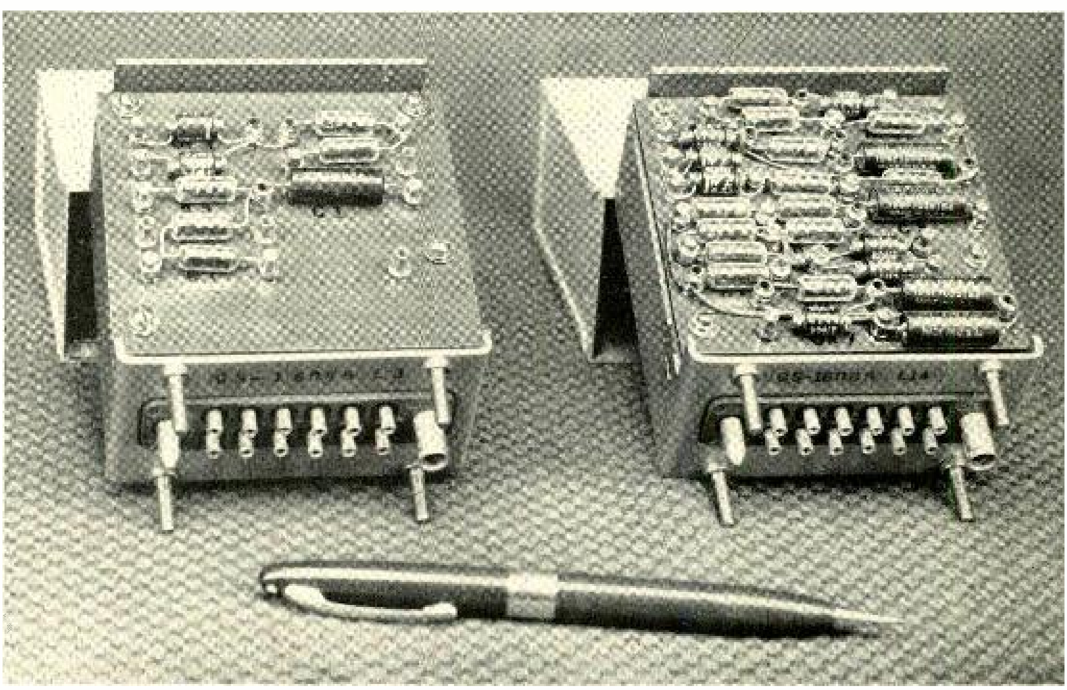
the sides, the "C" will be transformed into a satisfactory "U". The symbol "D" is formed, in a similar fashion, by applying a sine wave across the vertical and a half-wave rectified voltage across the horizontal plates.

In this symbol generator the wave forms needed for each character are produced entirely by the combination of a specially designed miniature transformer and a passive network completely housed in a compact plug-in container. A photograph of one such unit, used to form the symbol "C", is illustrated at the left of Figure 3, and the associated circuit diagram in Figure 4. The full-wave rectified voltage applied to the horizontal plates, is produced through the use of two germanium rectifiers as shown in the lower branch of the network in the diagram. The upper branch of the network contains a conventional R-C combination that shifts the phase of the impressed 10-kilocycle sine wave by 90 degrees. The load resistor in each branch of the network consists of two resistors in series and the output is taken off across one part of this voltage divider. The choice of values for these two resistors, together with the selection of the number of turns in the transformer secondary windings, determines the size of the character.

In the examples given above, the characters can be formed by a single trace. Some symbols, however, require two or more traces to complete. The "P", for example, is formed by first producing a small "D" as described and then adding a short vertical line in the proper place. A "B" consists of a combination of two "D's"; after the first is formed, a second is placed directly below it. In all characters generated by two or more elements, these elements must be positioned accurately with respect to each other. This is done by the use of small fixed dc bias voltages applied between the networks used to generate each element and a common reference point. AC voltages from additional transformer secondary windings are rectified by germanium diodes and filtered by R-C networks to provide these dc bias voltages. Adjustable positioning voltages applied between the reference points on each network

*Fig. 3—Plug-in units that develop wave forms used in forming characters. The unit at the left contains all the components required to generate the wave forms for a "C" and that on the right, a "2".*



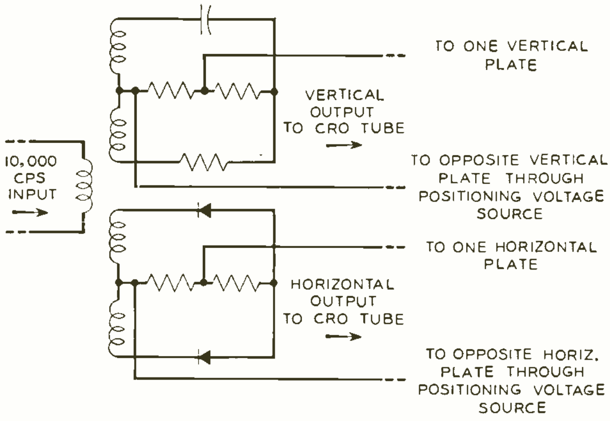
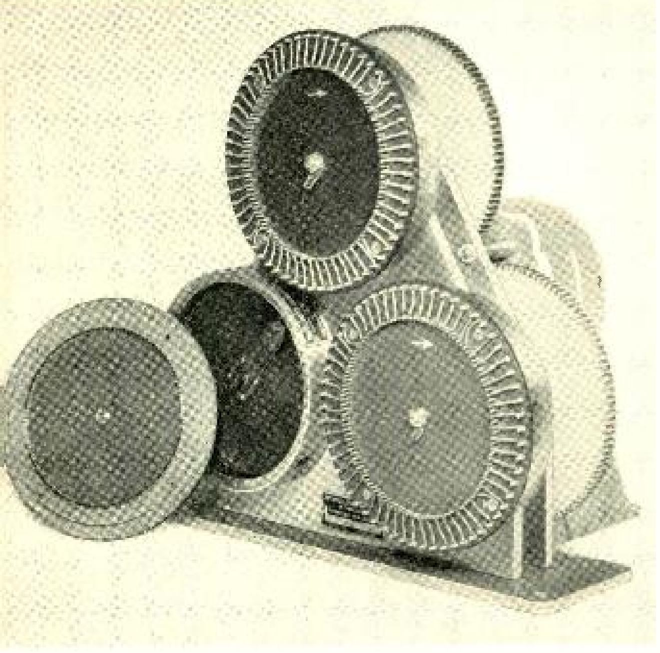



*Fig. 4—Simplified schematic for the network used to produce the wave forms for the letter "C". This network is shown at the left of Figure 3.*

and ground will cause the character to change position on the screen of the CRO tube as these voltages are varied.

An example of a complex character is the numeral "2" which requires two elements in its formation. The first is a "C" oriented to open downward and the second is the element ∠. The first element is produced by using the same type of networks used to form the "C" and interchanging the signals on the horizontal and vertical plates. The second element is formed by applying a half-wave rectified voltage to the vertical plates, produced through the use of a transformer secondary and a single germanium rectifier, and a similar full-wave rectified voltage impressed across the horizontal plates. Two bias rectifiers are also used, one in the vertical branch of the network and the other in the horizontal branch to position the two elements with respect to each other. When the two elements are combined on the screen, the result is a well-formed "2". The right-hand portion of Figure 3 shows the unit used to generate the wave forms for this numeral.

*Fig. 5—Switch assembly with contact plate removed from one switch to show contacts and wiper arm.*



To produce the symbols that require more than one element, or a display of several characters, some arrangement must be provided to paint the elements in the proper order and in rapid succession. The minimum frequency at which the successive elements must be retraced is determined by the persistence of vision of the human eye and the storage effect of the phosphor of the cathode ray tube. This painting of more than one symbol is accomplished through the use of a motor-driven three-pole, multicontact, rotary switch assembly developed for the laboratories by the Applied Science Corporation of Princeton, N. J. The switching system is designed to apply the symbol generating wave forms to the horizontal and vertical plates of the cathode ray tube. After one element has been traced, the switch applies the output of the next element network to the tube and due to persistence effects, the combination of these two elements appears to form a complete character. This process can be extended to trace forty or more symbols, formed by sixty elements in a display that appears simultaneous to the eye. The switch is also used to brighten the traces while the symbols are being generated and to blank out the trace lines that would otherwise connect the various characters and so tend to obscure the pattern. A switch assembly consists of three switches, each with a series of sixty large and sixty small contact pins arranged alternately in a circle on its contact plate, and an associated wiper arm. These arms are synchronized and driven through a gear train by a common motor. Figure 5 shows the motor, gear train, and the three switches comprising a switch assembly. The contact plate of one switch has been removed to illustrate the details of the contacts and the wiper arm. Figure 6 is a close-up view of this plate showing the large and small contacts in detail.

One switch in the assembly is wired to connect the horizontal output of the networks to the horizontal deflection plates of the tube. The second connects the vertical output to the vertical plates, and the third is connected to provide brightening pulses to the grid of the CRO tube.

The two switches used to apply the signals to the horizontal and vertical deflection plates are wired in such a way that only the large contacts are active. Since the large and small contacts are alternately placed on the face of the contact plate, the wiper arm will move off a live contact and across a dead one before encountering the next live position. By placing a dead contact between the two live ones in this way, transient short circuits that might be

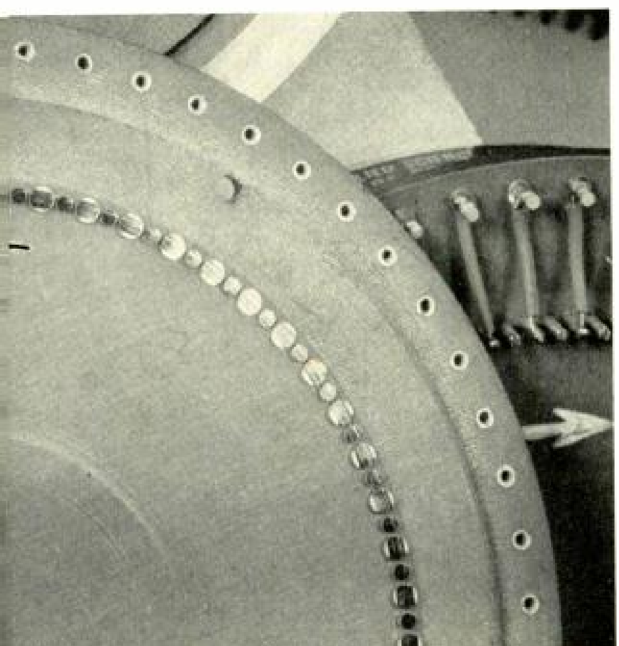


*Fig. 6–Detail of large and small contacts on switch plate assembly.*

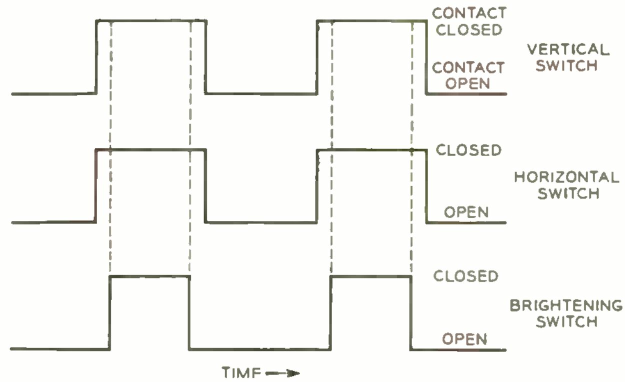



*Fig. 7–A diagram showing the magnitude and time relationship of the open and close times of the horizontal, vertical, and brightening switches.*

caused by the wiper arm bridging a pair of adjacent live contacts are eliminated. One switch then, contains sixty active contacts, each forming a path through the wiper arm from a passive network producing a horizontal or vertical wave form for one symbol element, to a pair of plates in the tube. The corresponding contact on a second switch applies the associated wave form to the other pair of tube plates. Since each character requires either one or two elements in its formation, such a unit is capable of producing about forty symbols. The actual number may be somewhat higher or lower depending on the complexity of the characters chosen.

As the motor drives the wiper arms over the corresponding contacts on these switches, a character element is displayed on the screen. The arm remains in contact with a particular pin for about 0.3 millisecond and hence each element is formed at least three times during this period by a signal source of 10,000 cycles per second. After the brushes have passed over the dead contacts, the next element is formed and this process is continued through the complete cycle. It has been found that a wiper arm speed of twenty cycles per second paints each element sufficiently often to remove all flicker when an amber filter is used with a CRO tube which has P-7 phosphor.

The third section of the switch is used to control the brightening of the trace pattern. With this section in an off position,

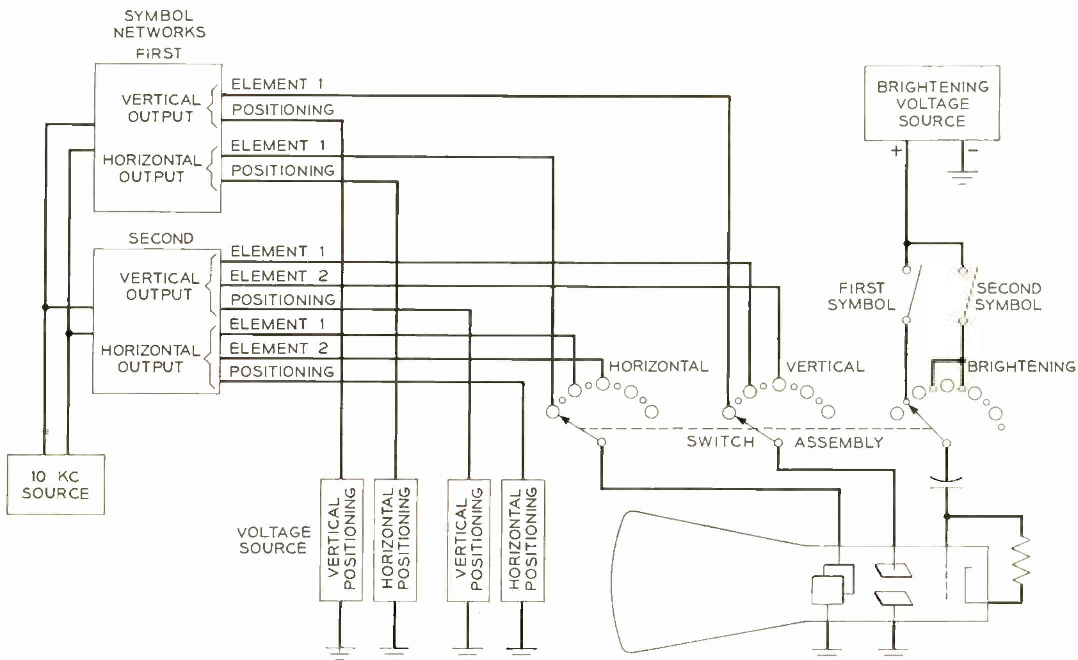



*Fig. 8—A simplified diagram illustrating the use of the switch assembly in applying the wave forms for a single and double-element character to the CRO tube.*

the voltage on the grid of the cathode ray tube is adjusted to a point where the trace on the screen is just extinguished. Then, as the switch operates, it applies a positive pulse to the grid of the cathode ray tube which accelerates the electron stream sufficiently to produce a visible trace on the screen for the duration of the pulse. The brightening switch is identical in design to the other two in the group but is wired with the small contacts active and the large ones inactive. The three switches are synchronized so that the wiper arms on the switches used in the horizontal and vertical deflection circuits are in contact with large-diameter contact pins at the same instant that the wiper arm on the brightening switch is in contact with a small-diameter pin. Due to the difference in pin size, the horizontal and vertical wiper brushes will make contact first and break last. The brightening pulse therefore is applied to the CRO tube grid for a shorter period of time than the symbol writing information is applied to the deflection plates. Switching transients and noise produced when

**THE AUTHOR:** C. Wilson Norwood, a member of the Military Electronics Department, joined the Laboratories at the outbreak of World War II. Prior to that he had his own business, a radio shop, from 1927 until 1942. At the Laboratories Mr. Norwood was assigned to work on Navy radar equipment. After the war he worked on the design of AM and FM broadcast transmitters, and since 1947 he has been engaged in the development of electronic apparatus for the government.

the wiper brushes make and break contact therefore do not appear on the CRO screen. The path of the electron beam as it moves from one symbol to the next would normally appear as a trace, but this is also blanked out. Figure 7 shows diagrammatically the magnitude of the open and close times of the three switches involved, and their time relationship.

The diagram in Figure 8 illustrates the use of this switch assembly in applying the outputs of two sets of symbol networks to the tube; one set for a single-element character and one for a double-element character. For the single-element character, four leads come from the network—two for the horizontal wave form, and two for the vertical wave form as shown in Figure 4. One horizontal wave form lead terminates at a contact on the horizontal switch and one vertical wave form lead terminates at the corresponding contact on the vertical switch. The other horizontal and vertical output leads are carried to ground through the positioning-voltage sources. The brightening voltage is applied to the corresponding contact on the third switch from a separate, adjustable, dc source. As the wiper arms touch these contact pins, the wave forms are fed to the plates of the tube and a positive pulse is applied to the grid to make the resulting trace visible. The two-element symbol is formed in a similar fashion with the wave forms needed to produce the first element applied to one set of contacts and those required for the second fed to the adjacent live contacts. Since the wiper arms rotate at twenty cycles per second, these elements are retraced every twentieth of a second and at this rate, the resulting image appears continuous.

The particular characters desired for a display are selected through the use of manually operated single pole switches connected in the brightening circuit between the voltage source and the rotary switch contact corresponding to each symbol. By opening the appropriate switches, the brightening voltage can be eliminated from any desired contacts and the corresponding symbols will not appear in the display. This means that, although the wave forms for all thirty characters are applied to the deflection plates, only those selected by the operator are made visible.

As a means of producing letters and numerals on a CRO screen, this symbol generator is simple and effective. In comparison with methods previously used it requires much less apparatus and appears to be much more versatile in its application. Present design calls for the generation of the numerals 0 to 9 and the capital letters of the alphabet. By use of the fundamentals here described, however, network units may easily be designed to generate the lower case letters, Greek letters or geometric symbols as they may be required for future applications.

The development work for this symbol generator was done under contract with the Bureau of Ordnance of the U. S. Navy.

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## Customer Toll Dialing at Englewood

Having completed a year's successful trial, nation-wide customer toll dialing at Englewood, N. J., is to be continued on a regular basis by the New Jersey Bell Telephone Company. During 1952, Englewood customers dialed about 130,000 long distance calls, or more than 96 per cent of the foreign area calls it was possible for them to dial.

## York, Pa., and Atlantic City Added to Television Network

A microwave installation making network television service available to York, Pennsylvania, has been placed in operation by Long Lines. Network service has also been made available to Atlantic City, New Jersey, by radio relay out of Philadelphia. With the addition of these two facilities, network programs are now available to 114 television stations in 71 cities.

# The N1 Carrier Oscillators

J. J. DE BUSKE
*Transmission Systems Development*

Oscillators for the N1 carrier system must meet the same general objectives established for other components in the system —reliable equipment and apparatus, relatively low cost, small size, and ease of installation and maintenance. These objectives have been realized and the oscillators for the Type-N system have given very satisfactory performance.

Two types of oscillators are required: (1) those for use in terminals, where twelve frequencies are required at intervals of 8 kc, starting at 168 kc up to and including 256 kc; and (2) those for group units and repeaters, with a frequency of 304 kc. Since the repeaters may be mounted on poles along the cable route, their oscillators had to be designed for operation over rather wide variations in temperature and supply voltage. The channel and group carrier oscillators, on the other hand, are located indoors, and thus are not subject to such severe requirements.

Because of the need to hold the frequency within ± 25 cycles at 304,000 cycles, quartz crystal oscillators* are employed. One basic oscillator circuit is used, and the different frequencies are established by inserting different crystals in the circuit.

The equivalent electric circuit of a piezoelectric quartz crystal is shown in Figure 1, where:

$L_1$ is the equivalent electrical series inductance

$C_1$ is the equivalent electrical series capacitance

$R_1$ is the equivalent electrical series resistance

C is the equivalent electrical shunt capacitance

* Record, *October*, 1929, *page* 54.

Electrically, the crystal is a "high Q" (low loss) tuned circuit possessing series and parallel resonances. By connection the proper capacitance across the crystal and using an electron tube to overcome the circuit losses (including those of the crystal), oscillations can be generated and sustained. The frequency of oscillation is determined by the crystal, but depends to a small extent on the value of the circuit capacitance shunted across the crystal. During manufacture, the crystal is ground and adjusted so that the series and parallel resonances occur within the desired limits of the nominal frequency for this crystal. If this adjustment of the crystal resonance is within the specified limits, the frequency of the oscillator will be very near the right value. Changes in temperature of the crystal, however, change the frequency at which it resonates, and thus the output frequency of the oscillator. Crystals for the 304,000 cycle oscillator are thus adjusted during manufacture to a resonance frequency that is within 9 cycles of the desired value, and variation in the resonance frequency due to changes in temperature are within ± 10 cycles.

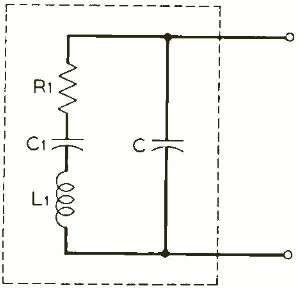



*Fig. 1 – Equivalent electrical circuit of a quartz crystal.*

The circuit of the 304 kc oscillators for both group units and repeaters is shown in Figure 2. A 408A electron tube is used, with feedback from the screen grid to the control grid. The plate, or output, circuit is electronically coupled to this oscillator, that is, the electron stream between the cathode and the plate is coupled to the electron stream between cathode and screen so that variations in this latter stream cause the plate stream also to vary. This method of coupling the load to the oscillator has the major advantage that it practically eliminates the effect, on the frequency of oscillation, of the load impedance connected to the output terminals. This is necessary because oscillators supply the carrier frequencies to copper oxide modulators, which vary widely in impedance, and the frequency of the oscillator must not be affected by these variations.

None of the circuit components, except for the crystal and capacitor $C_6$, need be held to close limits. The capacitors and resistors are small in size and relatively inexpensive; the most severe tolerance is ± 5 per cent. The oscillator output transformer, like the other transformers used in the N1 system, is small, and inexpensive to manufacture.

The harmonic content of this type of oscillator is high, and thus filtering of the fundamental frequency is required for repeater use. Part of this filtering is obtained by designing the output transformer as a tuned transformer, using capacitor $C_6$ to tune it to the fundamental frequency. This is a matter of economics – it is much less expensive to build a capacitor within 1 per cent limits than to hold the inductance of the transformer to close limits. The remainder of the harmonic filtering is done by the filter circuit containing $L_2$, $C_{10}$, $C_{11}$.

To obtain the accuracy inherent in the crystal in the complete oscillator, there are two conditions that must be realized at the crystal: both the magnitude of the oscillating voltage applied to the crystal, and the capacitance of the circuit terminating the crystal must be held within specified limits. In the oscillator circuit of Figure 2, $R_2$ and $C_2$ form the screen load impedance, and in part determine the magnitude of the oscillating voltage applied to the crystal. Capacitor $C_3$, in addition to blocking the dc screen voltage from the crystal, couples the signal from the screen grid of the tube to the crystal. Grid leak bias for the control grid is provided by $C_5$ and $R_5$ and, with the crystal and capacitor $C_3$, form the feedback circuit.

When power is applied to the tube, the circuit will oscillate at a frequency somewhere between the series and parallel resonance of the crystal, depending on the value of the total shunt circuit capacitance as determined by $C_3$, $C_5$, $C_2$, and the grid-cathode and screen-cathode capacitances of the tube. With the tolerances of the components used, (including the crystal) the accuracy requirements of the oscillator have been met. The only elements, other than the crystal, which influence the frequency are capacitors $C_3$ and $C_5$. A one mmf change in either one results in approximately a

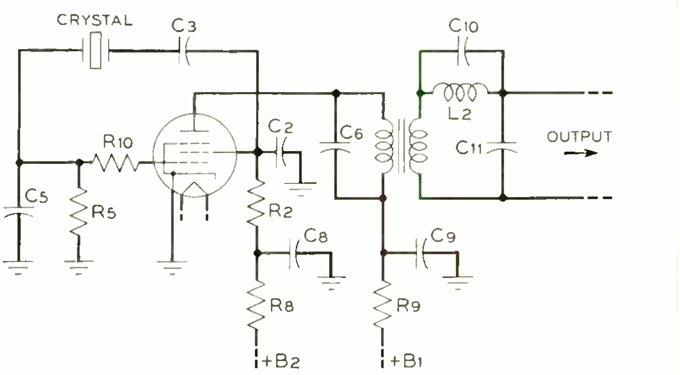



*Fig. 2–Circuit of the 304 kc (group unit and repeater) oscillator.*

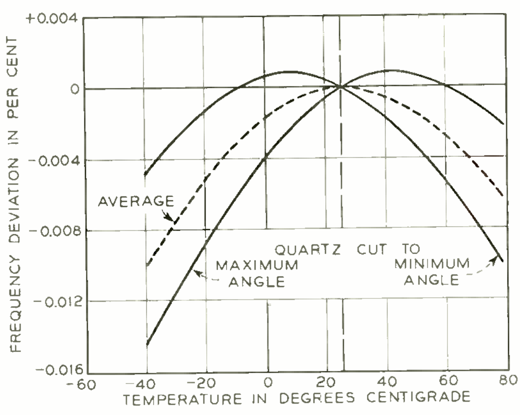



*Fig. 3–Temperature characteristics of a typical crystal used in repeater oscillators.*

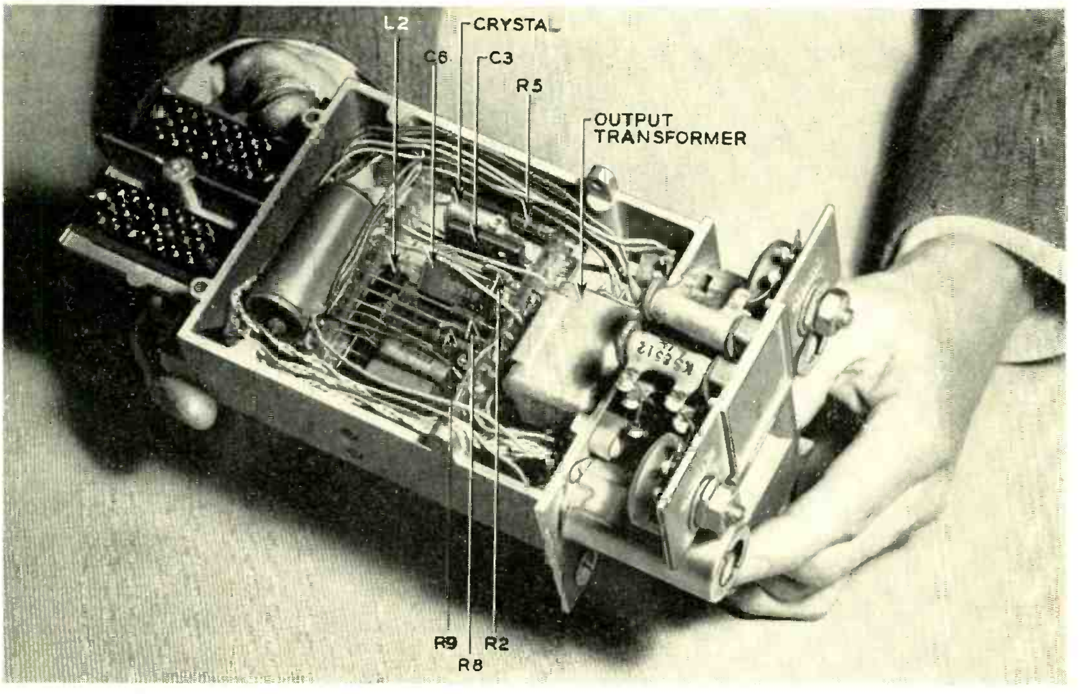
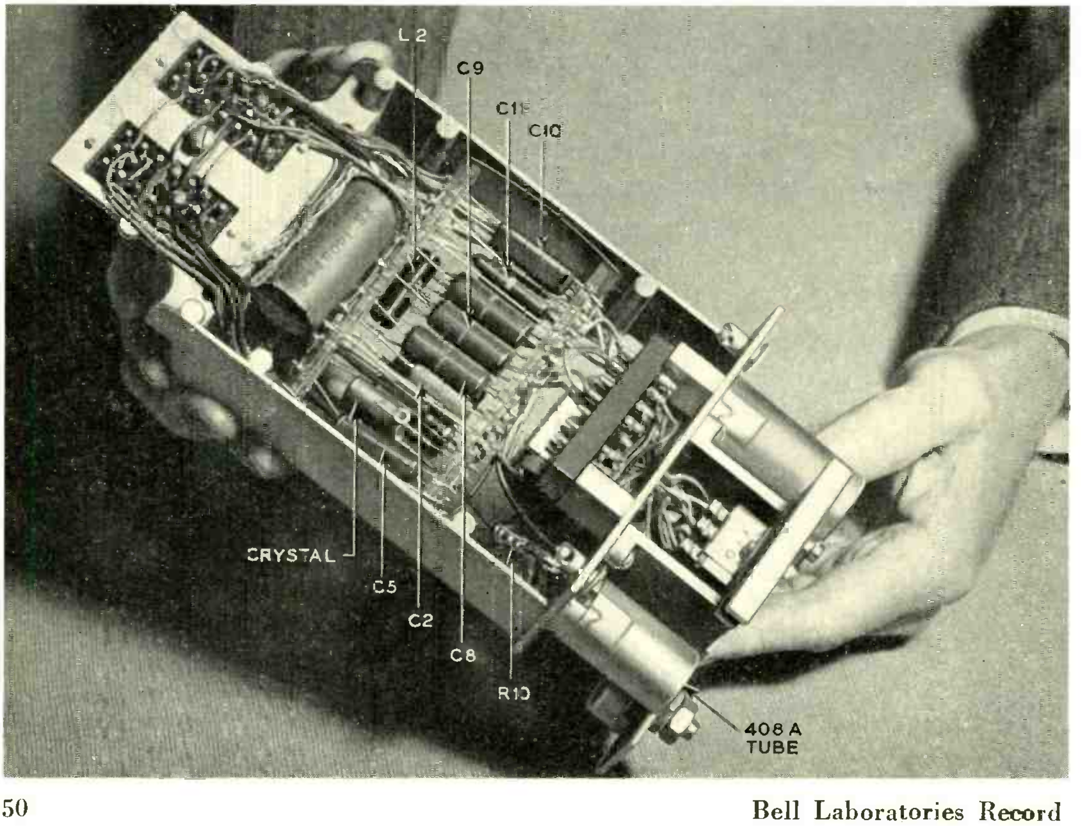



*Fig. 4—The oscillator components are mounted on a sub-assembly panel along with other components. The top of the panel is shown above and the back at the bottom.*



half-cycle change in frequency. Since the maximum possible change in capacitance due to the tolerance of $C_3$ and $C_5$ is approximately 5 mmf, a maximum change in frequency of 2.5 cycles is possible. Capacitor $C_2$ is less critical than $C_3$ and $C_5$; it requires a 10 per cent change to produce a 0.3-cycle change in frequency.

Plate and screen filter circuits are provided by $R_9$ and $C_9$, and $R_8$ and $C_8$; these have negligible effect on the frequency of oscillation. Resistor $R_{10}$ is inserted in series with the control grid to prevent spurious oscillations at a frequency of approximately 200 megacycles. Variation in frequency due to variations in the tubes is less than half a cycle, and a 10 per cent change in plate voltage also has negligible effect on the frequency. A change in screen voltage has little effect on the frequency but does give a relatively large change in oscillator output power. Since power for the repeaters is furnished over the cable, and its voltage changes with variations in cable resistance due to temperature, the screen voltage is obtained from the regulated voltage provided for the heaters of the tubes.

Crystals used in the repeater oscillators have a variation with temperature as shown in Figure 3. Frequency accuracy, as measured in a crystal test set, is specified as ±0.007 per cent over a temperature change from —10 degrees to +50 degrees C (14-122 degrees F). This includes, besides the variation with temperatures, the accuracy (±0.003 per cent) to which the crystal is manufactured. To obtain a symmetrical plus or minus tolerance, it is necessary to adjust the frequency of the crystal, at room temperature, about 8 cycles above the nominal frequency. This is because the change in frequency at the lower temperatures is greater than at the higher temperatures. This value is called the "offset" frequency.

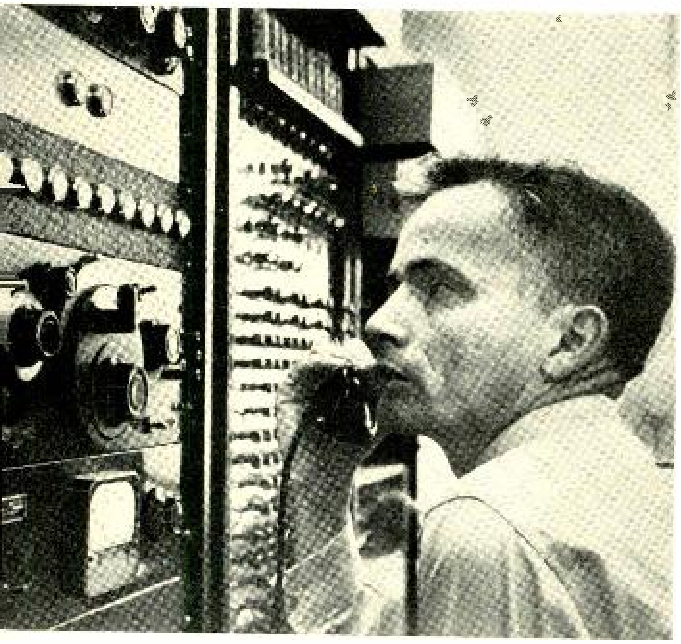
The temperature range over which the repeaters must operate is —10 degrees to +60 degrees C (14 to 140 degrees F). Over this range, frequency variations of ±10 cycles can be expected. Added to the manufacturing accuracy previously mentioned (±0.003 per cent, or ±9 cycles), the total crystal accuracy is ±19 cycles. This means that at room temperature the crystal frequency may be 304,008 ±9 cycles, but over the entire temperature range it will be 304,000 ±19 cycles. Tolerances in circuit components will add a maximum of ±3 cycles; hence the repeater oscillator frequency will have an over-all variation of ±22 cycles – which is within the design objective of ±25 cycles.

Group carrier oscillators are identical in design to the 304 kc repeater oscillators except for minor changes in circuit components necessary for operation on stable central office battery. The channel carrier oscillator is similar in design to the repeater carrier oscillator, and utilizes the same types of components. Since Type-N terminals are located in heated central offices, the temperature range is not so large as that for the repeater carrier oscillator. The circuit for all twelve channels is the same except that the required frequencies are obtained by using the appropriate crystal. No suppression of harmonics is required for channel use.

**THE AUTHOR:** J. J. DE BUSKE received his B.S. in E.E. degree from Newark College of Engineering in 1941. As a technical assistant in the Systems Development Department, while attending Newark College Evening School, he was engaged in the testing and maintenance of laboratory test equipment. In 1941 he was assigned to engineering of repeaters for carrier systems, and in 1943 became a Member of the Technical Staff. During World War II, he worked on microwave radio telephone systems and radar for the Armed Forces. Since the war, his activities have been concerned with short-haul carrier-telephone systems.

# Automatic Digit Recognizer

An electronic device that can understand and intelligently react to spoken numbers has been built at the Laboratories. Named "Audrey," which is a contraction of "automatic digit recognizer," it is a special circuit that can automatically determine which of ten numbers, from 1 through 0, has been spoken into a telephone.



*An electronic telephone device which can understand and intelligently react to spoken numbers is put through its paces by K. H. Davis. "Audrey," as the device is known, has a special circuit which automatically determines which of ten numbers has been spoken into an ordinary telephone, and flashes an appropriate light.*

In its present form, the device responds by flashing an appropriate light, but it may equally well control other operations, such as dialing mechanisms. Ultimately it is hoped to extend the device's vocabulary to include additional sounds – words other than numbers – and it is expected that the device may even be taught to say some words on command.

The newly constructed recognizer operates on a principle of memory and matching. It listens to the human voice, then sorts the speech sounds into electrical categories that conform in their own medium to sound wave patterns. These categories are analyzed by matching against a memory cell containing standard reference patterns already set up electronically. When the standard pattern is found which best matches the electrical pattern of the spoken number, the appropriate light flashes on. When the device is adjusted for best performance with a particular speaker, it operates with high accuracy, but it is not yet in a state to answer reliably to a wide variety of talkers unless it is readjusted for each one. It will not tolerate careless enunciations or accents.

The automatic recognizer is the subject of a technical paper, published in the November, 1952, issue of the *Journal of the Acoustical Society of America*, by K. H. Davis, R. Biddulph, and S. Balaskel. A technical article will also be published in a forthcoming issue of the RECORD.

## Additions to Nation-Wide Radio Relay Network

During December, three links were added to the Bell Telephone System's nation-wide radio relay network, providing expanded facilities for telephone message and television service. An additional westbound channel has been placed in service between Chicago and the West Coast on the transcontinental route. This channel parallels existing radio relay facilities, which are routed to the Coast by way of Omaha and Salt Lake City.

On the Pacific Coast, two additional channels have been opened, one northbound and one southbound between Los Angeles and the San Francisco area. The northbound channel originates at Los Angeles and it is routed to San Francisco via Oakland. The southbound channel connects Oakland with Los Angeles. Both of these channels are joined to the transcontinental group opened by the Bell System on August 17, 1951.

# The AMA Computer:

## Chargeable Time and Message Unit Computations

MARY E. PILLIOD
*Switching Systems Development*

Although the computer of the AMA system has many functions, the one from which it derives its name, and its chief one, is computing. The computing operations are all related to the determination of charges for calls, and include: the calculation of the conversation time, the deduction of a fixed allowance from the calculated conversation time to compensate for recording variations, the rounding off of the net conversation time to whole minutes, and, for calls that are to be bulk billed, the conversion of chargeable time into message units.

The computations are based on information found in the three entries that the computer receives for each completed AMA call. From the answer entry and the disconnect entry, the conversation time can be calculated. After this conversation time has been adjusted and rounded off, it becomes chargeable time. How this chargeable time is used depends on whether the call is a message-unit call or a toll call. This information is contained in the initial entry. Message-unit calls are rated by the computer in terms of message units, and the charges for all such calls are lumped together at subsequent stages of processing and appear as one item on the subscriber's

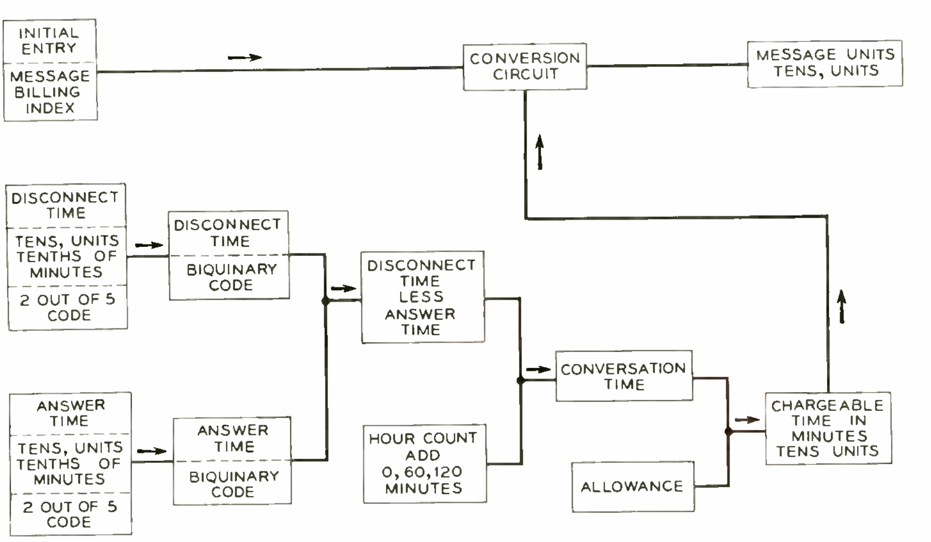



*Fig. 1—Block diagram of the computing operations.*

TABLE I — THE TWO-OUT-OF-FIVE AND THE BI-QUINARY CODES.

| *Decimal Digit* | *Two-out-of-Five* | | *Bi-Quinary Equivalent Bi* | *Quinary* |
|---|---|---|---|---|
| 0 | 4 | 7 | 0 | 0 |
| 1 | 0 | 1 | 0 | 1 |
| 2 | 0 | 2 | 0 | 2 |
| 3 | 1 | 2 | 0 | 3 |
| 4 | 0 | 4 | 0 | 4 |
| 5 | 1 | 4 | 5 | 0 |
| 6 | 2 | 4 | 5 | 1 |
| 7 | 0 | 7 | 5 | 2 |
| 8 | 1 | 7 | 5 | 3 |
| 9 | 2 | 7 | 5 | 4 |

bill at the end of the month. Toll calls are rated at a subsequent accounting stage after the computer has determined the chargeable time, and all of these calls will appear individually on the bill that is sent to the customer.

A diagram of the computing operations is shown in Figure 1. The first step in the computations is to translate the disconnect and answer times from the "two-out-of-five" code in which they were originally recorded to the "bi-quinary" code, which is to be used for computing. The "two-out-of-five" and "bi-quinary" codes are given in Table I. Although there are many codes available for use in computing, the "bi-quinary" most nearly meets the requirements of the situation. These are: easy translation to and from the "two-out-of-five" code, which is employed in AMA, easy translation to and from the decimal code for the convenience of accounting and maintenance personnel who work with the machine, relatively simple computing networks, economy of apparatus—only seven elements are required to represent the ten decimal digits—and the ability to be made self checking.

The computation of conversation time requires the subtraction of the answer time from the disconnect time. Since both times are recorded in tens, units, and tenths of minutes after the last hour, this amounts to the subtraction of one three-digit number from another. Although a direct subtraction operation might have been performed the "complements adding" process, which has been fully described previously*, is used for calculating the conversation time.

In calculating conversation time, the computer must also take into account the passage of hours. Entries are recorded at the beginning of each hour and are registered and checked by the computer as has already been described†. To compute conversation time, it is necessary to know how many hours have passed between answer and disconnect times. The computer has an "Hour Count" circuit which supplies this information, and, after the answer time has been subtracted from the disconnect time, an adjustment is made for the passage of hours. Let us assume a call that was answered at 17.3 minutes after an hour and disconnected at 35.7 minutes after an hour. Subtracting the answer time from the disconnect time gives a result of 18.4 minutes. If the hour count shows that no change has taken place in the hour between the answer and disconnect times, then 18.4 minutes is the conversation time. If the hour changes once, the answer being at 9:17.3

TABLE II — REPRESENTATIVE CHARGING PLANS IN USE IN THE BELL SYSTEM

| *Billing Formula* | *Initial Charge in Message Units* | *Initial Period in Minutes* | *Overtime Charge in Message Units* | *Overtime Period in Minutes* |
|---|---|---|---|---|
| A | 1 | 5 | none | .. |
| B | 1 | 5 | 1 | 5 |
| C | 2 | 5 | 1 | 3 |
| D | 3 | 5 | 1 | 2 |
| E | 4 | 5 | 1 | 2 |
| F | 5 | 5 | 1 | 1 |
| G | 6 | 3 | 2 | 1 |
| H | 6 | 4 | 1 | 1 |
| J | 7 | 3 | 2 | 1 |
| K | 7 | 4 | 2 | 1 |
| L | 8 | 3 | 2 | 1 |
| M | 3 | 3 | 1 | 1 |
| N | 4 | 3 | 1 | 1 |
| P | 5 | 3 | 1 | 1 |
| Q | 4 | 5 | 1 | 1 |

* RECORD, *December*, 1946, *page* 457.

† RECORD, *July*, 1952, *page* 289 *and November*, 1952, *page* 422.

and the disconnect at 10:35.7, for example, then sixty minutes must be added to get the conversation time of 78.4 minutes. Similarly, if the answer had been at 8:17.3 and the disconnect still at 10:35.7, the hour would have changed twice, i.e., from 8 to 9 and then from 9 to 10, and 120 minutes must be added to get the conversation time of 138.4 minutes.

After the conversation time has been calculated, a small time allowance is made to cover any delay that might have occurred at the central office between the actual disconnect and its recording on the tape. The conversation time adjusted in this manner is then rounded to whole minutes. With an allowance of 0.1 minute, a call with conversation time of 18.4 minutes would fall in the interval 18-19 minutes (designated by 19) while a call with conversation time of 18.1 minutes would fall in the interval 17-18 minutes (designated by 18).

The subsequent treatment of this chargeable time depends on the message billing index, which was registered as part of the initial entry. If the billing index indicates that the call is a toll call, the chargeable time is registered and the computing operation is completed for the call, since the charges will be determined at a later time. If, however, the billing index indicates that the call is of the bulk billed variety, message unit charges must now be computed according to the billing formula designated by the billing index.

There are many billing formulas in use throughout the Bell System, and the conversion of chargeable time to message units depends on which billing formula applies to the particular call. Each formula specifies an initial time interval and the charge in message units for this interval, and also the length of and the charge for the overtime interval. Some typical billing formulas are listed in Table II. The message-unit charge for each length of chargeable time from zero to thirty minutes for eight of these billing formulas is given in Table III. If a call lasted for fourteen minutes, for example, and billing formula C applied, the charge would be five message units.

In calculating the number of message units applicable to each call, the computer employs circuits that are equivalent to a set of tables, like Table III, but with a chargeable time running from zero to ninety-nine minutes. Calls which last longer than ninety-nine minutes or for which the charge is more than ninety-nine message units are recorded on a special output tape and are rated manually.

The circuit for converting chargeable time to message units may employ any number of billing formulas up to a total of eight. Although there are many more than eight formulas employed in the Bell System, there will not ordinarily be more than

Table III — Message Unit Charges for the Billing Formulas of Table II and for Chargeable Time Up to Thirty Minutes

| Chargeable Time | Billing Formula | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | J |
| 00 | 01 | 01 | 02 | 03 | 04 | 05 | 06 | 07 |
| 01 | 01 | 01 | 02 | 03 | 04 | 05 | 06 | 07 |
| 02 | 01 | 01 | 02 | 03 | 04 | 05 | 06 | 07 |
| 03 | 01 | 01 | 02 | 03 | 04 | 05 | 06 | 07 |
| 04 | 01 | 01 | 02 | 03 | 04 | 05 | 08 | 09 |
| 05 | 01 | 01 | 02 | 03 | 04 | 05 | 10 | 11 |
| 06 | 01 | 02 | 03 | 04 | 05 | 06 | 12 | 13 |
| 07 | 01 | 02 | 03 | 04 | 05 | 07 | 14 | 15 |
| 08 | 01 | 02 | 03 | 05 | 06 | 08 | 16 | 17 |
| 09 | 01 | 02 | 04 | 05 | 06 | 09 | 18 | 19 |
| 10 | 01 | 02 | 04 | 06 | 07 | 10 | 20 | 21 |
| 11 | 01 | 03 | 04 | 06 | 07 | 11 | 22 | 23 |
| 12 | 01 | 03 | 05 | 07 | 08 | 12 | 24 | 25 |
| 13 | 01 | 03 | 05 | 07 | 08 | 13 | 26 | 27 |
| 14 | 01 | 03 | 05 | 08 | 09 | 14 | 28 | 29 |
| 15 | 01 | 03 | 06 | 08 | 09 | 15 | 30 | 31 |
| 16 | 01 | 04 | 06 | 09 | 10 | 16 | 32 | 33 |
| 17 | 01 | 04 | 06 | 09 | 10 | 17 | 34 | 35 |
| 18 | 01 | 04 | 07 | 10 | 11 | 18 | 36 | 37 |
| 19 | 01 | 04 | 07 | 10 | 11 | 19 | 38 | 39 |
| 20 | 01 | 04 | 07 | 11 | 12 | 20 | 40 | 41 |
| 21 | 01 | 05 | 08 | 11 | 12 | 21 | 42 | 43 |
| 22 | 01 | 05 | 08 | 12 | 13 | 22 | 44 | 45 |
| 23 | 01 | 05 | 08 | 12 | 13 | 23 | 46 | 47 |
| 24 | 01 | 05 | 09 | 13 | 14 | 24 | 48 | 49 |
| 25 | 01 | 05 | 09 | 13 | 14 | 25 | 50 | 51 |
| 26 | 01 | 06 | 09 | 14 | 15 | 26 | 52 | 53 |
| 27 | 01 | 06 | 10 | 14 | 15 | 27 | 54 | 55 |
| 28 | 01 | 06 | 10 | 15 | 16 | 28 | 56 | 57 |
| 29 | 01 | 06 | 10 | 15 | 16 | 29 | 58 | 59 |
| 30 | 01 | 06 | 11 | 16 | 17 | 30 | 60 | 61 |

eight used in the area covered by an accounting center, and the computers for each center are equipped only for those formulas that apply to the local area.

Chargeable time, after being computed as described above, is registered on two groups of relays: one group representing the tens digit, and the other, the units digit. Leads from the contacts of these relays together with leads from the register for the message billing index run to the conversion circuit as indicated in Figure 1. At the output of the conversion circuit there are twenty message unit relays—ten for the units digit and ten for the tens digit. The function of the conversion circuit is to operate the proper tens and units message unit relays to give the number of message units corresponding to the chargeable time and the message billing index.

A diagrammatic over-all view of this conversion circuit is given in Figure 2. There is a CP relay corresponding to each billing formula for which the computer is equipped, and each relay is operated over one of the eight leads from the message billing index register. The operation of the CP relay connects the ten tens leads from the chargeable time register to a group of TA and TB relays. As shown in greater detail in Figure 3 there is a TA and a TB relay for each

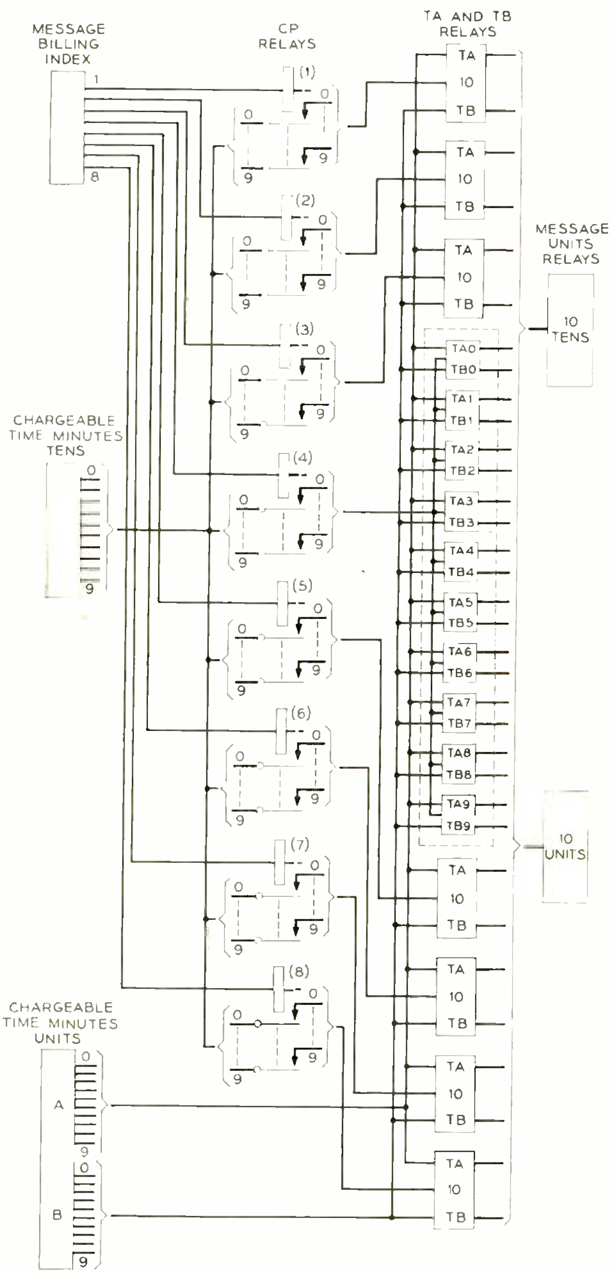



*Fig. 2—Simplified schematic of the circuit that converts from chargeable time to message units.*

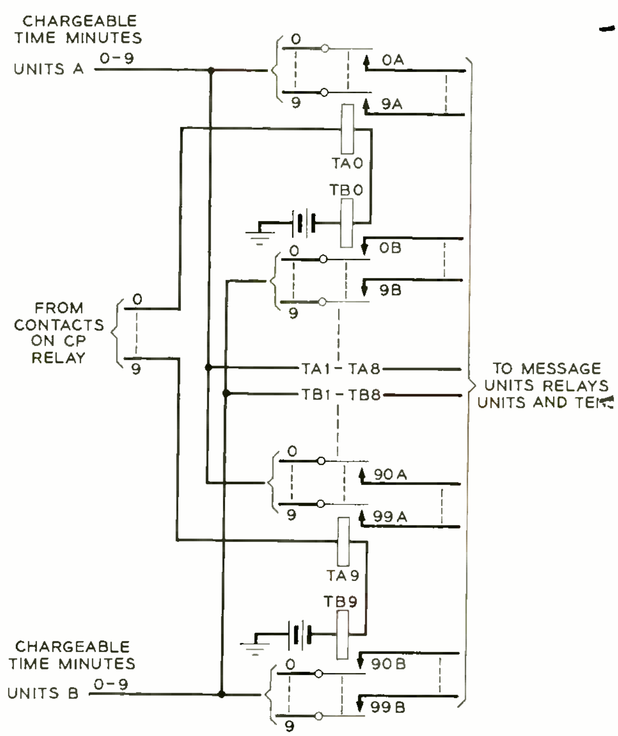



*Fig. 3—Schematic showing the arrangement of the* TA *and* TB *relays associated with each* CP *relay.*

of the ten tens leads coming from each CP relay, but for the sake of simplicity Figure 3 shows only the TA and TB relays associated with one CP relay.

Each units digit in the chargeable time register is represented by ground on two leads. There are thus two groups of ten leads for the units digit of chargeable time, and one lead in each group will be grounded for any one units value of chargeable time. One of the groups of leads multiples to springs on all the TA relays, and the other, to springs on all the TB relays. The front contacts of the TA and TB relays connect respectively to the windings of the units and tens message-unit relays, Figure 2, in accordance with the billing formula represented by the CP relay with which the particular TA and TB relays are associated.

When a CP relay is operated, the ground on one of the tens digit leads of the chargeable time register will operate the correspondingly numbered TA and TB relays in series. As a result of the operation of a TA relay, the ground on one of the units digit leads from the chargeable time register will be connected through to one of the message-unit units relays, while as a result of the operation of the TB relay, ground will appear on one of the message-unit tens relays. Figure 4 shows the circuit involved when the CP relay number 3, corresponding to billing formula D, is operated and when the tens digit of chargeable time is one. Had the tens digit of the chargeable time been other than one, a different pair of TA and TB relays would have been operated. A similar circuit is controlled by each of the seven other CP relays.

It will be noticed that Figure 4 corresponds to the parts of two columns of Table III set in bold face type; it covers all message-unit charges for formula D when the tens digit of the chargeable time is one. Contacts 10 to 17, inclusive, of the TB relay are all multiplied together and connected

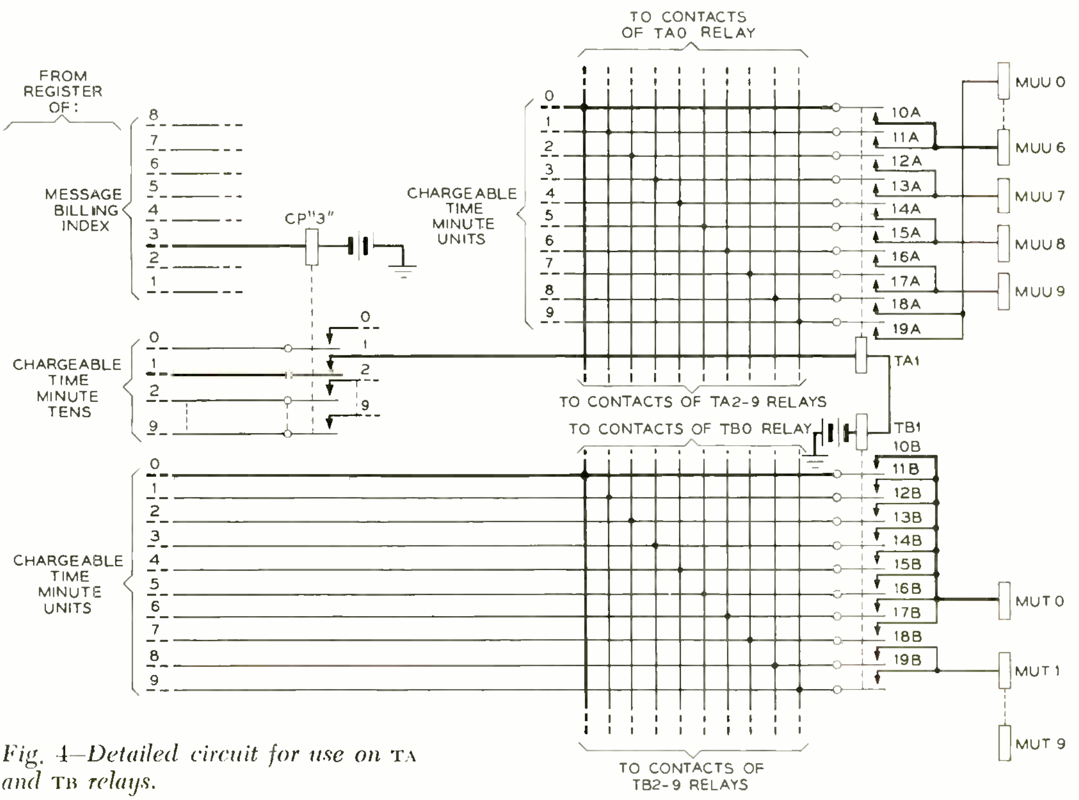



*Fig. 4—Detailed circuit for use on TA and TB relays.*

to the "zero" message-unit tens lead, while the 18 and 19 contacts connect to the "one" message-unit tens lead. Contacts of the TA relay are multiplied in pairs; contacts 10 and 11 connect to the number six message-unit units relay; contacts 12 and 13, to the number seven message-unit units relay, etc.

The fully equipped conversion circuit corresponds to a table, like Table III, extending to ninety-nine minutes of chargeable time. Each of the CP relays corresponds to one of the eight lettered columns, and each pair of TA and TB relays associated with a CP relay, correspond to ten lines of the column.

When chargeable time has been converted to message units, the computing functions are completed. The total time required to make the computations for the call is approximately one tenth of a second. This time, small though it is, includes time to check at each step of the computations that the required result has been obtained. Checks are made throughout the entire AMA system, but they are nowhere more important than here where the actual charges for calls are calculated. The proof of the efficiency of the checks is the fact that from July, 1949 to March, 1951, almost two years of AMA operation, during which time more than 100 million calls were processed by AMA computers, there was no known case of a call being wrongly charged due to misoperation of any of the computing circuits described in this article.

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**THE AUTHOR:** Since joining the Laboratories in 1945, Mary E. Pilliod has been concerned with AMA development, primarily the circuit design and laboratory testing of accounting center machines used in this system. She participated in pre-cutover tests of nationwide subscriber dialing in Newark and Englewood in 1951, in accuracy tests in 1948 at Philadelphia, where the first No. 5 installation with AMA was made, and a year later in similar tests when No. 1 crossbar and AMA were used together for the first time. Miss Pilliod has helped the American Telephone and Telegraph Company prepare training and instruction material for use by the associated companies in operating AMA accounting centers. She was graduated from Vassar College in 1945 with an A.B. degree.

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## Telephone Statistics

Each year, the A T & T Co. issues a report on "Telephone Statistics of the World." The information, which takes almost a year to collect from more than 250 governments and companies throughout the world, shows that during 1951, 4,600,000 telephones were added throughout the world, bringing the total in service on January 1, 1952, to 79,-400,000. More than half of the increase was in the United States where there was a telephone for one out of every three persons. Outside of this country, one out of 68 persons has a telephone.

New York City, with 3,349,323 telephones on January 1, 1952, had more than any other city in the world, more than all of France, or the whole continent of Asia. Greater London, with 1,710,000, was highest among foreign cities. Washington, D. C., had the greatest density of telephones, with about 64 for every 100 persons. Atlantic City was second with nearly 55, and San Francisco was third, with about 54. The foreign city reporting the greatest telephone saturation was Stockholm with almost 50 telephones per 100 persons. Canadians averaged 378 telephone conversations per person during 1951, the highest per capita usage reported. The United States ranked second with approximately 376 conversations and Sweden was third with about 309.

Besides the Bell System, comprising the A T & T and twenty principal Bell Telephone Companies, telephone service in the United States was provided by nearly 5,500 other privately-owned telephone companies.

# Direct Reading Inductance Bridge for Frequencies Up to 5 Mc

L. E. HERBORN
*Transmission Development*

One of the many problems that plague transmission engineers is that of obtaining accurate measurements of inductance as the frequencies used for communication go higher and higher. Although measurements at audio frequencies may readily be made with bridges that have been in use for many years, these bridges are not suitable for the frequencies that have come into use in carrier and radio circuits within the past ten or fifteen years. This is because the effect of the parasitic capacitances and inductances in the elements that make up the bridge, and even in the connecting leads, impair the bridge performance more and more as the frequencies become higher and higher.

A direct reading inductance bridge that yields accuracies comparable to those of audio frequency bridges (of the order of 0.3 per cent) has been developed for use at megacycle frequencies. Basically, the circuit is that of a Maxwell bridge, shown in simplified schematic form in Figure 2. The product arms BC and AD contain the fixed resistors. The standards arm AB contains an adjustable capacitor in parallel with an adjustable resistor, and the unknown impedance is connected across the test arm CD. A transformer across the diagonal corners AC connects to the detector.

The balance equation for the Maxwell bridge is (Figure 2),

$$Z_x \cdot \frac{1}{Y_s} = R_1 \quad R_2$$

which, by separating $Z_x$ and $Y_s$ into their components, simplifies to

$$L_x = (R_1 \ R_2)\, C_s$$
$$R_x = (R_1 \ R_2)\, G_s$$

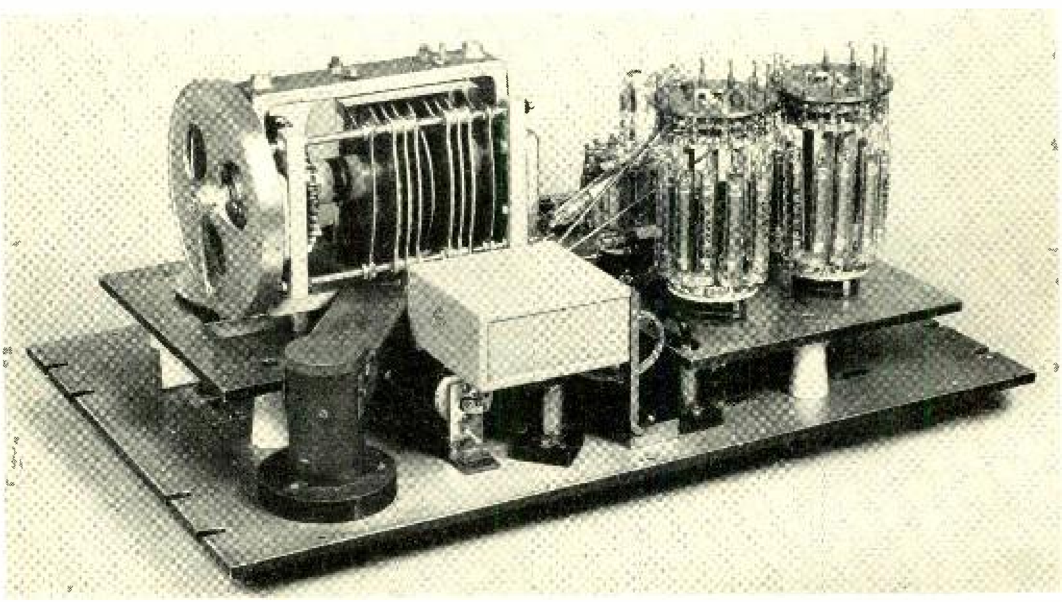


*Fig. 1—Interior of the bridge. Standard capacitor* $C_s$ *is on the left and decade conductances* $G_s$ *on the right.*

In the simplified schematic, Figure 2, the fixed arms $R_1$ and $R_2$ are shown as pure resistors; that is, they are assumed to have no capacitance or inductance, and hence the phase angle of each is zero. In the actual construction of a resistor, it is difficult to obtain this purity, because there is always present some inherent distributed inductance and capacitance. Because of these characteristics, when such a resistor is used on alternating current, it becomes a complex impedance. Besides, at high frequencies a change in the magnitude of the resistance also takes place due to "skin effect," the tendency of the current to flow chiefly along the periphery of the conductor because of the magnetic field set up by the current in the conductor itself. These effects tend to introduce a non-linear phase angle and variable effective resistance, the magnitudes of which depend upon the frequency, size of wire, and the type of winding used.

To minimize these effects, and still maintain the required area of conductor surface for heat dissipation, each of the fixed-arm resistors for the new bridge consists of six very fine wire-woven* units connected in parallel and mounted on a Teflon spool. Teflon is a solid dielectric having a relatively low dielectric constant (about 2). The advantages of this construction are two-fold: The skin effect is negligible, and the distributed inductance and capacitance are at a minimum, thus producing an almost pure resistor.

For the most practical design, the detector transformer is connected so that the inner shield capacitance falls across the AD arm of the bridge. This arm, therefore, actually consists of a low "Q," two-element network in the form of a lumped resistance in parallel with a lumped capacitance. This is compensated in the BC arm by connecting a lumped inductance wound of stranded wire in series with the resistor. The arms BC and AD thus contain inverse networks; that is, the phase angles of the product arms BC and AD are, at all frequencies, equal in magnitude and opposite in sign, so that their sum is always zero. This scheme of compensation, together with the shielding arrangement is shown in the complete schematic of Figure 3.

Similar refinements were also made in the adjustable arm of the bridge. Capacitance standard $C_s$ is an air capacitor of a commercial design, but provided with improvements to make possible very accurate settings. A cast metal frame gives it the necessary rigidity, and a spring loaded worm drive is used for setting the capacitor precisely and with

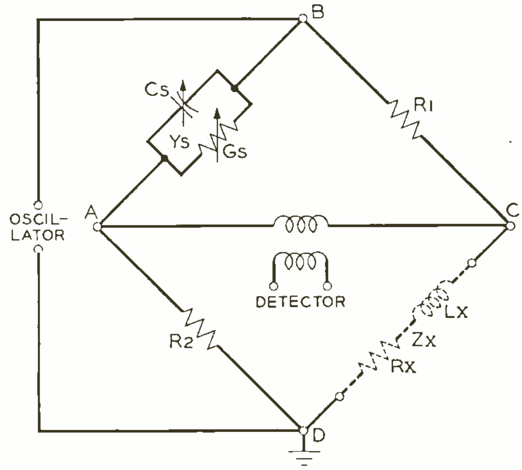



*Fig. 2—The basic circuit is that of a Maxwell bridge.*

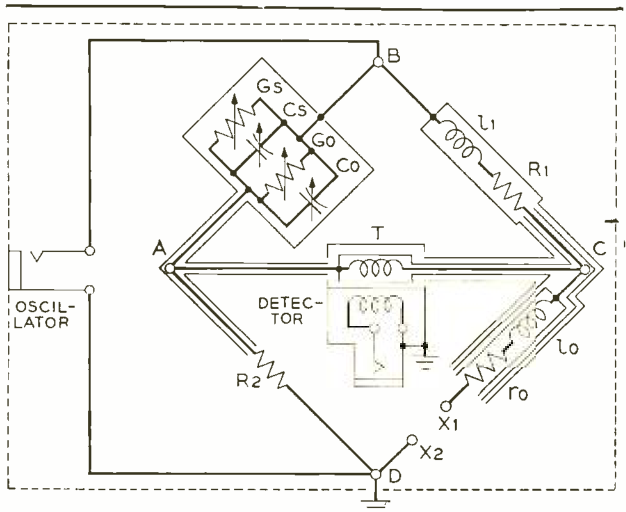



*Fig. 3—The complete schematic of the bridge, including the shields.*

* RECORD, *January*, 1935, *page* 136.

no back lash. Electrical connection to the rotor is made by a brush that makes contact with a disc located half way up on the rotor shaft. With the connection to the stator also at the mid-point, this capacitor is equivalent to two capacitors in parallel, and the series inductance and metallic resistance are only about one fourth those of a similar capacitor having the take-off terminals at the end. In addition, the A and B bridge corners (Figure 3) are located on the capacitor stator and rotor take-off terminals. thus eliminating leads and minimizing series resistance and inductance.

Conductance standard $G_s$, Figure 3, consists of resistors that are controlled by three rotor decade switches and a continuously adjustable dial. Each decade switch and the continuously adjustable resistor are connected independently to the A and B corners of the bridge by short rigid leads.

A developed diagram of a rotor switch is shown in Figure 4. The switch is essentially an eleven position contact wafer and an eleven position short-circuiting wafer, both mounted on a common shaft. As indicated in the figure, the shorting wafer connects all the switch terminals except one to the B corner of the bridge when the shaft is in a given position in order to avoid parasitics through the unused resistors. The contact wafer makes connection with only the one unshorted terminal at the same time. Between each switch terminal and the B corner are connected a resistor and a small trimmer capacitor in parallel, except for number zero, which has only the small trimmer capacitor. Each resistor has a different resistance value, so as to obtain the desired decade range, and each trimmer capacitor is adjusted so that all resistors, with their associated contacts and wiring, have the same effective residual capacitance. As the contact arm of a decade switch is moved, only one resistor unit and its associated capacitor is in the circuit at one time, while all the remaining units are short circuited to the B corner. Since the effective residual capacitance is adjusted to be the same regardless of the setting of the decade, this capacitance is considered as a part of the standard capacitor residual capacitance, and the decade switching arrangements are thus equivalent to pure conductances.

The resistors used on the decade switches are physically alike and of the hermetically sealed deposited carbon type*, in order to assure maximum stability, small distributed capacitance, and low skin effect. The resistor used with the continuously adjustable dial consists of a hermetically sealed carbon resistor in series with a slide wire that is wound non-inductively and mounted on a molded insulating drum so as to have minimum capacitance to the shield.

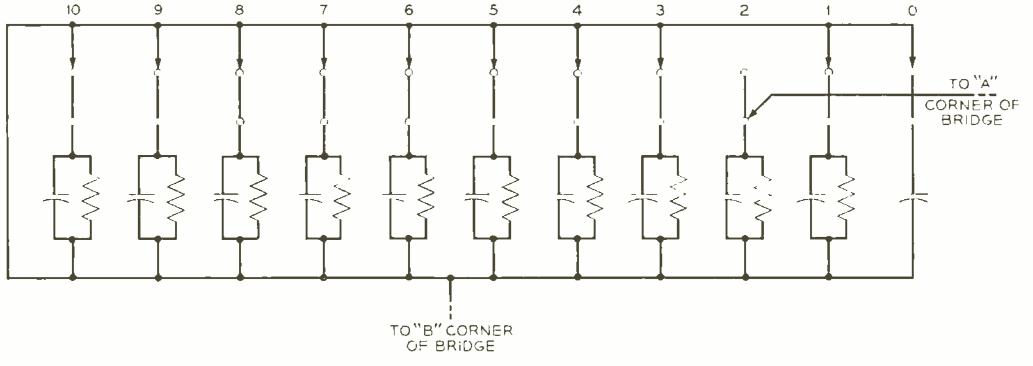



*Fig. 4—A developed circuit of the decade conductances. Rotor switches connect all resistance-capacitance networks to ground except one, for each position of the decade dial.*

To obtain a bridge balance all the way down to zero impedance across the test terminals, a shielded coil, indicated in Figure 2 as $L_0$, and $r_0$, is connected between the C corner and the $X_1$ terminal. This coil is tension wound on a form having a low temperature coefficient of expansion, in order to

* RECORD, *October*, 1948, *page* 401.

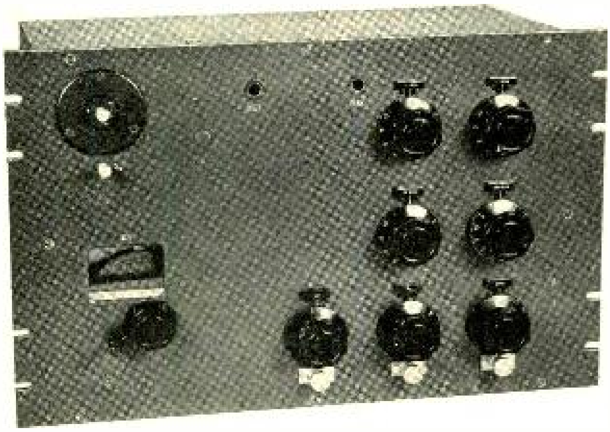


*Fig. 5—Front view of the complete bridge.*

maintain maximum stability of impedance. Its impedance is equivalent to the residuals of the capacitance and conductance standard as reflected through the fixed arms of the bridge. In addition, the $x_1$ terminal is of small physical dimensions to minimize the effect of capacitance to ground across the unknown impedance. The arrangement of these component parts is shown in Figure 1.

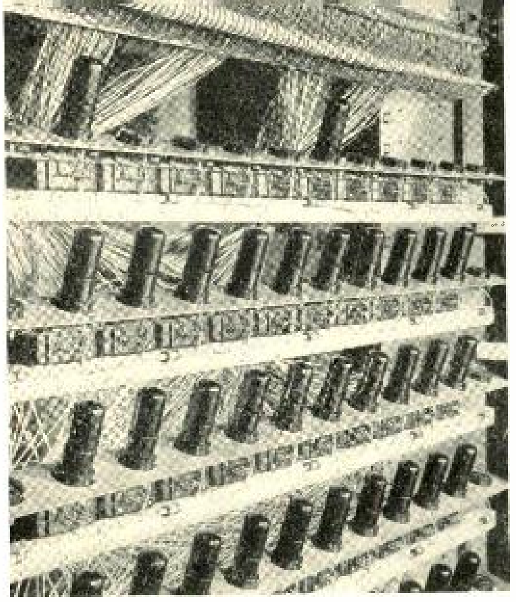
A front view of the bridge is shown in Figure 5. Terminals $x_1$ and $x_2$, for connecting the unknown, are located in the upper left-hand corner, remote from the bridge dials in order to minimize the effect of hand capacitance of the operator. Since this bridge is designed to be direct reading, the conductance dials are engraved to read OHMS, and the capacitance dial is engraved to read $\mu$H (microhenries). Two dials in the lowest row, marked $L_0$ and $R_0$, serve to establish a bridge zero balance when all the standard dials are set to zero, and the bridge terminals $x_1$ and $x_2$ are short circuited.

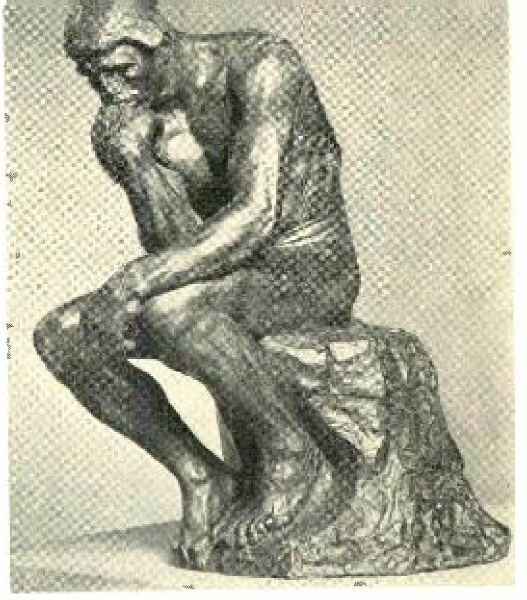
The dial in the lower right-hand corner marked OHM, and having steps of 0.02, 0.01 and 0.005 serves to introduce additional fractional resistance above the "10" setting of the 0.01 ohm dial, or the "11" setting of the 0.001 ohm dial in the middle row. This facilitates bridge balancing by avoiding resetting these dials to the next higher decade when only a small increment is required.

Impedance measurements can be made at frequencies as high as 5 megacycles, with inductances up to 10 microhenries and resistances up to 11 ohms. Minimum steps of 0.0005 microhenries (¼ division on the vernier dial) are possible, as well as resistance steps of 0.00005 ohm (¼ division on the 0.001 ohm continuously adjustable dial).

The bridge is direct reading, and requires no calibration corrections. It is now being used in the inductor laboratory in connection with the development of component parts of transmission networks for megacycle carrier systems.

THE AUTHOR: L. E. HERBORN joined the Technical Staff of the Laboratories in 1923, and until 1928 was associated with the Research Department on the development of terminal equipment for high-speed submarine cables. At the completion of this work he transferred to the Apparatus Development Department, where he engaged in the development of precision impedance measuring equipment. During the war he collaborated in development of circuits for military equipment. Mr. Herborn has the degree of B.S. in E.E. from Cooper Union.





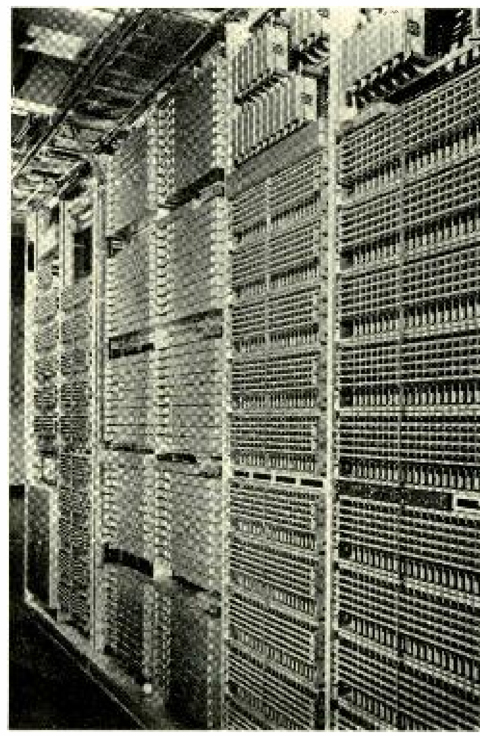
# Switching Systems as Mechanized Brains

JOHN MESZAR
*Switching Systems Development*

*Editorial Note: Common control switching circuits and the various forms of electrical computers operating on similar principles have often been referred to as electrical brains because of the distinctly rational operations they are able to carry out. To just what extent the actions of the human brain can be duplicated by electrical circuits is still a moot question. Some members of the Laboratories feel that probably no switching circuit could duplicate all the acts of the mind, while others feel that it is at least theoretically possible to design a group of electrical circuits that would duplicate many functions of the human brain. John Meszar gives here a brief outline of one position. It is intended that other views on this question will eventually be published in forthcoming issues. The question is one of such general interest that* Bell Laboratories Record *feels it worthwhile to present these differing opinions although recognizing that at the present time they are opinions – not established facts.*

Can the functions of the human brain be reproduced by switching systems? This subject has been thought about lately by many people, inside and outside Bell Telephone Laboratories. It is a loose and controversial (but fascinating) subject whose ramifications quickly bring into play different interpretations of the human mental process, most of which are based – like this article – on opinions and speculations rather than facts. It is also a subject which can be discussed casually as the weather, or pursued doggedly at the risk of one's peace of mind. Best of all, one does not have to know a great deal about switching

"The Thinker," the photograph at the right, by Auguste Rodin, is published through the courtesy of The Metropolitan Museum of Art.



*To establish requested connections, automatic telephone switching systems accurately link-up appropriate sections of a maze of paths.*

systems to feel the equal of experts in appraising them as mechanized brains.

Let us be a little more explicit about the subject. As is well known, the most fundamental characteristics of the switching art — the characteristic responsible even for the name of the art — is its use of the "switch," an elementary two-valued (open or close) device, and corresponding two-valued (on or off) signals. Based on these elementary devices and signals, switching systems have been conceived and brought into existence which can receive a lot of information, and manipulate it automatically through a sequence of internal steps until some predetermined final objective is accomplished. To telephone engineers, the best known example of such a system is, of course, the common-control dial telephone switching system which receives from thousands of subscribers information specifying the telephone they want to be connected with, and which accurately links up the appropriate sections of a maze of paths to establish these requested connections. Outside of the telephone field, it is the automatic digital computing systems, such as the ENIAC, UNIVAC, and ORDVAC, that receive the most attention as switching systems of truly significant capabilities. With appropriate instructions they can, for instance, calculate the trajectory of a gun shell faster than the shell can fly it.

From the standpoint of this article, the chief item of interest about any of these systems is that in accomplishing the over-all objective of the system, its component circuits perform such functions as: counting, remembering, selecting, deciding, translating, locating, and calculation — functions that strongly imply operations commonly associated with human mental effort. This then brings up the natural question: Are such implications justified and significant, or are they simply the result of poetic license in the use of words by switching people? In other words, do switching circuits truly reproduce certain processes of the human mind or, like costume jewelry, are they but superficial imitations that do not stand critical examination? The question becomes even more appropriate in the light of the limited knowledge that neurophysiologists are acquiring of the human brain's own internal processes, which seems to indicate that — like a switching system — the brain also accomplishes its functions by internal rearrangements of its superlative network of two-valued elements, the neurons.

Before anyone gets the impression that this article is going to be a dissertation on "machines that think," that anticipation will be disposed of forthwith. The subject of "thinking machines" receives more than its just share of attention in articles of those writers who extract the last ounce of speculative excitement out of it. One such article in a respectable weekly magazine, for instance, noted that during the post-war peaks of telephone traffic certain crossbar central offices misbehaved in a manner that baffled the engineers. Since a working crossbar office depends on the dynamic interplay of thousands of relays, such a situation was not surprising to those of us who have often been puzzled by the misbehavior of a single complicated switching circuit during laboratory tests. The subtle implication conveyed by the article, however, was that such systems therefore have characteristics akin to capricious will. In fact it is not doing much injustice to the article to infer that some day Telephone Companies might decide to hire psychoanalysts to help switchmen maintain crossbar central offices. Such views about machines that think and act according to their thoughts are intuitively repugnant to most of us.

It is appreciated that this assertion is subject to quick retort along the lines that intuitive feelings can be wrong. There was a time, for instance, when it was also against common sense to admit that the earth is round, not flat, and that it is wandering as a speck in the universe, rather than being its center. Ancient, deep-rooted concepts are not readily changed even if ultimately they prove to be wrong. However, on mechanical thinking we can buttress our intuition by tangible, factual supports. We know that an automatic system is but hardware, shaped of steel, and copper, and glass, and other dead materials. Such materials can move, expand, and contract in response to forces; some can be magnetized; some can transmit electrical energy and so on; but these properties do not even remotely resemble the ability to think, which is the highest, most exclusive endowment of the living human mind. Design engineers who have brought into existence such outstanding examples of automatic systems as our modern common-control central-office systems know best how pro-

*The operator functions as a highly intelligent and versatile switching system.*

saic is the hardware employed, and how common-place are the details that make such systems tick.

This answer to the basic question looks—and is – arbitrary. If the question of mechanized thinking could be disposed of that easily, this article would stop right here; in fact it would not even have been started. There is much more to the subject. Just what do we mean by thinking? What operations of the human mind come under this term? Let's discuss a few elementary examples that may confirm the doubts of those not sure of the answer, and may create doubt in those who feel they know the answer.

Someone requests the Laboratories' telephone operator for a connection to extension 752. The operator makes a busy-test, receives an indication that the extension is in use, and therefore refuses to comply with the request. In so doing, did she use her head? She certainly did and her supervisor would unhesitatingly agree. Testing for and respecting a busy line, however, is also one of the simplest accomplishments of an automatic switching system.

At the switchboard of a manual exchange, the operator receives a call for line No. 4700. She promptly locates the jack terminating this line, and is set to make a busy-test. However, she notices a distinctive mark at this jack, indicating that 4700 is a line to a Private Branch Exchange, which is served by a multiplicity of adjacent lines, all usable when 4700 is called. If the first of these lines is busy, therefore, she does not turn down the request for connection. Instead, she hunts in an orderly manner for an idle line in the 4700 group. Did the operator go through some mental process in this short sequence of actions? One would be reluctant to say no. However, locating the physical termination of a subscriber line, noticing that it's a PBX line, and hunting for an idle one in the group, is one of the many features of dial telephone system circuits.

Mr. X is with a group of people in a particular Conference Room. One of us wants to talk to him and so asks the operator to ring this Conference Room. She consults her records and finds that she has to ring extension 131. In translating the room number into a telephone extension number, did the operator do any mental work? There seems no doubt she did. However, that is exactly what the crossbar system translator does when it translates a subscriber equipment location number into a subscriber directory number.

A conventional problem in telephone message accounting may involve the following charging plan: initial conversation interval of five minutes chargeable at three message units; overtime conversation intervals of two minutes, each chargeable at one message unit; a very short (say six seconds) deductible allowance on all messages. Now, an operator's ticket shows that a certain telephone conversation started at 58.6 minutes after 2:00 P.M. and ended at 25.8 minutes after 3:00 P.M. If the message-rater of the accounting center bills the customer fifteen message units, did she do any thinking in arriving at this answer? Not many will deny it. However, that is exactly what one of the automatic message accounting machines accomplishes.

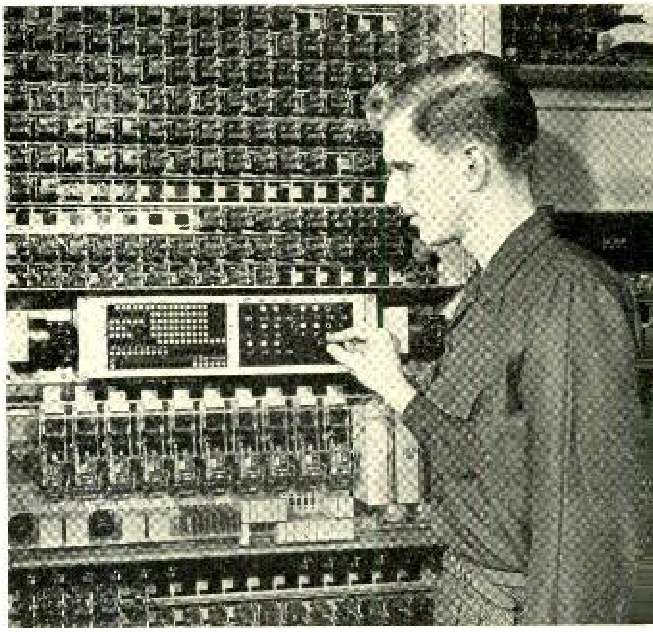
A grade-school student is given the following problem:

$$574968 \times 759826$$

After some minutes of calculations on paper (with indications of erasures, perhaps) he comes up with the correct answer. In doing this problem, did he go through a process of thinking? Most everbody will unhesitatingly — and perhaps unwarily — answer yes. Some would even compliment themselves silently for good mental performance if they went through all the steps of the problem in a number of minutes and obtained the correct answer. However, a digital computer will also give the correct answer and do so in a split second.

So much for elementary examples of human mental operations which are reproduced exactly by switching circuits. A whole series of other examples could be readily cited. None of these examples is impressive by itself, but a switching system may include a great many such simple features, and the resultant versatility of the system, its composite competence to perform a relatively complex series of mental operations, may therefore be truly remarkable. Thus the question: What is thinking? is very much in order. Is mental effort the same as thinking?

If we do not want to be trapped into admitting that automatic systems think, we can give only one answer to the question. We do not think every time we use our head. Much of our mental effort consists of recalling facts stored in our minds (the multiplication table, for example), and manipulating such information in accordance with a set of rigid rules, also stored in our minds. The facts and the rules of manipulation have been implanted in our minds some time or other as part of our training, and are treated as inviolate, unalterable. Mathematical computations — be they simple or intricate — are typical examples of this type of mental effort. The simple multiplication problem used above



*A switching system is a physical structure of relays, tubes, wires, etc., combined with a wealth of stored information.*

could be given to a thousand individuals and they would all use the same mentally stored information, and follow an identical pattern of procedure step by step. Deviations in the procedure, if any, simply represent optional rules.

Mathematical computations are, however, not the only acts falling into the category of "non-thinking mental effort." Any problem, any situation which demands the exercise of rigorous logic, where the procedure and the final outcome is inherent in

*Machines are taking over many areas of mental effort. Above, one of the machines of the automatic message accounting system.*

the statement of the initial conditions, where the "if . . . . . then" relationship holds, is of the same type. Solving such problems, taking appropriate action in such situations is mental effort, but it is not thinking. Each new problem and situation of this type calls simply for the reuse of the same stored facts and the application of the same rigorous rules of procedure to a set of new variables to arrive at a new but inherent conclusion. The facts and the rules can be implanted into human minds by training, or they can be incorporated into automatic systems by design. For a given set of initial variables they will both go through identical steps and arrive at the same answer.

Now the theme of this article has emerged. It is an emphasis on the necessity of divorcing certain mental operations from the concept of thinking, and thus pave the way for ready acceptance of the viewpoint that automatic systems can accomplish many of the functions of the human brain. From this viewpoint, it is not the physical structure of relays and tubes of an automatic system that functions as the brain. The mechanical brain is the combination of that structure with all the information it possesses. Such a loaded structure, in certain areas of mental effort, may even outperform the human brain. In those areas, therefore, the analogy between switching circuits and the human mind is not that of imitation versus genuine jewelry, but that of artificial crystals grown by the Western Electric Company versus natural crystals mined in South America. Performance, uniformity, and price are actually in favor of the artificial ones.

Divorcing thinking from what we regard at the present time as routine, logical mental operations is not enough. As time goes on, it will be more and more essential to cultivate a completely undogmatic and open-minded attitude for the concept of thinking. Perhaps the most flexible concept is that any mental process which can be adequately reproduced by automatic systems is not thinking. There are several basic virtues in this flexible concept. First, it avoids the extremely difficult, if not impossible task, of defining positively what thinking is, by stating what is not thinking.

Second, it is easy to apply and results in straightforward conclusions. Once a machine performs a certain type of mental operation, that operation is not thinking. Third, it makes full allowance for the increasingly versatile automatic systems of the future, which are unquestionably coming and which will force an accelerated shrinkage in the area of mental effort to which the term "thinking" remains applicable. It is well to recognize that in time this shrinkage may become very extensive as switching systems come into existence to perform more and more spectacular feats of logic, such as automatic weather predicting, automatic language translating, etc.

We are faced with a basic dilemma: we are forced either to admit the possibility of mechanized thinking, or to restrict increasingly our concept of thinking. However, as is apparent from this article, many of us do not find it hard to make the choice. The choice is to reject the possibility of mechanized thinking but to admit readily the necessity for an orderly declassification of many areas of mental effort from the high level of thinking. Machines will take over such areas, whether we like it or not.

This declassification of wide areas of mental effort should not dismay any one of us. It is not an important gain for those who are sure that even as machines have displaced muscles, they will also take over the functions of the "brain." Neither is it a real loss for those who feel that there is something hallowed about all functions of the human mind. What we are giving up to the machines – some of us gladly, others reluctantly – are the uninteresting flat lands of routine mental chores, tasks that have to be performed according to rigorous rules. The areas we are holding unchallenged are the dominating heights of creative mental effort, which comprise the ability to speculate, to invent, to imagine, to philosophize, to dream better ways for tomorrow than exist today. These are the mental activities for which rigorous rules cannot be formulated – they constitute real thinking, whose mechanization most of us cannot conceive.

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**THE AUTHOR:** John Meszar was graduated from Cooper Union in 1927 with a B.S. degree in E.E. He has been employed by the Laboratories since 1922 when he began work as a technical assistant working on the testing of toll switching circuits. In 1942, after several years as a supervising engineer in toll switching circuit design work, he became an instructor in the Laboratories' School for War Training. Following the war, he returned to circuit design supervision and devoted much of his time to AMA. Since June, 1952, he has been Director of Switching Systems Development II. In 1951 the American Institute of Electrical Engineers awarded him first prize for the best paper in the communication division presented during 1950.

# Bombardment Conductivity

E. G. Miller
K. G. McKAY
*Physical Electronics*

One of the most interesting aspects of electrical insulators is how they conduct electricity. Although by definition they are non-conductors, it is well known that under the proper circumstances they will conduct. It was demonstrated over seventy-five years ago that light shining on certain insulators could render them slightly conducting. However, it is only within the past decade that it has been shown that comparatively large currents could be produced in certain insulators by bombarding them with high speed particles of atomic size. The particles liberate charge carriers within the insulator, and these may move if an electric field is applied.* By studying the behavior of these induced currents we can extend our knowledge of the electrical properties of solids and can also study what happens when a solid body is struck by a high speed particle, such as alpha particles that are emitted during radioactive decay, or high speed electrons, such as exist in a beam of a large TV tube.

This is not as academic as it sounds. If a high speed particle can produce mobile charges in an insulator which can then be measured, a method of detecting particles becomes available; this is of considerable interest to nuclear physicists. Moreover the action of solid-state devices, such as varistors, or transistors, depends on electrical conduction through non-metallic solids. If the physics involved is well understood, it will certainly be used eventually in devices. Conductivity induced by bombardment is one of the tools at our disposal to study the underlying physics. In the following pages is a brief résumé of the basic processes and some of the information that has been gleaned from the studies at Bell Telephone Laboratories.

Let us first consider why an insulator

* In this study we are not dealing with permanent changes produced by the bombarding particles. The induced currents in general cease when the bombardment is terminated or very shortly thereafter.

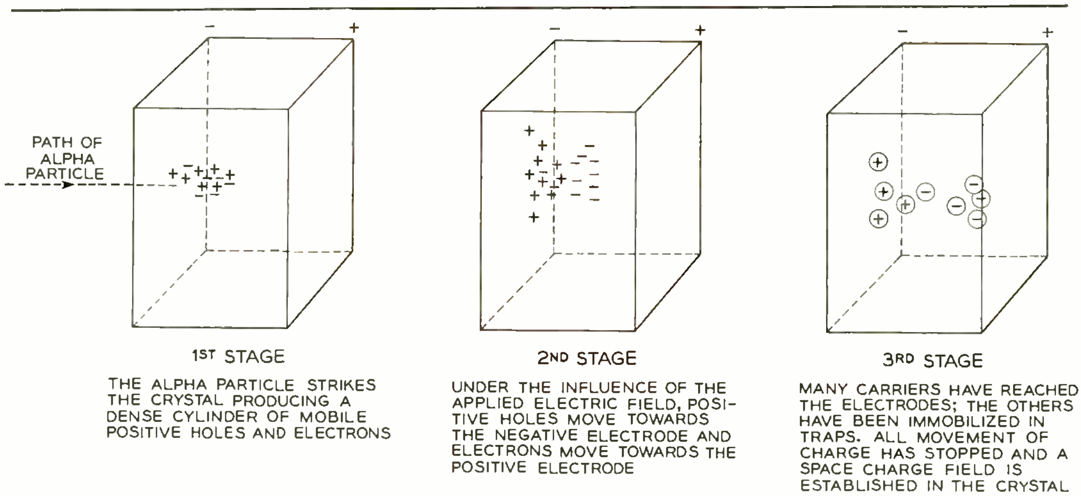



*Fig. 1—Simplest case of alpha bombardment conductivity.*

does not normally conduct electricity. To be specific we shall consider the case of diamond, which is a simple but excellent insulator. Diamond is composed of nothing but carbon atoms. The outermost group of electrons of each atom act to hold the different atoms together. If there are just the right number of these electrons present, the atoms will be very tightly bound together, thus forming the hard diamond structure. It happens that each carbon atom brings with it just the right number of electrons to attach it strongly to its surrounding atoms so there are no electrons left over. Now if an electric field is applied to the diamond, none of the atoms will move appreciably, since they are all tightly bound together. Moreover the electrons are all occupied holding the atoms together, and thus they cannot contribute to a current flow. Consequently there is no current flow. This is the simplest possible picture of an insulator.

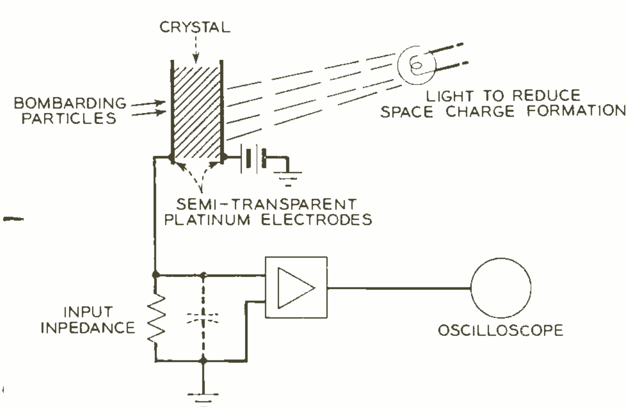



*Fig. 2—Typical schematic for studies of bombardment conductivity in insulating crystals.*

It appears reasonable that if some electrons can be supplied which are not bound to the atoms, then these should be able to move more or less unimpeded through the solid, and thus render it conducting. This can be accomplished by shooting particles such as high speed alphas into the insulator. Practically all of the energy of the alphas will be dissipated in collisions with the electrons which bind the atoms together. These collisions knock the erstwhile bonding electrons loose, setting them free to roam through the crystal. However, these free electrons are not the only current carriers. Another type of carrier arises because the places formerly occupied by the free electrons are now empty. In some crystals like diamond, the electrons in neighboring bonds (positions) can exchange places with each other readily. If an electron in, say position A, jumps into neighboring position B where a bonding electron is missing, there will no longer be an electron in position A. This is the same as saying that the vacancy has moved from B to A and thus, in this case, is mobile. Since the vacancy occurs in what is normally a neutral crystal, it forms a region of positive charge, and the fact that it is mobile permits it to act as a charge carrier in a crystal. Thus each significant collision made by a bombarding particle produces both a free electron and a positive hole. Under the influence of an electric field, the electron moves off in one direction, the positive hole moves off in the other direction, and both contribute to the observed current.

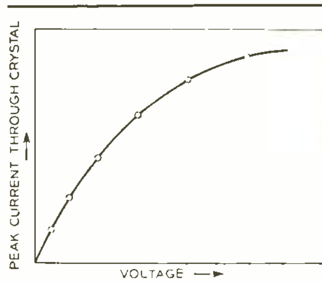



*Fig. 3—Variation of electron current through crystal as a function of applied voltage. This is for a diamond crystal bombarded by 10-kilovolt electrons.*

One of the first things we would like to know is how the induced current should vary with applied voltage, with the intensity and the type of bombardment, and with any other relevant variables such as time. It is to be expected that a free charge carrier will bounce around in the crystal and drift in the direction of the applied field with a velocity equal to the field times a constant which is called the mobility. It is also expected that in any actual crystal likely to be used, there are local imperfections that disrupt the symmetrical arrangement of the atoms. These imperfections might consist of foreign atoms (impurities) or merely misplaced atoms of the crystal. From experience it is known that these im-

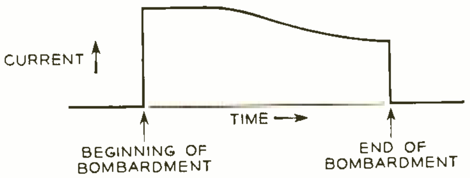



*Fig. 4—Electron current flow through a diamond as a result of bombardment by a 10 μ-second pulse of 10-kilovolt electrons. The decrease in current near the end of the pulse is caused by the formation of an internal space charge field during the period of the bombardment.*

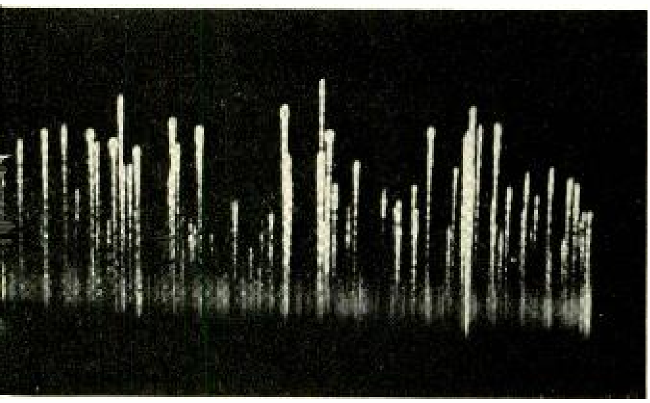


*Fig. 5—Pulses from a diamond crystal bombarded by monoenergetic alpha particles. Observe the scatter in pulse heights due to nonuniform response.*

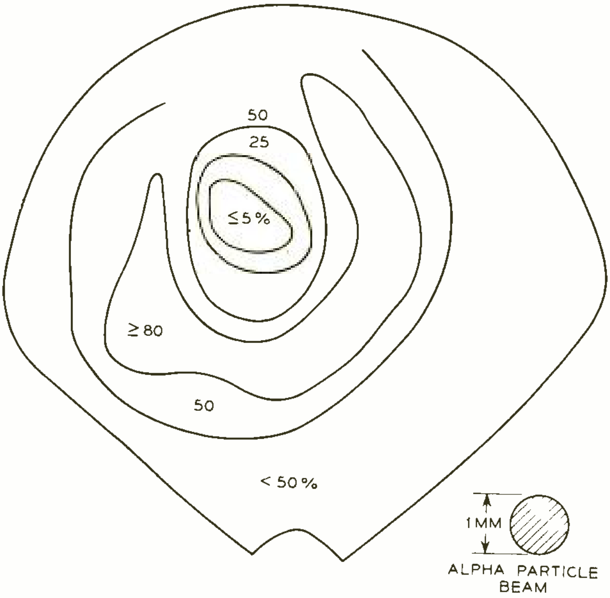



*Fig. 6—Plot of the counting efficiency in per cent of a large flat diamond when bombarded by alpha particles. Such wide variations in sensitivity in different parts of a diamond are usually encountered.*

perfections may prove very attractive to free carriers; a carrier drifts into the region around an imperfection, exchanges energy with the surrounding atoms, and then finds that it doesn't have enough energy to leave the region because of the peculiar local electrical disturbance set up by the imperfection – the carrier has been trapped just as a billiard ball is pocketed. The longer an untrapped carrier remains free in the crystal, the more likely it is that it will drift into such a region and be trapped. At low field strengths, the carriers drift more slowly and take longer to traverse the crystal; trapping becomes more effective and smaller currents may be expected. Moreover, the trapped carriers, by virtue of their electrical charge, set up internal electric fields which oppose the applied field and cause the current to diminish with time. This is a nuisance but, for measurement purposes, it can be avoided by releasing the trapped charges by applying heat or light, or through the use of ac fields in which on alternate half cycles, positive holes are supplied by bombardment, and these recombine with the trapped electrons and vice versa. All three methods have been successfully used and thus it may be assumed from here on that the crystals considered are free of space charge unless otherwise stated.

To make actual measurements on a diamond crystal, a thin slice, such as a segment cut off a gem stone prior to polishing, is taken and the two major faces are coated with thin metallic films, which serve as electrodes. A voltage is applied between the electrodes, and an amplifier and oscilloscope are connected to amplify and record any current flow through the crystal (Figure 2). The bombarding particles penetrate one of the electrodes and dissipate their energy in the crystal. If alpha particles are used, the current pulses due to the incidence of individual alpha particles are studied. When electrons of about twenty kilovolts energy are used the response to individual electrons cannot be measured, and so a pulsed beam of electrons is used. The crystal is usually mounted in a vacuum chamber to prevent the bombarding particles from losing energy to air molecules.

Bombardment by alpha particles or by electrons produce essentially the same effects although each emphasizes certain properties of the target more effectively than the other: electrons are more suitable for the study of the over-all electrical properties of the target while alpha particles are singularly appropriate for the investigation of crystal inhomogeneities. Experiments show that both free electrons and positive holes are mobile in diamond at room temperture, and that the average amount of energy required from the bombarding particle to produce one free electron and one positive hole in the crystal is about ten electron volts. Thus a 20,000-volt electron striking a diamond crystal will produce about 2,000 electron-hole pairs. In any particular crystal, it is possible, by studying the observed relationship between the current and the applied voltage, to make estimates of the density of the traps, and to get some idea of the amount of energy required to release a charge carrier once it has been trapped. This is the kind of information necessary for future theoretical studies. However, as will be discussed below, such estimates must be treated with caution unless there exists independent evidence that the electrical properties of the crystal that is used are fairly uniform.

In addition to these quantitative results, the experiments have also forced us to change our mental picture of the electrical structure of many insulators. On at least one selected diamond, very careful studies were made of the dependence of induced current on applied field and on the energy of the bombarding electrons. Moreover, after the internal space-charge fields had been neutralized, they were allowed to build up under controlled conditions, and their rate of production was measured. The results agreed very well with theoretical predictions based on the assumption of a uniform electric field throughout the crystal and of a uniform distribution of traps. This is a very satisfying result, but unfortunately it is very rare.

If a diamond is bombarded with alpha particles, each with the same energy, the simple theory with the above assumptions predicts that each resultant conductivity pulse will be of the same height when seen on an oscilloscope. Actually this is almost never the case; the observed heights scatter very widely. This implies that since the different alphas enter different regions of the crystal, these regions must differ in their electrical properties. For other reasons it is believed that the variation occurs in the conducting properties of the crystal and not in the carrier excitation process.

The simplest explanation of this effect is to postulate an inhomogeneous distribution of traps so that one alpha particle strikes a relatively trap-free region and the resultant carriers travel a long distance before

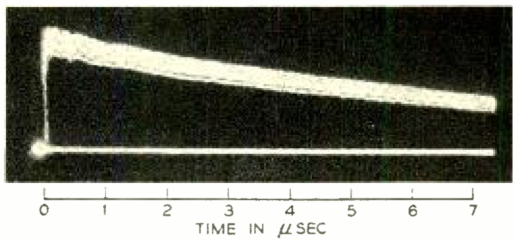



*Fig. 7—Sixteen superimposed pulses from alpha particles striking a germanium* n-p *junction shown on an expanded time scale. The very fast rise time indicates that the electrons and holes produced by the bombardment are swept across the junction in a time less than* $10^{-8}$ *seconds.*

being trapped, while the next alpha hits a trap-rich region and the carriers are immobilized before they can drift at all. Undoubtedly this is an important factor. However, the results of subsidiary measurements on some diamonds indicate that variations in trap density do not tell the full story. It has become evident that even an excellent insulator may possess more or less localized regions of appreciable conductivity in the absence of any bombardment. This means that if a voltage were applied to a crystal before any bombardment occurred, the electric field might vary greatly within different parts of the crystal. Thus a region that responds exceptionally well to bombardment may be one in which the carriers are produced in an exceptionally high local field. G. H. Wannier has shown that the introduction of an extremely small quantity of impurities into a really good insu-

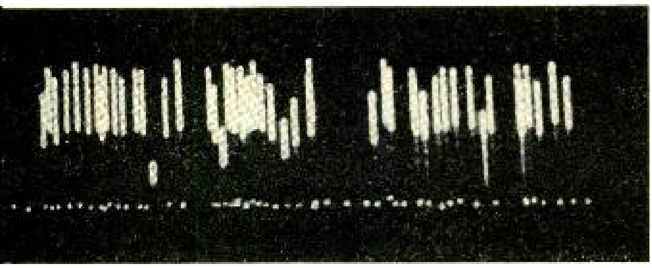


*Fig. 8—Pulses from a germanium* n-p *junction bombarded by monoenergetic alpha particles. With a few exceptions, most of the pulses are the same height.*

lator should, in theory, lead to just such a result, and our experiments appear to confirm it.

Although this behavior holds for diamond, does it for other insulators? A. J. Ahearn has tested over a hundred different species of insulators and found only seven that yielded a measurable response to alpha particle bombardment. All of these exhibited wide distributions of pulse heights, and thus so far there is no reason to expect a different behavior. One annoying aspect is that in those cases where the value of the internal field is not known, many of the measurements we would like to make cannot be properly interpreted. Under high field conditions, for example, trapping can be neglected and, mobility $\mu_e$ is given simply by

$$\mu_e = \frac{l}{\tau E}$$

where $l$ = the distance between electrodes
$\tau$ = the time taken for the electrons to traverse the distance $l$
E = the electric field

This equation is applicable when the field E is a constant, and since we can measure $\tau$, $l$ and E, we can determine $\mu_e$. However, if E is not constant but varies in an unknown manner, measurements of $\tau$ are useless to determine $\mu_e$.

One solution of this difficulty is to study materials where the distribution of field strengths is known: as for a crystal of a a semiconductor such as germanium which has been grown under certain well controlled conditions. J. N. Shive has described the properties of germanium in the RECORD* and from that discussion it is evident that a barrier layer, as set up by a point contact or by an *n-p* junction, acts very much like a thin layer of insulating material separating two conductors if the proper voltage is applied. A high field can be established across such a barrier and trapping normally plays a negligible role. Although bombardment conductivity studies have been made on the barrier layers around point contacts and on surface barrier layers stabilized by chemical treatment both with alpha particle and electron bombardment, the clearest interpretations have been obtained using *n-p* junctions. The number of carriers produced per bombarding particle of a given energy is well defined, and corresponds to the production of one electron-hole pair for every three electron-volts energy of the bombarding particle. This should be compared with the corresponding figure of ten electron-volts per pair in diamond and about thirty-five electron-volts per electron-ion pair in air.

Although diamond and germanium appear at first glance to be dissimilar elements, this is not entirely true. They have the same crystal structure, they are members of the same chemical "family", and many of their properties are only quantitatively different. Thus measurements on one element, if properly interpreted, may be very useful in predicting the behavior of the other element. Bombardment studies on germanium *n-p-n* junctions – the junction transistor structure – yield results of the type to be expected in some insulators as a result of peculiar internal field configurations. This ties right back to Dr. Wannier's concept of the behavior of diamond.

From this discussion it is evident that the use of bombardment conductivity has proved fruitful in the study of the behavior of electrons in certain types of solids. One additional point to be noticed is that bombardment conductivity is a means of producing current multiplication; one high speed electron bombards a crystal and many free carriers are produced inside. This property suggests possible applications such as high speed electronic switching or

* *August*, 1950, *page* 337.

storage tubes, or detectors for nuclear particles, but some of the problems described above have hitherto prevented this approach from competing with other methods of performing these tasks.

The work at the Laboratories which has formed the basis for this article was initiated by D. E. Woolridge. The alpha bombardment and supplementary measurements on insulators has been carried on by A. J. Ahearn. We wish to acknowledge the many contributions by other members of the staff and, in particular, those of J. A. Burton who, for a while, directed the work in its early stages, and those of R. R. Newton who calculated the rate of production of internal space charge fields. The technical assistance rendered by R. A. Maher and H. C. Meier has been most valuable in these investigations.

THE AUTHOR: Since 1947 KENNETH G. McKAY has been conducting fundamental research on electron bombardment conductivity in insulators and semiconductors. Dr. McKay received B.Sc. (1938) and M.Sc. (1939) degrees from McGill University and in 1941 an Sc.D. degree from Massachusetts Institute of Technology. He then joined the National Research Council in Canada to work on the design of radar equipment. In 1942 he was commissioned in the Royal Canadian Air Force and was assigned to duty with the research council. He remained in service until 1946, when he became a member of Bell Telephone Laboratories. He developed pulse techniques for the study of electron emission from insulators for about a year, before going into the work that he is now doing.

# Papers Published by Members of the Laboratories

Following is a list of the authors, titles, and place of publication of recent papers published by members of the Laboratories:

Anderson, J. R., Ferroelectric Storage Elements for Digital Computers and Switching Systems. Elec. Engg., **71**, pp.916-922, Oct., 1952, and Communications and Electronics, 4, pp.395-401, Jan. 1953.

Coy, J. A., and E. K. Van Tassel, Type-O Carrier Telephone. Communications and Electronics, 4, pp.428-437, Jan. 1953.

Keller, A. C., A New General-Purpose Relay for Telephone Switching Systems. Communications and Electronics, 4, pp.413-428, Jan., 1953.

Lewis, H. W., and G. H. Wannier, Spherical Model of a Ferromagnet. Phys. Rev., **88**, pp.682-683, Nov. 1, 1952.

Mason, W. P., Properties of a Tetragonal Antiferroelectric Crystal. Phys. Rev., **88**, pp.480-484, Nov. 1, 1952.

Mason, W. P., and B. T. Matthias, Piezoelectric, Dielectric, and Elastic Properties of $ND_4D_2PO_4$ (Deuterated ADP). Phys. Rev., **88**, pp.477-479, Nov. 1, 1952.

Matthias, B. T., see W. P. Mason and B. T. Matthias.

Olmstead, P. S., How to Detect the Type of an Assignable Cause. Ind. Quality Control, **9**, pp.32-34, 36+, Nov., 1952.

Peterson, G. E., Application of Information Theory to Research in Experimental Phonetics. Jl. Speech and Hearing Disorders, **17**, pp.175-188, June, 1952.

Shockley, W., Interpretation of e/m Values for Electrons in Crystals. Phys. Rev., **88**, p.953, Nov. 15, 1952.

Sparks, M., Junction Transistor. Sci. Am., **187**, pp.29-32, July, 1952.

Van Tassel, E. K., see J. A. Coy and E. K. Van Tassel.

Wannier, G. H., Nature of Solids. Sci. Am., **187**, pp.39-48, Dec., 1952.

Wannier, G. H., see H. W. Lewis and G. H. Wannier.

Wright, E. E., Stress Relaxation in Plastics and Insulating Materials. A. S. T. M. Bull., **184**, pp.47-49, Sept., 1952.

# Talks by Members of the Laboratories

During the month of December, a number of Laboratories people gave talks before professional and educational groups. Following is a list of the speakers, titles, and place of presentation.

Andrews, E. G., A Review of the Bell Laboratories Activities in Digital Computer Developments, A. I. E. E., Ithaca Section, Ithaca, N. Y.

Becker, J. A., The Field Emission Microscope and Its Use in the Study of Chemisorption, Catalysis Club, Philadelphia, Pa.

Chapman, A. G., How Crosstalk and Noise Affect Capacitance Unbalance Requirements, Particularly in Spiral-Four Cables, Signal Corps Symposium, Asbury Park, N. J.

Darrow, K. K., Magnetic Resonance, A. I. E. E., North New Mexico Section, Albuquerque, N. M.

Evan, H. W., TD-2 Radio Relay Systems, A. I. E. E. Student Branch, Worcester, Mass.

Ferrell, E. B., Control Charts for Log-Normal Universes, A. S. Q. C., Princeton, N. J.

Fox, A. G., Microwave Propagation on Dielectric Rods and in Ferromagnetic Media, I. R. E.-A. I. E. E. High Frequency Measurement Conference, Washington, D. C., and Performance of Ferrites in the Microwave Range, I. R. E. Section, New York, N. Y.

Galt, J. K., Domain Wall Motion in Ferrite Single Crystals, I. B. M. Seminar, Poughkeepsie.

Geschwind, S., The Determination of Nuclear Masses from Microwave Spectra, Physics Colloquium of New York University, New York, N. Y.

Goertz, Miss M., Action Pictures of Ferromagnetic Domains, Society of Women Engineers-American Association of University Women, New York, N. Y.

Harvey, F. K., Focussing Sound with Micro-Wave Lenses, A. S. M. E., Faculty Club, M. I. T., Boston.

Herbert, N. J., Information Theory, Lafayette College, Easton, Pa.

Hines, M. E., Latest Developments in Traveling Wave Tubes, A. I. E. E. and I. R. E. Pittsburgh Sections, Pittsburgh, Pa.

Honaman, R. K., Frontiers of Communication, Rotary Club, Washington, D. C.

Karlin, J. E., The Construction of a Subjective Scale of Weight, Psychology Seminar, Drew University, Madison, N. J.

Keister, W., Switching Circuits for Automatic Control, I. R. E. Philadelphia Section.

Kircher, R. J., Transistor Circuit Network Aspects, I. R. E. Princeton Section, Princeton, N. J.

Kock, W. E., Physics of Music and Hearing, A. I. E. E. New York Section, New York, N. Y., and A. I. E. E. Philadelphia Section.

Lawson, C. C., and A. N. Gray (Western Electric Company), Neoprene Jacketed Drop Wire, Signal Corps Symposium, Asbury Park, N. J.

McKay, K. G., Experiments and Thoughts on Secondary Electron Emission, University of Toronto, Toronto, Canada, and McGill University.

McMillan, B., The Modern Theory of Communication. Management Division, A. S. M. E., New York, N. Y.; Society of Sigma Xi, New York University, New York, N. Y.; and Conference on Methods in Philosophy, New School for Social Study, New York, N. Y. Information Theory, Institute of Mathematical Statistics, Chicago, Ill.

Odell, N. H., Physical Phenomena in Transistors, Lehigh University, Bethlehem, Pa.

Olmstead, P. S., SQC in Engineering Research and Development, A. A. A. S., St. Louis, Mo.

Raisbeck, G., Transistor Tetrodes, I. R. E. Baltimore Section, Baltimore, Md.

Read, R. K., Dislocation Theory of Grain Boundaries and Dislocation in Crystals, General Electric Company, Schenectady, N. Y., and Columbia University, New York, N. Y.

Riesz, G. W., Stress Analysis, Society for Experimental Stress Analysis Meeting, New York.

Schelkunoff, S. A., Radiation Theory in Retrospect, Univ. of California, Berkeley, Calif.; Univ. of California, Los Angeles, Calif.; Naval Ordnance Test Station, Inyokurn, Calif.; Naval Electronics Laboratory, San Diego, Calif.; and U. S. Naval Air Missile Test Center, Pt. Mugu, Calif.

Sears, R. W., Electronic Memory Tubes, University of Illinois, Urbana, Ill.

Shewhart, W. A., Statistical Control in the Conservation and Utilization of Resources, Princeton University, Princeton, N. J.

Shockley, W., Transistor Physics, Summit Association of Scientists, Summit, N. J.

Sittner, W. R., Transistors, University of Kentucky and University of Louisville.

Struthers, J. D., Peacetime Applications of Atomic Energy, Mens Club, Basking Ridge, N. J.

Teal, G. K., The Chemistry of Transistor Materials, Lafayette College, Easton, Pa.

Terry, M. E., Sensory Differences and Quality Control, Princeton University, Princeton, N. J., and The Adaptation of the Rank Analysis to Threshold Values, American Statistical Association, Chicago, Ill.

Trenting, R. G., Some Examples of Fundamental Research in Communications Metallurgy, Johns Hopkins University, Baltimore, Md.

Valdes, L. B., Transistors, A. I. E. E. and I. R. E. Students Branches, City College of New York.

Wyman, C. T., Cable Sheath, Signal Corps Symposium, Asbury Park, N. J.

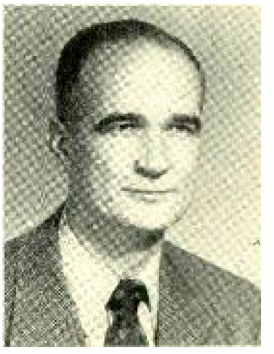
## Committee Appointed to Advise on Defense of North America

The Department of Defense has appointed a temporary committee to advise the Secretary of Defense on certain aspects of the problem of defense of the North American continent against possible atomic attack. Chairman of this temporary committee is M. J. Kelly. The other members are Walker Cisler, President, Detroit Edison Company; S. C. Hollister, Dean of Engineering, Cornell University; F. L. Hovde, President, Purdue University; C. C. Lauritsen, Professor of Physics, California Institute of Technology; Arthur E. Raymond, Vice President, Douglas Aircraft Company; H. S. Vance, Chairman of the Board, Studebaker Corporation, and R. E. Wilson, Chairman of the Board, Standard Oil Company of Indiana.

*M. J. Kelly, President of Bell Telephone Laboratories, recently appointed Chairman of Advisory Committee of the Department of Defense, is shown above (right) being congratulated by Cleo F. Craig, President of the American Telephone and Telegraph Company, on completion of thirty-five years service in the Bell System.*

The committee will be assisted in its work by associates appointed from the Department of Defense. The committee will concern itself with over-all Department of Defense policies, and programs aimed at achieving a more effective condition of continental defense. Particularly, it will study the possibilities of improved methods of warning of hostile attacks, and the relation of such warning systems to other major continental defense measures.

## W. Shockley Awarded Solid State Physics Prize



William Shockley received the first annual Oliver E. Buckley Solid State Physics Prize of the American Physical Society at a banquet at Harvard University during the January 22-24 meeting of the Society. The award was made for Dr. Shockley's contributions to the physics of semi-conductors.

Named for the former President of the Laboratories, the prize of $1,000 is awarded to a person adjudged to have made a most important contribution to the advancement of knowledge in solid state physics within the five years immediately preceding the award. The recipient of the prize is chosen by a committee appointed by the American Physical Society.

During this past five years, Dr. Shockley has made many contributions to solid state physics including the theory predicting junction transistors more than three years before working units were announced publicly. He is the author of *Electrons and Holes in Semiconductors*, one of the recent books in the Bell Laboratories Series.

A member of the National Academy of Sciences, he is the holder of the I. R. E.'s Morris Liebmann Memorial Prize, awarded in 1951 in connection with his transistor work. He is a Fellow of the American Physical Society, and a member of Tau Beta Pi and Sigma Xi.

# Bell System Report for 1952

During 1952, A T & T reports, one new telephone was added every four seconds of each working day. Use of the telephone continues to increase, and to meet public demands and improve service still further, all Bell System companies are keeping on with heavy construction programs. In accordance with long range plans, new devices and equipments are being put to work in the over-all system, one objective of which is to make it possible ultimately for telephone users to dial their own long distance calls.

At the end of the year, there were about 39,350,000 Bell System telephones in service, and people throughout the country were using them at the rate of 149 million conversations per day.

Achievements of the System during 1952 include the following:

Subscribers in Englewood, New Jersey, are able to dial directly to eleven million telephones in and around a dozen large cities from coast to coast. This trial of customer long distance dialing has indicated that the service is practical and fast.

Eight out of ten Bell System telephones are now dial operated, and four out of ten long distance calls are being dialed by the originating operator directly to the called telephone.

New major long distance switching centers were placed in operation in Omaha, Houston, and Cincinnati. There are now 18 of these centers which, interconnected with other smaller systems, enable operators to dial through to distant telephones in 1,625 cities and towns.

About 3,100 miles of coaxial cable and radio relay routes were installed in 1952. Altogether, 16,300 route miles of these facilities provide thousands of long distance telephone circuits as well as 31,500 channel miles for transmission of network and theatre television programs over the nationwide system. Coaxial cable and radio relay extensions brought 14 more cities into the national television network.

New construction programs of the associated companies required expenditures of approximately one and a quarter billion dollars. More than 1,900,000 telephones were added, 2,000,000 miles of long distance circuits installed, and 850,000 requests handled for changes in service — to a line with fewer customers or to an individual line. About one quarter million telephones were added in rural areas, about half of them on lines with more than four parties, and progress continued in furnishing the kind of service where it is only necessary to lift the receiver to get the operator or dial tone. At the year's end, about 94 per cent of rural telephones were of this type.

A new coaxial cable system, "L-3," was developed by the Laboratories. It will enable one pair of coaxial "pipes" to handle simultaneously more than 1,800 telephone conversations or 600 telephone conversations plus one television program in each direction.

The transistor was given its initial trial in the switching apparatus at Englewood. Licenses to manufacture transistors under Bell System patents were made available to thirty-seven other companies by agreement with Western Electric, whose own output has been mostly for military uses.

Plans were completed for the maintenance of essential telephone service in the event of emergency. Aircraft warning systems were set up for civil defense and Air Force filter centers. The Laboratories and the Western Electric Company designed and produced top secret electronic devices as well as guided missiles, fire control equipment for anti-aircraft guns, radar, atomic weapons, and a new field telephone for the Signal Corps. Assistance was also given the Signal Corps in the construction of vital long distance communications linking strategic areas in Alaska. More telephone facilities were made available in training camps and stations.

Bell System employees, including the Laboratories and Western Electric, reached nearly 700,000. A T & T share owners passed 1,200,000, a gain of about 125,000 for the year.

*H. S. Black joined Bell Telephone Laboratories in 1921. In 1925 he was placed in charge of groups developing repeaters, regulators, filters and other circuits for carrier systems, and later invented the stabilized feedback amplifier. He also proposed the use of thermistors for the regulation of telephone circuits. During World War II he was concerned almost exclusively with war developments. Since that time he has been engaged largely in studies and designs of radio pulse relay systems, and, more recently, in transmission research.*

*The plaque awarded to Mr. Black "for his invention and development of the negative feedback system . . . and also to recognize a prolific inventor whose achievements are attested by many publications, patents, and contributions in recent years to the development of military systems . . . Application of negative feedback has made possible the enormous amplifications . . . upon which rest substantially the structures of multiplex telephony, the servomechanism art, the computing art, the entire field of industrial control mechanisms . . ."*

# H. S. Black Receives Research Award

H. S. Black, Transmission Research Engineer of Bell Telephone Laboratories, was awarded the 1952 Research Corporation Annual Award for Contribution to Science at a dinner at the Waldorf-Astoria on January 23. This award was in recognition of Mr. Black's invention and development of negative feedback systems and other contributions to communications. Negative feedback has come into general use not only with carrier systems, but with radio broadcasting, and other electronic and communications fields.

In 1940, Mr. Black was honored by the National Association of Manufacturers as a Modern Pioneer and later was awarded the John Price Wetherill Medal of the Franklin Institute. He was also awarded a Certificate of Appreciation by the War Department in recognition of his development work in connection with World War II. He is a Fellow of the A. I. E. E., also of the I. R. E., and a member of Tau Beta Pi, Sigma Xi, and of the American Association for the Advancement of Science.

The annual award of Research Corporation is made to scientists who have made outstanding contributions to human knowledge. It consists of a $2,500 honorarium, a five-by-seven-inch bronze plaque, and a citation. First given in 1925, it was granted irregularly during the next decade, and in 1935 was established on an annual basis contingent upon the availability of a suitable candidate.

Research Corporation is a non-profit foundation which distributes its total net income as grants in aid of research to colleges, universities, and scientific institutions. It was established in 1912 by Dr. Frederick Gardner Cottrell, scientist, teacher, and inventor, with the gift of his patent rights in the field of electrical precipitation. Its objectives are: (1) to receive and to acquire inventions, and to render the same more available and effective in the useful arts; (2) to provide means for the advancement of scientific investigation by contributing the net earnings of the corporation to scientific and educational institutions, and (3) to receive moneys and properties and to apply them to the object specified.

## Deal-Holmdel Colloquium

The third meeting of the Deal-Holmdel Colloquium for the season was held at Holmdel, December 12. H. J. Williams spoke on *Ferromagnetic Domains.* In his talk, Mr. Williams showed slides of the domain patterns obtained in polycrystalline perminvar, which studies had been made in cooperation with Matilda Goertz. Some of this work was published in the October, 1952, issue of the RECORD. Mr. Williams also showed motion pictures of domain patterns in silicon-iron crystals and discussed the observation of domains in cobalt, work which was done in cooperation with Mrs. E. A. Wood and F. G. Foster.

The fourth meeting of the Deal-Holmdel Colloquium for the season was held at Holmdel on January 2. The speaker was W. Shockley who discussed transistor physics. He described the physical characteristics of transistors and discussed new theories in the operation of them.

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# Patents Issued to Members of Bell Telephone Laboratories During November

Anderson, F. W. — *Current Supply Apparatus* — 2,619,626.

Bardeen, J., and W. H. Brattain — *Semiconductor Amplifier and Electrode Structures Therefor* — 2,617,865.

Brattain, W. H., see J. Bardeen.

Clutts, C. E., G. A. Pullis, A. K. Schenck and L. A. Weber — *Alarm Signaling System* — Re 23,571 (Reissue of Patent No. 2,583,088).

Buchanan, R. B. — *Toll Supervisory Operator's Telephone Circuit* — 2,619,549.

Cutler, C. C. — *Frequency Changing Regenerative Pulse Repeater* — 2,617,885.

Cutler, C. C. — *Regenerative Pulse Generator* — 2,617,930.

Cutler, C. C. — *Frequency Changing Pulse Repeater Employing Phase Modulation* — 2,619,543.

Dehn, J. W. — *Register Control of Coin Return* — 2,616,974.

DeLange, O. E. — *Distortion Indicator* — 2,618,686.

Eppel, S. L. — *Precautionary Circuit* — 2,619,178.

Etheridge, H. A., Jr. — *Automatic Measurement of Transmission Characteristics* — 2,617,855.

Fay, C. E. — *Electron Discharge Device* — 2,617,959.

Gilmer, P. E. — *Method of and System for Measuring Impedance Mismatch* — 2,617,853.

Gray, F. — *Coder for Pulse Code Modulation Systems* — 2,617,980.

Gray, F. — *Coder for Pulse Code Modulation Systems* — 2,617,981.

Griest, R. H., and D. E. Wooldridge — *Electrical Computing System* — 2,616,625.

Hamilton, B. H., and H. H. Spencer — *Regulating Apparatus* — 2,619,631.

Heidenreich, R. D. — *Surface Treatment of Germanium Circuit Elements* — 2,619,414.

Hersey, R. E. — *Telephone Calling Line Identification and Recording System* — 2,619,545.

Holden, W. H. T. — *Counter Circuit* — 2,616,627.

Houghton, E. W. — *Apparatus for Power Measurements at High Frequencies* — 2,619,545.

Kannenberg, W. F. — *Automatic Volume Control* — 2,616,971.

Kelsay, L. W. — *Cable Terminal* — 2,619,518.

Koehler, D. C. — *Pretensioned Spring* — 2,616,993.

Lewis, W. D., and J. R. Pierce — *Pseudohybrid Microwave Filter* — 2,617,881.

Mallina, R. F. — *Recording System* — 2,617,704.

Meszaros, G. W. — *Current Supply Apparatus* — 2,617,087.

Myers, O. — *Party Line Identification System* — 2,619,546.

Pierce, J. R. — *Communication System Employing Pulse Code Modulation* — Re 23,579 (Reissue of Patent No. 2,538,266).

Pierce, J. R., see W. O. Lewis.

Pullis, G. A., see C. E. Clutts.

Schenck, A. K., see C. E. Clutts.

Shann, O. A. — *Key Actuated Double Custody Lock* — 2,617,289.

Slezak, S. T. — *Audible Alarm for Telephone Systems* — 2,616,979.

Spencer, H. H., see B. H. Hamilton.

Stone, J. R. — *Regulating Apparatus* — 2,619,630.

Tinus, W. C. — *Object Location System* — 2,617,094.

von Gugelberg, H. L. — *Multicathode Gaseous Discharge Device* — 2,618,767.

Vroom, E. — *Selective Signaling System* — 2,619,528.

Weber, L. A., see C. E. Clutts.

Wooldridge, O. E., see R. H. Griest.