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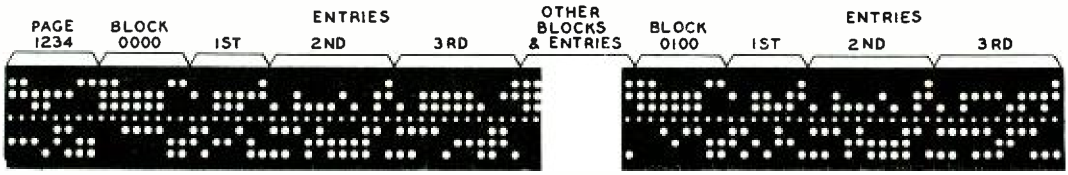
Development
Engineer

A RELAY COMPUTER FOR GENERAL APPLICATION

'ransmitter and tape bins of computer easily accessible by hinged covers and removable side panels

Mathematical computation plays an important part in all scientific development and research. Manual pen-and-pencil methods were long ago supplemented by mechanical auxiliaries such as slide rules and adding and calculating machines. These, however, are at best tools in the hands of mathematical workers, and although they save much time and manpower, that remaining may still be very large. The full advantage of mechanical computation can be obtained only with apparatus that takes over the complete and automatic solution of involved problems. Prior to the war, the Laboratories built a computer that carried out calculations with complex numbers. Based on experience with this apparatus, two other computers* were built during the war. One of these was built as a model for the Army, and has been in operation on an experimental basis for some time. These relay computers, although designed to handle specific types of problems, have proved so reliable and generally satisfactory that it seemed worth while to develop a general purpose computer that could solve any type of problem likely to be encountered. The very broad field of use of such a computer, and the large savings possible

*Record, *December*, 1946, *page* 457, *and January*, 1947, *page* 5.

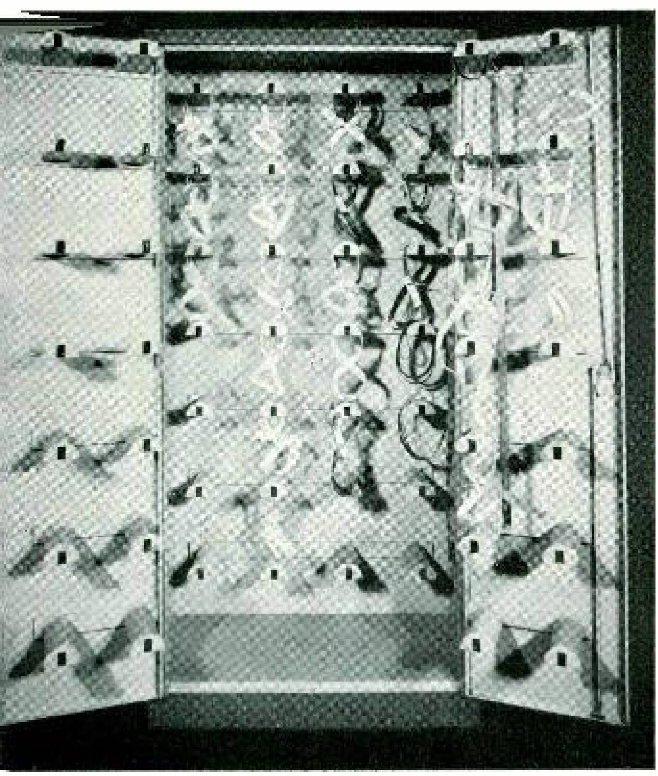


Two sections of a table tape showing page, blocks, and entries used with the relay computer

where extensive computation is required, promise a wide demand in the future.

Computation consists in substituting given data for general expressions in mathematical formulas, and then carrying out the various processes indicated by the formula to obtain the value of the quantity being solved for. Besides the substitution of given data, the solution of an equation in general requires reference to tables of functions, trigonometric, logarithmic, etc., and perhaps to tables of physical constants,

A library of table tapes is readily available for those tapes that are not in use



and then the carrying out of a wide variety of mathematical processes. Whatever the form, these mathematical processes can always be reduced to the four basic functions of addition, subtraction, multiplication, and division. A fully automatic mechanical computer must thus be able to carry out not only mathematical calculations, but all the other operations, such as reference to tables of functions or physical constants and storing partial results for later use, and all these operations must be performed in their proper sequence. This is what the new relay computer for general application is able to do.

All data are supplied to the computer in the form of punched teletype tapes, and the answers are printed on a teletype page printer. Three types of tape are employed. One, called the problem tape, carries all the data that are to be substituted in the formula for solution. Another, called the table tape, carries the various tables of functions to which the computer may have to refer in solving the problem. Provision is also made for permanently wiring some of the most frequently used table information on relays instead of tapes. Information may be obtained more quickly from relays than from tapes, but to provide all the table data on relays would require an excessive amount of relay equipment.

The third type of tape, called the routine tape, carries the information to guide the operation of the computer at every step it takes. Before this tape is punched, the problem is broken down into the simple successive steps that would be followed if the solution were to be performed manually. These steps are then punched manually in a suitable code on the routine tape.

Teletype transmitters are provided for each tape, and they operate under direction of the control circuits to feed in the problem or table information as required. The routine tape is prepared in the form of a loop, which may be as much as thirty feet long, so that a continuous sequence of solutions may be obtained without interruption.

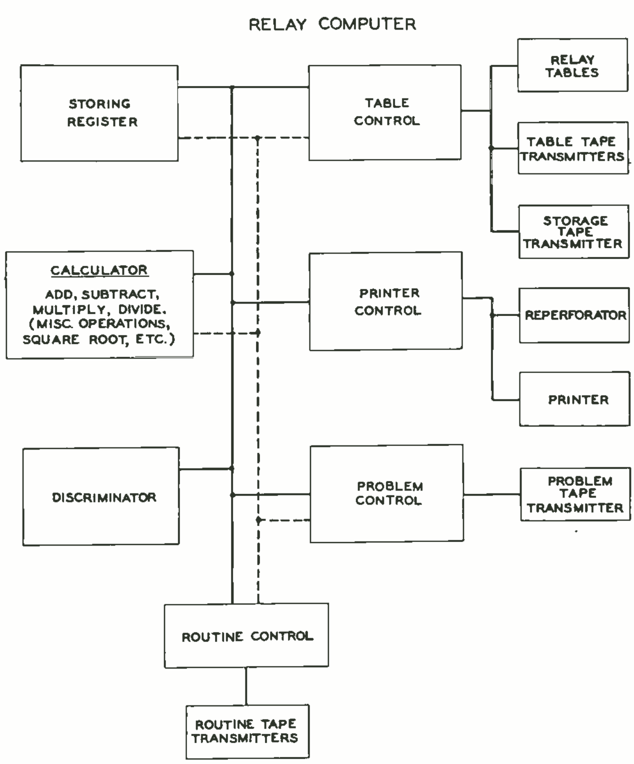
Transmitters for the table tapes are made to move the tape in either direction so that the desired information may be reached in a minimum of time. Coded information on this tape is arranged in pages, blocks, and entries, which roughly correspond to the pages, lines, and items on the line of an ordinary book of tables such as tangents or logarithms. Under orders from the routine tape, these transmitters move the tape to the desired page, block, and entry, and then transmit the information found there to the computer.

The association of the various components of the computer is shown in block form herewith. At the bottom of the diagram is the routine tape transmitter and the routine control circuit, which is connected to the other circuits over a double trunk system for passing orders back and forth. During the course of the computation, many intermediate results will be obtained that must be temporarily stored for later use. A group of relay storing registers is provided for this purpose and indicated at the upper left of the diagram. To provide enough of these registers to take care of all possible situations would be wasteful of relays. Provision is made, therefore, for storing additional results on teletype tape when the relay registers are full. Information for the storing tapes is passed through the printer control circuit to operate a reperforator. Associated with this reperforator is a storage tape transmitter that feeds its signals through the table control circuit as required. The diagram shows the functional arrangement of these units: the reperforator associated with the printer control and the storage tape transmitter associated with the table control. Physically, however, the storage tape transmitter and the reperforator are located in the same unit as the page printer.

The discriminator indicated at the lower left chooses the particular computing procedure to be used for the next phase of the problem. Suppose, for example, that the answer to a problem will increase up to a certain value and then decrease. Further suppose that one routine is required for computing the increase in values and another for the decrease. It is thus necessary to know when the peak of the curve is reached. The discriminator is provided to determine this point and to direct the use of another and suitable routine.

All computation is performed with sets of bi-quinary* adding relays as already described for other computers. Subtraction is performed by the addition of the complementary number; multiplication by repeated addition; and division by repeated subtraction. The calculator and its control circuits are indicated by the box at the left center. It includes two sets of biquinary relays for the two numbers to be

**Loc. cit.*



Block diagram for the relay computer

added and a similar set on which the sum is recorded. The control circuit can place numbers on the adding relays, either from some other part of the computer or from some of its own storing registers, and simply add them or multiply them by successively adding the number to itself the required number of times, or can cause the adding relays to subtract, divide, or extract square roots. It receives in code from the routine tape merely instructions that certain operations are to be carried out on two numbers whose locations are given, and then on its own initiative it carries out the indicated calculations and transmits the answer to the specified register or the printer control.

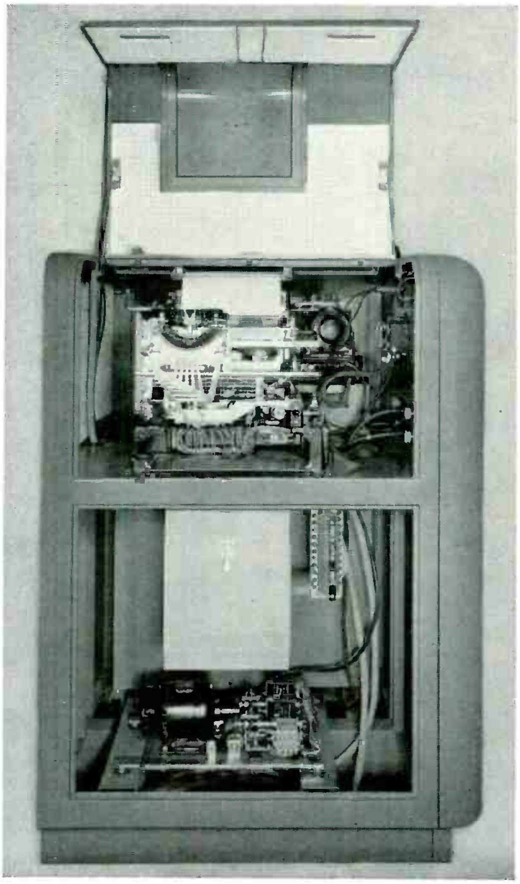
Large numbers of U-type relays are required, and for the most part these are mounted in enclosed cabinets on standard relay racks. Since access is only occasionally required, they are usually located apart from the space occupied by the rest of the apparatus. The routine, table, and problem tape transmitters are enclosed in a streamlined housing called the position table. This unit carries transmitters for six table tapes, five routine tapes, and one problem tape, arranged in three compartments on each side. Access to the transmitter and the tape bins beneath is secured by lifting hinged covers and removing side panels. There will usually be a sufficient number of these units in a complete installation so as always to have one available for setting up new problems. At one end of this unit are keys and lamps for controlling its operation.

Closed view of the position table showing control panel and pilot lamps on top above it

The page printer for the answers, and the reperforator and storage tape transmitter are housed in the unit called the recorder table. This unit also opens on both sides, with the page printer in one side and the reperforator and storage tape transmitter in the other. There is one of these units for each set of calculations to be carried out simultaneously.

Besides these units there will be one or more perforator tables on which all tapes are originally punched. Numbers on these tapes are punched in the usual decimal notation in teletype code. Such numbers are not convenient for use in the computer, however, because of difficulty with the decimal point. An exponential system is therefore used for guiding the computer. The number 123.45, for example, would be expressed as 0.12345×10^3 while 44.876 would be expressed as 0.44876×10^2, thus bringing the decimal point to the same position for all numbers. The tapes actually used by the transmitter are in this form of notation, but in a coded form that reduces the amount of tape required.

These computer tapes are made from the original tape in the processor table. The original tape is passed through a transmitter, and the resulting signals passed to a relay circuit that transforms them into the coded computer notation, and controls the perforating of a new tape. Two of the original tapes may be made from the same original data by two typists, and each of these tapes is placed in a transmitter in the processor table. Digits drawn from the two tapes are compared by a relay circuit,

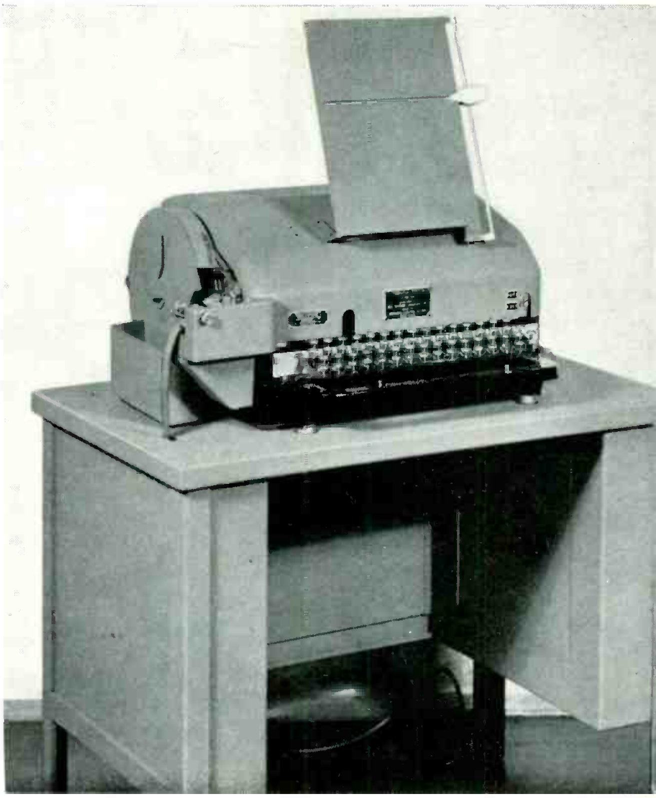


A recorder table with cover lifted on one side to show the page printer. All of these tables are sound treated to quiet the operating room

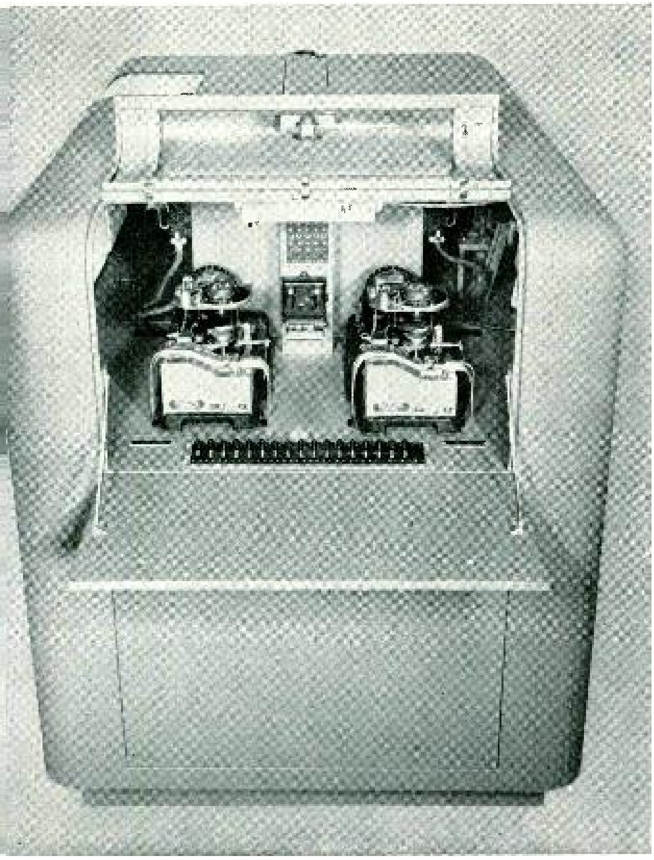
and only when the two sets of signals are identical is the third or computer tape punched. Any discrepancy between the two original tapes will stop the processor and give an alarm so that the error can be corrected. Besides giving a shorter tape in computer notation, this processing also avoids errors due to the original punching of the tape. Each installation will have at least one of these processor tables.

For the relay computing system, 50 volts d-c is required for operating the relays, and a 110-volt 60-cycle supply for the various motors. This latter power may be taken directly from the a-c mains, while a motor generator set is provided to supply the direct current. A storage battery is normally floated on the d-c supply so that it will absorb the current surges that occur during the operating of the calculator, and so that should the a-c supply fail, d-c will be available to hold up any operated relays. Computing would cease because of the stopping of the transmitter motors, but when the power came back, the computer would go on from where it had left off. The battery is large enough to carry the relay load for half an hour, which is ample to tide over the great majority of power interruptions.

Automatic computation can be carried out, of course, by other devices than relays, and in some respects other methods might have certain advantages. The Laboratories' long experience in designing relays, however, and the Bell System's very extensive experience in their use and maintenance, made it possible for Laboratories' engineers to design a relay computer promptly with full assurance that it would give a long life of dependable service. Experience with the relay computer built for the Army and placed in operation at Fort Bliss,



A perforator table mounting the machine with which all tapes are originally punched



The processor table showing the two transmitters

Texas, bears this out. This computer has 1,300 relays, and during eleven months operation at from twenty to twenty-four hours a day some of the relays operated as many as one hundred million times. In this entire period, however, there were only twenty-eight relay contact failures. The self-checking and alarm system built into the computer prevents such occasional failures from causing errors in the computation. Operation is temporarily stopped and an alarm given so that the trouble can be corrected before allowing the computation to continue. In one case, the computer ran sixty-two hours without stopping, and stopped then only because there were no more problems to solve.

These various self-checking features have a very valuable by-product by reason of the fact that the computer operations are stopped at the exact time of failure. This fact, together with the extensive use of progress lamp signals such as are commonly used in various dial systems telephone circuits, makes for easier analysis of the cause and location of the failure. The length of time that the computer is out of service is therefore materially reduced because of the shorter time for trouble location. This increases its over-all efficiency.

THE AUTHOR: S. B. Williams, who retired from the Laboratories on May 31 of last year, took an active part in the development of telephone switching systems during his forty-five years of Bell System service. In more recent years he devoted much of his attention to electrical computing systems, culminating in the system described in this issue. A résumé of Mr. Williams' activities in the Bell System was given on page 252 of the Record for June, 1946.

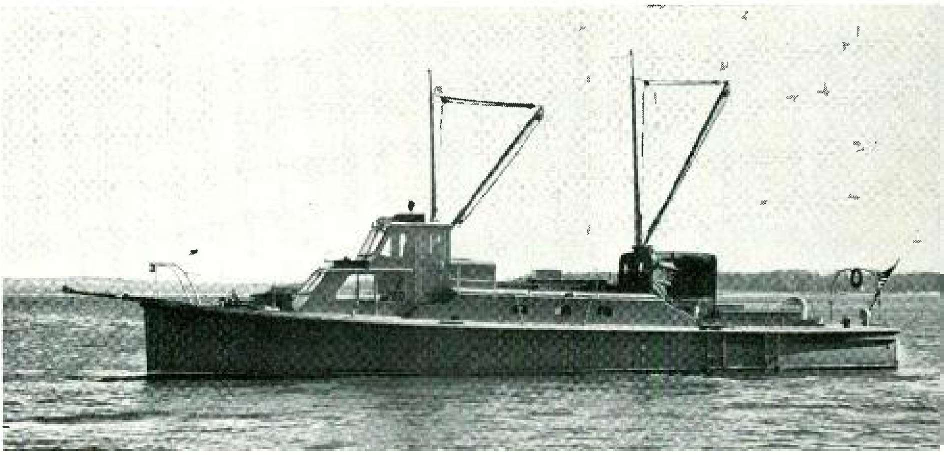
A. C. KELLER
Special
Apparatus
Development

SUBMARINE DETECTION BY SONAR

As recently stated* by Fleet Admiral Chester W. Nimitz, "The United States and British navies sank nearly 1,000 German and Japanese submarines during the war. Their most useful weapon perhaps was sonar, their underwater eyes, ears, and mouth. Kept under wraps until quite recently, sonar ferreted out subs lurking deep in Davy Jones' locker." The word Sonar is formed from the phrase "SOund, Navigation, And Ranging," and applies broadly to underwater sound devices for listening, echo ranging, and locating obstacles. During the war a number of sonar systems were developed by the Laboratories and produced by the Western Electric Company, and the QJA system described here is one of these.

Three major functions are built into this underwater detection system; sound listening, echo ranging, and telegraph communication. Acting as a listening device, it can determine the bearing of a source of noise or signal within the frequency range from 10 to 30 kc. In addition, a trained operator, by listening to the sounds, can estimate the type, size, and speed of the source. By echo ranging, it can determine the range and bearing of submerged or partly submerged objects such as submarines. Its telegraph facilities permit it to communicate with nearby vessels provided with suitable equipment.

Apparatus for the QJA consists chiefly of a control equipment rack and a retracting gear. The control rack, which is usually mounted topside near the wheel house, contains most of the electronic equipment, while the retracting gear provides means for raising and lowering a transducer and associated dome. The transducer employs new piezo-electric crystals which are used for both transmitting and receiving. The dome containing the transducer is lowered into the water through the bottom of the ship's hull when in use, and is held retracted within the hull at other times.



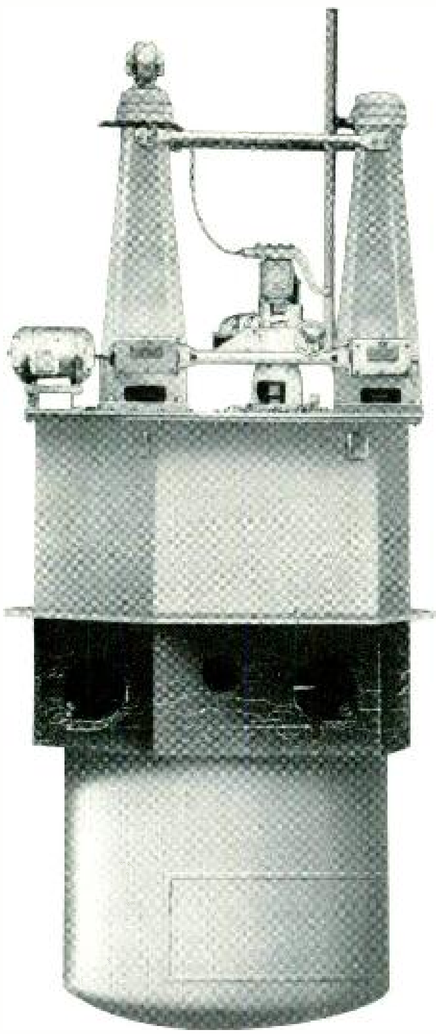
The Elcovee—*Floating Test Laboratory for studies of sonar systems*

**The National Geographic Magazine, June,* 1946.

For echo ranging, a short pulse of supersonic sound, usually about 25 kc, is transmitted into the water by the transducer. This instrument translates electrical energy into sound energy and emits a highly directional beam that can be directed in any desired position below the keel of the ship. Immediately after a short pulse of sound is transmitted into the water, the electrical system is transferred to a receiving condition, and the transducer will then act as a hydrophone to pick up sound, in particular a reflected portion of the outgoing signal from any enemy submarine. The received energy is amplified and converted into both visible and audible indications. The time required for the pulse of sound to travel to the submarine and return is a measure of the range, and is determined from the speed of sound in water—approximately 4,800 feet per second. This elapsed time is automatically indicated as target range by two types of indicators. One of these, on the second panel, gives the range on a calibrated circular scale where the echo is shown as a bright flash of light on a revolving disc. The other is a cathode ray oscilloscope, on which the range is indicated by the distance the spot has moved vertically from its starting point. The oscilloscope is part of the BDI (Bearing Deviation Indicator) unit, and although it indicates range, its major function is to show by a suitable deflection of the spot whether the target is to the right or left of the transducer bearing. This indication is then used to train the transducer in the proper direction to reach the ON target position.

Control equipment rack of the QJA system

The crystal type transducer and its associated dome were the subject of considerable work at the Laboratories. Both were developed in a relatively short time, and became standard equipment on other sonar systems designed by the Laboratories and manufactured by the Western Electric Company and by other organizations. The streamline dome design in particular was standardized by the Navy for use on all the larger anti-submarine vessels. The streamline shape of the dome was worked out with the Taylor Model Basin of the Navy to provide a minimum of self noise as it passes through the water. The acoustic and mechanical features of the dome were designed by the Laboratories, and the dome was manufactured by the Edward G. Budd Manufacturing Company as subcontractor to the Western Electric Company. Many tests were made at lake testing stations, and also on the *Elcovee*—a floating sonar laboratory used during the war by the Laboratories to test and study the operation of sonar equipment while under way. This new type streamline dome was the result of urgently needed development covering a wide range of experimental



Retracting gear of the QJA showing the streamline housing at the bottom

work, and made it possible to operate at about twice the ship speeds previously used in anti-submarine warfare.

The crystals used for these sonar transducers were developed and manufactured during the war, and were known as ADP crystals,* which is an abbreviation for Ammonium Dihydrogen Phosphate. They are highly stable and efficient when used in properly designed instruments. Because of their importance, the Naval Research Laboratory, the Brush Development Company, and Bell Telephone Laboratories co-operated actively in their development. Later, the Western Electric Company in Chicago produced approximately one million of them during the war. The first commercial ADP crystal sonar transducer to be put into service was designed by the Laboratories and produced by the Western Electric Company.

In addition, the Laboratories developed for the Western Electric Company a special test tank commonly referred to as an artificial ocean because of its suppression of echo effects. This tank was used for testing every transducer manufactured at the factory for sensitivity, output, frequency characteristic and beam pattern. Such under-water factory tests had never been attempted before, and by their use the Western Electric Company was able to insure the transducers delivered to the Navy were all within carefully specified limits of performance. Over the frequency range used, the efficiency of transformation from electrical to acoustic energy with these transducers was about eighty per cent.

Because of this high efficiency, it was possible to considerably reduce the size of the electronic equipment required for sonar previously. For the QJA system, for

The stainless steel streamline dome of the QJA is transparent to sound over most of its surface

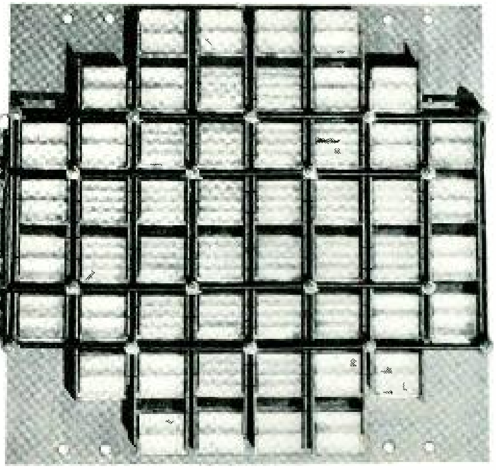
*Record, *July*, 1946, *page* 257.

example, a relatively small power amplifier of about 150 watts output was used, while 400 watts was required for previous systems. The compact design of the electronic equipment was an important advantage because of the reduction in topside weight on the ship which this smaller equipment made possible.

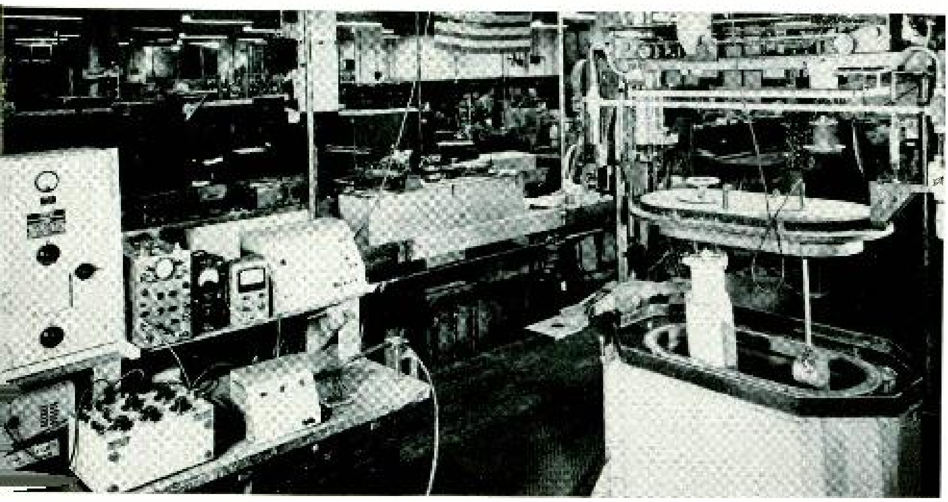
Simplicity and convenience of the controls for operating equipment was particularly stressed in the Laboratories' designs, and the uni-control of the frequency of operation of the system is one example of this. By this arrangement, the operating frequency of the entire system can be changed by resetting a single calibrated dial that controls all of the circuits required for transmitting and receiving.

Another feature of the electronic apparatus of the QJA sonar system was the MTB unit—an abbreviation for "Maintenance of True Bearing." This is a servo system that maintains the position of the transducer in true bearing, even though the ship yaws or changes course. Another feature was the TVG—an abbreviation for "Time Variation of Gain." It electronically established the rate at which the receiver gain was restored following the outgoing pulse. This TVG could be set to one of a number of time rates to minimize reverberation effect set up by the outgoing pulse.

The ADP crystal transducer was designed to operate over a range of frequencies from 10 to 30 kc instead of at a single frequency as with previous Navy equipments used in echo ranging service. This wide frequency response not only eliminated the need for critical tuning of the electrical equipment, a real trouble with earlier systems, but made it possible for a ship to change the operating frequency merely by changing the setting of the frequency dial. Previous equipment required changing the heavy transducer, which is an operation taking considerable time and requiring a number of transducers to be available if several frequencies are to be used. The wide frequency response of the transducer in the listening or hydrophone condition was also a marked improvement over previous echo ranging transducers. The combination of high efficiency, wide



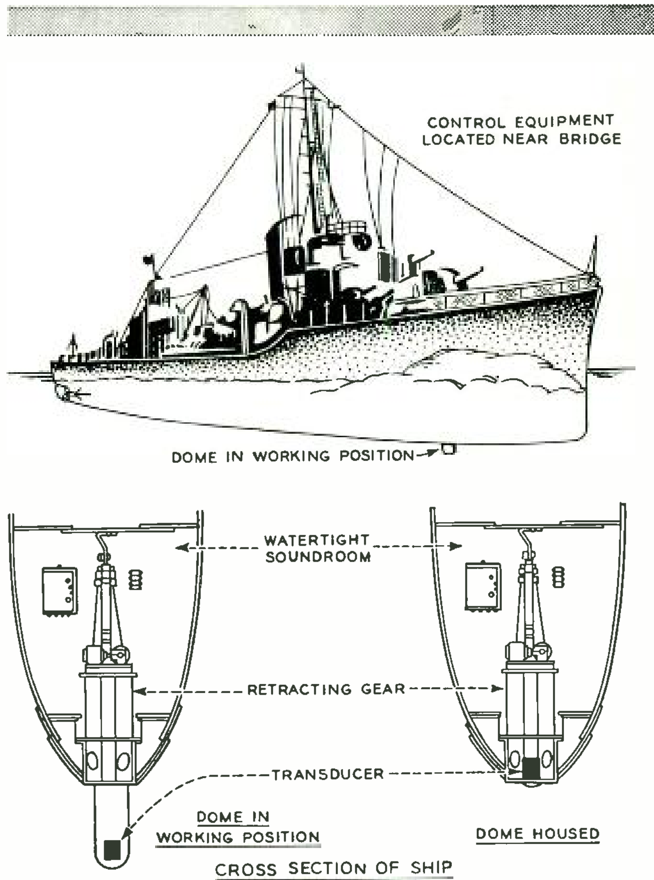
The crystal array of the transducer uses the new ADP piezo-electric crystals



A section of the sonar production department at the Hawthorne Works showing a transducer being lowered into the artificial ocean in the right foreground frequency range and the beam pattern of the QJA transducer made it an outstanding listening system. The supersonic frequencies received are demodulated to audible frequencies, and the audible signals are adjustable for band width and mid-frequency.

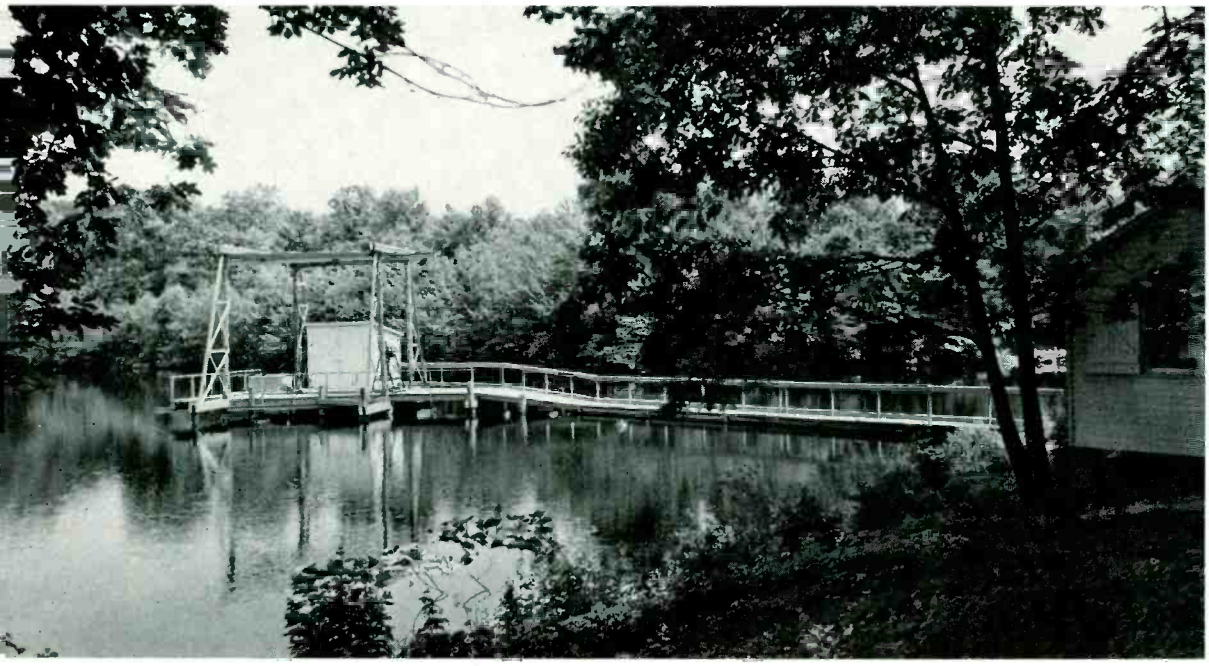
Previous equipments had used magnetostriction transducers which required carefully filtered direct current for polarization. Since the QJA transducer does not require polarization, the system did not require this power supply. Accordingly, the need for a rather bulky and heavy power supply unit was eliminated, the power to operate the sonar system was reduced and, equally important, it eliminated a source of background noise which had been troublesome in earlier systems due to filter limitations.


The transducer unit contains the ADP crystal array and rotates within the streamline dome



Typical mounting of the retracting gear unit in a typical Navy anti-submarine ship

As in the work with telephone apparatus and systems, the Laboratories devoted a great deal of effort to the development of quantitative measurements and testing of sonar devices and systems, including production control testing. In fact, the Laboratories' first underwater sound work—undertaken just prior to World War II, and later sponsored by NDRC—was the development of precise methods of measuring underwater sound, a field in which little quantitative work had been done. This work at the Laboratories provided groundwork for the standardization and improvement of Navy sonar equipments and techniques in the field of underwater sound. As has also been found desirable in designing and manufacturing telephone



Sonar test station at Birchwood Lake, Mountain Lakes, New Jersey

equipment, which must give good service over long periods, field testing of sonar equipment developed by the Laboratories was stressed. The *Elcovee* was a floating test laboratory on which all of the sonar systems and many of the sonar devices were tested before they were submitted to the Navy to insure meeting the rigorous requirements of the sea trials needed to anticipate combat duty. The *Elcovee* made it possible to work out the sonar system operation and installation problems completely and also was used to demonstrate operating systems to Navy personnel at an early date. By this arrangement the development work was expedited, changes in design were anticipated, and the Navy got better equipment at an earlier date.

THE AUTHOR: A. C. KELLER, Switching Apparatus Engineer, directs a group responsible for the fundamental study and design of new switching apparatus. His earlier experiences included work with telephone instruments, sound recording and reproducing, and switching apparatus. During the war, as Special Apparatus Development Engineer, he supervised the work of a group of engineers in the development and design for manufacture of sonar systems and apparatus for NDRC and the Navy. He has degrees of B.S. and E.E. from Cooper Union and M.S. from Yale University, and later did additional post-graduate work in Physics at Columbia University. He is a member of the I.R.E., S.M.P.E., Acoustical Society of America and American Physical Society.

board modified to become a No. 6 toll board

S. W. ALLISON
Switching Development

TOLL SWITCHBOARD NO. 6

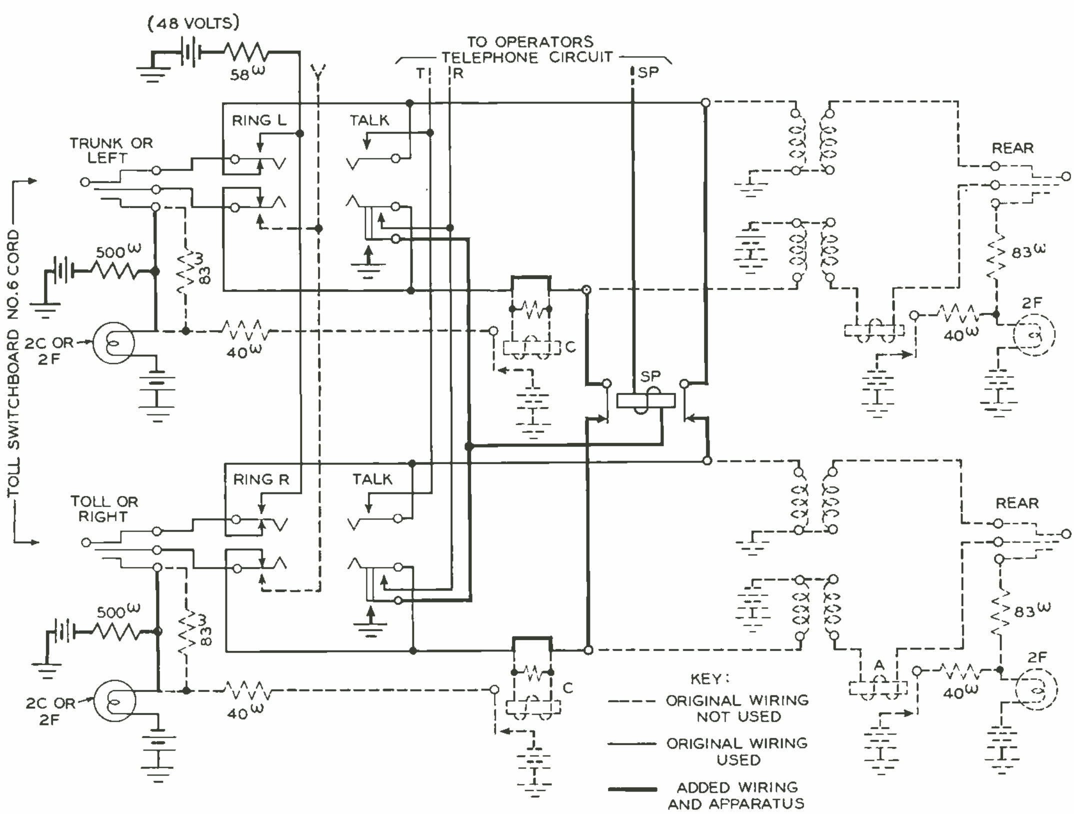
Although most of its effort during the war was applied directly to combat devices, an appreciable amount of the Laboratories development contributed to the war effort in a less direct manner. Increasing production accompanying our defense program, which accelerated in pace after Pearl Harbor, made unprecedented demands for telephone service. Limitations of equipment became particularly severe in the toll system. Additional toll positions were badly needed, but shortages in material and manufacturing facilities limited their production. Although there were no excess manual toll boards available, a survey showed that there was a considerable number of manual local boards that had been made available by the installation of dial offices in the preceding years.

It was decided, therefore, that the Laboratories would devise methods of modifying these manual local boards so that they could be used as outward toll positions. Necessary drawings and descriptions were to be prepared from which the boards could be rebuilt locally. The modified positions were called No. 6 toll positions, but all were not alike. This was to be expected since the original manual boards were of various types, even PBX positions, and they were modified for use in all types of toll offices from the older No. 1 type to the modern No. 3C toll office. Manual B boards were also modified for use as toll tandem boards, and these were known as toll tandem switchboard No. 6B.

Only outward positions were taken care of by the No. 6 design. Since outward positions require only from four to six cords, while inward positions require twelve or more, the outward positions are easier to supply. With additional No. 6 outward positions available, however, existing outward toll positions could be modified for inward positions, and in this way the shortages of both types could be taken care of.

Typical of the type of changes required are those made to adapt the No. 1 local board to work in lines of No. 3 toll boards. The No. 1 local board is arranged for seventeen cord pairs; the rear cord of each pair is used for answering and the front cord for completing. In front of each cord pair is a pair of lamps, and in front of these is space for talking and ringing keys. Where four-party ringing is required, there may be four ringing keys, and thus the space available for keys occupies most of the key shelf in front of the lamps. The ringing keys are associated only with the front cord of the pair, since this is the cord that is plugged into the line of the called party being called.

At an outward toll position, on the other hand, ringing and dialing may be required on either cord. By disconnecting the rear cords from the front cords, and connecting adjacent front cords together to form a toll pair, ringing facilities would be available on both cords of each pair, and yet there would be enough pairs for toll operation. A relay controlled by the talk and position keys was installed to permit separation of the two cords of a pair during pulsing or dialing. Since talk and ring keys were already associated with each of the cords used, they could be retained. The supervisory relay of the manual cords was



Schematic of two No. 1 local cord pairs as modified to become one No. 6 toll pair

A No. 1 *local manual board, not equipped for dialing or key pulsing*

short-circuited, however, since, with a No. 3 toll position, supervision is obtained over the sleeve lead. The sleeve lead was therefore disconnected from the supervisory relay and connected to a lamp and resistance combination. The changes required in the cord circuit are indicated in the diagram, where the light lines show the portion of the original circuit that was re-used, the dotted lines the portion that was not used, and the heavy lines the connections added to adapt the circuit for toll operation.

Keys are required at the No. 6 toll positions for monitoring, dialing, key pulsing, coin collection, and generally for busy testing. They are located in the key space of the ninth cord which is in the center of the key shelf. The ninth cord is not used in the modification. A bulletin holder, used for displaying traffic routings, is located on the key shelf in front of the ringing and talking keys required for toll operation. An extension can be added to the key shelf to provide additional bulletin or writing space. Spiral ticket holders instead of built-in boxes were generally employed to simplify the change-over, and electric clocks were added to the position equipment. The headset worn by the operator at the No. 6 toll position is the new 52 type, shown in the illustration on page 61, which provides greater comfort for the operators and better transmission.

The demand for the No. 6 toll installations was so great that, even though supplementary cabinets* were used to relieve the load on toll positions, some thousand No. 6 toll positions were still required. They were used by about fifteen of the Bell System Companies throughout the United States, with the number per company varying from 7 to 170 positions.

*Record, *January*, 1943, *page* 110.

THE AUTHOR: S. W. Allison received his Sc.B. degree from Brown University in 1915 and then joined the Engineering Department of the Western Electric Company. After serving in World War I as a Second Lieutenant, he returned to West Street to undertake analyses of the power requirements of manual, step-by-step, and panel circuits. In 1928 he transferred to the panel switching laboratory, and in 1930 to the Switching Development Department. Here he designed toll switchboard circuits and test circuits for maintaining them. During the recent war he continued the same type of work, but almost exclusively in connection with special and emergency systems made necessary by the war needs and dangers.

NAVY FIRE-CONTROL RADARS

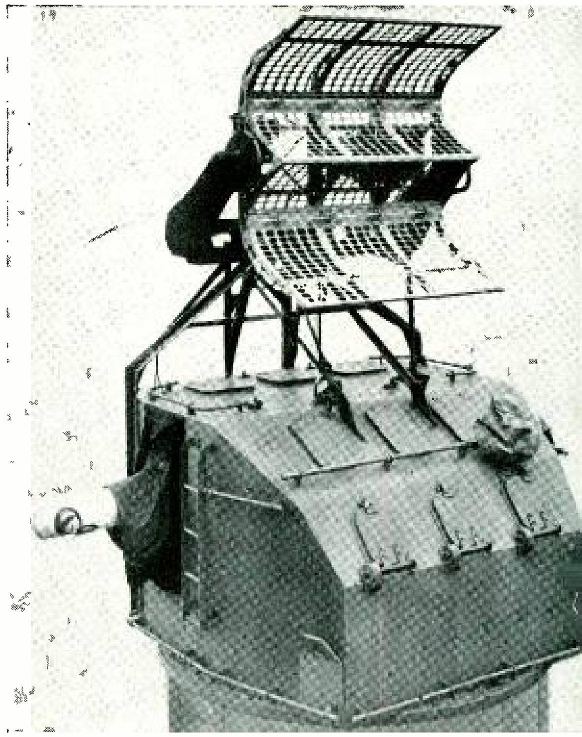
W. M. KELLOGG
Radio Development

For directing gunfire against surface targets and shore installations, the U. S. Navy has had effective optical methods for a great many years. Following World War I, these methods were perfected, and the 5-inch batteries were equipped for action against aircraft. Before World War II, therefore, the Navy was well equipped with the best available methods for directing its gunfire, but it recognized the limitations of optical fire control under conditions of bad visibility or at night, and the difficulty of obtaining accurate and continuous measurements of target range by optical means even under the best conditions. When radar principles of target detection were developed and applied by the Navy during the late 1930's, therefore, it evinced great interest in the development of radar techniques that would go beyond search and detection, and supply precise measurements of target positions to supplement or perhaps replace optical methods of fire control; as a result, the development of radar into a fire-control instrument became a matter of first priority.

Beginning in 1938, the Laboratories established a group at Whippany to acquire familiarity with radar principles and to carry forward a program of improving radar measurements and applying higher radio frequencies than had previously been employed in radar work. In 1939, on contract with the Navy Bureau of Ordnance and in close coördination with Navy personnel, the development of fire-control radar equipment was undertaken for naval vessels. The FC and FD radars, later carrying the designations Mark 3 and Mark 4, were the first microwave radar fire-control equipments suitable for extensive production. They were placed in production on an urgent basis, and by the time of the Pearl Harbor attack were being delivered in quantity to the Navy from the Hawthorne plant of the Western Electric Company. The Mark 3 radars were applied on cruisers and battleships for controlling the main gun batteries of 6-inch caliber and larger, while the Mark 4 radars were applied on destroyers, aircraft carriers, cruisers, and battleships for control of the secondary gun batteries of 5-inch caliber against aircraft or surface targets.

Typical of the optical methods of fire control was that which included the Mark 37 director and the Mark 1 computer for control of the secondary batteries. The director is an observation turret mounted on

Mark 37 director with antenna of Mark 4 radar. Illustrations in this article showing antennas or apparatus installations are U. S. Navy photos



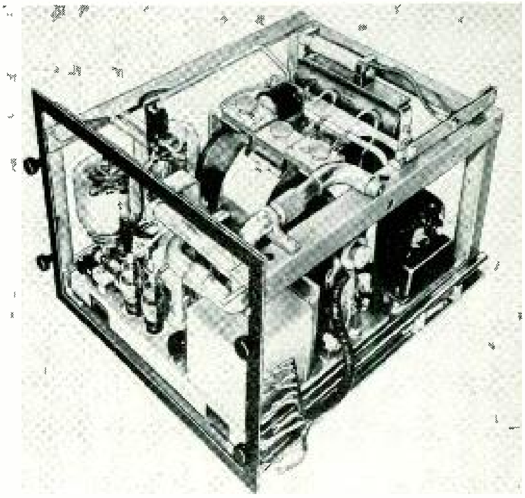
the higher parts of the ship's structure, housing precision telescopes and optical range finder equipment for securing precision data defining the position of the target. This information is automatically transmitted to the computer, a complex

Main frame installation of Mark 3 and Mark 4 radars

mechanism located deep below decks, which develops motions of its internal rotary elements in correspondence with the components of the target's motion in space for prediction of the future position of the target if it continues on a straight course. The computer automatically controls the guns to place the explosive shells on the target as it arrives at the position predicted for it after elapse of the short time required for fuse setting and shell travel. The entire operation is continuous, and shells are fired in rapid succession as long as a target is under observation and the computer solution is correct.

The difficulties of visibility mentioned above, and the further difficulty in continuously determining target range with the speed, accuracy, and smoothness required for a satisfactory computer solution, seriously handicapped the effectiveness of this method, and it was recognized that in the radar principle lay the possibility of overcoming these limitations. As radar development progressed and the utility of it in fire control became more definite, two types of radar equipment for ship fire control purposes were indicated: one to provide target position data in range and bearing for main battery applications, and another that would extend these measurements to include elevation angle data for secondary battery applications.

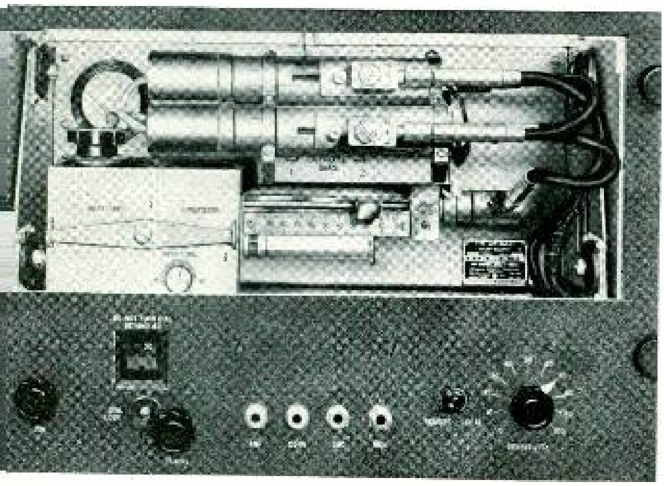
The radar equipments to be employed in ship fire control were necessarily required to adapt themselves to an existing highly developed system based upon optical observations. Existing directors were constructed solely to house optical equipment and the associated personnel, and since naval design is extremely compact so as to utilize the limited space to greatest advantage, there was little room for the required radar instruments. Thus the design of these instruments posed severe problems not only in requiring a compact design to fit available director space and at the same time permitting ready adjustment and use, but also in the matter of shock mounting to protect the cathode ray



Transmitter of Mark 3 and Mark 4 radars

tubes and other vacuum tubes of these instruments, since the radar devices called for the first use of these fragile elements in ship directors.

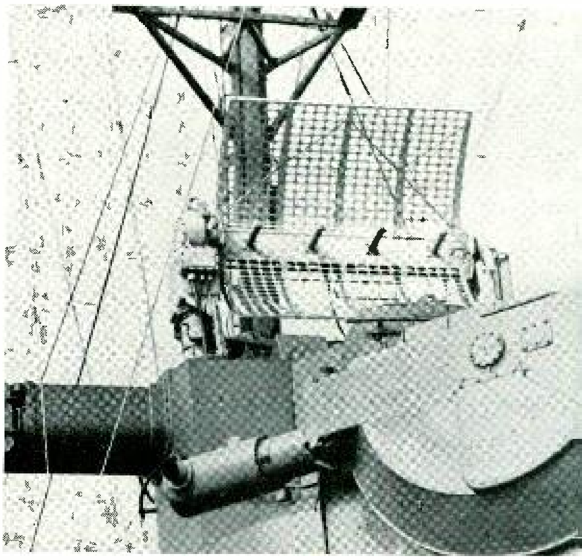
For both the Mark 3 and Mark 4 radar



Receiver of Mark 3 and Mark 4 radars

The radio receiver unit amplified the echo pulses to a level suitable for application to the video circuits of the indicating equipment. The receiver employed the superheterodyne principle and included coaxially tuned r-f amplification and converter stages, a beating oscillator, and a 30-mc I.F. amplifier. GL-446 "Lighthouse" tubes were used for the two stages of a radio-frequency amplifier, which was added to equipments in service as a field change to make it possible to operate on pulse echoes having a power level as low as 0.1 micro-microwatt.

Duplexing facilities were mounted in the



Antenna (6 feet x 6 feet) of radar Mark 3

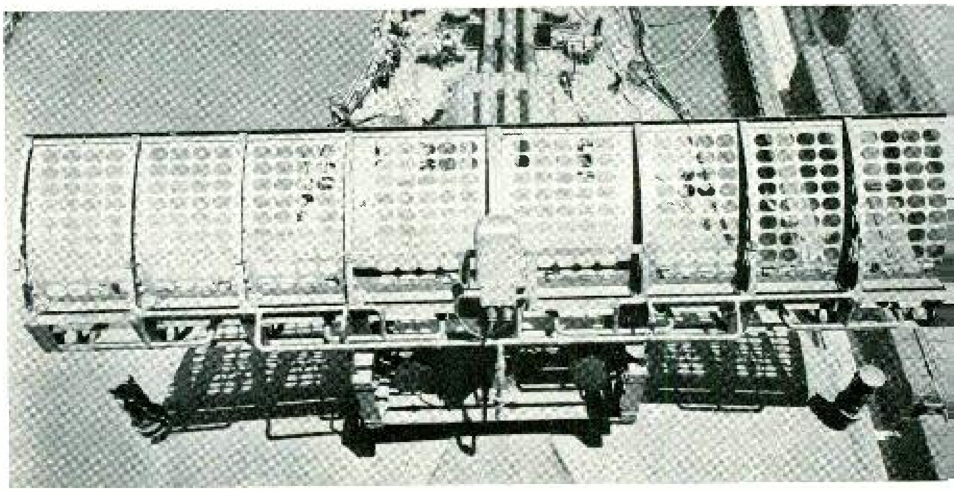
systems, the same main equipment frame was employed, arranged for installation below decks. It included a control panel, a modulator, radio transmitter, high-voltage rectifier, and a receiver—all constructed as drawers. The modulator unit established a periodic pulse rate of 1,640 pulses per second, generated the required pulse levels to actuate the transmitter unit, and provided the sine wave voltages at the fundamental pulsing frequency of 1,640 and at the 18th harmonic thereof, both precisely related in phase to the transmitter pulses, for use in the range unit of the director in securing accurate measurements of target range.

The radio transmitter included a pulse amplifier and a magnetron transmitter tube with its associated magnetic field structure. It operated in the frequency range from 680 to 720 mc, depending upon the operating frequency of the magnetron installed. The pulse from the modulator unit was applied to the pulse amplifier, which by capacity coupling supplied corresponding pulse power to the magnetron. The r-f power output level of the magnetron was about 40 kw during the pulse intervals of about 2 microseconds. A ⅞-inch gas-filled coaxial transmission line carried the output of the transmitter to the antenna.

The high-voltage rectifier in the lowest compartment of the main frame provided the 12-kilovolt d-c power that was required by the transmitter.

right-hand compartment of the equipment frame to enable a single line and antenna to serve for both transmission and reception. These arrangements consisted of adjustable sections of coaxial transmission line and a special gas-filled tube that during the transmitter pulse was driven into ionization, thus becoming a low impedance and a restricting power flow to the receiver and favoring flow to the antenna. After the pulse, the tube recovered quickly to a high impedance and, in conjunction with the high off-impedance of the magnetron, permitted low level received signals to pass from the antenna into the receiver during the intervals between pulses.

Antennas for the Mark 3 and Mark 4

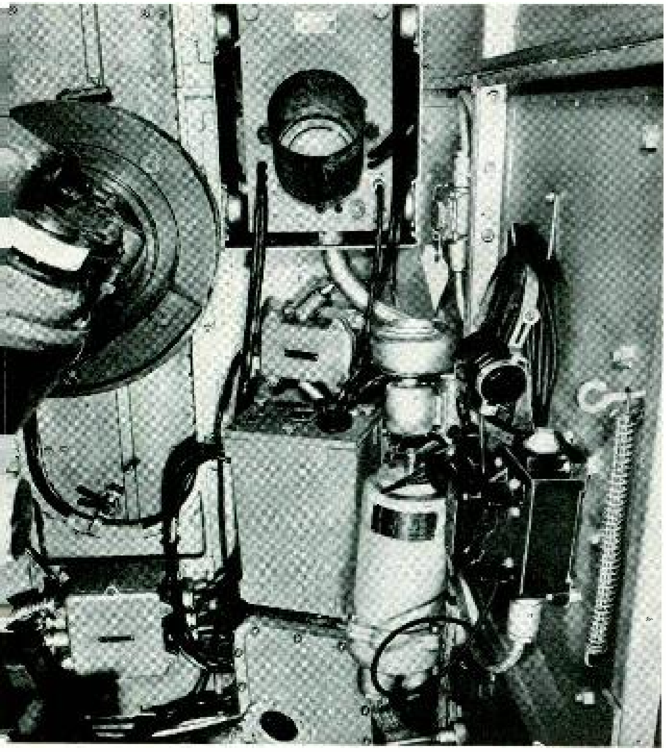


Antenna (3 feet x 12 feet) of radar Mark 3 showing coaxial feed lines

radars were horizontal cylindrical parabolas fed along the focal line by a row of dipole radiators. During transmission, in-phase dipole currents generate a plane wave front at the aperture of the parabola, and during reception, the dipoles respond in phase to a plane wave-front incident at the aperture. The radiated energy is concentrated into a beam with a solid angle inversely proportional to the size of the aperture. The greater the antenna aperture dimension for a given frequency, the narrower will be the beam both in transmission and reception. For the Mark 3 radar, antennas with either 6 feet x 6 feet or 3 feet x 12 feet apertures were employed for the main battery director, depending on whether or not the directors were equipped with automatic levelling. For the Mark 4 radar, the antenna consisted of two horizontal cylindrical parabolas one above the other and each 6 feet long by 3½ feet high which were joined rigidly together in order to form a single structure.

The radiation pattern obtained from these antennas, called a lobe, is relatively flat on the front and thus nearly the same strength of echo signal would be returned whether the antenna were pointed directly at the selected target or a degree or so to one side or the other. A little farther off the axis, however, the change in signal strength with angular displacement is very great. To secure high precision in determining the direction of the target, therefore, a method known as lobe switching was employed. The direction of the lobe is automatically switched back and forth from a position a few degrees to one side of the axis to a few degrees to the other side. The pulse echo signals received during each position of the lobe are separated in the receiver and displayed on the oscilloscope of the indicator as separate pips. For a target directly in front of the antenna, the two pips would be of the same height, while for a target a little to one side, one pip would be higher than the other. By directing the antenna so as to keep the pips of the target of equal height, the antenna is held accurately on the target at all times. Lobe switching was used for both the Mark 3 and Mark 4 antennas. In the Mark 4, the beam was deflected not only to the left and right, but up and down, and in addition to segregation of signals for right and left comparison, similar arrangements were provided for the comparison of up and down signals.

Because of the erratic effects of target orientation on signal amplitude, lobe switching must be rapid, and the rate adopted was thirty complete shifts of the beam per second. This lobe switching was accomplished by alternately shifting the dipole phase relationship in one side or the other of the antenna for horizontal angles and in the upper and lower portions for vertical angles. This shifts the lobe by the desired angle without moving



Range operator's position in Mark 37 director

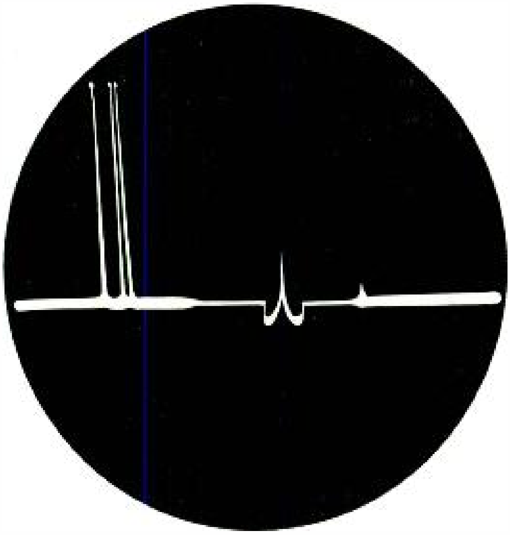
the antenna itself. The lobe switching device consists of two narrow fixed condenser plates projecting from the center conductor of the coaxial transmission line feeding each half of the antenna, with a motor-driven semi-circular rotor engaging each set of condenser plates for approximately half of each revolution.

In the directors, each operator was provided with the radar instruments in accordance with his function. In the Mark 3 radars for main battery control there were only range and train operator positions, while in the Mark 4 for secondary battery control there were range, train, and elevation operator positions; the indicating equipment employed in the corresponding coördinate was identical in both systems. The indicating equipment of the Mark 4 in the Mark 37 director included a control and indicator unit and a range unit for use by the range operator, an indicator unit and a meter for use by the train operator, and the same for the elevation operator.

The control and indicator unit carried a 5-inch cathode ray oscilloscope tube and the associated power supply for presenting the received echo pattern on a sweep base line as shown in the illustration on the next page. The vertical deflections of this pattern showed the direct pulse signal from the transmitter followed by the echo signals received from the targets for all positions of the lobe. This pattern of vertical deflection signals was distributed along the screen of the cathode ray tube by horizontal sweep voltages generated in the control and indicator under control of the phase shifting elements of the range unit. The downward "notch" deflection at the middle of the sweep trace served as a reference mark in range measurements. The notch and a portion of the trace to the right and left of the notch were subject to expansion under control of the operator for magnification of the pattern of echo reflections in the neighborhood of the one placed in the notch for range measurement.

The phase relationship between the sweep voltage and the echo pattern was under control of the range unit, which permitted the operator, in effect, to move the echo pattern with respect to the sweep such that the echo signal pip of a target up to a maximum range of 100,000 yards could be placed in the notch by turning the dials of the range unit. These dials were calibrated in yards and thus indicated the true slant range of the target placed in the notch. The range unit measurements were transmitted to the computer by a range transmission unit.

The indicator units and meters for the train and elevation operators enabled them to observe deviation of the antenna from direct angular alignment with the target so that each could apply corrective control in his respective coördinate to bring the antenna into correct and continuous alignment with the target. Each of the latter indicator units contained a 3-inch cathode ray oscilloscope with its power supply and the video circuit elements required to present the two pips of the signal on the screen. The meter supplied to each operator contained a conventional milliammeter movement and showed antenna deviation from target by pointer deflection. These meter movements



Control and indicator unit presentation

were actuated by integrated pulses. In the train position, the pulses received during the right positions of the antenna beam were balanced against those of the left. Similarly in the elevation position the pulses received during the up position of the beam were balanced against those of the lower. Thus zero deflection of both meters indicated true alignment of the antenna. To prevent erroneous interpretation when the signals were not strong enough for reliable meter deflection, an indicating lamp served as an indication of satisfactory signal level.

The first production equipments of the Mark 3 and Mark 4 radars were delivered to the Navy in October, 1941, and during the period of their manufacture, which continued through 1942 and well into 1943, a total of 139 Mark 3 and 670 Mark 4 equipments were produced. After the initial period of installation and training of ship personnel in the use of this new tool, these fire-control radars became an important part of both offensive and defensive naval undertakings. The many ship targets destroyed during darkness by guns under complete radar control have provided striking demonstrations of the value of fire-control radar to the fleet. It was also of inestimable value in guiding the guns to the destruction of attacking aircraft obscured by clouds, direct sunlight, or conditions of low general visibility, and for obtaining smooth and accurate range measurements on fully visible targets of all types. Fire-control radar thus became one of the important factors that gave our fleet its telling advantage over the enemy.

As the war progressed, replacement equipments of improved design became available, and by V-J day only about half of the total Mark 3 and Mark 4 equipments remained in service. On these two radars, however, rested the great burden of the early part of the war when such an advantage over the enemy was so vital to our Navy.

THE AUTHOR: W. M. KELLOGG received his B.E.E. degree from Ohio State University in 1923. He spent the following year as an Instructor in the Electrical Engineering Department of Cornell University. During the period from 1924 to 1928 he served as Instructor and Assistant Professor of Electrical Engineering at the University of Arizona, and in 1927 received the M.S. degree. From 1928 to 1930 he was employed in the research laboratories of the National Carbon Company, after which he joined the Technical Staff of Bell Telephone Laboratories, becoming a member of the radio apparatus development group. Here, until 1939, he was engaged in the design of radio receiving and measuring equipment. Since then, his efforts have been applied to the design of Navy radar equipment for control of gunfire. Mr. Kellogg is a senior member of the Institute of Radio Engineers.

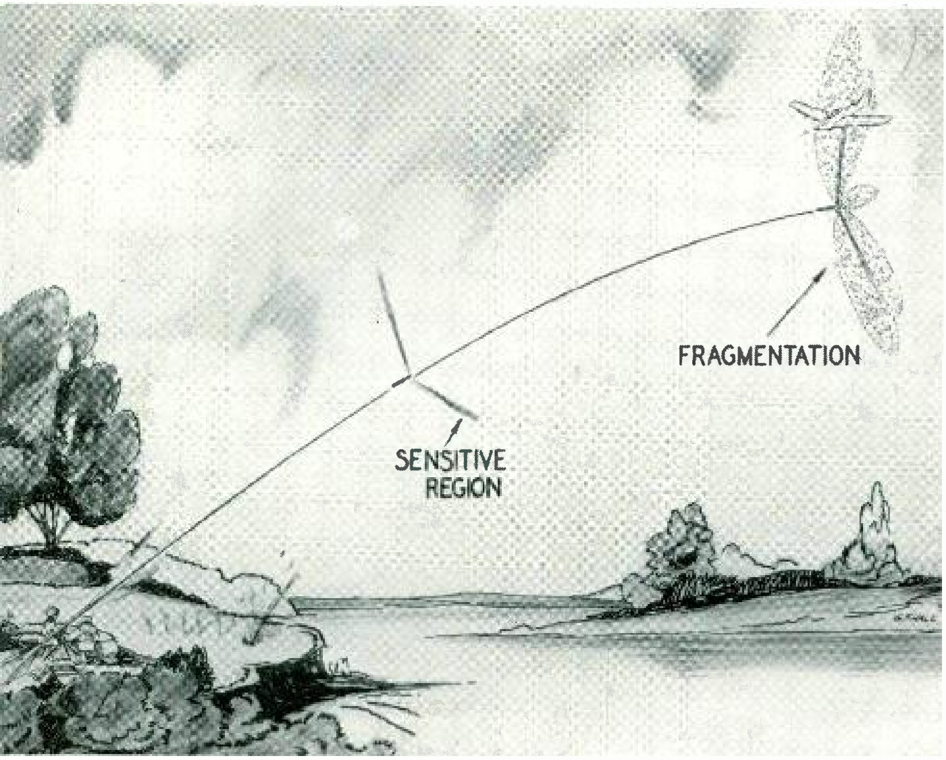
THE OPTICAL PROXIMITY FUZE

F. A. ZUPA
Switching
Apparatus
Development

As acknowledged by the War Department, proximity fuzes rank high among the many new developments that helped our fighting forces to complete victory. A variety of these fuzes were developed both for Army and Navy ordnance devices. One of these, in which both the Laboratories and the Western Electric played an important part, was the optical proximity fuze developed for use on 4½-inch rockets.

Theoretically the proximity type fuze is the perfect time fuze because its time of operation is designed to be automatically varied by the target itself when the latter is within lethal range of the projectile. With the older type of fuzes, which are preset for their time of operation, although the trajectory of the projectile places the target within its range, comparatively small errors in the determination of the time, or deviations in the time mechanisms, may cause the projectile to explode too far from the target. The need for accurate timing can be appreciated when it is realized that even a low velocity projectile, such as a 4½-inch rocket, travels nearly 100 feet in

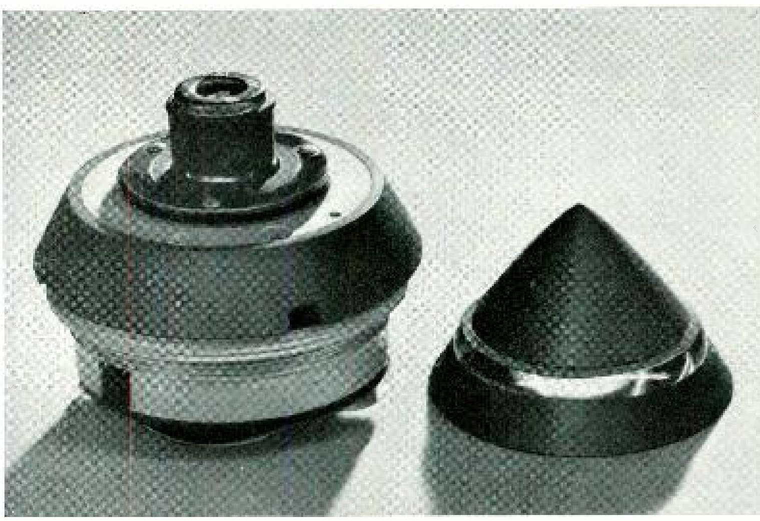
The proximity fuze does not become "armed" until well on its trajectory



one-tenth of a second when approaching its target.

As the name indicates, the optical proximity fuze is a device on a projectile which operates on the light signal produced by the target as the projectile approaches it. Basically it consists of a toroidal lens, a photocell, and an amplifier. The lens forms part of the conical nose, while the photoelectric cell is incorporated in the small cylindrical container fastened in the top of the unit containing the amplifier. This lens screws onto the amplifier housing. The lens is arranged to collect light from all directions during its line of flight, and to focus it upon the sensitive cathode of the photocell through an annular transparent section evident near the bottom of the photocell unit. The photocell transforms the light into electrical energy which is then applied to the amplifier. The amplifier output, however, is nil until there is a sudden change in the amount of light entering the lens, a change such as produced when the projectile approaches the target. The amplifier output then develops the voltage value necessary to operate a thyratron tube which, in turn, starts the chain that ignites the explosive charge in the projectile. To operate the fuze, the change in the amount of light entering the lens need be but a very small percentage of the total light regardless of the ambient light level from dawn to dusk.

The fuze is provided with arrangements designed to prevent the functioning of the amplifier and the application of a firing pulse to the fuze detonator until the projectile has been fired and is well along on its trajectory, as indicated in the illustration on the first page of this article. The fuze is equipped with the usual safety features designed to prevent premature operation should the projectile associated with it be dropped accidentally. It is also provided with a self-destruction arrangement so that if the projectile should miss the target it will explode before reaching the ground. This arrangement is very desirable if the projectiles are likely to fall in one's own territory.



Upper section of the optical proximity fuze showing lens at the right, and photocell in the top of the amplifier unit at the left

Assembled cap unit of the optical proximity fuze

Many models were produced and many experiments made on optical fuzes, both in England and in our country, before the type here described was developed. In 1942 Dr. Alexander Ellett, Chief of Section E of the National Defense Research Committee in Washington, assigned the Laboratories the task of developing for the Army Ordnance Department a working design of an optical fuze to fit on the 4½-inch rocket, especially for use against aircraft. It was planned also to fire these rockets from aircraft. Collaborating with the engi-

Lens cap of the optical proximity fuze

neers of the National Bureau of Standards, the Apparatus and Transmission Development Departments at the Laboratories jointly undertook the design and development of such a fuze. The project was to design a fuze unit which fitted the ogive or nose end of the rocket, and to make it capable of withstanding the forces of acceleration existing during the firing of the rockets. These forces were specified as being 1,000 times that due to gravity. This meant that when the projectile is fired, the forces acting on the parts and their mountings are as high as 1,000 times those due to their weight when at rest. To avoid reducing the explosive load or the range of the projectile, the unit had to be small in size and in weight, and it had to be suitable for rapid production at a low cost.

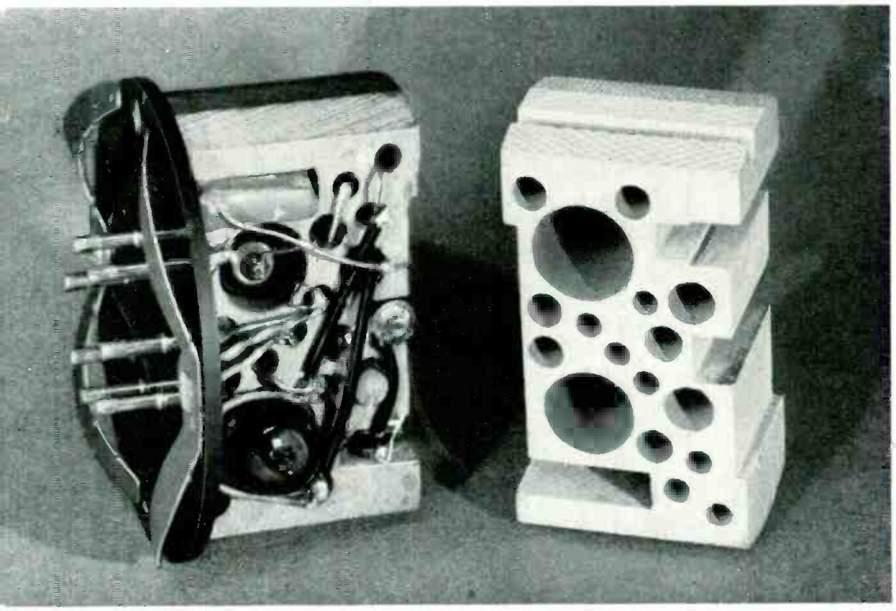
There was little precedent to guide us in producing an assembly of a photocell, a lens, electronic tubes and other circuit components which could withstand the large forces of acceleration mentioned above. We did have, however, a background of knowledge of materials built up in our long experience with telephone apparatus. We had available also a store of information on the processing of plastics, die casting, impregnating compounds and electrical wiring. It was largely this knowledge and background that enabled us to produce the highly satisfactory optical proximity fuze shown in the accompanying illustrations.

The toroidal lens is an integral part of the nose piece, the entire part being made of optically clear methyl methacrylate, commercially known as lucite or plexiglas. The curvature of the toroidal lens was designed to transmit only the light which came through a narrow angle, throughout its circumferential surface, and to have the focal axis at any point around the lens lie on a conical surface. It was manufactured by injection molding to the final dimensions, and no polishing of the lens surface is required after the molding. The portions of the surfaces that had to be opaque to light were coated with a black finish by spraying. Close coöperation between the Laboratories and the Manufacturing Department was required to determine the correct molding time and temperature to produce this part to the required accurate dimensions. The choice of opaque finish presented some difficulties because a number of the common lacquers were found to be destructive to the lucite, the destructive action being known as crazing. A similar difficulty was encountered in the choice of a waterproofing compound, which had to be applied at the junction of the lens piece and housing to protect the photocell from moisture.

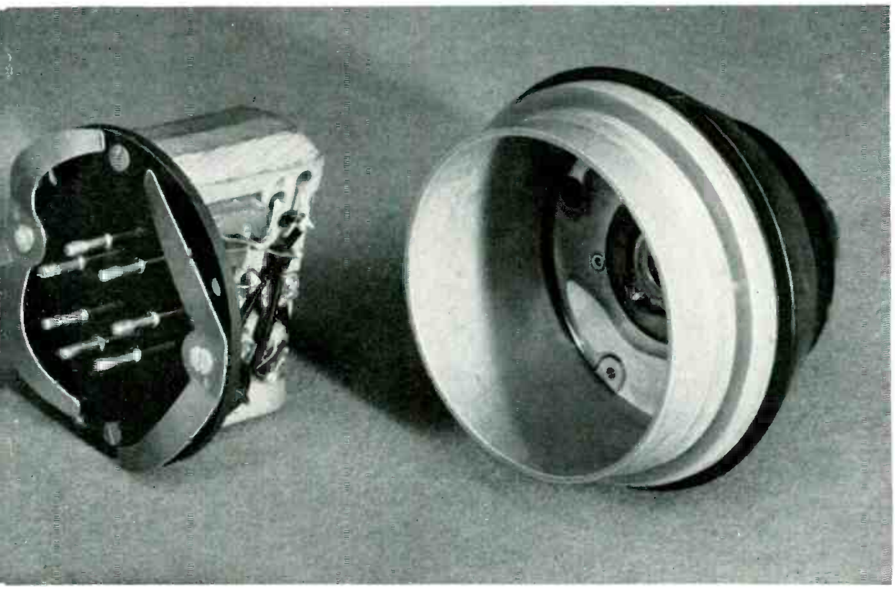
To obtain the desired sensitivity to light when the projectile is in the most effective position with respect to the target, the glass tube portion of the photocell was made opaque to light except for a slit suitably located with respect to the lens. Many designs were conceived for providing such a slit opening, but the search was for a simple and durable construction. As finally adopted, the glass tube is first completely covered with the opaque finish and then the slit is produced by cutting away part of the finish. This technique was new, and it required rather skillful development work before it was reduced to a simple manufacturing process. The photocell and the lens were held in proper relation to each other by securing both parts to a molded phenol plastic part, which accurately positioned the photocell cathode in the focal plane of the toroidal lens. With this arrangement the photocell cathode was made to "see" the target at the angle required to place the target in the densest part of the fragmentation pattern when the projectile exploded.

To provide a shockproof mounting for the amplifier, the components were individually mounted in holes in an impregnated wooden block, and the housing was potted so as to completely surround the components with a ductile wax. The amplifier unit is attached to a phenol fibre terminal plate with plug-type pins. Besides this unit, the optical proximity fuze includes a cylindrical battery unit and the inertia-type switch referred to above. The battery unit contains plug-in type sockets for connections between the amplifier unit and the inertia-type switch. The three connected units are securely enclosed by the cylindrical casing which screws onto the amplifier housing.

The type of mounting adopted for the tubes, resistors, condensers and wiring made it possible to obtain a correct and permanent space relation between the components, thus avoiding capacitance coupling or regeneration in the amplifier circuit. The requirements for the amplifier



The amplifier unit, at the left, is formed by assembling tubes, resistors, condensers, etc., in a wooden block as shown at the right

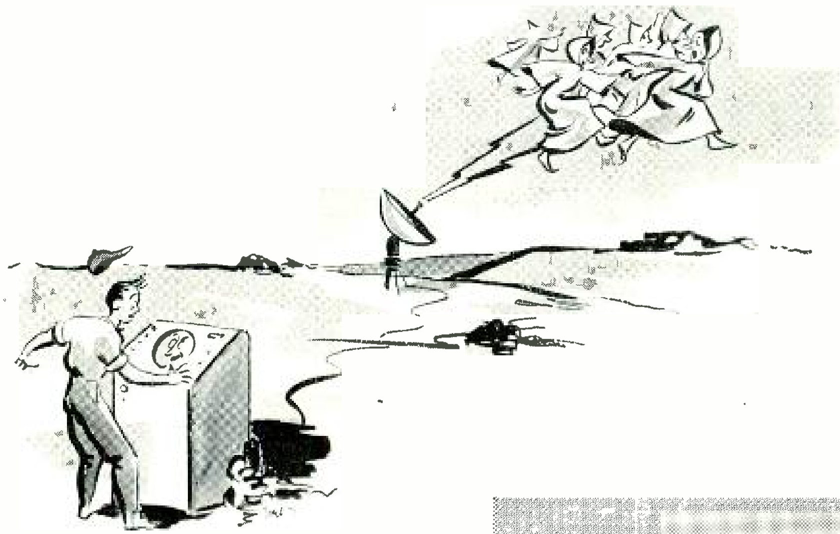


The amplifier unit fits within the cap housing, and is held in place by screws through its terminal plate were met on a straight line assembly basis without any serious difficulty. The variable characteristics of the miniature amplifier tubes were compensated for by preselecting the tubes and matching them with suitable grid-bias resistors and by-pass condensers before these parts of the fuze reached the assembly line.

Large quantities of the optical proximity fuzes were manufactured by the Western Electric Company, and the product satisfactorily met the rigid specification requirements. A suitable number out of each lot of 1,000 fuzes were given a field operation test by the Signal Corps engineers before each lot was approved for acceptance. This type of apparatus was not adjustable. It had to function satisfactorily only once, but it had to function properly on the first operation. The satisfactory results obtained in the acceptance-performance tests on over one hundred lots is further evidence of the creditable performance of Western Electric Company products.

A complete fuze in its container

THE AUTHOR: F. A. Zupa came to the Laboratories in 1918 and was engaged first in testing and development work on materials and telephone apparatus in the Physical Laboratory. He obtained his technical education at the College of the City of New York and Cooper Union, evening sessions, receiving the degree of B.S. in electrical engineering from the latter school in 1922. In 1924 he was transferred to Apparatus Development and engaged in the design and development of telephone relays, chiefly the U, Y and UA type relays. During the war he was in charge of an apparatus group engaged in the design and development of proximity fuzes, rocket-firing mechanisms and magnetic mines.



ECHOES FROM THE ATMOSPHERE

Indicating that perhaps modern man doesn't yet know everything about the air he lives in, two sets of unusual echoes from the lower atmosphere have been noted by members of the Laboratories. By interesting coincidence, both sets of observations, one with high-frequency radar waves and the other with sound waves, took place during the summer of 1944.

"Ghost" radar echoes were reported that year by Millard W. Baldwin, Jr., of the Laboratories, field engineer for a new, three-centimeter, anti-aircraft fire-control radar which was undergoing tests at a site near Chesapeake Bay early in that summer. The radar had been tracking airplanes passing overhead when the testing group became aware of echoes that had no visible reason for existence. They appeared as small bright pips moving slowly across the radar scope and they were present when there were no airplanes or any other discernible reflecting objects in the sky to cause them.

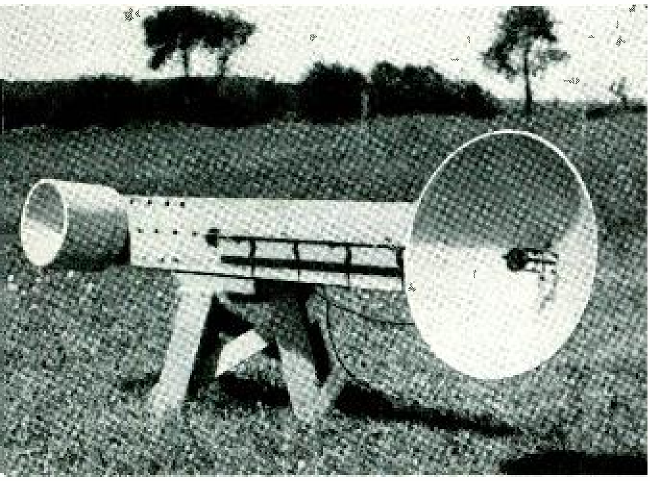
They were as sharply defined as the echo from an airplane target many times as far away, Baldwin reports, and strong enough to enable the radar to follow them for several minutes at a time with fully automatic tracking:

"The motion in all coördinates was quite smooth with none of the jitter and jump which are characteristics of extended or multiple targets. For this reason we concluded that the source of the reflection was well localized in space, probably extending for no more than ten or twenty meters in any direction."

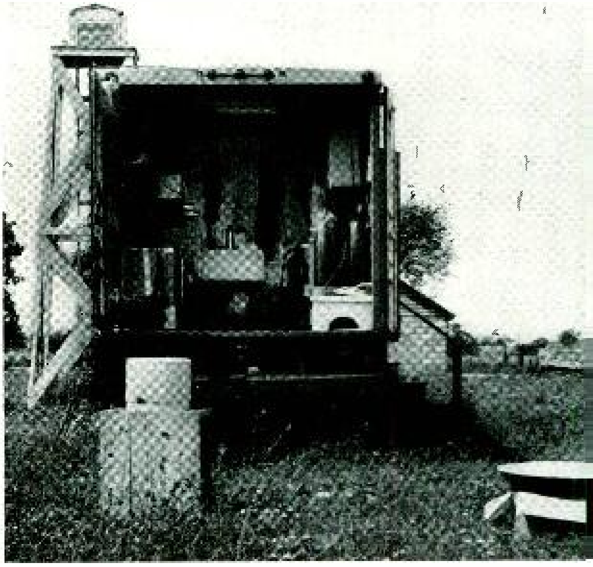
The reflecting regions were found at all altitudes from the surface up to 2,000 meters and were generally in motion on courses which were "fairly" straight and level at speeds usually greater than that of the surface wind. In some cases, however, there were periods of several seconds when there was virtually no motion at all.

A few weeks later, Baldwin's observations were supported from across the Atlantic by R. R. Hough, another member of the Laboratories, who was touring anti-aircraft sites in the European theater. Hough heard reports of similar phenomena from Army AA radar crews, by whom the mysterious echoes had been christened the "Normandy ghosts." In the report of his trip, Hough mentions a morning in August at a site in Normandy about three miles from the Channel coast when he watched a radar track a number of these echoes. He states that the invisible targets could be followed for as long as ten minutes at ranges up to 6,000 yards.

Several explanations have been advanced. The most obvious one—birds—has been discounted because in both instances the radars were equipped with artillery telescopes synchronized to follow the movement of the antenna. Nothing could be seen through them, even when the target approached within a few hundred yards. Suggestions that the "ghosts" might be swarms of insects are looked upon with some doubt since they have been observed on foggy nights when it seems unlikely that insects would be flying about, and since the echo is stronger than might be expected from insects, stronger even than that obtained from birds.



"Sodar" receiver and transmitter used for studies of atmospheric conditions over the microwave radio path between New York and Neshanic, N. J.



Some of the truck-installed apparatus that was used in connection with the "Sodar" tests

"The most attractive possibility," in Baldwin's words, "is that the echoes are returned from clumps of water vapor drifting on the wind, perhaps forming into very small and very tenuous clouds which would be invisible against the sky."

Whatever the cause, a radar experiment set up at Cambridge, Mass., to observe the phenomena reported by Hough and Baldwin turned up only one rather doubtful echo of the "ghost" type. No one has advanced an explanation for that, except that the experiment took place in September and the previous observations occurred during the summer.

Directly connected with characteristics of summer weather were the experiments conducted with sound waves by a group from the Laboratories supervised by G. W. Gilman and including H. B. Coxhead and F. H. Willis.

It had been noted that during the summer, atmospheric conditions involving relatively stable air accompanied by strong temperature inversions had an adverse effect on micro-wave radio transmission. Reasoning that masses of air having temperature and humidity gradients great enough to affect radio propagation might also reflect waves of sound, Gilman and his group decided to try to observe these inversions with an acoustic radar apparatus.

Dubbed "Sodar" because it used sound instead of radio waves, the equipment put together by Coxhead consisted essentially of a loudspeaker that launched audio-frequency sound wave pulses vertically into the atmosphere; a directional microphone receiver connected through an amplifier to a cathode ray oscilloscope with a synchronized sweep representing about 800 feet of altitude; and a motion picture camera to record the echoes displayed on the oscilloscope. The equipment was set up in an open field near the Neshanic end of the New York-to-Neshanic, N. J., experimental micro-wave radio circuit. At this point the line of sight between the two radio antennas was about 400 feet off the ground.

Strong echoes were picked up on the night of June 1, 1944, at a time when micro-wave propagation over the radio circuit was considerably disturbed. Continued observation throughout the summer demonstrated that pronounced temperature inversion and apparently stable air in the first few hundred feet of the atmosphere were generally accompanied both by the greatest Sodar activity—with amplitudes several times as great as were obtained from standard atmosphere—and by periods of disturbed micro-wave transmission.

Significant are the comments of Gilman and Willis that "the echoes actually observed on the oscilloscope during active periods were very much stronger than one would expect from the distribution (of the atmosphere) postulated . . ." (*i.e.*, a quiet, smooth distribution, uniform horizontally but with small slow variations upward). "This leads to the possibility that the source of the returning echoes may lie in aggregates of moving 'boulders' or 'puffs' of air having temperature and humidity differing sharply from their general environment.

"While the experimental evidence," they conclude, "seems to indicate a distribution in space and time too complicated for complete analysis, the Sodar, even with its practical limitations, does indicate the presence of nonhomogeneities, and the principle might perhaps find application in such fields as meteorology, radio, and fluid mechanics."

Connection between the phenomena responsible for the Sodar and for the radar echoes has been discussed, but neither confirmed nor denied. It is pointed out that radar indications were obtained from higher levels than the Sodar echoes. The men who reported the experiments are noncommittal. "Maybe and maybe not," is what they say.

A PB4Y-2 in flight

U. S. Navy P

AN ELECTRICAL COMPUTER FOR FLIGHT TRAINING

R. O. RIPPERE
Switching Development

The PBM-3 operational flight trainer, having the appearance and operating characteristics of the Navy's Martin "Mariner" patrol bomber, has already been described in the RECORD.* Following the completion of the PBM-3 trainer, the Laboratories developed F6F-5 and PB4Y-2 trainers, simulating the Grumman Hellcat fighter and Consolidated Privateer patrol bomber.

Each of these trainers is essentially an electrical computer. The motion of an airplane can be described by a number of mathematical equations, and an airplane itself might be considered as an automatic computer that continuously solves these equations of motion as it flies. Speed in the direction along the line of flight, for example, is the time integral of the forward acceleration, which in turn is proportional to the resultant of all the forces acting along the line of flight: thrust, drag and a component of weight. Mathematically, this could be expressed as:

$$V=\frac{1}{M}\int_0^t F_x \, dt$$

where F_x, the accelerating force, is equal to the thrust minus the drag, minus the weight times the sine of the angle of climb. Thrust, drag and angle of climb, however, are each derived from other factors.

Thus the thrust, for example, is equal to the engine power times the propulsive efficiency divided by the forward speed, and corresponding equations apply to the other two factors. By designing an electrical computer to solve the same equations, and to display the answers on instruments having the same appearance as the instruments in the airplane, the operating characteristics of an airplane can be reproduced on the ground. This is what the flight trainers do. By means of motor-driven potentiometers, the computers of the trainer can add, subtract, multiply, divide and integrate.

Illustrative of the methods employed in computing is the arrangement of potentiometers shown in the first diagram. The positions of the potentiometer wipers are proportional to the values of the functions A, B, C and D. The voltage at the A slider is thus proportional to the value of the function A. Similarly, the voltage at slider B will be proportional to the product of A multiplied by B. Also, the voltages at slid-

*RECORD, *February,* 1945, *page* 33.

ers C and D will be proportional to those functions. Since potentiometers A and C are connected to the same phase of 60-cycle voltage, and since potentiometer D is connected to an exactly opposite phase of voltage, the resultant voltage at the summing point "S" is proportional to AB+C−D. Division is a special case of multiplication, in that the potentiometer is arranged to provide a voltage proportional to the reciprocal of the function.

If point S is connected to a motor control circuit that operates a motor geared to potentiometer D, as in the second diagram, and the control circuit is arranged to always run the motor in a direction to reduce the summing point voltage to zero, an equation-solving device has been created that solves for the value of D in the equation AB+C−D=O.

All of the integration performed is with respect to time. The altitude of an airplane, for instance, is the time integral of the rate of climb. If a voltage proportional to the rate of climb is maintained at the summing point, and the motor control circuit is arranged so that the motor speed is correctly proportional to the summing point voltage, the potentiometers driven by the motor will register changes of altitude at the proper rate. For the general case shown in the first diagram, if the voltage at the summing point is proportional to the rate of change of D, or dD/dt and the motor speed is proportional to this voltage, the system solves for D in the equation

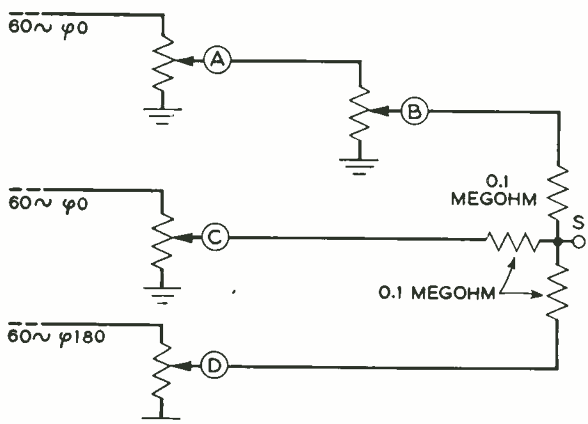
$$D=\int \frac{dD}{dt} \cdot dt=K\int_0^t (AB+C-D)dt$$

where K is a function of the motor speed characteristic and the gearing provided.

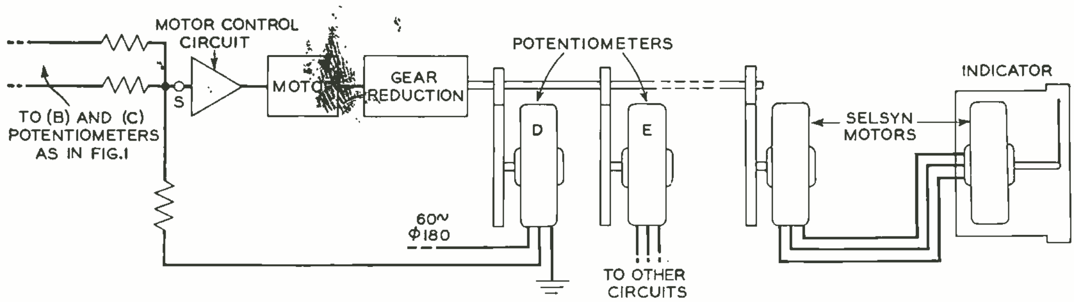
With these building blocks, the operational flight trainers have been put together. The performance equations of the engines and the airplane are each represented by a system of potentiometers similar to those shown in the first diagram. Each such system controls a motor which solves continuously for the value of one function, such as engine speed, horsepower, air speed, rate of climb or altitude.

To display answers on the instruments in the flight unit, a Selsyn motor is geared to the equation solving motor. Another Selsyn motor, operating the pointer on the instrument, is electrically connected to the one in the computer equipment. Since two Selsyn motors connected together attempt to keep their rotor positions synchronized, the Selsyn in the instrument will turn its pointer to the position dictated by the computer motor.

The control of the air speed indicator in one of the trainers will serve as an example of the application of these principles. As mentioned previously, the velocity is the time integral of the forward acceleration: $V=\frac{1}{M}\int_0^t$(thrust-drag-weight x sine of climb angle)dt, where M is the mass of the airplane. The circuit shown in the last diagram represents the forces in this equation. The voltage at summing resistance (1) is proportional to thrust, while that at resistance (2) is proportional to drag of the wing of the airplane. The voltage at resistance (3) when the wing flaps are up corresponds to the drag of the body and tail of the airplane. Lowering the wing flaps causes this voltage to increase proportionately to the increased drag. The voltage at resistance (4) represents the drag due to the landing gear if it is not retracted, plus any additional drag caused by sideslipping or skid-



An arrangement of potentiometers combined with phasing of the a-c supply to evaluate the expression AB+C−D



By allowing the voltage at point S of Figure 1 to operate a motor driving potentiometer D, as indicated above, D may be held in a position to make $AB+C-D=O$

ding. Finally, the voltage at resistance (5) corresponds to the component of weight along the flight path. If the airplane is climbing, this voltage will oppose the thrust voltage, while if the plane is descending, the voltage will aid the thrust voltage. The magnitude of the weight component is established by multiplying the weight by the rate of climb and dividing by the true air speed.

The circuit shown in this diagram covers the airborne condition. Prior to take-off, and after landing, an additional leg of the circuit (not shown) is connected by relay contacts whereby potentiometers operated by the brake pedals introduce the effects of brake operation on the air speed.

The resultant voltage created at the summing point is proportional to the unbalanced forces along the line of flight. This voltage is connected to the input of a motor control circuit where it is first amplified, and then connected to a pair of thyratrons, one of which controls the speed of the indicated air speed motor, and the other (which is phase sensitive) controls a relay which in turn controls the direction of rotation of the motor. The combination of the amplifier gain and the gear ratio between the motor and potentiometers is designed to represent 1/M, the inertia characteristic of the airplane.

In similar fashion, solutions for other functions are obtained. In the PB4Y-2 trainer, for instance, the fifty functions listed in the table are derived. These fifty functions are mutually interacting under control of the flight crew, and in addition are affected by symptoms of trouble and other conditions injected by the instructor.

Take, for example, the simple act of partially closing the throttles after having established steady cruising conditions. The manifold pressure circuit for each engine responds, indicating a reduction in manifold pressure, and in turn causing a reduction of brake horsepower. A momentary reduction of engine speed occurs while the propeller pitch circuits are reducing the pitch of the imaginary propellers. The propeller efficiency also changes, as do the fuel flow and cylinder and oil temperatures. The thrust circuit recognizes the changes in engine power and propeller efficiency, and causes a reduction in the thrust voltages affecting the flight circuits. The reduction in thrust causes the air speed to

CONTROL FUNCTIONS IN A PB4Y-2 TRAINER

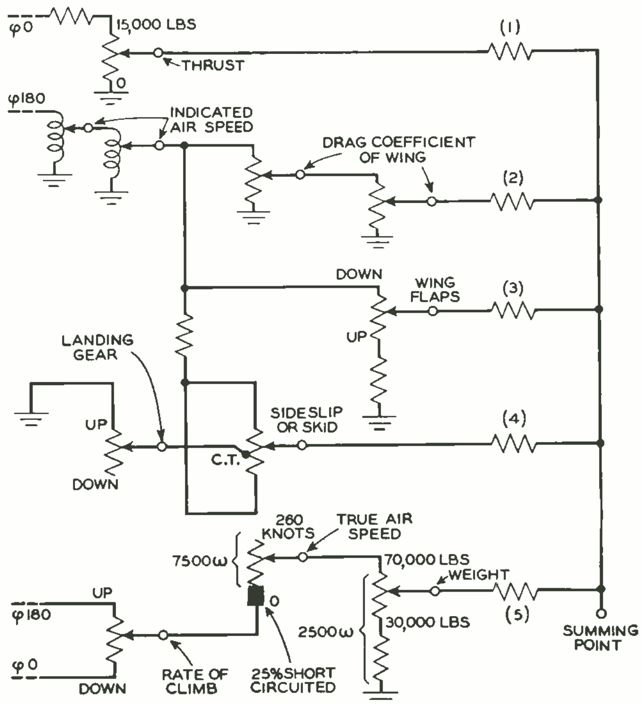
For each of four engines	Indicated rate of climb
Manifold pressure	Altitude
Engine speed, rpm	Horizon elevation
Brake horsepower	Rate of roll
Fuel flow	Bank angle
Cylinder and oil temperatures	Rate of turn
Propeller pitch	Compass heading
Propeller efficiency	Angle of yaw
Thrust	Ball bank angle
Weight	Ground speed
Indicated air speed	Ground track
True air speed	Elevator trim
Rate of pitch	Aileron trim
Angle of attack	Rudder trim
True rate of climb	Loading for elevator, aileron and rudder

decrease, and the rate of climb to show gradual descent. These latter two functions interact with each other in damped oscillatory fashion, gradually approaching a steady state condition. The oscillatory period is of the order of one minute. The changing rate of climb causes changes in the altimeter indication, and also in the elevation of the horizon bar in the artificial horizon instrument.

Further, if the changes in engine power do not occur simultaneously, the rate of turn circuit will be affected, causing changes in the compass heading, rate of roll, bank angle and angle of yaw. In actual use, of course, the pilot would provide further control of the trainer by the elevator, aileron and rudder controls.

The computation of these systems need not be extremely accurate for use as flight trainers. A tolerance of about five per cent was considered satisfactory. It was thus possible to use commercial potentiometers and other devices not manufactured to precision standards.

A trainer is ordinarily used to familiarize the crew with the operating and handling characteristics of the particular airplane. This is usually done by making short "trainer flights" around the air station. At one West Coast station, however, the trainer was used for a dress rehearsal prior to making the actual transpacific flight to Hawaii. For a total of six hours (with time out for lunch) the crew was required to go through all the motions of filing a flight plan, getting clearance, starting, warming and checking the engines, taxiing, taking-off, flying, navigating by radio compass, "loran" (LOng RAnge Navigation—by radio) and radar, keeping in touch by radio with ground stations and landing at Hawaii. The actual flight was permitted only after this rehearsal was successful.

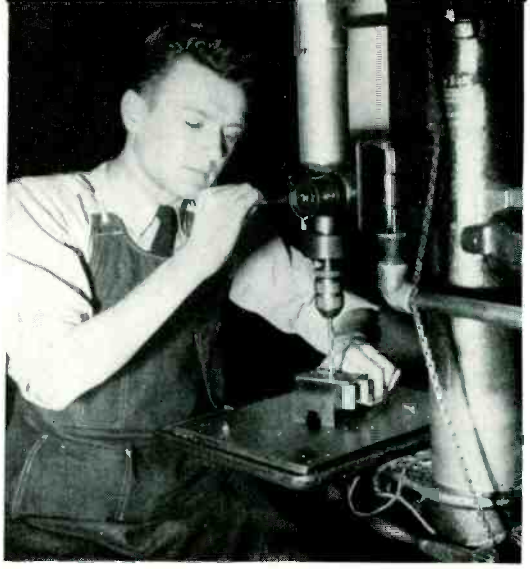


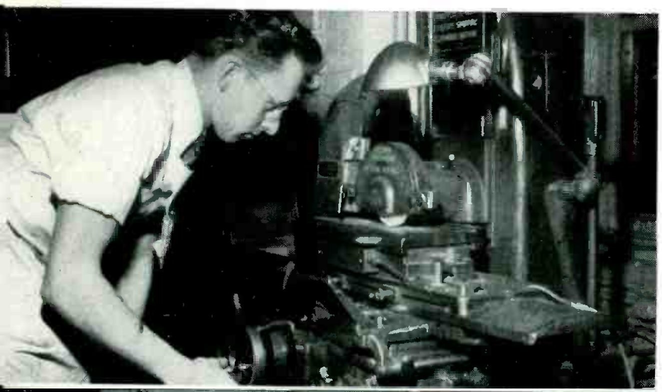
Computing circuit used for the air speed indicator

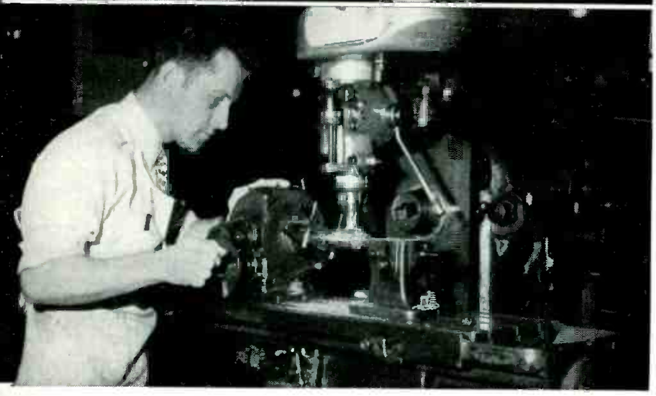
THE AUTHOR: R. O. Rippere received the E.E. degree from the Polytechnic Institute of Brooklyn in 1929, and then joined the Laboratories. For several years he was engaged in circuit development problems associated with the step-by-step dial system, primarily those concerned with dial pulsing. During 1941 and 1942 he designed circuits for private branch exchanges and air raid warning systems, and then devoted practically all his time to the development of operational flight trainers. At present he is assisting in the design of circuits for use in the accounting centers of the Automatic Message Accounting project. He is a member of the A.I.E.E.

Making a jig for drilling mounting brackets engrosses R. L. Norton at a drill press in the Development Shop

A small die plate held on a magnetic chuck is being ground in this surface grinder by J. D. Olesko







William Wiegmann's interest is centered on the group of cams which he is index-milling

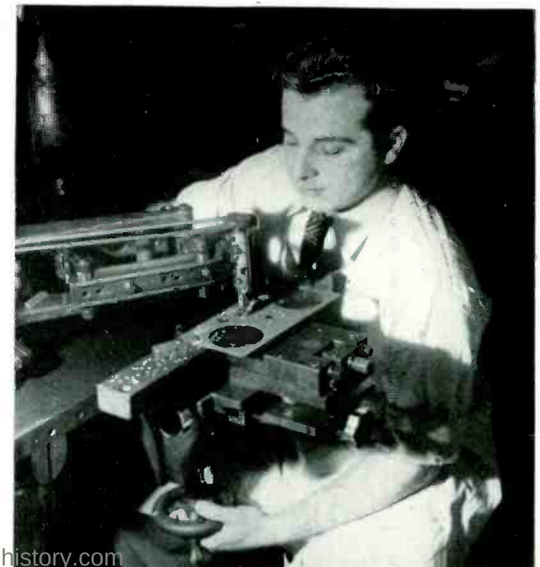
C. W. Peterson, center above, under instruction of his Development Shop supervisor, Robert Wighton, assembles a magnetically operated paper punch

NEWS AND PICTURES OF THE MONTH

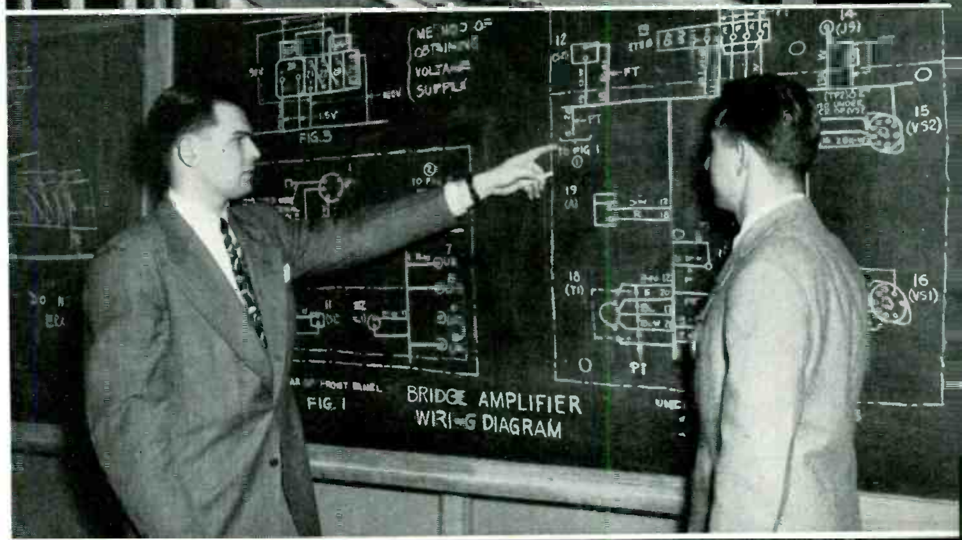
JUNIOR MECHANICS

Junior Mechanics returning from military service were welcomed back to their jobs and their training program resumed. Formal training in instrument making, inaugurated in 1918 by the Personnel Department and presented in collaboration with the Development Shops Department, was conducted continuously until the program was interrupted by World War II. The course now provides three years of coördinated practical and in-hours classroom training in the fundamentals of instrument and tool making.

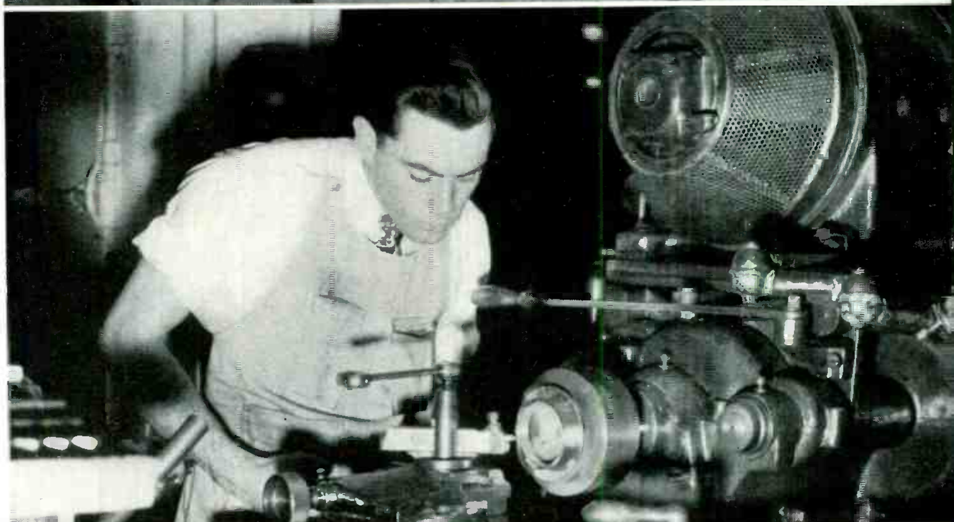
J. A. Whittaker concentrates on the engraving of characters on an aluminum panel



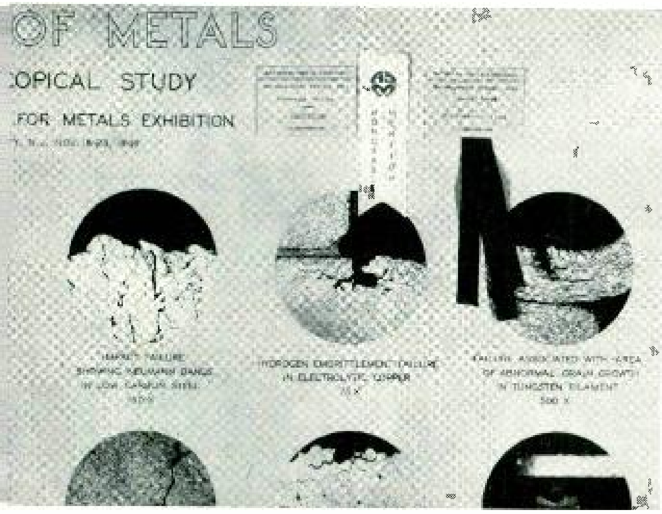
*group of Junior Mechan-
s are learning electrical
rafting practices by mak-
ng sets of drawings of the
lass project, a bridge am-
lifier, shown at left*



*. A. Seifert, one of the
classroom instructors, ex-
plains the preparation of
an air-line wiring diagram
o W. T. Reck in a class in
electrical drafting*



*Using an engine lathe, H.
C. Bell machines a brass
ring for a project on which
he is working*



Portion of the eighteen micrographs on "Failure of Metals" shown by F. G. Foster at the first A.S.M. Metallographic Exhibit in Atlantic City during the National Metal Congress. His exhibit received one of the three awards for unusual groups of micrographs and honorable mention in the "Transitions" group

Vannevar Bush a Director of A T & T

At a meeting of the Board of Directors of the American Telephone and Telegraph Company, January 15, Vannevar Bush was elected a Director. Dr. Bush is President of the Carnegie Institution of Washington and Chairman of the Joint Research and Development Board of the War and Navy Departments. During the war, Dr. Bush was Chairman of NDRC and later Director of OSRD, and so was well known to many members of the Laboratories.

Organization Changes

Effective January 1, 1947, E. F. Watson was appointed Telegraph Development Engineer reporting to H. M. Bascom, Director of Switching Engineering. Also effective as of that date, H. W. Everitt was appointed Assistant to the Commercial Relations Manager, and J. A. Sherwin, as Case System Supervisor, assumed the duties formerly performed by Mr. Everitt.

R. J. Heffner, Personnel Planning Director, will be absent on sickness for an extended period of time. The following changes in Personnel Department organization became effective on January 20: F. D. Leamer was appointed acting Personnel Planning Director in charge of personnel analysis, planning, studies and related matters; M. L. Wilson is appointed Personnel Manager, New Jersey Operations, reporting to the Personnel Director; H. W. Gillette, General Employment Manager, now reports to R. A. Deller, Employment Director; and D. D. Haggerty, in charge of housing, home and lease disposal, and relations with Bell Telephone Laboratories Club, reports to Morton Sultzer.

Western Electric Electron Tubes

A bulletin giving in concise tabular form the essential data on its electron tubes has recently been printed by the Western Electric Company. The material has been arranged with a view to guiding the circuit designer to the Western Electric tube which will meet his requirements for a particular application. Included are 53 general purpose tubes, 52 transmitting tubes, 20 rectifiers, 4 special purpose diodes, 10 thyratrons, 13 cold-cathode tubes, 17 ballast lamps and 89 basing diagrams.

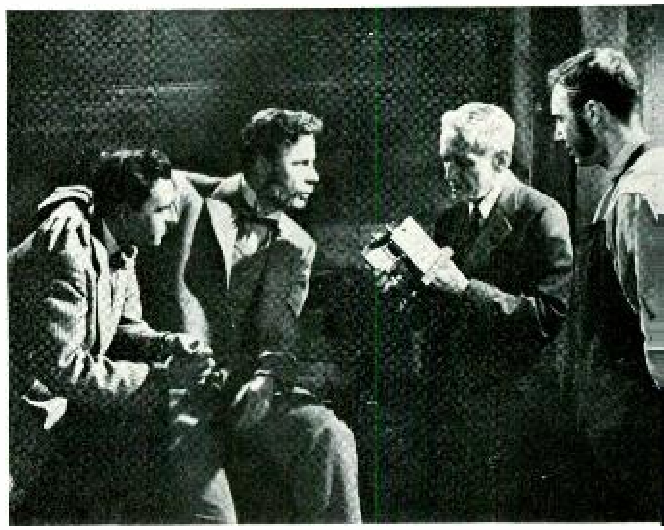
Chambers Street Shop Closed

Removal of the last group from 157 Chambers Street early in December marked the end of the Laboratories' occupancy of some 18,600 square feet of space at that location. Leased in November, 1943, the four floors housed principally a part of the Preproduction Shop* and the expediters and inspectors associated with their work. Among the jobs done there were the radar for the Bat,† and several other

*Record, *May*, 1946, *page* 188. †Record, *April*, 1946, *page* 137.

Instrumental in teaching these two nine-year-olds to talk is the Laboratories' cathode-ray-tube translator, now installed at the Rackham School of Special Education at Ypsilanti, Michigan. Miss Harriet Green, who joined the Laboratories temporarily to participate in the development, is now an assistant professor and conducts the program of educational experiment with the visible speech equipment radars for submarines and airplanes. It was at Chambers Street that, in April, 1945, a group of Commercial Relations, Accounting and General Service people took off their coats and worked from Saturday morning until Sunday morning, with scant time for meals and rest, to get a final shipment of submarine radar into some 400 cases and shipped.*

Last group to move was Protection Development, headed by A. H. Schirmer, which now is domiciled on the sixth floor at West Street. This group is concerned with the protection of equipment, telephone personnel and the public against foreign voltages and lightning. Among recent problems are tests of the protection given by copper jacketing of buried cable; and protective features of rural power line telephones.



Between "shots" in the production of the motion picture based on the life of Alexander Graham Bell, W. C. F. Farnell, curator of the Historical Museum, describes the workings of Bell's first telephone. Left to right: Richard O. Fleischer, director; Raymond Edward Johnson, who plays the rôle of Bell; Mr. Farnell; and Mason Adams, who portrays Watson

The War Department and The Navy Department

express to

Oliver Buckley

their appreciation for patriotic service
in aiding the prosecution of the war as a member of the
NATIONAL INVENTORS COUNCIL
stimulating, guiding, and evaluating inventions
for the benefit of the Armed Forces, 1940 - 1946

Secretary of War — Secretary of the Navy

Washington, D. C., December 12, 1946

Motion Picture on the Life of Bell Produced for Centennial

The story of Alexander Graham Bell, the scientist, teacher and humanitarian, is recorded in a motion picture which has been produced in connection with the 100th anniversary of the birth of the telephone's inventor, March 3. The movie, which will play a part in the Bell System's nation-wide tribute to Bell, was produced at the New York studios of RKO Pathe, Inc., under the supervision of the Motion Picture Division of the A T & T.

The half-hour film depicts significant events in the life of Bell. It will be released about March 1 for showing to employees of the Bell System and to the general public.

Included in the picture are a number of Bell Laboratories scenes taken on location at West Street and Murray Hill. The early experimental instruments used by Bell and Watson were taken from the Bell System Historical Museum at West Street, supplemented by replicas built especially for the picture. W. C. F. Farnell and Henry Kostkos served as technical advisers during the filming.

The River Grove Fire

When flames recently destroyed the telephone central office at River Grove, Ill., a suburb of Chicago, 10,000 subscribers lost their telephone service and half a million dollars in telephone equipment and facilities were destroyed. Yet, within eleven days, telephone service was fully restored. This remarkable restoration of service was the result of the close coöperation of the Illinois Bell, Western Electric's Chicago Distributing House, its Hawthorne and Kearny Works, together with the O & E of the A T & T and the Laboratories, who, assisted by the Western and Illinois Bell, quickly formulated immediate and long-range reconstruction plans. In this connection G. H. Peterson of Switching Engineering made a trip to River Grove.

*Record, *May,* 1945, *page* 164.

X-acto Crescent Products Co., Inc.

Meet the Champs. The Babcock Team: Ernest Babcock, Jr., who flies the Jughaid, *and his father, Ernest, Sr., of Whippany Laboratories*

When President Truman addressed the new Congress on January 6, the scene was televised. The video signal was transmitted from the scene, by Bell System local video pair, to the coaxial terminal in Washington. From there it was sent, via the coaxial system, to New York where it was distributed by local video pairs to CBS, Dumont and NBC. A laboratory television monitor at 180 Varick Street received the video signal via a video line from NBC. On the viewing tube, the image was about 8 by 6 inches. Photo by A. L. Stillwell

"Jughaid" and the Babcocks

Jughaid, an article by Ernest Babcock, Sr., of Whippany, appeared in the December 1946 *Air Trails and Science Frontiers.* In it Mr. Babcock reveals the details of the model plane of that name which catapulted himself and his son, Ernest, Jr., to national fame among modelers and others as co-holders of the national speed record for model planes. It all began four years ago Christmas when he gave his son a model plane kit. From that gift evolved the *Jughaid,* capable of flying 130 miles an hour, which has won for them two ercoupes and more first, second, and third prizes, ranging from trophies to television sets, than they can enumerate. Incidentally, they won second prize at the Murray Hill Hobby Show during which Ernest, Jr., formerly of Whippany, demonstrated his skill by controlling a plane, stunt-flying 75 miles an hour, while tethered to his hand. He also gave a demonstration on the Whippany grounds.

Bell Companies Introduced Mobile Telephone Service in 25 Cities in 1946

Mobile telephone service has come a long way since its introduction at St. Louis last June. At the close of 1946, the picture throughout the country was as follows:

Bell companies were providing mobile telephone service in 25 of the Nation's leading cities. Service was introduced into those cities in the following order: St. Louis, Green Bay, Wis., Cincinnati, Detroit, Philadelphia, Newark, Chicago, Washington, Cleveland, San Francisco, Boston, Houston, Pittsburgh, Atlanta, Baltimore, Milwaukee, Columbus, New Orleans, New York, Indianapolis, Miami, Denver, Oklahoma City, Kansas City and Fort Worth.

By the end of the year, licenses had been granted to operate stations in Dayton, Memphis, Salt Lake City and Birmingham, and for a second channel in Boston.

As the old year gave way to the new, several major highway telephone systems were rapidly nearing completion. Licenses had been granted for all five stations in the Chicago-St. Louis system, which will be the first chain in the country to provide highway service, and for all six stations comprising the Boston-New York highway mobile system, in itself a link in the proposed Boston-Washington chain.

Among the other highway routes whose mobile telephone systems are well advanced are New York-Albany-Buffalo, Cleveland-Columbus-Cincinnati, Los Angeles-San Diego, and several systems in Texas.

February Service Anniversaries of Members of the Laboratories

40 years

D. D. Haggerty
R. S. Hoyt

30 years

C. J. Beck
H. R. Clarke
J. B. Kelly
A. A. Mayer
E. L. Nelson
C. E. Ramsbotham
May Reilly

25 years

Elizabeth Culbert
Christopher Hartley
D. H. King
W. V. K. Large
J. R. Riker
C. W. Stevens

20 years

R. B. Blackman
R. A. Broomfield
J. R. Haviland
Peter Larkin
Halvard Lofsgaard
A. J. Lovecky
E. J. McCarthy
G. J. Mihm
Einar Reinberg
H. C. Rorden
Thomas Ryan
A. A. Skene
W. E. Smith
A. L. Stillwell
E. J. Thielen
R. J. Tillman
L. E. Van Damme
W. O. Waldecker
Augusta Welsh
Arthur Wright

10 years

J. J. Barrett
P. R. Brookman
W. P. Connery
Leo Ehrmann
H. C. Fleming
W. L. French
G. L. Gamble
John Grossmann, Jr.
Cleo Houle
W. H. Kossman
P. M. Ness
H. J. Wallis
R. S. Williams

News Notes

To ACQUAINT its operators with the new headset, Michigan Bell secured 550 reprints of the Laboratories' October, 1946, advertisement, "The hat that became a headset." Reprints were posted on Traffic bulletin boards.

J. C. KENNELTY and E. G. ANDREWS, with C. A. Calhoun of Western Electric, were at Langley Field on the relay computer for the National Advisory Committee on Aeronautics.

R. R. GAY visited the Power Equipment Company at Detroit in connection with the manufacture of rectifiers for radio relay systems.

W. W. BROWN discussed operators' chairs with Western Electric engineers at Hawthorne.

E. T. BALL was at Jamestown, N. Y., for discussions on framework problems with the Dahlstrom Metal Company.

C. A. COLLINS conferred at Hawthorne on design problems pertaining to senders and registers for the No. 5 crossbar system.

G. W. GILMAN spoke on *Transmission Engineering* at the Deal-Holmdel Colloquium.

V. T. CALLAHAN went to the General Motors Diesel Engine Division at Detroit and the Duplex Truck Company at Lansing on engine alternator problems.

R. W. LANGE presented a paper on *Resonant Cavities and Measurements of High Q* before the Boston Section of the A.I.E.E.

These girls in the 9A Files furnish service and blueprints to engineers and draftsmen of the Systems Development Department. In the first row (left to right) are Katherine Gilburn and Josephine Monte; in the second row, Marian Canavan, Supervisor; Mary Cea, Pauline Joslin, and Lorraine Moss; and in the rear, Rose Sena, Gloria Iannone and Rita Ohnasty

"The Telephone Hour"

NBC, Monday Nights, 9:00 p.m.

February 10	*Bidu Sayão*
February 17	*Artur Rubinstein*
February 24	*Helen Traubel*
March 3	*Helen Traubel and Jascha Heifetz*

C. W. Carter served as a member of both the New York State and the Middle Atlantic District committees for the selection of Rhodes Scholars.

C. T. Wyman discussed general cable problems early in December at Hawthorne.

R. J. Kent witnessed a trial on Long Island of a new design of sleeve for placing corrosion-protected cable in an underground duct.

J. B. Dixon and W. J. Farmer reviewed problems on bridging connectors at Point Breeze.

R. H. Colley is continuing coöperative experiments with suppliers in Minneapolis and St. Paul on the control of bleeding in pressure-treated lodgepole and Douglas fir poles.

A. H. Hearn made experimental treatments of Douglas fir poles at Orrville, Ohio. He also started an investigation of the causes of occasional weak wood in creosoted pine poles.

J. M. Hardesty attended meetings of the A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates held in Washington.

J. B. Howard and B. A. Stiratelli conferred on insulated wire problems at the Hercules Experiment Station in Wilmington.

J. B. DeCoste visited Kearny in connection with adhesive problems on alpeth cable.

C. H. Amadon returned from Denver, where conferences were held on lodgepole pine and Douglas fir treatments.

The Laboratories were represented in interference proceedings at the Patent Office in Washington by G. C. Lord before the Primary Examiner.

O. E. Buckley attended a meeting of the National Inventors' Council held on December 2 in Washington.

D. A. Quarles attended a meeting in December of the Committee on Electronics of the Joint Research and Development Board in Washington.

C. M. Hill witnessed the experimental molding of cable seals of new design at the Toledo plant of H. H. Buggie and Company.

A doll and a cuddly toy made Christmas in St. Vincent's happier for this little patient. Helen Gino (left) and Gloria Yurman, members of the Doll and Toy Committee, helped to distribute the gifts. Nearly four thousand other children in 53 institutions also received toys from the Laboratories

Noon hour in the West Street Auditorium finds this group of chess players engrossed in their favorite pastime. Front to back: W. Gansz playing K. E. Schucraft; F. A. Anderson with R. Weihs; D. Varone with B. Stauss; J. R. Glaser awaiting an opponent; and E. G. Andrews with H. D. Cahill

The year 1914 marked the first organized bowling activities at West Street. William Bodenstedt, a charter member, hasn't missed a year since. Here we see him receiving a bowling ball on his 35th service anniversary. Left to right: Herman Scheider, Jim Shindle, Gus Kallensee, Bill, himself, Marty Kastner, Dave Anderson, Reinhold Weihs and Henry Rosenbohm

R. D. Mindlin, a wartime member of Electronics Development, and now returned to Columbia, has been elected president of the Society for Experimental Stress Analysis. Dr. Mindlin is a consultant to the Laboratories on mechanical problems.

R. G. McCurdy has been designated as one of the Telephone Group representatives on the Standards Council of the American Standards Association. He succeeds R. L. Jones, who served for nine years on the Council.

A. L. Matte and R. B. Shanck attended the convention of the Association of American Railroads—Communications Section at Detroit.

C. A. Webber and W. J. King attended a conference of the Army and Navy Radio Frequency Cable Coördinating Committee on Coaxial Cables at the Bureau of Ships in Washington.

J. F. Barry and F. Caroselli visited Allentown in connection with the manufacture of crystal units.

W. E. Kahl and J. J. Cozine checked on the manufacture of filters at Winston-Salem for the new carrier telephone system used in power-line circuits.

C. D. Owens discussed the manufacture of compressed molybdenum permalloy powder cores at Hawthorne. He also conferred on measurements on magnetic recording tape at the Armour Research Foundation in Chicago.

V. E. Legg and J. E. Ranges participated in discussions on loading coils and loading coil cases with Western Electric engineers.

C. V. Lundberg was at Point Breeze on problems related to insulated wire.

W. H. Doherty spoke on *Western Electric FM Broadcast Transmitters* in a symposium on FM conducted by the New York Section of the Institute of Radio Engineers.

G. F. J. Tyne was at Winston-Salem on the manufacture of coils for the rural power line carrier system.

M. H. Cook and W. J. Adams conferred at Burlington and Winston-Salem on Bell Laboratories projects in that area. Other Whippany men who were at Burlington were A. C. Peyman and A. K. Bohren; and at Winston-Salem, J. W. Smith and F. E. Nimmcke.

N. C. Olmstead visited the Amertran Company on the design of power equipment for FM transmitters.

R. W. DeMonte visited Haverhill for conferences on transformers.

William Atkinson Dies

William Atkinson of the General Service Department died suddenly on December 28. Mr. Atkinson joined the Engineering Department of the Western Electric Company in 1918 as a shipping clerk. He left the company late in 1921 but returned to his former work the next year. More recently he has been assistant to the foreman of the Shipping Department.

H. G. Bandfield

R. D. Parker

W. T. Pritchard

H. M. Haglant

C. H. Hitchcock

O. F. Vollheim

RETIREMENTS

Recent retirements from the Laboratories include O. F. Vollheim, with 44 years of service; H. G. Bandfield, 41 years; H. M. Hagland, 40 years; C. H. Hitchcock, 39 years; R. D. Parker, 34 years; and W. T. Pritchard, 25 years.

Harold G. Bandfield

Upon graduation from the University of Michigan with a B.S. degree in 1905, Mr. Bandfield entered the Western Electric Company in the Clinton Street shop in Chicago. He came to New York in 1907 and worked on the development of protection apparatus, coin collectors, and ringing systems.

In 1916 Mr. Bandfield transferred to the Patent Department and his initial assignment was to a group concerned with the fields of protection and miscellaneous telephone and telegraph apparatus. A few years later he was assigned to the fields of submarine cable and magnetic alloys. In 1925 he was made supervisor of a group responsible for the preparation of applications on carrier-wave transmission and submarine cable systems. Subsequently, he was in charge of patent work relating to chemistry. For the past few years he has specialized on cords, capacitors and the field with which his career began, protection apparatus.

Ralzemond D. Parker

Mr. Parker, Telegraph Development Director, attended the University of Michigan, from which he received his B.S. degree in 1905 and an M.S. in 1906. He immediately joined the student course of the Western Electric Company at Hawthorne but left three months later to become an instructor of electrical engineering at his alma mater, being appointed Assistant Professor in 1909.

Mr. Parker joined the Engineering Department of the A T & T in 1913 to investigate special telegraph problems and was soon placed in charge of the telegraph equipment group at the time that printing telegraph applications in the Bell System were begun. Mr. Parker's early work in printing telegraph had to do largely with studies to determine the basic requirements of printing telegraph systems to meet Bell System needs.

In the immediate ensuing years, Mr. Parker's other responsibilities were the determination of the needs of the Bell System for all types of telegraph systems, including teletypewriter; outlining requirements and gauging the feasibility of individual projects; passing on new designs from the standpoint of practicability; arranging for field trials; and the issuing of information which standardized the new arrangements. He soon became engaged in the development of metallic telegraphy for cables, the first commercial application of which was on the New York-Philadelphia cable. He then was associated with the work to obtain more telegraph channels from telephone circuits by carrier currents. During World War I he was actively engaged in developing a cipher telegraph system in coöperation with the Signal Corps. His group developed a system of picture transmission which was demonstrated in 1923. Under his direction there has been initiated and carried forward the development of teletypewriter switching systems for private lines and TWX services.

In 1934, when the D & R was merged with the Laboratories, he was placed in charge of the Telegraph Facilities Department; and in 1940 was made Telegraph Development Director and took charge of an organization formed by uniting groups from several departments. During World War II he directed the development of a number of facilities which were used by the Armed Forces, including radio teletypewriter systems, improved teletypewriter cipher systems, carrier and d-c telegraph systems for use on field wire, spiral-four cable, and other facilities as well as a new system for use on submarine cables.

Mr. Parker has been appointed Chief, Research Branch, Civil Communications Section, Tokyo, by the War Department to take the place of K. E. Gould, who is returning to the Laboratories. He will supervise all telephone and telegraph research engineers.

William T. Pritchard

After completing an engineering course at Lewis Institute, Chicago, Mr. Pritchard was engaged for several years in the production of electrical apparatus and small tools. He joined the Manufacturing Planning Division of the Western Electric Company at Hawthorne in 1921. When the Installation Department was separated from the Manufacturing Department he was transferred to New York and placed in charge of time study and efficiency work in the General Installation Engineer's Office. In March, 1926, he transferred to the Switching Apparatus Development Department of the Laboratories, and was responsible, until 1941, for the design of maintenance apparatus, tools, and gauges for relays in panel step-by-step and crossbar systems. He then transferred to Outside Plant Development, which shortly thereafter moved to the Murray Hill location, where he has been concerned with the design of plant tools and apparatus.

Harvey M. Hagland

Mr. Hagland entered the Western Electric Company in the old Clinton Street, Chicago, factory and worked for a year on the inspection of subscribers' telephone sets. He then went with the Chicago Telephone Company. Until coming with the Western Electric Engineering Department in 1919 he worked on telephone installing, central office maintenance, local test work and switchboard repair. As a member of the Equipment Development Department he has been engaged on the engineering of toll equipment, local operating desks, local test desks and standard practices.

Since 1928 Mr. Hagland has also been concerned with the development activities on all kinds of manual and dial PBX's as well as a large variety of equipment on subscriber premises, including communications systems at large commercial airports. In World War II he engaged in the development of air-raid early warning systems involving radar equipment—permanent systems for large cities and portable types, both of which were made available to the Army and Navy.

Carl H. Hitchcock

In 1905 Mr. Hitchcock left the University of Chicago and a year later joined the Western Electric Company at Clinton Street in Chicago. Later he came to the New York Telephone Company and then, in 1910, transferred to inspection work at West Street. Following this he joined the lead-covered cable development group at Hawthorne, later shifting with part of the group to the Kearny plant, where he participated in many of the cable development projects, including that of the unit-type cable. In 1935 he transferred to what is now Switching Apparatus Development at West Street, and for several years he was engaged in base metal contact studies. During World War II he assisted in vibration and shock tests on components used in equipment developed for the Armed Forces. Since then he has been concerned with the development of apparatus for providing protection against fire and abnormal electrical effects.

Otto F. Vollheim

When Mr. Vollheim first joined the Western Electric Comany he worked on the assembly of relay coils and the inspection of desk stands. In 1914 he transferred to what is now the Development Shops, assembling coils, and later worked on the heat treating of steel. More recently he was placed in charge of impregnating and potting coils, capacitors and resistors.

At the Murray Hill Art Exhibit oils had an interest for L. K. Degen, G. E. Hanan and Ann Tremallo. G. P. Spindler was chairman for the 1946 exhibit, O. J. Barton, vice-chairman, and Dorothy V. Mason, secretary. First prize winners were V. L. Lundahl, Julius Andrus and J. P. Leis

News Notes

P. H. Smith addressed an I.R.E. Antenna Committee meeting in Washington.

E. T. Mottram, C. R. Wischmeyer, J. R. Logie, J. F. Sweeney and H. H. Bailey are in Boca Raton, Florida, flight-testing radar equipment.

J. E. Tarr is visiting Winston-Salem in connection with the manufacture of airborne radar equipment.

R. O. Wise participated in a conference on radar equipment at Wright Field.

W. H. C. Higgins and R. R. Hough conferred in Washington with Army Ordnance and Signal Corps engineers.

H. A. Baxter discussed solenoids for radar at the National Acme Company in Cleveland.

J. H. Hershey's visit to Winston-Salem was to obtain data from targets for system test specifications for newly designed radar.

V. I. Cruser visited the Harris-Seybold Company in Cleveland to discuss antennas for naval radar.

L. A. Dorff and R. H. Ricker spent three days in Detroit visiting Ford, General Motors and Chrysler plants in connection with the design of mobile radio-telephone equipment.

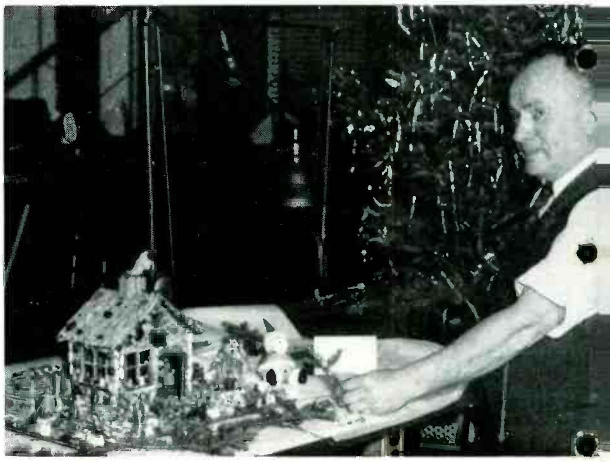
J. C. Bain and E. C. Hutchinson went to the Palmer-Bee Company in Detroit during December.

J. N. Walter and W. F. Smith spent some time at Kansas City investigating the initial installation of amplifiers having voice-controlled gain for use in centralized intercept and information service.

Mary Brainard was a member of a panel which spoke before the Parent-Teachers Association of the Rutherford Senior High School on December 10. The subject of the meeting was *Opportunities for the High School and the College Graduate in Industry.*

F. D. Leamer was the guest speaker at a recent Summit Rotary Club's luncheon meeting. He talked on *Job Evaluation.*

Constance Boesgaard of Transcription is ready to take your telephone dictation. This service requires less time than stenographic dictation, and it is hoped that you will use it for short, well-prepared material



C. R. Geith, who made this all-candy Hansel and Gretel house for his nine-year-old daughter, exhibited it in the Development Shop at the Murray Hill Laboratory on Christmas Eve

The Murray Hill Chorus enters the stage of the Arnold Auditorium to rehearse their Christmas program

HARVEY FLETCHER has been appointed chairman of the program committee for the spring meeting, May 8 to 10, of the Acoustical Society of America.

W. S. GORTON was a member of the Committee on Arrangements for the meeting, January 30 to February 1, of the American Physical Society in New York City.

M. B. GARDNER, J. R. POWER and F. M. WIENER, at the National Bureau of Standards in Washington, conferred with the Bureau on steps to be taken to re-establish audiometric reference levels for European use.

W. B. SHOCKLEY has been appointed one of six scientists to serve as an advisory group to the Policy Council of the new Federal Joint Research and Development Board. This group, which has recently had a series of week-end conferences at Washington, will advise on scientific problems relating to national security and on strategic matters in which scientific decisions are involved.

J. BARDEEN visited Purdue University where he spoke on *The Theory of Crystal Rectifiers* at a Physics Colloquium.

ELIZABETH J. ARMSTRONG has been elected secretary of the American Society for X-Ray and Electron Diffraction for a three-year period

New winter accident facts, based on research and tests by National Safety Council, reveal alarming increase of skidding and poor visibility crashes during snowy, icy weather. Authorities urge equalized brakes, using tire chains, windshield wipers, defrosters, good lights and lower speeds to minimize the added seasonal hazards of inadequate stop-and-go traction on snow or ice and reduced visibility

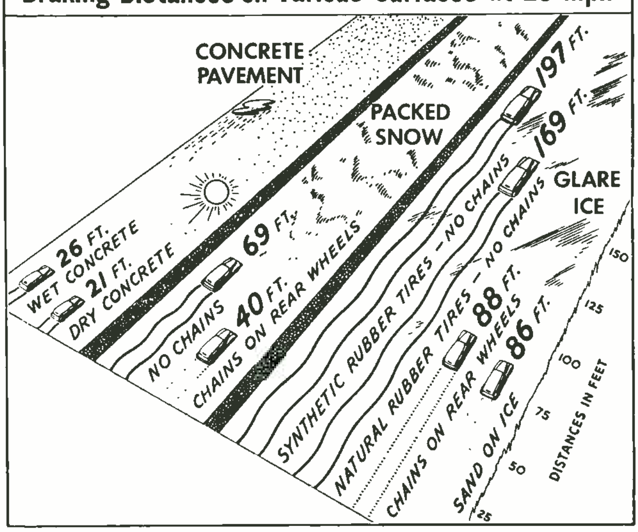
C. S. FULLER spoke before the Wooster, Cleveland and Pennsylvania-New York Border sections of the American Chemical Society. His subject was *The Interpretation of the Properties of Thermoplastics.*

R. W. HAMMING and J. W. TUKEY attended meetings of the American Mathematical Society at Swarthmore.

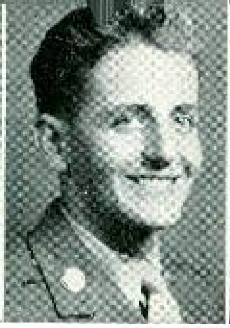
W. L. BOND gave two of a series of lectures on crystals to a group of Western Electric engineers at their Allentown plant. He spoke on *The Sawing, Grinding and Lapping of Crystals,* and on *The Specification of Axes in Piezoelectric Crystals and Their Determination by X-Ray and Optical Means.*

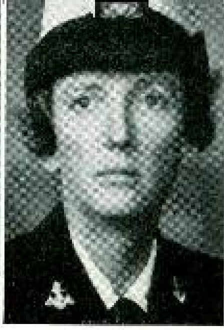
G. L. PEARSON visited the laboratories of Stanford University, Palo Alto, California, to inspect experimental work on superconduction.

Braking Distances on Various Surfaces at 20 mph




LIEUT. GERBORE


W. N. LEUFER


LT. COMDR. GRAY


R. E. HORNBRUCH


LT. COMDR. BAILEY


COL. FORI

RECENTLY RETURNED VETERANS

LIEUT. ALEXANDER E. GERBORE has returned to the Laboratories after serving as a B-29 navigator for thirteen months on Okinawa, where he flew weather missions and routine patrol missions. He also served as Communication Officer in charge of a telephone exchange with the 8th Air Force.

WILLIAM N. LEUFER was with the 7th Division on Hawaii and Okinawa shortly before the war's end and after that, for sixteen months, on Korea where he was a member of the Military Police in a machine-gun outfit.

LIEUT. COMMANDER MARGARET GRAY served four years in the Navy, the first fourteen months of which were in Washington with the engineering section of the Bureau of Aeronautics where her work was the coördination of miscellaneous aircraft instruments. Commander Gray was then assigned Women's Reserve Representative at Pensacola, Florida, where she was in charge of all enlisted and officer WAVES of the Naval Air Station. She was responsible to the Captain for the housing, welfare, discipline, recreation, messing facilities and uniform regulations of women on the base.

Leaves of Absence

As of December 31, there had been 1,055 military leaves of absence granted to members of the Laboratories. Of these, 961 have been completed. The 94 active leaves were divided as follows:

Army 48 **Navy 32** **Marines 3**

Women's Services 11

There were also 8 members on merchant marine leaves and 1 on personal leave for war work.

Recent Leave

United States Army
Howard L. Bond

R. E. HORNBRUCH has returned to the Murray Hill Laboratory after twenty months of Army service, sixteen of which were spent in Italy. He was engaged in the installation, repair and maintenance of communications equipment while overseas.

LIEUT. COMMANDER HAROLD M. BAILEY, a graduate of the Merchant Marine Academy at Kings Point, sailed as a cadet on Liberty ships in the Pacific in the deck and at times as a radio operator. Upon receiving his commission as an ensign, he sailed various merchant vessels on three trips around the world, receiving advances in rank as a result of each of these trips. He is now a member of the Systems Development Department.

COL. RAYMOND O. FORD, who was awarded the Legion of Merit at Nauheim in 1945, has returned to the position of assistant purchasing agent which he held before he entered military service in September, 1940. In addition to the Legion of Merit, he also received the Bronze Star, the French Croix de Guerre with palm and the Belgium Croix de Guerre with palm. Col. Ford held the reserve rank of major when he was called to active duty as an ordnance instructor in the R.O.T.C. at Cornell University. He taught there for a year before being assigned to Headquarters 1st Army as commander of the 41st Ordnance Battalion. In February, 1942, he received the rank of Lieutenant Colonel and in June, 1942, became an instructor in supply and transportation at the Command General Staff School, Fort Leavenworth. Col. Ford shipped to London in April, 1944, was assigned to the G-4 section of the 12th Army Group, and with that outfit arrived in France on D + 4. He remained with that group until it was disbanded in August, 1945, having in the meantime become a full colonel, and then joined the G-4 section of the 15th Army as a member of a board studying an analysis of the campaign. In February, 1946, he was assigned to the Office of Theater Chief of Ordnance at Frankfort, where he remained until he returned to this country and reverted to inactive duty.

UT. YAEGER D. W. GRAHAM F. J. DEMPSEY E. J. MAY A. H. SPECK LIEUT. WILLIAMS

LIEUT. ROBERT E. YAEGER received his Navy indoctrination at Fort Schuyler, studied radar at Princeton and Massachusetts Institute of Technology, and served aboard the U.S.S. *Saidar*, Fleet photo ship of Able and Baker days at the atom bomb test.

DOUGLAS W. GRAHAM was in military service three years, saw action in France and Germany, and after the war worked in the Paris military carrier-repeater station.

FRANKLIN J. DEMPSEY served approximately two years in the United States Navy Hospital Corps. He was on shore duty in Hawaii for seven months.

EDWARD J. MAY'S military service included A.S.T.P. training at Clemson College and clerical duties in Georgia and on Governor's Island in the Adjutant section of Headquarters.

ALBERT H. SPECK, following his boot training with the Marine Corps at Parris Island, was assigned to the Asiatic-Pacific Theater, where he spent the majority of his time at Peiping in electrical maintenance and repair work.

LIEUT. ROBERT S. WILLIAMS has returned to the Systems Drafting Department after three years of Signal Corps service. His overseas duties took him to Puerto Rico, where he was an outside construction officer, and to Trinidad, where he became a company commander of an Antilles Department Signal Service Battalion.

THE LABORATORIES has granted a personal leave of absence to the following veterans who are studying under the GI Bill of Rights: R. L. PRITCHARD, G. M. DEWIRE, J. F. LEYDEN, EDWARD FILIPOVITS, MARYROSE HANAVAN and J. F. MARTIN.

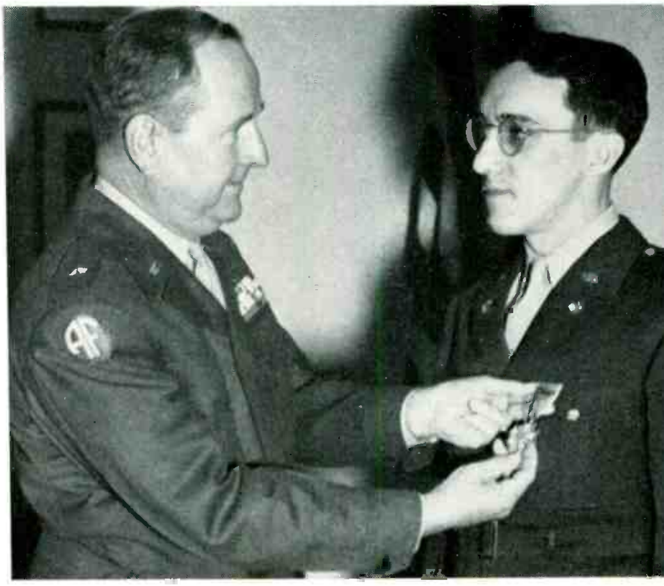
News Notes

F. E. HAWORTH and L. H. GERMER attended the December meeting in Pittsburgh of the American Society for X-Ray and Electron Diffraction.

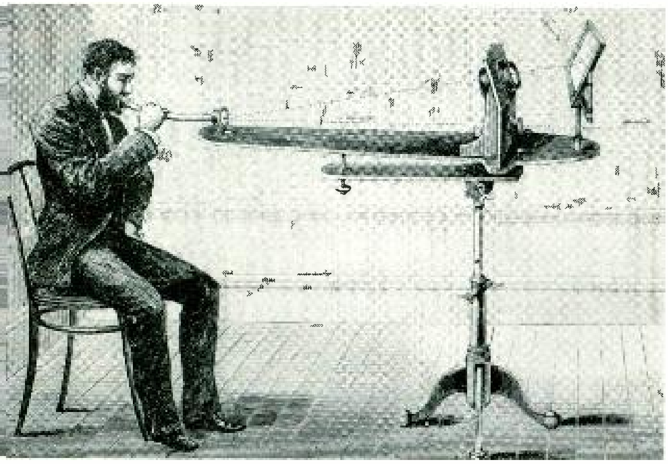
K. K. DARROW, J. E. KARLIN, R. M. BOZORTH, A. N. HOLDEN and R. B. GIBNEY attended meetings of the American Association for the Advancement of Science at Boston. Dr. Darrow has been appointed to the Committee on International Scientific Unions of the National Research Council.

W. P. MASON is author of *Elastic, Piezoelectric, and Dielectric Properties of Sodium Chlorate and Sodium Bromate,* published in the October, 1946, issue of the *Physical Review.*

F. F. ROMANOW attended Microphone and Executive Committee meetings and H. F. HOPKINS Loud Speaker and Executive Committee meetings of the Sound Equipment Section of the Radio Manufacturers' Association at Cleveland. Mr. Romanow and F. M. WIENER attended a meeting in New York of a special subgroup of the American Standards Association Subcommittee Z24B on Fundamental Sound Measurements.



Major William H. Lichtenberger received the Legion of Merit Medal from Brig. General J. V. Matejka, Commanding General of Fort Monmouth, during ceremonies on December 16. The citation read, in part, "Major Lichtenberger significantly contributed to the successful production and procurement of unprecedented quantities of vital signal equipment. He repeatedly demonstrated his unusual technical skill, high qualities of leadership and loyal devotion to duty."



Bell's original experiment transmitting speech over a beam of light made use of the optical system, above, and the parabolic reflector at right on the opposite page

When Bell Heard a Shadow

Take a beam of light, bright sunshine preferred. Let it fall on a mirror and so be reflected to a convenient target. Now let a sound wave flex the mirror; the spot of light on the target waxes and wanes. Bell did this back in 1880, and the pattern of sound traveling from mirror to target was the first instance of telephony without wires.

His mirror was the vibrating diaphragm of the telephone transmitter into which his assistant talked, his target a light-sensitive selenium cell. The parabolic reflector scooped up the sound-bearing light and focused it on the selenium. As the beam flickered, so changed the electrical resistance of the selenium and so, the current which flowed through it to the telephone receiver at the listener's ear.

Thus it was that Bell could write to his father: "I have heard articulate speech produced by sunlight! . . . The Photophone is an accomplished fact . . . I have been able to hear a shadow . . ."

Over in France, the scientist, Mercardier, promptly rechristened the device "Radiophone," marking the first use of the word "radio" in its modern sense.

Bell's method was not practical but the basic idea of talking over a beam of radiation was far ahead of its time, so far indeed that it took the communication art two generations and more to catch up, first in beamed microwave telephony and more recently in systems for talking by infar-red, achievements made possible by tools which Bell did not have: vacuum tubes and photoelectric cells.

Reminiscent too of Bell's experiment are the sound-bearing light beams of talking movies: the beam which deposits the sound pattern as a sequence of light and shadow when the film is made and the beam which later transfers the pattern to a photoelectric cell when the film is shown.

Engagements

*Eileen Fitzgerald–*Roy S. Boughrum, Jr.
*Helen Duerr–John G. Fernandez
Dorothy Evans–*John E. Galbraith
*Ruth Brundage–Edgar W. Hamilton
*Phyllis Mitchell–*William P. Harnack, Jr.
*Mary Pavlic–*John W. Hoell
*Jane Utting–Arthur A. Kopta
*Ruth Dempsey–Carlton R. Liddance
*Norma Malecki–Arthur A. Presby
*Muriel Brown–Maurice F. Rafter

Weddings

*Margaret Wehner–Russell A. Bowman
Catherine Groot–*A. O. Christiansen
*Hilda Lefkowitz–Selwyn Cooper
Yvette Jamneau–*Douglas W. Graham
Evelyn Boise–*John W. Kittner, Jr.
Barbara Taylor–*Donald R. Schoen

*Members of the Laboratories. Notices of engagements and weddings should be given to Mrs. Helen McLoughlin, Room 803C, 14th St., Extension 296.

New York-Chicago Radio Relay System

For an experimental radio relay system between New York and Chicago, application has been filed by A T & T with the Federal Communications Commission for authority to install terminal stations in the two cities. About three years will be required for development, engineering, and construction. Experience gained from the New York-Boston system, on which field trials will be made this summer, will be applied to the longer system. Since problems of circuit design and operation become more complex with distance, A T & T considers it important to gain experience in transmitting telephone conversations and television programs over longer distances. About 40 relay stations will be required along the route.

Income and Expense Records

Income and Expense Records have been distributed by Personnel to members of the Laboratories requesting them. The booklet is made up of a number of work sheets to aid in preparing a budget and in classifying expenses to help one to account for receipts, balances, disbursements, savings and insurance. Copies are still available on Extension 435 at West St.