the blood stream. If a bacterium or virus is in the body at the point where these molecules are being formed, the molecules are so changed as to assume structures complementary to those of the bacterium or virus, and in this way they acquire the property of combining with the bacterium or virus. These changed protein molecules, called antibodies, remain in the blood stream after the original bacterium or virus has been disposed of. On the later infection by bacteria or virus, these antibodies are able to combine with the invaders and to assist the body in destroying them.

"The procedure followed by the investigators at Caltech in manufacturing antibodies in the laboratory was to unfold normal protein molecules, the protein used being serum globulin, and then cause the molecules to fold up again in the presence of the antigen, which in this way is able to impose on the protein molecules configurations complementary to its own.

"The antigen is the substance which plays the role of bacterium or virus in disease. The unfolding of the protein molecules was accomplished with use of alkali or heat or some similar agent, which was then removed slowly, permitting the molecules to refold. In presence of the antigen they fold up in such a way as to acquire the facility of combining the antigen.

"It was found that a protein solution subjected to this treatment acquired the various characteristics of a natural blood serum which would be obtained from an animal which had been immunized with the same antigen. The investigators have prepared in this way antigen bodies against various simple chemical antigen, and also against pneumococcus polysaccharide."

MILLIKAN RETURNS FROM COSMIC RAY EXPEDITION

Dr. Robert A. Millikan, and his associates, Dr. William H. Pickering, and Dr. Victor Neher have recently completed a successful expedition to Mexico for the purpose of investigating cosmic ray effects.

Their observations were aided greatly by a specially built laboratory-on-wheels, which was practically self-sufficient. Equipment consisted of a superhetrodyne receiver, a directional antenna mounted on the roof of the truck, and elaborate test panel. The last performed the charging of the batteries, electrical testing, and the calibration of geiger counters. In order to simplify the reading of the counters, a scaling circuit was set up which divided the number of clicks by two, up to 64.

Housed in the storage space were 24 flight sets; in an ice box were 40 balloons. For the inflation of balloons on windy days, a huge tent was taken along.

Complete facilities were to be had for supplying 110 volts from a gasoline engine generator or from a main line source. Art McCoubrey of Ricketts house constructed a good deal of the laboratory.

Ten flights were made altogether, four at Acapulco and the others at Victoria and Valles.

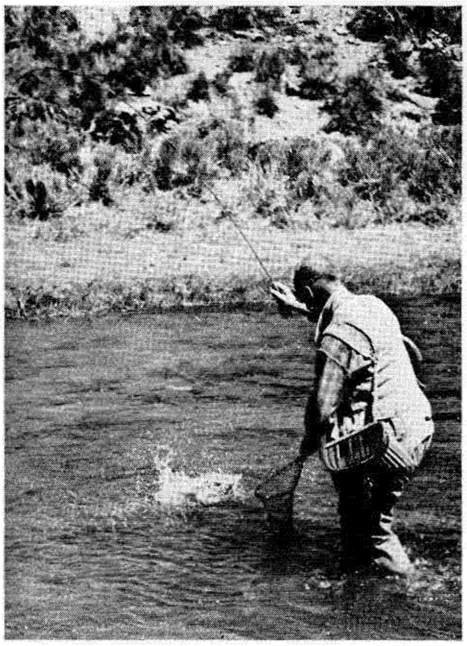
The scientists, journeying through the jungles, observed the lack of curiosity of the natives in what they were doing. Further aiding the men was the characteristic hospitality of the Mexicans. The Meteorological service of Mexico was very cooperative.

Similar trips have carried the investigators to India, the Hudson Bay region, a high-altitude lake in Peru, North Dakota, and Oklahoma. Readings have also been taken from ships all over the world. Their next venture: It is to be in the City of Pasadena. Although the date has not yet been organized, in the opinion of Dr. Pickering, "it looks pretty good."

FIFTH ANNUAL ALUMNI SEMINAR

Donald P. MacFarlane, Chairman of the 1942 Alumni Seminar Board, has announced that in spite of the war activity, the generous cooperation of already heavily burdened members of the Institute staff has made possible the preparation of an interesting and timely program for the 1942 Seminar. As announced in the January Alumni Review, the program has been limited to one day, Sunday, April 12th.

Program announcements, reservation forms, and guest invitation cards are being mailed to alumni, who are reminded that return of the reservation forms by April 6th will greatly aid the committees in completing arrangements for the Seminar. Alumni who do not receive reservation forms may secure reservations by addressing the Alumni Association Secretary at the Institute. As in the past, members of the Association may invite two male guests to whom they should give their invitation cards, signed by themselves for identification of their guests.



Professor W. W. Michael hooks a big one. He will tell how it is done with slides and pictures at the Alumni Seminar lecture at 11:00 a.m., April 12.

As registration will be quicker and easier for those whose dues are paid in advance, alumni not now members of the Association are urged to become members before April 12th. However, for those who fail to pay their dues prior to that date, the Association office will be open to receive payments on the day of the Seminar. It should be noted that those who have not paid their 1941-42 dues may become members for the remainder of this period at the reduced rate of one dollar when this payment is accompanied by $2.50 to cover the 1942-43 dues.

Admission to all meetings will be by identification card given to each alumnus and guest when he registers at Registration Headquarters in Throop Hall. Registration will begin at 8:30 on the day of the program and the fee will be fifty cents per person. Although registration will be simplified for those who have secured reservations in advance, those who have not done so may register upon presentation of membership cards or other evidence of paid-up membership. Each guest must present a guest invitation card signed by his host when applying for registration.

It is important that all alumni and guests visit Registration Headquarters before attempting to attend any of the meetings, regardless of whether or not the registration fee has been paid in advance. Information regarding possible last-minute changes in locations and times of the meetings will be available and lunch tickets may be obtained at Headquarters.

The Seminar program will open at 9:30 with Chapel Exercises arranged by Paul Ackerman, Secretary of the Tech Y.M.C.A. Dr. Eugene C. Blake of the Pasadena Presbyterian Church will be the guest speaker.

At 10 o'clock alumni and their guests will divide into two groups, one to hear Prof. R. W. Sorensen discuss "New Conceptions of Energy Flow in Electrical Circuits", the other to hear Prof. G. R. MacMinn tell of "Walt Whitman and American Democracy".

At 11 o'clock the more technically inclined may hear Dr. Carl Niemann or Dr. J. B. Koepfli on "Poison Gases and How to Combat Them", while those interested in angling may be instructed and entertained by Prof. W. W. Michael who will discuss the "Science of Fishing". Professor Michael will illustrate and explain his points with the aid of slides and motion pictures.

Lunch will be served at 12:10 in the student houses for those who purchase tickets at Registration Headquarters. The charge for these tickets will be $.75 each

At 1:30 those interested in defense against bombs may attend talks by Prof. R. R. Martel and Harald Omsted on "Protection from Aerial Bombardment."

(Continued on page 24)

Mr. Omstead gained first-hand knowledge of this subject from the German invasion of Norway which occurred while he was there. The other meeting at 1:30 will be addressed by Prof. R. D. Gray on "The Engineer's Place in the Present Emergency".

At 2:30 those who wish to go further into the problems of engineers in war work, particularly with regard to what action they themselves should take to more greatly aid in the war effort may attend a seminar conducted by Prof. Gray with the assistance of Prof. Robert L. Daugherty, Prof. Phillip S. Fogg, and Mr. Trevor Gardner. Also at 2:30 another group may hear an historian's interpretation of present events by attending Dr. J. E. Wallace Sterling's talk on "The War in Review and in Prospect".

Alumni will be pleased to learn that, in spite of his many pressing duties, Dr. R. A. Millikan has consented to appear briefly before the closing session at 3:30.

Further information is contained in the Seminar announcements being mailed. Remember, return the reservation forms by April 6th and if you haven't yet paid your dues, take advantage of the reduced rate for the remainder of the year so that you may attend the Seminar.

EMERGENCY PROTECTION PROVIDED

Following the Pearl Harbor attack December 7th, the faculty set up and appointed a Faculty Committee for Emergency Protection which serves to implement emergency protection activities provided by the students. Four students, in conjunction with Prof. W. W. Michael, chairman, Dr. J. B. Koepfli, Mr. E. C. Barrett, Dr. Hardin Craig, Mr. Wesley Hertenstein, and Prof. J. P. Buwalda, and Mr. Joseph Manildi form the Committee for Emergency Protection.

The students have been organized into six groups, each headed by a Warden. Fire, first-aid, information, blackout, utilities protection and gas decontamination are the six divisions of student protection activity, involving nearly 300 undergraduates in all.

The City of Pasadena, through the Civilian Defense Council, requested that Caltech be responsible for providing gas decontamination for the entire city. A series of ten lectures on war gases was given to some 90 students who are now prepared to identify and decontaminate all known war gases likely to be encountered should a gas attack occur. Nearly 50 students have attended a series of first-aid lectures and have been provided with first-aid equipment.

84 METEOROLOGISTS GRADUATE

Eighty-four men, trained to help win the war with more perfect weather forecasts, received their diplomas on February 14th. The commencement was unique in that it was the second defense graduation held on the campus during the current academic year. More than thirty of the graduates who studied as United States Army Air Corps cadets were commissioned as second lieutenants. Major Frank E. Benedict, commander of the U. S. Army Air Corps training detachment, and a former Pasadenan, commissioned the cadets.

Dr. Millikan addressed the graduates of Caltech's special national defense meteorology course, men from Army, Navy, Weather Bureau, and civilian life. To the entire class some of whom may have been wondering about the question, "What about after the war?" Dr. Millikan declared that he could not answer that question. Undiscouraged by the prospects, Dr. Millikan declared that there is no use to speculate on what is going to happen to men, to governments, to economics after the war. Though not much is yet known about the post-war period, Dr. Millikan mentioned that people know what they must do now, and that this class was a demonstration of that fact.

The scientist traced the history of meteorology back to the ancient Greek times. He spoke of the new importance of these "weather-wise" men, especially in connection with aviation.

Professor Franklin Thomas, chairman of the division of civil and mechanical engineering aeronautic and meteorology, delivered the opening address. Dr. Irving P. Krick, associate professor of meteorology, presented the diplomas, including completion certificates in a practical course of meteorology, certificates of meteorology and degrees of science. Among those receiving degrees of science was Capt. Medardo Gallardo of the Argentine Air Force.

FREE SURVEYING OFFERED

The California Institute of Technology has begun instruction in special tuition-free courses in surveying to help meet an urgent defense need for trained surveyors.

The federal government has announced that national defense requires mapping of the whole Atlantic, Gulf, and Pacific Coasts to a depth of 250 miles inland. This tremendous defense mapping program calls for the employment of 2000 men the first year.

The new courses in plane table topography and surveying instruments and procedure are designed to train men quickly for this important work. Students who satisfactorily complete either course will be in a particularly favorable position to qualify for the post of engineering aid under the Federal Civil Service.

SORENSEN TO DIRECT U. S. RADIO COURSE

Immediate Training for Vital Positions Necessary

A course in elementary radio operation and maintenance is being offered throughout Southern California under the auspices of the U. S. government, with Caltech's Prof. Royal W. Sorensen as regional coordinator. Similar training will be given at many other centers throughout the country under the nationwide program.

The intensive evening classes are to give men and women preliminary instruction which may lead to technicians' positions in industry and furnish the army with men for communications departments.

Immediate training of 20,000 is contemplated, this being about one-fifth of the needed number. Instructors will be drawn from the radio trade and junior colleges. Actual location of the classes have not yet been specified; they will probably be held at convenient locations wherever applicants can be collected.

The course will present everything that the active radio amateur should know, with an accent on mathematics.

DIET EXPERIMENTS HELD AT AIRCRAFT FACTORY

Los Angeles County is conducting an experiment with scientific feeding at the Lockheed Aircraft Factory at Burbank. Under the direction of Dr. Henry Borsook of California Institute of Technology's biology department, dosage of Vitamin A has been given to 1000 persons, who will be checked for results in better health at stated intervals. An ample supply of the vitamin has been assured to conduct the survey, despite the possibility of a rationing plan of Vitamin A to the general public. The source of the vitamin comes mainly from fish liver, and this supply has come chiefly from Norway and Japan in the past.

Dr. Borsook's research in the vitamin field has done much to enlighten social and industrial health workers as to the causes and cures of under-nourishment. The testing of the group at Lockheed will undoubtedly lead to the discovery of further facts in this field.

CALL DOCTOR KRICK TO ACTIVE DUTY

Dr. Irving P. Krick, noted California Institute of Technology meteorologist, has been called to active duty as a United States Naval Reserve officer. His rank is lieutenant, senior grade.

Orders to active duty came in connection with the current expansion of the military meteorological services. His initial assignment is to the Headquarters, Army Air Forces, Joint Weather Central, Washington, D. C. It is expected that he will continue in close contact with Caltech in connection with the Army's greatly expanded weather research project.

Alumni Business and Professional Guide

DBNY, STUDENT HOUSE RADIATOR BROADCASTING STATION

An article in the Saturday Evening Post early last spring was the germ of the idea that was to grow into what is now DBNY, Caltech's radiator broadcasting station.

The article told of how the students in some of the eastern colleges had built and operated student broadcasting stations and Gordon Woods, president of Dabney house, seized upon this idea.

Authorization by the faculty was the first step that had to be taken in organizing the station. By the end of March, only a few weeks after the article had appeared in the Post, the faculty committee on students houses had authorized the station and Dr. Clark, the resident associate of Dabney house, had been delegated the responsibility of approving all student house radiator broadcasting stations and the programs to be broadcast. The proposed station was assigned the definite wavelength of 1040 kilocycles and was allowed to broadcast only during the hours of 6 to 6:30 p.m. and 9:30 to 10:30 p.m.

Gordon and Jim Allen got together and by April of last year had their plans fairly well organized for the construction of the station. At least, so they thought. Jim was to build the audio stage of the transmitter and Gordon the radio frequency units. This work was to be done during the summer so that the station would be ready to go on the air the first week of school. Jim Allen upheld his part of the bargain in building and testing the audio stages during the early months of the summer, but Gordon soon found himself in deep waters.

In order to build the transmitter, Gordon sent home for parts of his "ham" outfit in April. It seems that a friend of his had the parts and in the course of events they had become lodged in the attic of his future father-in-law's home. The equipment finally arrived late in the summer when Gordon was working some seventy-two hours a week. The result was obviously — "no transmitter."

In the meantime, it was decided that it would be better to build the whole transmitter at once which was done in two days during the first week of school last September. The result of this plan was that all of Jim Allen's work was scrapped. However, due to the excellent technical ability of Gordon and Jim, the transmitter was built without any trouble and it worked well the first time it was tried.

Since DBNY has been broadcasting, the programs have been given in excellent fashion, with the exception of one or two very amusing incidents. One occured when

Here students operate DBNY for the 5:30 program. The transmitting equipment is coupled to the radiator. DBNY programs come in louder than any local station in any of the students houses. No signal can be heard more than 50 feet away from the buildings.

the phone rang while an announcement was being made. The phone could be clearly heard by those listening, and there was a momentary scramble as everyone attempted to quiet it. Since then, very careful precautions have been taken to prevent the recurrence of such an event.

Although DBNY has been in existence a comparatively short time, it has already made great headway. The first organization to realize the value of the radiator broadcasting station was the Caltech Musicale. This organization has taken over Tuesday and Thursday evenings in order that good classical music with interesting comments might be offered to the students in this manner. Hourly programs are broadcast Monday through Thursday at 5:30 p.m.. and at 9:30 p.m. The 5:30 hour is given over to popular music, announcements, and occasional special features, the 9:30 hour being devoted to the presentation of classical music and to brief musical commentaries by students.

Since the beginning of the war, DBNY has become of real service to the students. The station hopes to continue to serve as an information disseminating unit in event of blackouts or other emergencies. The staff has already pledged itself to keep the station on the air during such emergencies, rebroadcasting programs from the east and giving special news bulletins.

STUDENT BODY PROFITS TO PURCHASE DEFENSE BONDS

At the last meeting of the student body board of directors it was unanimously voted to invest the major portion of the student-body profits for the year to the purchase of $200.00 in defense bonds.

ALUMNI SEMINAR

ALUMNUS CAPTURED JAP RADIO

On February 8th the United Press listening post picked up a message broadcast by the Tokyo radio from five men of the United States Marine Corps who are being held prisoners in Japan. Included was a message from *Lieut. Jack William Schwartz* '35, to his wife, Jennie, of 409 Cloverdale Ave., Los Angeles: "Dearest darling Jennie:

"I know you must all be worried about me but I am safe and in good health so please do not worry any more. I am in a camp in Southern Japan and we are being treated better than you and I thought. I lost a little weight at first but have not been sick and do not expect to be. I hope that the allotment went through so that you have enough money to get along on. The food we get is adequate but if there is any way for you to send me anything I would like some books, candies and canned meats. All our possessions are in Guam except your picture and Penelope's, which I brought with me. As I can send only one message, I know you will tell mother I am well. When the war is over and we are together again we will get a new start together and I am sure that it will be as wonderful as the first. I hope all of you keep well and happy. Incidentally, I did not get seasick on the trip to Japan. I love you, darling, and hope it will not be too long until I see you again.

Your loving, Jack."

NEW YORK ALUMNI MEET

The New York Alumni held a banquet at the Biltmore, New York, on January 30th. Professor Sorensen spoke to the group on the subject "Engineering Horizons, Limited". The members and their wives present included:

R. G. Ager, W. Gordon Abraham, R. W. Ahwenmaker, R. A. Axline, Ethel Billington, Cliff Burton, Max Bower, Harry and Melba St. Clair, Chester F. Carlson, Elsa Carlson, R. S. Custer, Mr. and Mrs. J. A. Davis, Walter B. Fisk, L. L. Ferguson, Fred J. Groat, Peg Groat, Mr. and Mrs. Howard Griest, Donald L. Holland, Morton Holland, Mr. and Mrs. George T. Harnes, Mr. and Mrs. Wm. V. Houston, A. E. Harrison, Claude D. Hayward, A. E. Harrison, Wm. B. Hebenstreet, Sydney B. Ingram, Charles A. Imsurgia, Evan Johnson, Mason A. Logan, W. A. Lewis, George E. Moore, Jule McMahon, Mr. and Mrs. H. E. Mendenhall, Gladys Moulton, Frederic H. Moore, John M. Pierce, Mr. and Mrs. G. Wilber Read, L. E. Swedlund, Mr. and Mrs. E. F. Thayer, Mr. and Mrs. Holley Wolfe.

SOCCER RETURNS TO C. I. T.

Harking back to the days when Caltech athletes found the sport attractive enough to journey to the Pasadena Athletic Club, soccer has once again come into its own. First organized last year under the enthusiastic backing of Al Landau, UCLA transfer student and formerly of Austria, soccer is now a recognized minor sport, drawing record attendances in Tournament Park.

Acting as coach for the 1940-41 season, Laundau took the green but willing squad to UCLA where they chalked up a 2-1 victory against the more experienced Bruins. Impressed by the spirit and success shown in the previous season, the ASB this year recognized soccer as a minor sport, and at the end of football season there was a turnout of 30 men for the varsity squad and 15 for the frosh.

During the past season nine games were played: San Bernardino J. C. was beaten twice, 2-1 and 4-0; UCLA, stung by last year's defeat, managed a 5-7 victory after a terrific battle. After the game the Uclans were lavish in their praise of the Beaver team, both as players and as sportsmen. Unable to find additional collegiate competition, the team began playing in the Los Angeles Soccer League where they found stiff and experienced competition; nevertheless they showed themselves quite capable of holding their own, winning over the Magyars and Vikings and losing to the Vikings and Clan Cameron.

The hi-lites of the year were two games with the RAF, the first of which proved the turning point for soccer at Tech. Although defeated 1-8 in their first game, the Beavers found the game of inestimable value in the lessons of style and technique which it offered. Watching the game was Mr. Liddell, a Scotsman whose interest was immediately aroused by the potentialities shown by the Caltech team. Mr. Liddel offered his services as coach, was heartily accepted, and forthwith introduced soccer, British style, to Caltech, pointing to the smooth and flashy RAF team as a model of excellence. The result was the most memorable game of the season, the second with the RAF squad. Demonstrating the remarkable progress made under Liddell ,the team was able to hold the British visitors scoreless for three-quarters of the game, only to have two goals scored in the final part of the game by the final thrusts of the more experienced RAF players. After the game the victors complimented the Tech team on its great improvement.

The relentless propoganda of Coach Landau in organizing the soccer team was such as to leave a lasting impression on all. Nor did this propoganda cease after organization had been successful, but was continued throughout the season, and every game was announced on signs and posters from one side of the campus to the other. Also organized were small teas after the RAF games to make the British boys perfectly at home. (Conspicuous at these teas wath the Scotch brogue of Tech player Ivor Macpherson Grant, a Canadian, who recently joined the RAF.) To close the season a soccer banquet was held, followed by a dance in Throop lounge.

NEWS OF CLASSES

1898

Harold G. Simpson, a Pasadena attorney, and charter member of the Gnome Club, recently deceased.

1915

Earl A. Burt, who is chief deputy road commissioner of Los Angeles County, is the author of an article describing the construction of the Los Angeles Forest Highway which appears in the March issue of "Civil Engineering".

1918

Frank Capra, Warner Bros. film director has gone to Washington, D. C., to report for active service with the Army Signal Corps. Mr. Capra, a chemistry student at Tech, was a private in the first World War and has been a member of the reserves. He completed filming "Arsenic and Old Lace" before leaving for active duty.

Carlyle H. Ridenour is now a Lieutenent Colonel in the Air Corps.

1922

Blake E. Beatty was recently elected president of the Structural Engineers Association of Southern California.

Jay J. DeVoe, was called into active service on December 11 and placed in the Signal Corps School at Fort Monmouth, New Jersey. He was transferred to Camp Crowder, Missouri on February 14, 1942 and is now in command of Company "C" of the 35th Signal Training aBttalion.

Major Douglas C. MacKenzie, is now Chief of the Military Construction Division at Savanna, Georgia in the Office of the United States District Engineer.

1923

Elmer L. Smith, assistant engineer of the Pasadena Water Department, is instructor in plane table surveying under the engineering defense training program at the Institute.

1924

Frederic A. Hough has been elected a director of the Southern Counties Gas Company. Mr. Hough became associated with the company in 1925 as a chemist, and became distribution engineer in 1931, which position he held until December, 1941, when he was named executive engineer for the company.

Emmett Irwin has left his former position as Chief Engineer at the Magnatest Corporation in Long Beach to become manager of the office of the Waugh Laboratories which have recently been opened in the Petroleum Building in Los Angeles.

1925

Edward D. Cornelison is on leave of absence from his position of Director of the Pasadena Junior College School of Trades and Technology to serve as training administrator for the ninth area of the Army Air Corps with headquarters at McClellan Field, Sacramento, and will supervise the training of civil and military personnel in all fields of aircraft, including flight and ground crews.

1925

Edwin Thayer was again in charge of the annual Christmas Party of the Industrial Advertisers Association of New York. We understand that Ed is an up and coming Squash player.

John D. Templeton is now connected with Basic Magnesium, Inc., at Las Vegas, having left the Columbia Steel Company to accept the position.

The February issue of the "Journal of the Patent Office Society" contains a long and comprehensive article by **William D. Sellers,** Patent Attorney for the Hoover Company, Chicago. The article: "The Activities and Functions of the Patent Department in a Manufacturing Corporation".

Markham E. Salsbury has recently been aopointed Chief Engineer of the Los Angeles County Flood Control District.

1926

Allan Dunn has been transferred to Fort Leonard, Missouri.

Ernest Maag is a director of the Structural Engineers Association of Southern California.

1927

Al Chapman has been in active duty for about 1½ years, and is now a Captain in the U. S. Engineer's Office in Galveston.

Dr. John H. Maxson, noted Caltech geologist now on active duty, has been promoted from first lieutenant to captain. The scientist-officer is on special duty for the War Department.

Leonard Snyder, left Byron Jackson in November to take a position as engineer with Lohman Bros. in Los Angeles.

1928

Major Kenneth R. Crosher, according to a letter dated November 7, 1941, is in command of the 31st Army Observation Squadron which is an integral part of the Fourth Support Command but is attached for operation to the Fourth Army. He is located at the Salinas Army Air Base at Salinas, California.

1st Lt. Jean E. Joujon-Roche, according to word received in the Alumni office the early part of this year, is located at Fort Belvoir, Virginia.

Captain E. H. Ross, is with the 10th Engineers Battalion at Fort Lewis, Washington according to a recent report sent to this office.

1928

H. E. Billig, Jr., M.D., has been called to Pearl Harbor Naval Hospital for active service in the Navy.

Joseph B. Ficklen, III, who has been with the Travelers' Insurance Company in Hartford, Connecticut is now living at 727 South Oakland Avenue in Pasadena. He is taking graduate work in the Biology Department at Tech preparatory to work on an M.D.

1929

Captain William H. Mohr, of the Engineer Corps, who has been at Fort Belvoir, is now on duty on the Pacific coast.

1st. Lt. Leslie O. Scott, we understand, is now with the 47th Engineers Regiment at Fort Ord.

Robert J. White, who has been confined to bed for the last two years with arthritis, is well on the way to recovery. On March 9th he is returning to work with the Baroid Sales Division, National Lead Company, Los Angeles, on a half day basis. Bob is married and is the father of a 2½ year old daughter.

1930

Ira C. Bechtold, who is process engineer for the Fluor Corporation, addressed the March meeting of the California Natural Gasoline Association on hydrocarbon hydrates.

Ernest C. Hillman was recently elected vice-president of the Structural Engineers Association of Southern California.

Sydney Zipser, of Technicolor, Inc., has been in Rio de Janeiro for the past two months, and expects to be there for another two months, working with Orson Welles on the film as camera technician. It took the party one week to arrive in Rio, flying from Hollywood to Florida, and from there on the clipper arriving at the South American city in time for the Mardi Gras. Recently the RKO Pictures made arrangement for all wives and mothers to talk to the group by telephone.

1931

William F. Arndt, left Warner Bros. Pictures, Inc., in February to go to Fort Trumbull, New London, Connecticut, where he is now employed by the New London Submarine Research Laboratories.

Lucas A. Alden, has accepted an appointment with the War Production Board at Washington, D. C.

Lieut. Perry M. Booth, writes us from the Bethlehem Steel Company, Terminal Island telling of the birth of a daughter, Lorraine Marcia, on August 31, 1941. Mr. Booth has just received an extra half-stripe in the Civil Engineer Corps, thereby deserving the rating of Lieutenant.

Lieut. Maynard Anderson, his wife, and his fifteen-month old son, Ronald, are now living in Hawthorne, Nevada. Mr. Anderson is supervising several million dollars' worth of Government work at the Naval Ammunition Depot there.

George L. Bussey recently returned to Southern California from Fort Wayne, Indiana and is now living at 2518 West 15th Street, Los Angeles. Shortly after their return, Mr. and Mrs. Bussey lost their three year old son.

George Langsner who is assitant district construction engineer for the California Division of Highways at Los Angeles, is now on temporary assignment as a right of way agent. He is also teaching a defense training course in highway engineering at the Institute.

1932

Glen Miller is now a Research Assistant at Caltech after coming from the Southern Counties Gas Company where he was heating and ventilating engineer for several years.

Howard W. Finney, who has been in public accounting for the last few years, recently joined the Los Angeles staff of the Hybrand, Ross Brothers, and Montgomery. John V. Chambers is another Tech alumnus with that company.

Carl F. Lind is now on the staff of the Maintenance Engineer at the Sacramento headquarters of the California Division of Highways.

1933

We understand that **Ray Cromley,** who was the Wall Street Journal correspondent in Tokyo, is very likely interned there now, according to a letter from Stephen Clark.

Bruce M. Dack is now employed by the J. H. Davies Company of Long Beach.

William W. Moore is secretary-treasurer of the Structural Engineers Association of Southern California for 1942.

1934

Lt. (j.g.) Francis Hebel, was killed at Pearl Harbor, December 7. He was with Fighting Squadron Six, Pacific Fleet at Pearl Harbor. Mr. Hebel was a Dabney House man while attending Tech.

John Read, who took a PhD in Physics, writes from Mount Vernon Hospital, Northwood, Middlesex, in answer to the request for payment of dues: "A British Government regulation forbids the sending of currency out of the country durin~ the war period so I regret that I shall not be able to send you dues until the war is over."

John Romoli, is now associated with Bardwell & MacAllister in Hollywood as a Mechanical Engineer, having left the California Import Company to accept the new position.

Jack Desmond returned from South America about two weeks ago.

1936

Meral Hinshaw, left the National Supply Company in Torrance to accept a position with Precision Bearings, Inc.

Lt. Frank Davis is passing the stogies —only two-time football captain in Caltech's history, is a father. Mrs. Davis and daughter are both reportedly in fine health and spirits. Lieutenant Davis, now cheif experimental test pilot for Vultee aircraft, is recovering slowly.

E. M. Getyman has just received reclassification as Assistant Civil Engineer with the Soil Conservation Service and has been transferred from the CCC Camp at Sebastapol to the new position at Yreka. The Getyman's now have a six months old Junior Engineer.

Tyler Thompson, of Singapore, was last heard from in a letter mailed November 14th, which arrived in Pasadena late in March.

Simon Ramo was given honorable mention in the Eta Kappa Nu annual award for outstanding Electrical Engineers who are under thirty-five and have been out of college for less than ten years. Last year Jessie Jobson, Ph.D. '35, won the award. Dr. Ramo was given the distinction for his work and inventions in the field of ultra high frequency at the research laboratories of General Electric.

At 10:30 Saturday morning, May 9th, Dr. Ramo will lecture in 201 Bridge, on the Caltech campus, on the subject "Ultra High Frequency Phenomenom", and all Alumni who can attend are invited.

Richard C. Lilly, President of the First National Bank of St. Paul, and a director of the Great Northern Railway, is much interested in some of the research work being carried on at California Institute of Technology. He spent considerable time on the campus during a recent visit to Pasadena.

Richard G. Casey, Australian minister to Washington, who spoke at the 1941 Tech Commnecement on "The Survival of Democracy", has been appointed by Prime Minister Churchill to be minister of state for the Middle East in the British War Cabinet. This is the first time in history that a dominion statesman has become a member of the British home government.

Clifford Downey is the father of a baby girl, Judy Lorean, born January 14th.

1937

Wendell B. Miller, has a new house at 823 Palo Alto Drive, Santa Anita Village, Arcadia. He is still with the Southern California Telephone Company.

Captain Richard Brice, is now working under one of the prominent Ordnance officers. He is in Fire Control which means the handling of carriages, bomb sights for anti-aircraft, optical materials, etc. In connection with his work he has met many representatievs of Ford, Gilbert and Barker, Allis-Chalmers, and Sperry Gyroscope.

Eugene H. Quinn, who has been with the Weather Bureau in Pomona, is now located in New York City at 119 East 60th Street.

Walter Wheeler, is now designer with the Mechanical Engineering Division of the Los Angeles Shipbuilding and Drydock Corporation at San Pedro having left the Byron Jackson Company to take the position.

William O. Wetmore, is the proud father of a baby boy, Donald Willaam Wetmore, born February 5, 1942.

1938

Robert S. Custer, has been transferred from Glendale to the Texas Company in New York City where he is employed at chemical engineer.

Boyne B. Grainger, is now living at Ojai, California, and is a Production Engineer for Tidewater Associated Oil Company at Ventura. In August, 1938, he was marrie dto Doris Smith and has a daughter, Darla Arlene, born February 28, 1940.

Harper Q. North, is with the Research Laboratories at General Electric in Schenectady as a Physicist. He has recently been doing some work at the Radiation Laboratory at M.I.T., but at the present time is again located in Schenectady.

Donald S. Taylor, left the Shell Development Company at Emeryville, California, to take a position as chemist with the Du Pont Company at El Monte in December, 1941.

Richard Wimpress and **Carlton Horrine** are back at Tech serving as Research Assistants.

Bill Nash is extremely busy these days after adding to his other duties, the instructorship of Physical Metallurgy in the night defense course four times a week.

Harold Sharp is now instructor in Metollography Laboratory for the ESMDT courses for two of the four classes a week in that subject.

Arthur C. Ellings left the Shell Development Company at Emeryville, California to accept a position as Chemical Engineer with Basic Magnesium, Inc., in Las Vegas.

1939

Charles F. Carstarphen, is, at the time of this writing, an Ensign, serving as acting Personnel Officer in the Production Division of the Puget Sound Navy Yard at Bremerton, Washington.

Stephen C. Clark, writes of his recent experience which resulted from his major in History at the University of Washington. Upon graduation he was selected to go to the Seventh America-Japan Student Conference in Tokyo. That was in 1940, after which he remained in Tokyo to teach school until March, 1941. Fortunately, Mr. Clark writes to us from Seattle, Washington where he is employed as a Physicist in the Dagaussing Section of the Thirteenth Naval District Bureau of Ordnance.

1940

Mark M. Mills, and Pauline Riedleburg were married on January 31. 1942. They are now living at 405 Northcliff Road, Pasadena.

Willys Lemm, left the Vortex Manufacturing Company last fall to accept a position with Du Pont Company at El Monte.

P.F.C. Gerald P. Foster, is attending the Fifth Candidates Class for Commission in the U. S. Marine Corps. He expects to receive his commission on April 25 at which time he will enroll in a three-month "Reserve Officers School" Course. He is now located at Quantico, Virginia.

Paul Longwell and **Bob Alcock** are now Research Assistants at Caltech.

George Todd is a research assistant in ME. He keeps very busy with both his Tech classes and ESMDT instruction.

Lt. Joe Trindle writes enthusiastically from England that he is thoroughly enjoying his experiences over there, although as yet he has seen no enemy action. When Joe received his commission, he chucked his old job, piled all his possessions into his old Model A, and made a quick trip to Seattle for a short vacation at home before leaving for army life. His mailing address is c/o Mrs. Cornaby, "The Grove," Rawdon, N. Leeds, Yorkshire, England.

1941

Wilton A. Stewart, was married on February 15 to Anna Kathryn Montgomery.

Glyn Frank-Jones, Sub-Lieutenant R.-N.V.R. Special Branch is now located at the British Advisory Repair Mission, 1139 Connecticut Avenue, N. W., Washington, D. C. He writes from the U.S.N. Hospital and it is hoped that this return address has no serious significance.

Willis E. Dobbins, is now in England with Electronic Training Group No. 3, according to a letter received from his mother on December 11. Having safely arrived in England on November 13, he is now taking special work in airplane warning service. His rank is that of Second Lieutenant in the Signal Corps.

Ensign Donald C. Campbell, and Miss Janet Partch announced their engagement early in February. No date for the wedding has been set. Mr. Campbell is a member of the United States Naval Reserve, stationed at the David Taylor Model Basin at Carderock, Maryland.

Bill Wagner is now among those present on the Caltech campus during working hours in the capacity of Research Assistant. The engagement of Bill to Miss Keitha Downs was announced recently, and they plan to be married in June.

Dave Wood has given up his graduate work for the present to take a Research Assistantship at Caltech.

Lt. Woodburn A. Brown has been assigned to be an instructor in the ground school at the new Air Corps Basic Flying School, Enid, Oklahoma. In addition to other duties, he is also assistant Post Weather officer. He served a month at March Field, Calif., in the summer of 1941, and then went to Randolph Field, Texas, where he was stationed until he reported to the Enid, Oklahoma field December 1, 1941.

Stanley Stroud who was with Colgate, Palmolive, Peet Co., Orange, New Jersey has been transferred to Kansas City, Missouri, and is living at 300 Armour Boulevard.

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