The author (right) and V. P. DiLullo examine one of the new wire supports. Mr. DiLullo holds a standard glass insulator.

A New Type Open-Wire Line for Rural Areas

R. G. WATLING *Outside Plant Development*

New equipment and techniques for installing rural open-wire lines have been developed to a point where a general field trial by the Operating Companies is getting under way. The unique feature of the new line is that it can be constructed entirely from the ground. For this purpose a newly designed wire support permits the wires to be strung, tensioned, and clamped without the necessity of climbing poles.

The extension and improvement of rural telephone facilities have always been important Bell System objectives. Since the war, Operating Companies throughout the nation have put special emphasis on a construction program to meet the unprecedented demand of residents of sparsely settled areas for telephone service. Between one and one-half and two million telephones have been installed on farms and ranches since 1945. For this increased service the Bell System has built thousands of miles of new pole line and has strung over a million and a half miles of wire.

Bell Laboratories has contributed to this vast construction program by developing new equipment and systems needed to furnish additional service of a better grade to farmers. New high-strength steel line wire has made possible long-span construction in many areas and has resulted in substantial savings in material costs by decreasing the number of poles required per mile; a new form of distribution wire, which is buried directly in the ground, has afforded construction economies in certain areas; new types of carrier systems have been developed for installation on telephone lines and on power lines; radio telephone links have been made available for extending telephone service to remote customers – these are representative developments which have helped the Bell System carry out its aims of incorporating in rural service as many of the features of urban service as is practicable.

Recent studies of rural outside plant indicated that greater economies in construction costs are more likely to result through the introduction of

Fig. 1 — Prior to erection, the pole and all of its fittings are being assembled on the ground by J. D. Apgar (left) and V. P. DiLullo of the Chester Laboratories.

new structures and techniques than through modifications of present materials. Development efforts have therefore been pointed in the former direction, with the result that a new type of light open-wire line has been designed. This line can be constructed entirely from the ground and can carry from one to four pairs of conductors, which, with the multiparty system, affords capacity to serve adequately many of the rural areas in the country. In those cases where more circuits are needed, carrier systems suitable for use on this as well as on other types of construction are being considered.

The elimination of pole climbing in line wire installation operations is made possible through the design of a new type of insulator used to support the wires. Unlike the conventional glass insulator, which is mounted on the top of the crossarm, the new insulator is mounted underneath (or suspended from a bracket) to facilitate installation of line wires from the ground.

The new line was developed primarily to reduce construction costs through the simplification of labor operations. Although designed for long-span construction, the line uses the lightest poles, crossarms, and guys consistent with strength and clearance requirements. All construction work can be done by a crew of three or four men.

In terrains suitable for the operation of motor vehicles, pole line construction operations, such as hole digging, pole setting, and guy anchor installation, can be expedited by the use of standard truck-mounted digging and hoisting equipment. In areas where these trucks cannot be conveniently used, the operations described are performed manually.

Poles, as in Figures 1 and 2, are completely equipped with pole brackets or crossarms, insulators, transposition brackets, and guy attachments before they are erected. The wooden crossarms carry two or four pairs of wires. In the case of the two-pair line (Figure 3), the wires on one side of the pole are in a horizontal position below the arm, and the wires on the other side are arranged vertically, one above the arm and one below. At each succeeding pole the position of the wires alternates between horizontal and vertical so that, in four spans, the wires of each pair make a complete helical turn, each around the other. This provides a transposition system that protects each circuit against noise and crosstalk interference. Wires of the four-pair line are transposed in a similar manner. Where only a single pair of wires is required,

Fig. 2 — A completely equipped pole being raised to it permanent position at the Chester Laboratories by (left t right) V. P. DiLullo, J. D. Apgar, and T. W. Rolph.

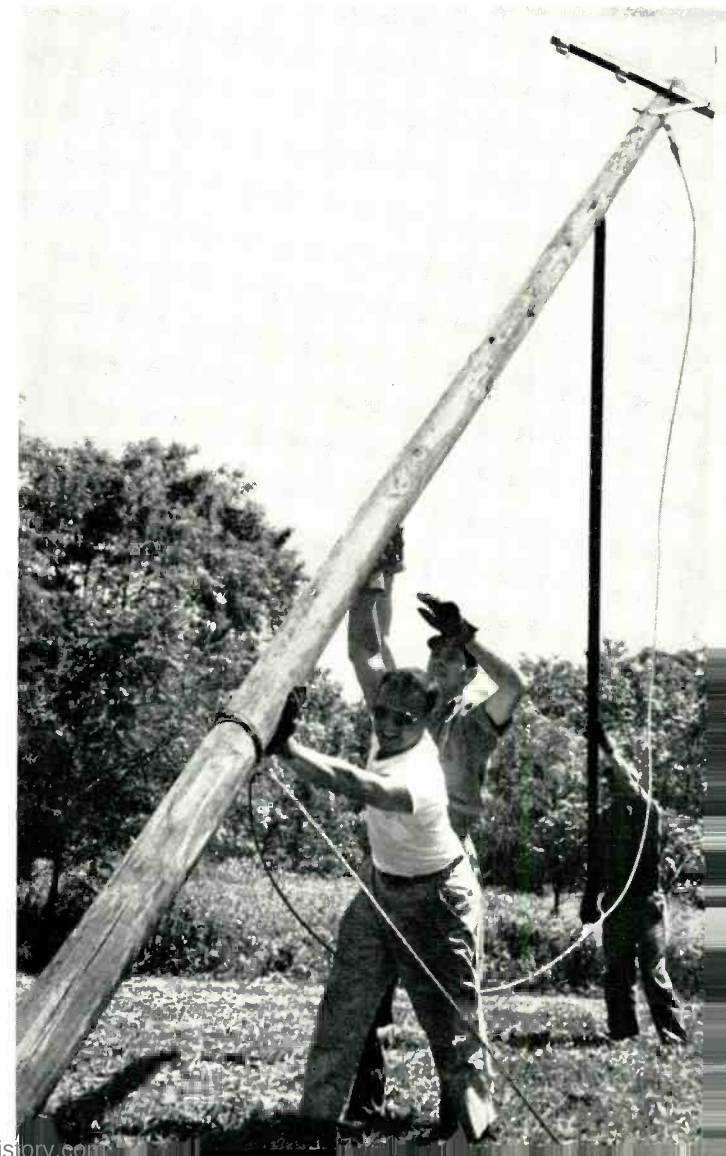


Fig. 3 — A complete ground-erected two-pair line, showing horizontal and vertical mountings of suspension insulators.

vehicles, the line wires may be payed out from trailer-mounted reels, as the trailer moves along the lead. If the use of motor vehicles is impracticable, the wires may be pulled along the lead by hand, or by horse teams, from reels located at accessible positions along the right-of-way. Usually one-half mile lengths of line are pulled in at one time. As the wires are pulled along the lead, in every span the relative position of each wire of a pair is changed, to provide for the helical turns of the transposition system.

Before the wires are raised to their insulators, vibration dampers (Figure 4) are placed on each wire in each span. The damper is a short length of plastic tubing, split helically along its length to facilitate its installation on the wire. This damper, by its flexing action as the wire moves under wind-

Fig. 4 — P. T. Packard demonstrates how a helically split vibration damper is placed on an open wire line prior to raising it to the insulated wire support.

these are supported by means of brackets of strap steel attached to the poles with lag screws or through-bolts.

The advantages of the new construction methods are, of course, most fully realized in the wire-stringing operations. Line wires are payed out along the right-of-way by one of two methods, depending on the nature of the terrain along the route. If the right-of-way permits the use of motor

inducted vibrations, will absorb energy as fast as the the wind puts energy in, thus damping out high-frequency, low-amplitude vibrations which might result in injury to the wire at the point of its support. The damper is effective at any position on the wire in the span.

The wires are then lifted from the ground with wire-raising tools and placed in the wire supports. This operation is shown in Figure 5. The wire-

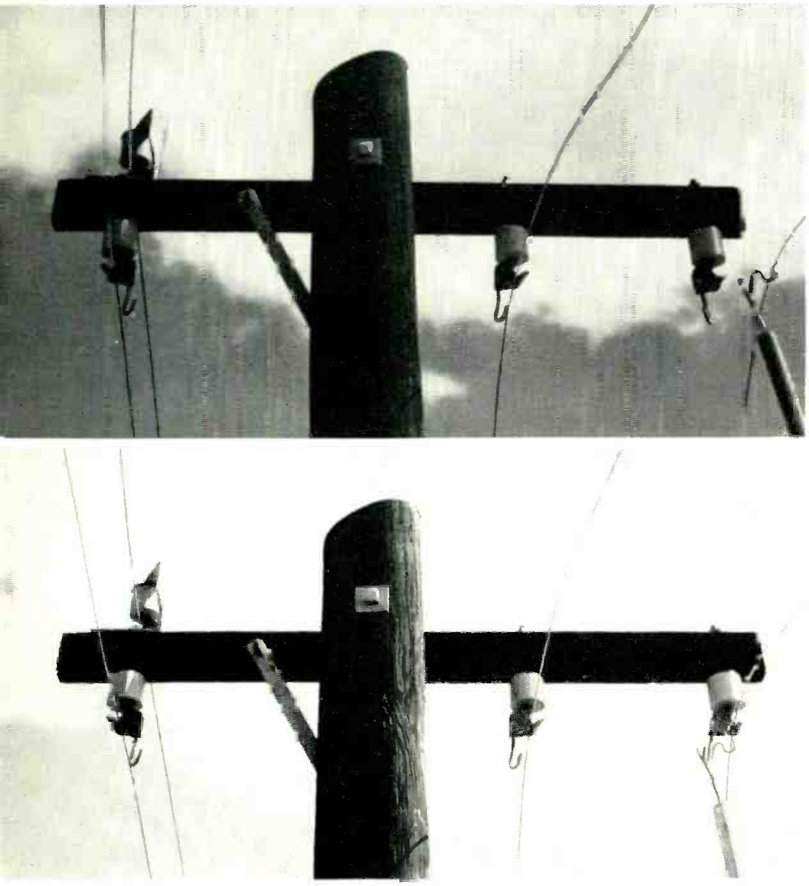


Fig. 5 — Left, two views of the wire-raising tool being used to place a wire on the insulated support.

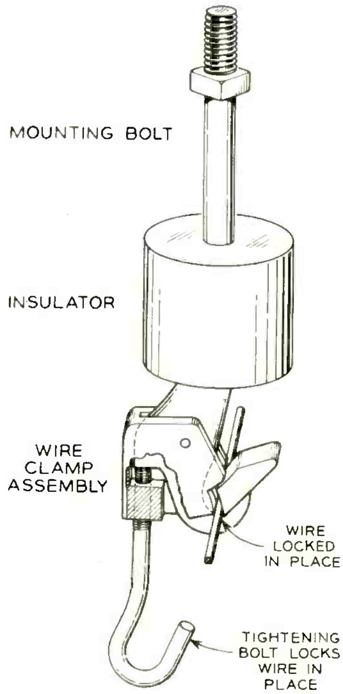


Fig. 6 — Drawing of the new insulated wire support, showing parts.

raising tool is of light and strong construction and has insulating sections to protect workmen against electrical shock in case of accidental contact with power wires. The head of the tool is designed to perform several functions: to hold the wire while it is being raised from the ground, to guide the wire into its support, to tighten the support after the wire is tensioned, and to open the support and remove the wire therefrom if this is ever required, either while construction is in progress or as a maintenance operation.

The wire support is the heart of the new system

Fig. 7 — Below, tensioning gear used to get correct tension in open wire lines from a ground position.

because its unique design makes it possible to install line wires without the necessity of pole climbing. The complete support consists of three major components: the mounting bolt, the insulator, and the wire clamp assembly. Supports can be seen in several of the accompanying photographs, and the parts are identified in Figure 6. The insulator is made of a tough plastic of the filled styrene polyester casting resin family which possesses excellent electrical and mechanical properties. The metal parts are molded into the insulator, which is in the form of a cylinder. Unlike the standard form of glass insulator with its flared petticoat designed to keep the under-surface dry, the new insulator does not have such a "dry path," but depends on rain to keep its surface clean. A clean surface, even though wet, does not permit much electrical leakage.

The wire clamp consists essentially of a hook member of aluminum, a keeper, also of aluminum, which pivots on and moves across the hook, and a steel locking screw. As the wire enters the hook, it pushes the keeper aside and drops into the slot of the hook. The keeper then restores, trapping the wire so that it cannot escape, but allowing it to move freely through the hook longitudinally to permit tensioning.

The wires are tensioned from the ground. The tensioning gear, seen in Figure 7, consists of a system of ropes and pulleys designed to equalize tensions in all four of the wires, grips for holding the wires, and a dynamometer to measure wire tensions. After the line wires are tensioned, the final construction operation, that of tightening the wire-support locking screws with the wire-raising tool, is performed as in Figure 8. The locking surfaces of

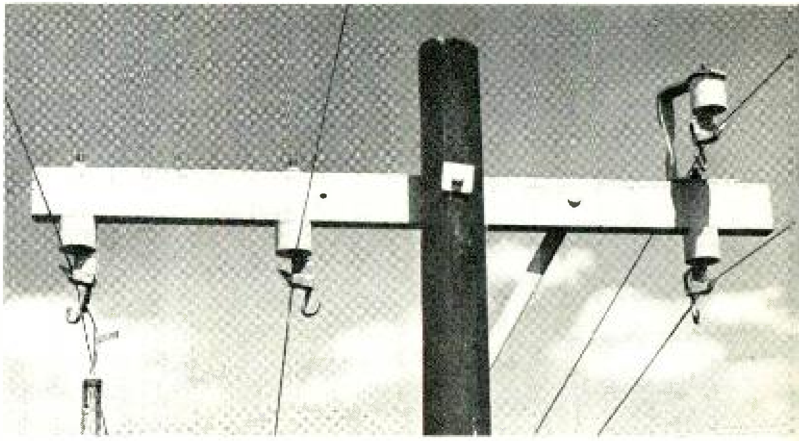


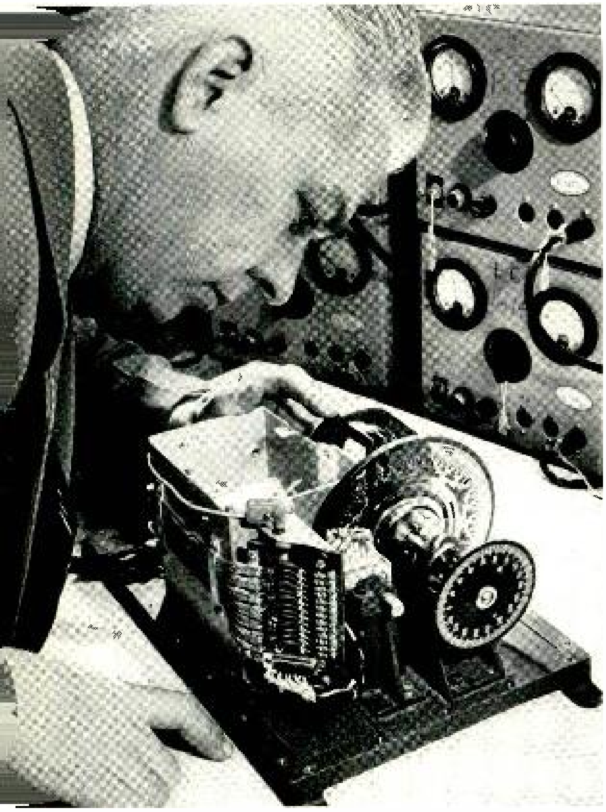
Fig. 8 — The wire-raising tool is here being used to tighten the locking screw of the insulated wire support.

the keeper and hook are such that a slight bend is put in the wire, thus helping to hold it tight. The keeper and hook have been designed to guard against injury to the wire surface.

Field trials of the new construction methods have been made in Virginia, Colorado, and Louisiana. The line in Virginia was built under difficult terrain conditions where the construction techniques of the new type line could be tested most effectively. The Colorado installation is in a dry region of extreme temperatures and high prevailing winds that will test the fatigue endurance qualities of the new line. The Louisiana line will operate under hot and humid conditions, and therefore will test the insulating qualities of the wire supports. Meanwhile, preparations are being made for a general field trial of this new rural line by the various Operating Companies of the Bell System.

THE AUTHOR

R. G. Watling received a B.A. degree from Occidental College in 1923 and the following year joined the Southern California Telephone Company. He was transferred to the Laboratories in 1926, serving first as an instructor in the training course for Technical Assistants, and later joining the administrative staff of Outside Plant Development. In 1940 he became supervising engineer in Switching Apparatus Development. The following year, on leave from the Laboratories, he served as assistant to the Director of Research at the U. S. Navy Underwater Sound Laboratory, New London, Conn. Returning to Outside Plant Development in 1946, he was concerned with the development of hardware and tools, and two years later was assigned to the plant systems studies group. He is currently in charge of a group working on wire and cable development problems. Mr. Watling is a member of the A.I.E.E., the A.S.T.M. and the New Jersey Society of Professional Engineers.



A Digital Code Wheel

J. J. J. KERNAHAN *Military Systems*

Frequently, digital computers are used to solve problems that are based on information obtained from indications on instrument dials. This information must be supplied to the computers in binary code and, especially in military applications, it is essential that it be done quickly and accurately. One method of accomplishing this is by means of a digital code wheel designed at Bell Telephone Laboratories.

When digital computers are used in gun-directing apparatus or other military applications, the original data are frequently supplied by the rotational position or angular velocity of an instrument shaft. The results of the computer calculations can be no more accurate than the original data, and the speed with which the solution to a problem can be obtained is limited by the time required to obtain data from the instrument shaft; therefore, it is highly desirable to provide a means of transmitting shaft position or velocity information – called analog data – directly to the computer. One method of encoding this type of analog data and supplying it to a computer is based on the use of a digital code wheel designed at Bell Telephone Laboratories.

In the encoding process, the code wheel illustrated in Figure 1 is rigidly mounted on an instrument shaft, and light from a broad line photo flash tube source is passed through the wheel and a 0.001 inch slit to a series of photoconductive detectors aligned radially behind the disk as indicated in Figure 2. The wheel contains thirteen concentric rings made up of alternately transparent and opaque areas decreasing in width from the center outward. In any shaft position, the arrangement of the thirteen transparent and opaque areas along the radius line containing the photocells represents a particular number. If a transparent window is located between the source and one of the cells, that cell will conduct, but if an opaque window intervenes, it will not. The outputs of the thirteen cells are fed to the computer and determine the number represented by the corresponding shaft position. A total of 8,192 number codes are included around the circumference of the wheel, and hence, a shaft position is determined to within an accuracy of approximately 2.5 minutes of arc.

If a particular application requires initial data determined by the angular velocity of a shaft, a special sampling circuit is added to the apparatus. This equipment registers the instantaneous position of the shaft at times separated by a pre-set interval. These position representations are then automatically subtracted to give a measure of the change in angular position during the established interval and thus, the angular velocity.

Bell Laboratories computers used with this code wheel base their operation on a binary rather than a decimal system of numbers. In the decimal system, the digits in each place in a number are multiplied by a power of ten corresponding to their position, and the sum of these products gives the number itself. Thus, the expression 5769 is merely a short method of writing $(5 \times 10^3) + (7 \times 10^2) + (6 \times 10^1) + (9 \times 10^0)$ or $(5 \times 1000) + (7 \times 100) + (6 \times 10) + (9 \times 1)$. This decimal system, based on the number ten, requires ten symbols for the digit designations. A binary number system, on the other hand, based on the number two, requires only two symbols – 0 and 1. The sequence 1101, for example, represents a binary number, and its decimal equivalent can be determined by multiplying the digit in each position by the proper power of two and adding the products. In this way, 1101 is equal to $(1 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$ or $(1 \times 8) + (1 \times 4) + (0 \times 2) + (1 \times 1)$ which is 13 in decimal notation. The binary expressions for the decimal numbers zero through 16 are given in Table I.

A binary system is well suited to use on the digital code wheel since any position must be either tranparent or opaque. An opaque area between the source and a particular cell represents a 0 in the binary system given in Table I. A transparent window, on the other hand, represents a 1. The way transparent and opaque areas could represent the binary numbers 0 to 16 is diagrammatically illustrated in Figure 3(a).

If this code were actually used on the code wheel, and the instrument shaft oriented in such a way that opaque windows covered the photocells

Fig. 1 — The digital code wheel.

in all except the outer three positions, the binary representation for the decimal number 7, as shown in Figure 3(a), would be fed to the computer. If the shaft moved slightly and a transparent window appeared only in the fourth position from the edge, the number 8, as shown in Figure 3(a), would be registered. A severe limitation in this arrangement would occur, however, if the shaft orientation were such that the photocells were aligned at the transition point between 0111, representing 7, and 1,000, representing 8. In this case, the cells might register a combination of the two arrangements which could be the binary number 1111 representing the decimal number 15. Similarly, at the transition point midway between 0 and 8191, an error of half a revolution could be produced.

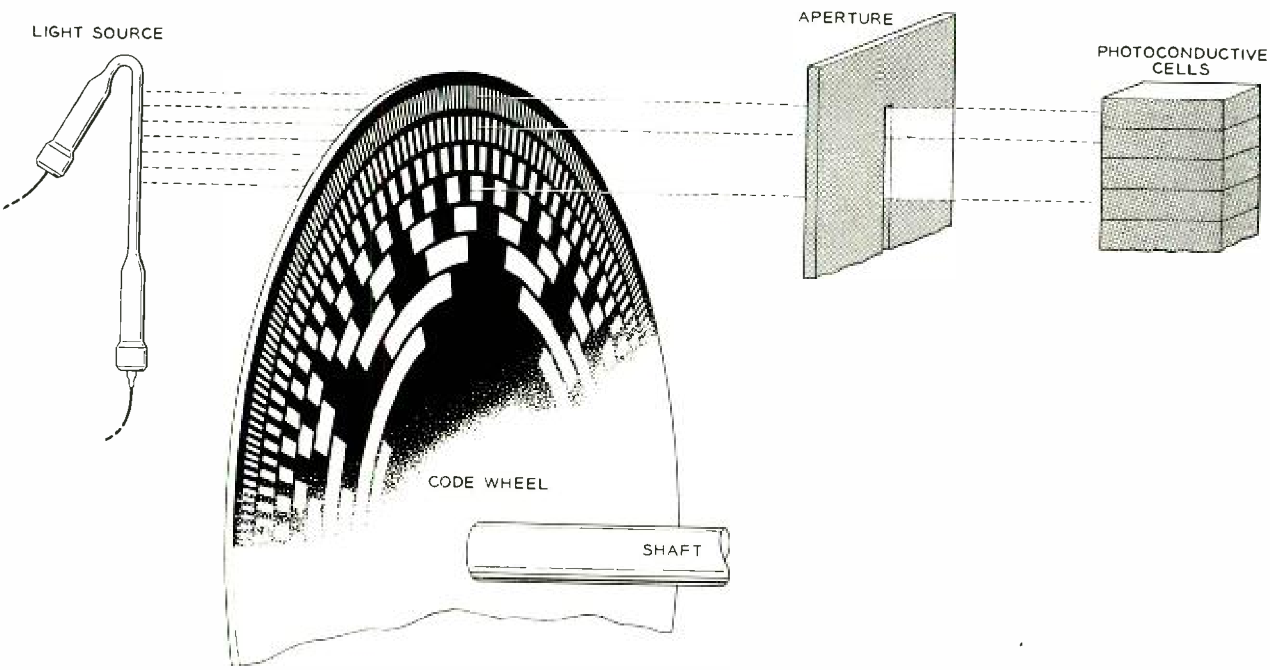


Fig. 2 — Schematic diagram illustrating arrangement of code wheel and associated light source, slit, and photoconductive cells used in encoding data.

To overcome this limitation, the digital code wheel is inscribed with a variation of the ordinary binary code known as the reflected binary code. This code was originated by G. R. Stibitz and was first proposed for pulse code modulation systems by F. Gray. Both of these men are former members of the Laboratories. The reflected code is so arranged that only one digit changes in going from any numerical representation to the next as indicated by the representations for the decimal numbers 0 through 16 in the center column of Table I. With this code, if the wheel is oriented with the photocells behind a transition between two adjacent number representations, one or the other is registered, and the maximum error is only one part in 8192, about one-hundreth of one per cent.

The diagrammatic representation of the ordinary binary code given in Figure 3(a) shows that the digital indication at the extreme right of each row alternates from one number representation to the next beginning with opaque for 0, transparent for 1, and this alternation contains indefinitely. Similarly, the second column from the right alternates at each second row, the third at each fourth row, the fourth at each eighth row, and the number of intervening representations between alternations continues to double moving from right to left on the diagram.

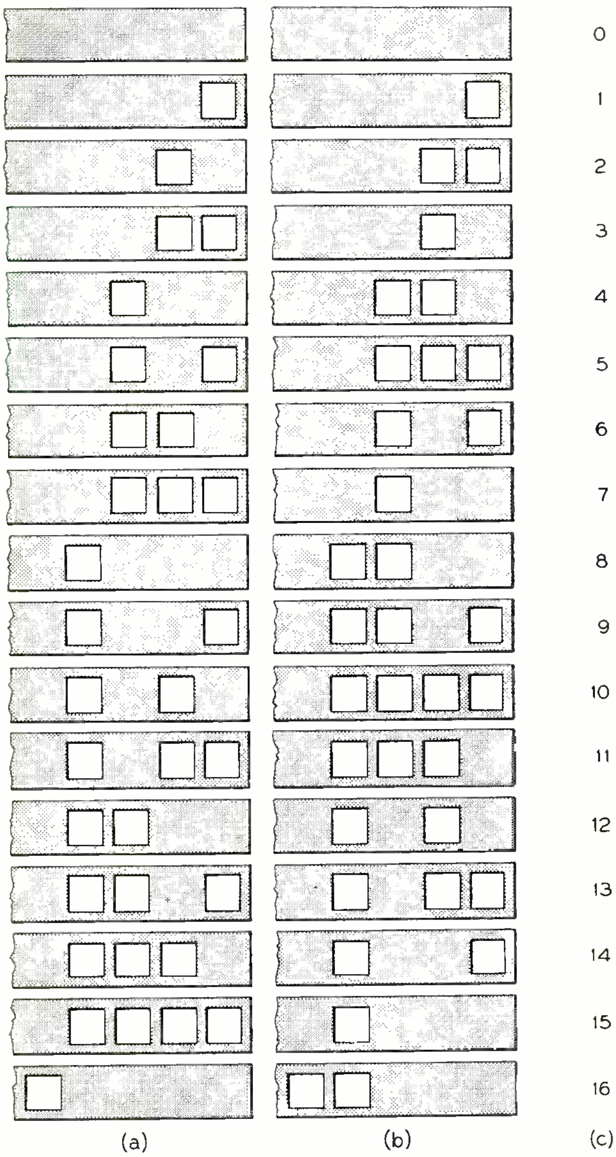


Fig. 3 — Diagrammatic representation of binary codes: (a) ordinary binary code; (b) Gray or reflected binary code used on code wheel; and (c) respective decimal equivalents.

The reflected binary code actually used on the code wheel is diagrammatically illustrated in Figure 3(b). As shown in that figure, the digit indication at the extreme right of each row – excluding the zero representation – changes after each second number representation as opposed to a change after each number in the ordinary code. Thus, transparent windows occur at the right in the rows representing one and two; the next two rows, representing three and four, have opaque windows at the right, and this column continues to alternate after every other number. The second column from the right in Figure 3(b) alternates after every fourth row rather than after every second as in Figure 3(a), and the third column, after every eighth row rather than every fourth. In this way, the code in Figure 3(b) is formed from that in Figure 3(a) by using the same representations for the numbers zero and one, and then merely doubling the number of consecutive rows between alternations in transparency in the corresponding columns.

This rather simple change results in a code that differs in only one digit position from one number representation to the next as is evident in Figure 3(b). Thus, if a wheel inscribed with this code should be oriented with the photocells aligned at a transition point between 7 and 8, a combination of the representations will result in registering a 7 or an 8 rather than a 15 as might occur with the ordinary binary code. The code wheel shown in Figure 1 is inscribed with this reflected binary code, and a section of the wheel, enlarged about 6 diameters, is illustrated in Figure 4.

A diagrammatic representation of the positions on the wheel corresponding to the decimal number 0 through 16 is shown in Figure 5. The area in-

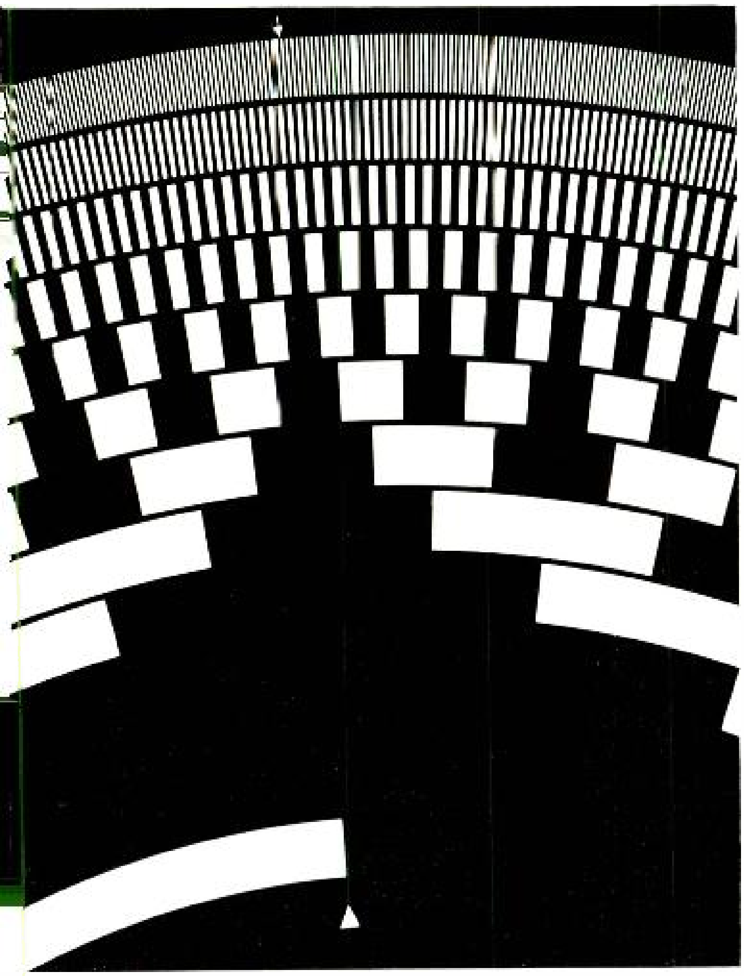


Fig. 4 — Part of the code wheel in Figure 1 magnified about six diameters, showing arrangement of the transparent and opaque areas. A radial line through the arrows indicates the transition between the code representation for the numbers zero and 8,191.

cluded in this diagram corresponds to a small part of the photograph in Figure 4 extending from the arrow at the top a short distance to the right. If the photocells should be arranged just to the right of a line extending from the arrow at the top of Figure 4 to the arrow on the bottom, opaque areas would cover each of the thirteen cells and the registered number would be zero. The corresponding arrow labeled "0" on Figure 5 represents the same position. Moving clockwise slightly on Figure 4 changes the window in the outside ring to transparent while the others remain opaque; this corresponds to a 1 as shown in Figure 5. Continuing to move in a clockwise direction changes the window in the second ring to transparent, representing a 2. In the next step, the outside ring changes back to opaque while the second remains transparent for a 3, and the process continues around the circumference of the wheel until the position just to the left of the arrows in Figure 4 is reached. This corresponds to 8,191, or two to the thirteenth power, minus one. Since the digital computers with which these code wheels are used operate on the ordinary binary code, the outputs of the photocells must be fed into a translating circuit to convert them to the usable representation before they enter the computer proper.

The completed code wheel is only 5½ inches in diameter and hence the individual divisions in the outside row are quite small — less than 0.1 of an inch long radially, and about 0.004 of an inch wide. The slit in Figure 2 must be small enough to accept light through only a portion of one of these divisions without being activated by light leaking through adjacent windows, and the photocells must then have a high sensitivity to light as well as small sizes; consequently, phototransistors[*] are used.

After the Laboratories designed this apparatus for encoding analog data, its components had to be procured, the wheel itself presenting the greatest difficulty. Previously available code wheels of lesser accuracy (fewer digits and therefore fewer transitions) were made by ruling or engraving each mark manually. In a code wheel having 13 or more digits, however, the number of marks and the precision with which they must be located makes the task difficult, if not impractical. These considerations led to the conclusion that a 13-digit wheel would have to be made automatically. This code wheel was made by W. and L. E. Gurley of Troy, New York, in cooperation with members of

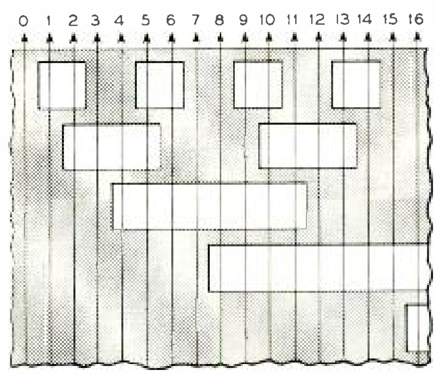


Fig. 5 — Diagram of a portion of Figure 4 showing the code representations for the numbers zero through 16.

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

the Laboratories, and with the aid of a relay counter-translator designed at Whippany.

To construct this wheel, Gurley mounted a light-sensitive-plate (master code wheel negative) on a dividing engine so geared that it could be rotated through one complete revolution in 8,192 discrete and equal steps. An optical system mounted over the dividing engine focused the image of a master sector of the code wheel in the light-sensitive plane of the master as shown in Figure 6. This image consists of thirteen slots, each approximately 0.090 inches long radially. The center to center distance between any two slots is 0.100 ± 0.002 inches. The angular width of each slot is approximately 158 seconds of arc, and the linear width of the outer slot is approximately 0.002 inches and that of the inner 0.001 inches. As shown in the figure, the slots resemble the form that would result from striking arcs across a wedge-shaped image. Shutters which could block any or all of the 13 slit images were placed in the light path between the master sector and the code wheel negative. The apparatus was so arranged that the image remained stationary as the master was rotated.

Two other major components were required to complete an automatic machine for inscribing a code-wheel master negative. One was a 14-digit relay binary counter and translator. In this circuit, two relays were used to count each input digit in binary code. This information was then stored in the circuit and the same relays were used to translate the count into the reflected binary code. The outputs, appearing on 13 wires connected to motor mechanisms, were used to operate the individual shutters in the optical path as shown in Figure 6. Actually, the complement of the reflected code was used to operate the shutters since a negative of the code wheel was being produced.

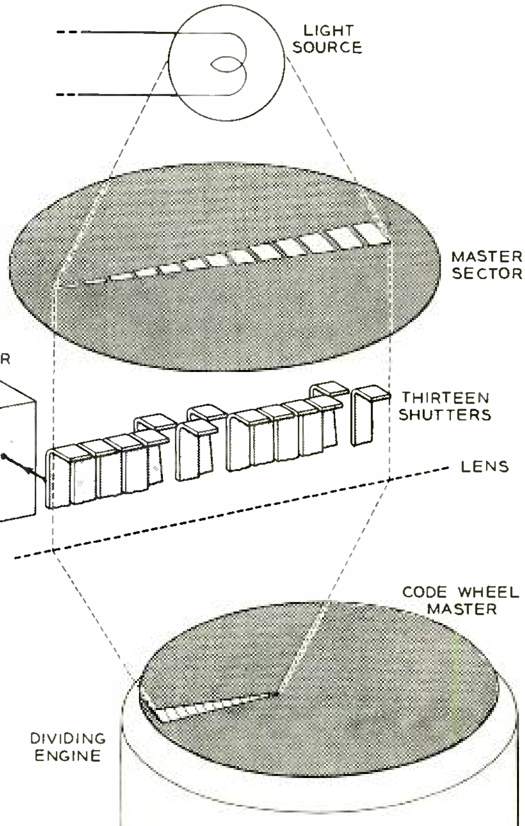


Fig. 6 — A diagrammatic representation of the process used in generating the original master-code-wheel negative.

The other major component was a sequencing device which operated on a time cycle of approximately nine seconds and controlled the following series of operations required to make the negative. First, this circuit positioned the 13 shutters from the initial output of the counter-translator and then flashed a lamp to expose the slit image on the master negative. Following this, it advanced the dividing engine one step and fed a new pulse into the counter. Acting on the resulting new 13-digit output of the counter, it changed the position of the shutter for the outermost slit. This cycle was repeated until, after a complete revolution of the engine, the counter supplied an output in the fourteenth digit which was used to shut down the process. A code wheel master negative was thus completed in approximately 20 hours of continuous unattended machine operation. Individual code wheels were made from

Table I

Decimal	Binary Code	Reflected Binary Code
0	00000	00000
1	00001	00001
2	00010	00011
3	00011	00010
4	00100	00110
5	00101	00111
6	00110	00101
7	00111	00100
8	01000	01100
9	01001	01101
10	01010	01111
11	01011	01110
12	01100	01010
13	01101	01011
14	01110	01001
15	01111	01000
16	10000	11000

the master negative by means of contact printing.

Specifications for the final code wheel allowed the graduations to deviate from their correct mean location by less than 15 seconds of arc. These deviations are due to irregularities in the dividing engine and in the photographic transfers involved.

There are eight triangular marks, four on the outer periphery of the wheel and four in matching positions nearer the center. Mutually perpendicular lines through suitable points in the four outer triangles will pass through the axis of rotation of the master. The code wheel, which in final form is a glass disk, one-fourth of an inch thick, is mounted and clamped on a shaft. By sighting with two microscopes on the graduations located by the triangles, the code pattern center can be centered before final clamping. The deviation of graduations from correct mean location with respect to the true axis of rotation of the code wheel shaft will not exceed 0.0002 inch measured at the outermost zone. Thus, it is expected that it will be possible to line up the photocells so as to look at any one of the 8,192 reproduced 13-slit images in the wheel along a line which is displaced no more than 0.0002 inch from the mean theoretical position of the slit. Rotation of the wheel brings each of the other slits in line with the photocells within the same error.

This code wheel method of encoding analog data is simpler and more accurate than other methods used to perform the same task. Moreover, the process yields essentially instantaneous results while other methods required a finite time to make each measurement and hence a shaft position may have changed during the measuring period.

THE AUTHOR

JOHN J. J. KERNAHAN became a design draftsman in 1943, two years after joining the Laboratories' Commercial Products Department. During World War II and immediately following the war his work consisted primarily of mechanical design drafting on radar equipment, shock and vibration problems associated with the development of military equipment, and mechanical design work on special devices related to Nike and other military projects. In 1951 he transferred to a group engaged in the application of transistors to digital computers. A Member of Technical Staff since 1952, he has been concerned with development work on the angular position optical encoder and associated transistor apparatus. Mr. Kernahan received the Associate E.E. degree (1938) from Newark Technical School, and the B.S.E.E. (1950) from Newark College of Engineering, Evening Division. He is a member of Tau Beta Pi.

Card-Punching Over Telephone Lines

Another telephone service was recently provided by the International Business Machines Corporation and Long Lines in an arrangement involving voice-frequency carrier telegraph techniques on telephone channels. The equipment has thus far been demonstrated over a New York-Roanoke-New York test circuit and over a New York-Washington private line circuit.

IBM's transmitting machine reads the data punched on cards and speeds it out over a telephone circuit – at a rate of about 1,000 characters a minute – in the form of coded impulses. At the distant point, the signals actuate a punching mechanism that simultaneously produces exact duplicates of the original cards. These are immediately ready for use with accounting machines and computers.

An added feature of the equipment is that it checks itself for accuracy. After sending the particulars for each card, the transmitting machine waits for a check signal from the receiving station. This signal is not delivered if a wrong character or other error has been received at the distant point.

New Gas Flow Indicator

Fig. 1 — An underground cable is tested by J. M. Jackson, using the new B flow indicator. The leak is to the right.

Certain telephone cables are maintained under internal gas pressure with dry nitrogen or dry air to protect them against the entrance of moisture. Then, if a sheath break should develop, the escaping gas prevents the entrance of moisture-laden air and it also reduces the gas pressure. If this reduction in gas pressure is great enough, a pressure switch operates, bringing in an alarm in the nearest central office or test room. A maintenance man is then dispatched to locate and repair the break.

The maintenance man takes a series of pressure readings at known distances along the cable. From these readings he plots a pressure gradient and from it determines the approximate location of the leak. In some cases, inspection of the indicated location does not reveal the gas leak, and it is then desirable to know which way from that point the leak is actually located. Since gas inside the cable is flowing toward the leak, an instrument that will indicate the direction of gas flow is extremely useful. This is particularly true in underground cable where leaks may be located in the ducts between manholes, and before replacement, it is desirable to verify that gas is flowing into the suspected section from the adjacent manholes.

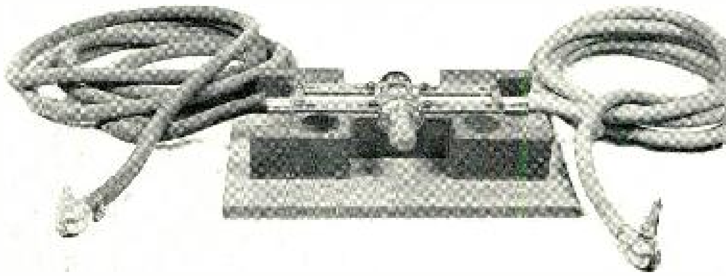
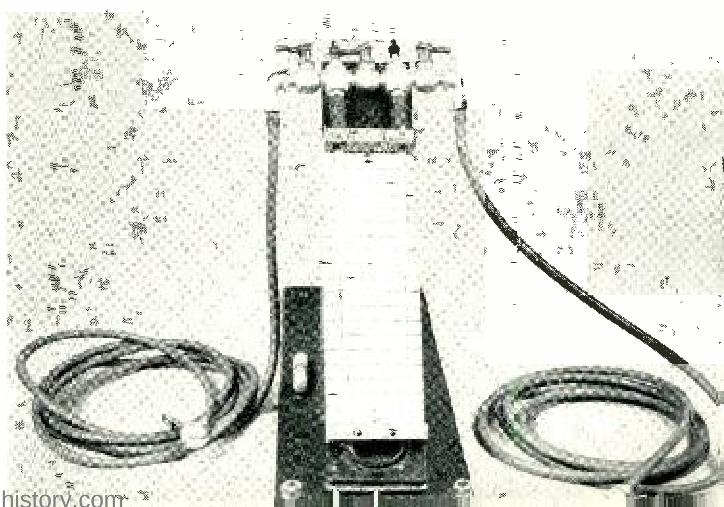


Fig. 2 — The earlier gas flow indicator uses pieces of chemically treated paper in the two glass tubes. Ammonia fumes in the central chamber follow the gas flow, and the paper toward the leak changes color.

In the past, the direction of gas flow has been determined by the gas flow indicator shown in Figure 2. This consists essentially of a glass tube with a chamber in its central portion. Pieces of paper treated with a chemical indicator are inserted in the ends of the glass tube, and it is then connected through hoses to two points on the cable. Turning the stopcock releases ammonia fumes from a previously inserted capsule, and they are carried through the glass tube in the direction of gas flow. The paper on the side toward which the gas is flowing, the side toward the leak, will then change color. This gas flow indicator has been used extensively and successfully in leak location work but it has recognized limitations of sensitivity.

Fig. 3 — A simple type of differential manometer forms the B flow indicator. The alcohol will rise in the tube toward the leak and drop in the other, indicating the direction, and the size of the leak is indicated by the difference in the alcohol levels.



In recent years, it has become desirable to locate smaller leaks than were sought at the time the gas flow indicator was developed; for this purpose a more sensitive device was needed. Since a flow of gas produces a pressure drop, a sensitive pressure-differential device will serve as a gas flow indicator. A simple type of differential manometer has a U-tube filled with a light liquid such as alcohol, which can be inclined at various angles; at a very small angle, a small pressure difference will produce a large linear deflection. The B flow indicator shown in Figure 3 is such a device. The U-tube of this instrument, containing colored alcohol, can be inclined at angles varying from 2° to 60° from the horizontal. At the 2° angle, it has a sensitivity of 0.00005 pounds per square inch (psi) per scale division; at 60°, a full scale deflection of 10 inches represents a pressure difference of 0.26 psi. This provides enough range to indicate the direction of gas flow for large or small leaks.

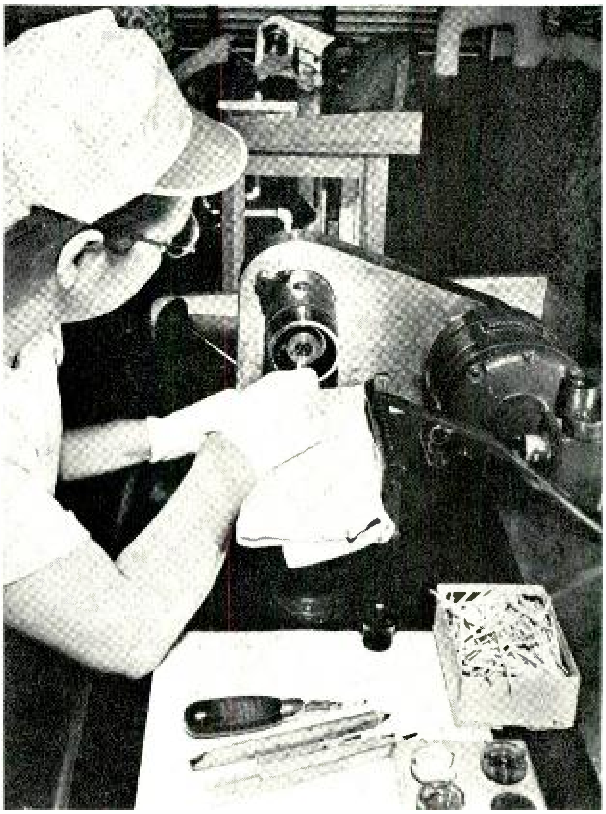
Compared to the earlier instrument, the new device has the advantage of giving a continuous and roughly quantitative indication of gas flow rather than a simple right or left indication. In some cases, connecting either instrument to a cable temporarily upsets the direction of gas flow and the chemical type of gas flow indicator can give misleading information. However, with the B flow indicator, a field man can observe the deflection until it has completely stabilized before he draws any conclusions.

Since the B flow indicator is a pressure differential device, it has the added advantage that the scale deflection is a measure of the size of the leak. That is, a large scale deflection would indicate a large leak, and a small deflection a small leak. This is particularly useful where two leaks are located close together and it becomes desirable to determine, by comparing readings at several locations, whether one or both leaks are in a particular direction from a given point.

Because of its reliability and ease of operation, the B flow indicator is often used to help locate leaks in cables buried in the ground. In such cases, the necessary pressure gradient is obtained from valves spaced approximately 3,000 feet apart, and the cable is exposed by digging at the indicated location of the leak. If the leak is not found at this point, it is usually close by. The question is, "Which way?" By using the B flow indicator, the direction of the leak can be determined, and thus the possibility of exposing a considerable length of cable in the wrong direction is eliminated.

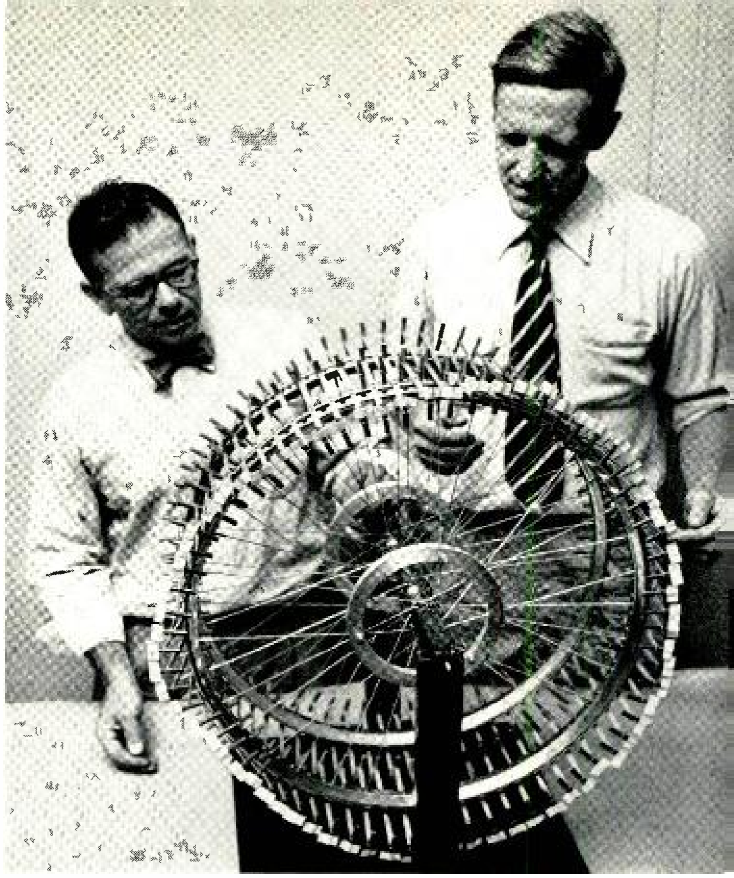
M. W. Bowker
Outside Plant Development

New Use for Toothpicks



The prosaic toothpick has been put to a new use at Western Electric's Tonawanda plant, helping to manufacture wire for Bell System equipment. Mounted in holders, the toothpicks are dipped in a mixture of diamond dust and olive oil and then worked back and forth in the fast rotating dies used in the drawing of copper wire. Ordinary round toothpicks worked well, but the occasional square one that turned up worked even better. The square ones being unfinished toothpicks that had slipped through inspection, Western Electric immediately made arrangements to secure a shipment of the unfinished variety – all in the interest of producing better wire.

A Mechanical Traveling-Wave Oscillator



C. C. CUTLER *Electronics Research*

New discoveries in the physical sciences are often such that they can be described only in mathematical terms. Frequently, such discoveries could be more completely understood and more easily described if it were possible to find a valid analogy in terms of more familiar objects and processes. The interaction of an electron stream and an electromagnetic wave that gives rise to amplification and oscillation in traveling-wave tubes is one such discovery for which it was possible to develop an adequate mechanical model. The model described in this article has, in turn, made it possible to learn a great deal more about the original interaction.

Many attempts have been made to formulate an acceptable physical picture of the interaction of moving electrons and traveling-waves such as gives rise to amplification and oscillations in traveling-wave tubes and magnetrons.* A physical picture of this sort is valuable as a basis upon which to build an accurate theory, and especially as a tool in educating young communication engineers in the use of devices based on this interaction.

An acceptable picture must be not too difficult to visualize, and must not raise a host of new questions and conflicts. Also, it must be accurate so that deeper consideration shows no violation of the physics of the actual situation. A really good analogy should make it possible to design a mechanical model which physically demonstrates the action involved in a way that is not difficult to comprehend. A search was made for a physical picture of traveling-wave and electron stream interaction, and a mechanical model was developed which brought out many aspects of the interaction which previously had not been fully appreciated.

The wave-electron stream interaction has been likened to more common wave-like phenomena such as the growth of water waves or the flapping of a flag in the wind. These pictures satisfy the requirement of familiarity, but soon come into conflict with the known theory of electron interaction,

Above — The author (right) and C. F. Chapman observing the mechanical traveling-wave oscillator in operation. Relative speed of the wheels is such that three wavelengths can be seen around the circumference.

* RECORD, *December*, 1946, *page* 439; *January*, 1951, *page* 14; and *November*, 1953, *page* 413.

and for this reason, they have been abandoned. The real difficulty, however, is not in the lack of similarity, but in the fact that few people really understand why water waves and flags flap.

Early work in electron dynamics indicated that an electron stream propagates waves and, in fact, has many of the properties of other wave transmission systems. There are indeed two waves, one traveling faster than the velocity of the stream and the other traveling an equal amount slower. They are similar in many ways to compressional waves, involving the electrical repulsion between electrons, and the inertia of the electron mass. The formation of these waves and the electric field lines resulting from bunching of the electrons is illustrated in Figure 1. These waves correspond to the forward and backward waves of a more conventional transmission line if the transmission line is moved at a velocity corresponding to that of the electron stream. Thus, one would expect that the usual transmission line terminology would provide a means of describing all the phenomena of the electron stream in terms which are familiar to telephone engineers.

The realization of this fact came as a surprise, for although people are still mystified by electrons, waves on transmission lines have become as familiar to the technically minded person as have water waves to the ocean bather. Why then, if the electron waves contain no special magic, has the interaction of the more common waves not yielded amplification and oscillation? The answer must have something to do with the fact that the propagating medium, that is the electron stream, is in motion. This kind of thinking led to a detailed investigation of the interaction of waves on coupled transmission lines. The investigation turned up a number of interesting wave phenomena which were already well known, as well as a few that were not at all common knowledge.

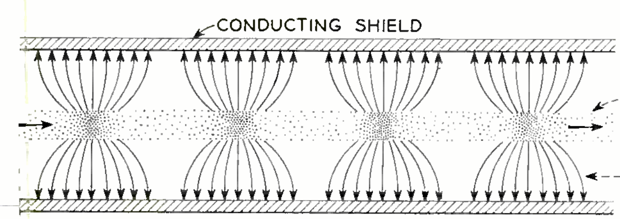


Fig. 1 — An electron stream can propagate waves as a result of the repelling force between electrons and their mass. Both the forward and backward waves appear to travel in the same direction, however, since the d-c velocity of the stream is high compared with the wave velocity.

A coupled pair of transmission lines involves four possible waves as indicated in Figure 2. When the magnitude of the coupling is zero, they are the usual independent forward and backward waves on each line. With coupling present, however, the waves are not independent, and they must be analyzed in terms of a more complex wave structure on the composite system. When relative motion between transmission lines is included, the coupling becomes even more effective in modifying the wave pattern. When the velocity of the moving line is high enough, the backward wave in the moving line and the forward wave on the stationary line, cooperate to form two new waves — conditions required for this phenomenon are illustrated in Figure 3. These new waves have identical velocities, and in addition, the amplitude of each varies with distance along the line. One has positive attenuation, analogous to a wave on a lossy line, and the other has negative attenuation, which means that the amplitude of the wave increases rather than decreases exponentially with distance. An increasing wave is an amplifying wave and this phenomenon is definitely analogous to amplification that

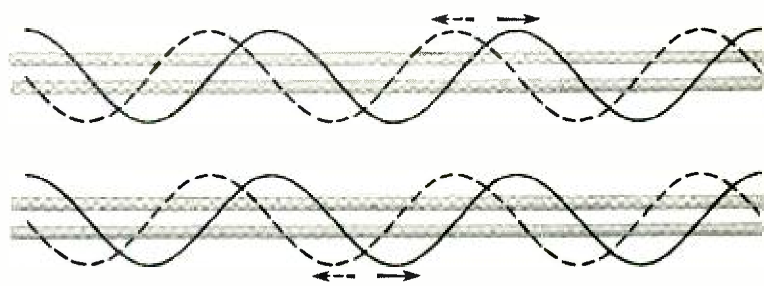


Fig. 2 — Two transmission lines can propagate four independent waves. In the absence of coupling they are the usual forward and backward waves on each line, but with coupling, the picture is more complex.

takes place in modern microwave tubes. Amplification takes place as a result of the interaction between the forward wave on one transmission system and the backward wave on another, when the waves on the two systems are moving at the same velocity in one direction.

What does this concept of coupled wave interaction mean to the person interested in developing a simple picture of traveling-wave tube operation? It does not furnish complete satisfaction, because few people have a clear picture of wave propagation itself. However, in the same way that it is often possible to visualize complicated wave phenomena by observing surface waves such as occur in water, perhaps a mechanical wave picture that is truly analogous to the phenomena that take place in a traveling-wave tube can be obtained.

To test the feasibility of developing such a picture, a mechanical traveling-wave oscillator was constructed at the Laboratories. This model is based on a transmission line made up of a series of weighted bars supported by a steel wire as illustrated in Figure 4. When one of these bars is rotated through a small arc, a low velocity mechanical wave is propagated along the line as a result of the torsion in the wire. The actual velocity of this wave is determined by the torsional rigidity of the wire and the rotational inertia of the weighted cross pieces. This kind of transmission system is commonly used for instruction in wave propagation in elementary physics courses. To easily introduce motion to this system, the line was supported on the rim of a bicycle wheel with the two ends connected to form a continuous circuit. Two such lines were built with the wheels supported on a common axle. The ends of the cross-pieces were weighted by small bar magnets polarized to produce an attraction between the cross-pieces of one transmission system and the cross-pieces of the other. Various views of this assembled model, built by C. F. Chapman, are shown in Figure 5, and in the headpiece of this article.

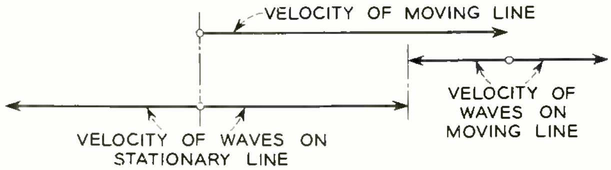


Fig. 3 — When the net velocity of the backward wave on the moving line is equal to the forward velocity of the wave on the stationary line, coupling results in an increasing and a decreasing wave.

As previously described, when one of the transmission line elements is displaced a disturbance moves slowly around the circumference of the assembly and returns to the initial point. The coupling between the two systems is also observable because a displacement on the first causes a wave tremor which moves around the second line. This reaction is not materially changed if one or both wheels are rotated slowly and, in fact, it does not change appreciably until the difference in the rim velocities of the two wheels becomes nearly equal to twice the velocity of the propagated wave. As the wheels are speeded up to this critical velocity range, a disturbance produced by touching one of the lines does not die down as it would below this velocity. When the velocities are just right, the disturbance builds up until the amplitude is limited only by the mechanics of the oscillating cross members and the wheel rim. This condition results in self-sustaining oscillations, indicating a conversion of the energy of motion into wave energy, and is indeed analogous to the traveling-wave tube or magnetron interaction.

This model has received considerable attention because of the convincing way in which it illustrates the amplification or oscillations that can be produced by moving transmission systems. It also serves a useful purpose in developing a reasonably accurate picture of the phenomena that give rise to amplification and oscillations in high frequency tubes.

The operation of this mechanical oscillator is best observed by spinning the two wheels with excess velocity in opposite directions. At first they spin apparently independent of each other until they slow down to the region of critical velocity. At a certain speed the very small residual effects of vibration are amplified and grow until a large disturbance is seen in the system. With the wheels turning in opposite directions, the resulting waves are nearly stationary and can be observed easily. Since the velocity of the waves on the wheels varies with the frequency of these waves, the wave-

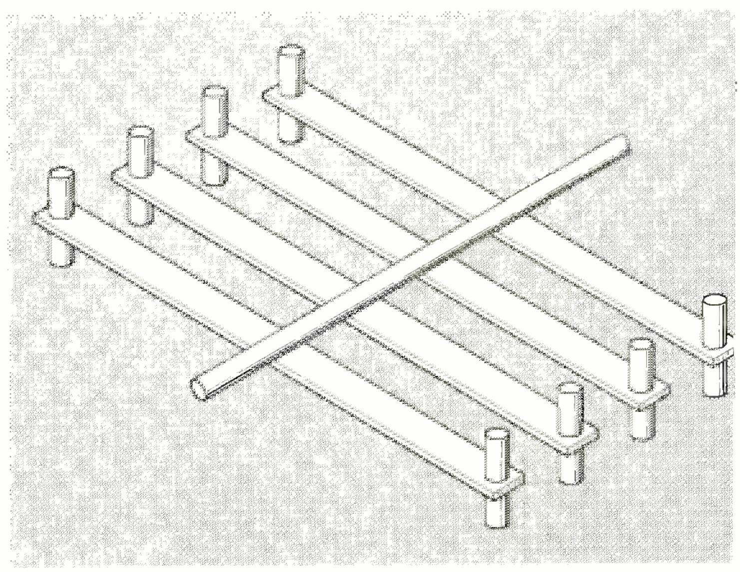
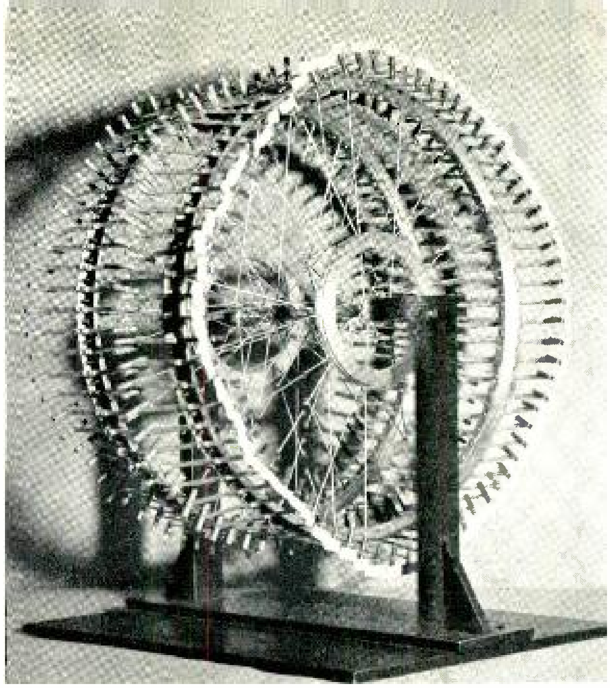
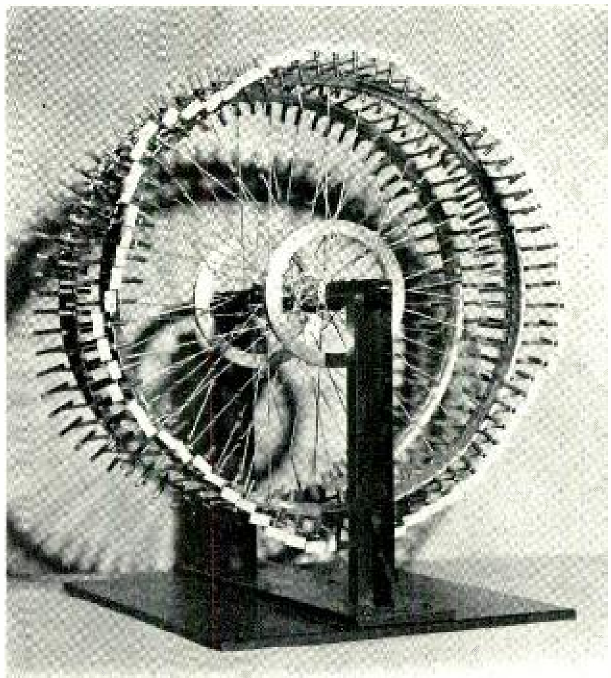
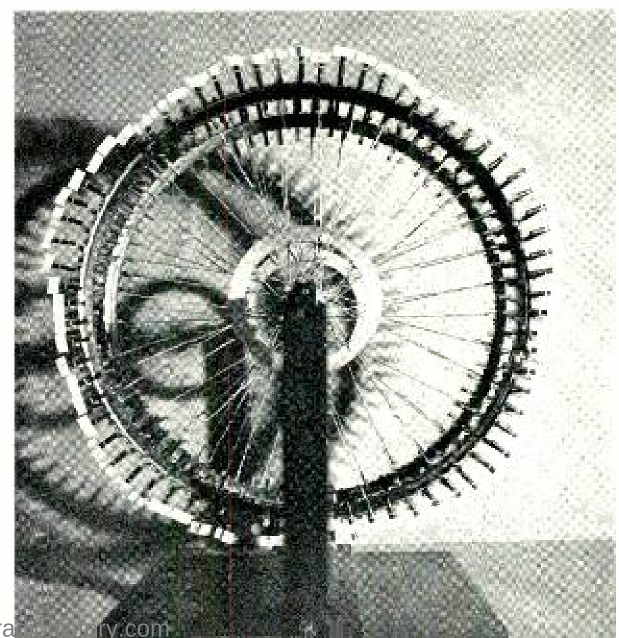


Fig. 4 — A transmission line consisting of a series of weighted bars supported by a wire

Fig. 5 — The mechanical traveling-wave oscillator in operation. Right, the relative speeds are such that four wavelengths are included on the circumference: center, here there are five; and, bottom, there is a combination of six and seven.







length of the oscillations observed will depend critically upon the relative velocity of the wheels. When oscillations start spontaneously there are only two wavelengths on the circumference of the wheels, and an ellipse is seen. As the phenomenon continues and the wheels slow down, the two-wavelength oscillation dies out and simultaneously one having three wavelengths appears. The oscillation appears to change continuously in frequency until finally seven wavelengths can be seen in the circumference of the wheel. The interaction then ceases completely. Examples of these oscillations are shown in Figure 5.

It is now possible to modify the popular picture of water and flag waves produced by the wind by postulating that air waves and the waves in the other medium are interacting. At first this seems to violate the interaction conditions because sound waves travel much faster than either water waves or the wind. However, there are other kinds of air waves called vortex waves which do travel at a low velocity. The most familiar of these can be observed in smoke rings or wind gusts which travel with a speed comparable to that of wind and water waves. Indeed, it seems likely that the physical wave motion produced by the wind might be explained accurately in terms of the interaction between these vortex waves in the air and surface waves in a fluid or cloth as illustrated in Figure 6.

An appreciation for this wave interaction may be gained by relating it to one's experience with water-waves. Such a wave may be produced by moving one's hand in water at a speed near the natural velocity of the wave motion. Similarly, one can imagine a linear array of "hands" moving parallel to itself and dipping into the water at equally spaced points. As it moves, each "hand" produces a wave disturbance. These many disturbances then cooperate to produce a train of waves moving in the same direction. The pushing forces of the "hands" on the water supply the energy which supports the water wave motion and causes it to increase in magnitude.

Now assume that the periodic structure of the pushing body is another wave in a moving medium. This reaction force also enhances the second wave in just the way that the water wave was affected, provided the second wave is naturally propagating backward in its supporting medium. To maintain the assumed phase relation between the two waves, the medium of this second wave must be moving forward at a velocity equal to the sum of the wave velocities. The decreasing wave arises from a different phase relationship between the assumed waves on the two systems but it is less easily seen.

A number of questions in electronics can be answered in terms of this wave picture. For example, if the propagation velocity of one of the transmission lines is made very small, that line becomes essentially a series of uncoupled oscillators. The reaction between the moving wave and such a series of oscillators has dynamics similar to those described, and can be used to explain the operation of electron tubes such as multi-cavity klystrons, or the newer "Easitron."

Designers of electron tubes constantly encounter a mathematical combination which has been called the "plasma frequency" because it is equal to the natural frequency of oscillation that would result from a small displacement of a section of the electron gas. The nature of this term is easily seen in terms of the new analogy. In transmission line terminology, the electron stream is equivalent to a moving low pass filter, and the electron plasma frequency corresponds to the cut-off frequency of this filter. When a wave source and receiver are moving with respect to each other, the wave at the receiver appears to have a different frequency than at the source, and the frequency difference is called the Doppler "shift." Similarly, a wave having a frequency much higher than the plasma or cut-off frequency, appears in the moving medium to have a frequency nearly equal to the plasma or cut-off frequency. For this reason the term often appears in design equations.

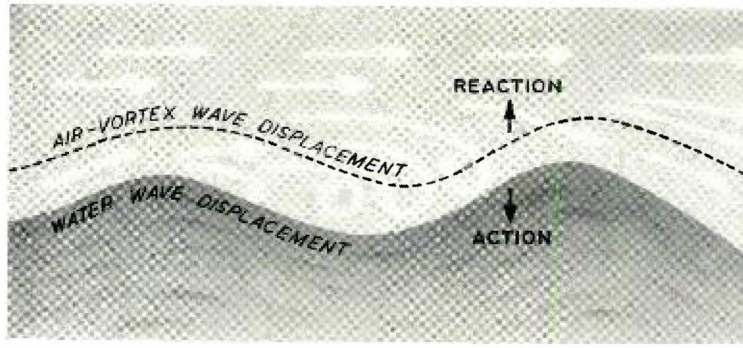


Fig. 6 — An air-vortex wave acting on a water wave and causing it to grow produces a reaction on the vortex wave which causes that to grow also.

It is believed that this wave picture for electron stream interaction is an accurate one. In addition to its use as an aid in visualizing many electronic interactions, it also reveals some interesting wave interaction characteristics which may have application in low frequency transmission line circuits.

The analysis of the moving wave interaction was worked out and shown to be consistent with traveling wave tube operation by W. E. Mathews.

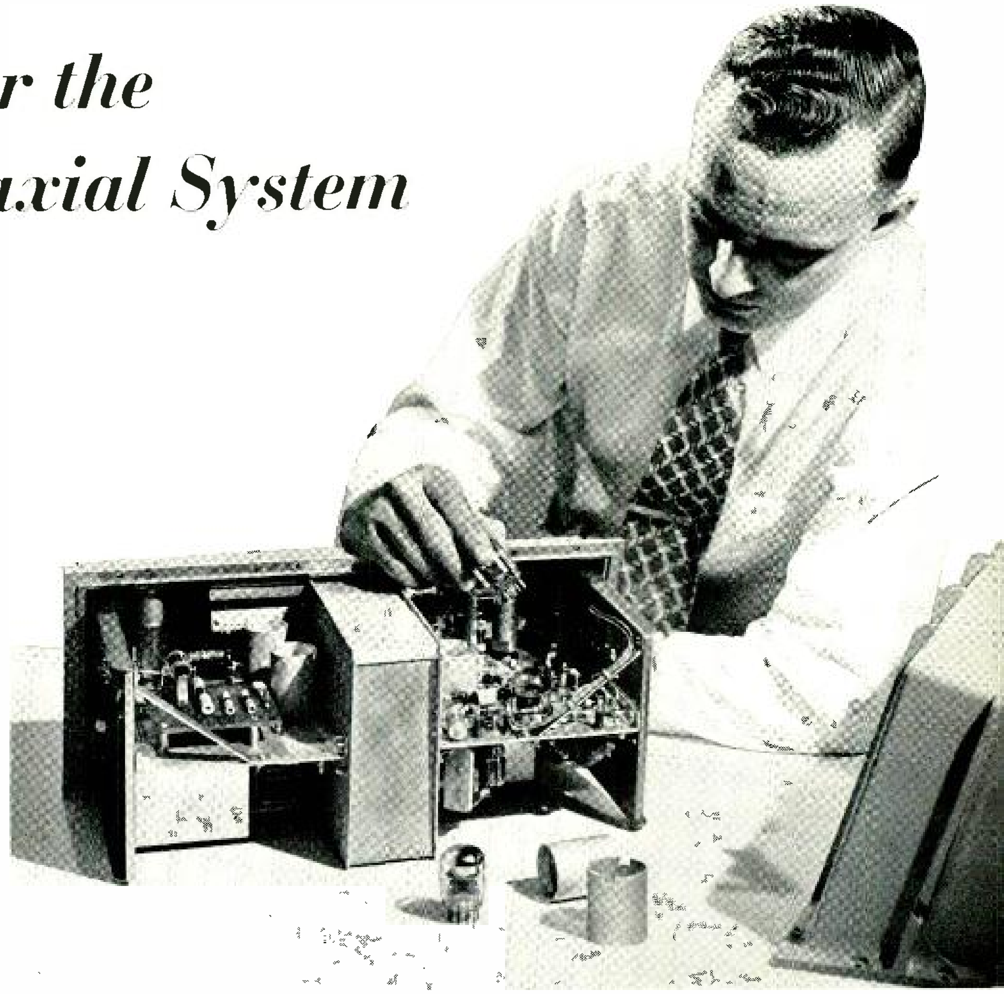
THE AUTHOR

C. Chapin Cutler received a B.S. degree from Worcester Polytechnic Institute in 1937 and did graduate work at Stevens Institute of Technology. His first assignment at the Laboratories in 1937 was in research related to the problems of the short-wave multiplex radio transmitter. During World War II he was engaged in research on the proximity fuse and microwave antennas for radar use. Since the war he has been concerned with research on microwave amplifiers and traveling-wave tubes. Mr. Cutler is a member of the Institute of Radio Engineers and Sigma Xi.

Amplifiers for the L3 Coaxial System

O. L. WILLIAMS

Transmission Systems Development II



The author replacing tubes in an L3 line amplifier.

In any transmission system the loss in signal strength occurring in a particular distance can be accurately calculated and overcome by suitably designed amplifiers. Manufactured units, however, may depart slightly from this design ideal, and although this departure may not be significant in a single amplifier, the cumulative effect of many such units on a long route could affect signal quality. Since more than 1,000 such amplifiers would be required on a four-thousand mile transcontinental L3 route, a special design and close control of manufacturing techniques are necessary to make this coaxial carrier system economically feasible.

Repeaters for the new L3 coaxial carrier system* are located every four miles along some of this nation's busiest communication arteries. At each location, weak carrier signals come in, must be amplified, and sent on to their destination — many miles away. Strengthening these signals which have been attenuated by passage along the cable is the principal function of the line amplifiers in the L3 system.

These amplifiers differ in an important way from the familar amplifying sections used in radio and television receivers, or carrier amplifiers of short-haul systems. Since L3 is a long-haul system, it may have circuits as long as 4,000 miles requiring more than 1,000 amplifiers in tandem. As a result, each amplifier must be free from minor imperfections that are not objectionable in simple transmitter-amplifier-receiver systems but become intolerable after being magnified more than 1,000 times. Simi-

* RECORD, *January*, 1954, *page* 1.

larly, the reliability of L3 amplifiers must be many times greater than home electronic equipment. A failure of a home receiver inconveniences one family; a failure of an L3 amplifier may interrupt as many as 1,800 telephone calls or a nationwide television broadcast.

Before describing these amplifiers in more detail, some of the other broad requirements placed on them by the system design may be summarized. For example, the transmitted frequency band extends from about 300 kilocycles to 8.5 megacycles, and hence they must be capable of operating over a band width of more than eight megacycles. Since no passive equalizers are used ahead of these amplifiers, the gain of each as a function of frequency must be the same as the loss characteristic of four miles of coaxial cable. The average amplifier must match this required gain with an accuracy more

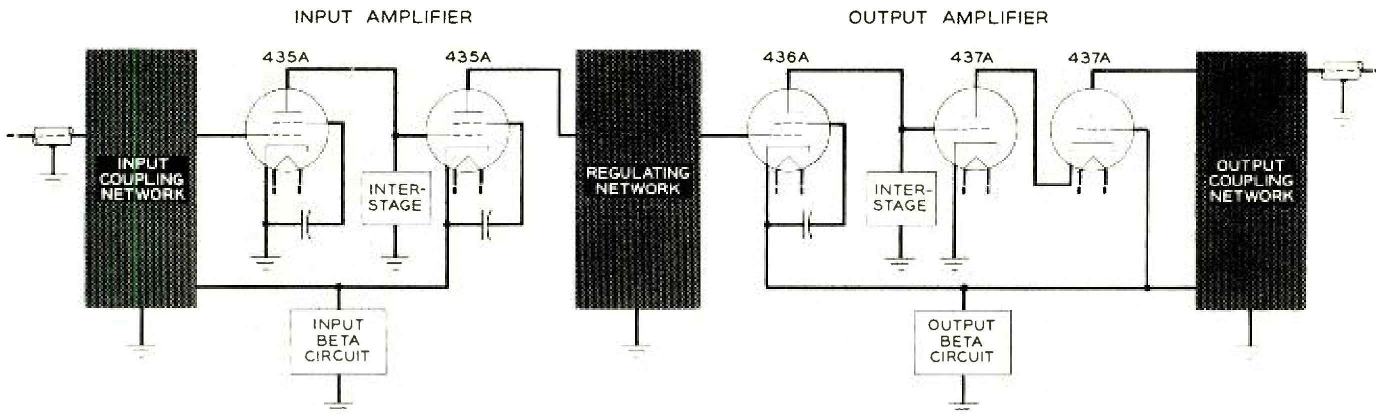


Fig. 1 — Block schematic of an L3 line amplifier.

in keeping with that of a precise laboratory instrument than a standard production item. To maintain interchangeability without requiring costly special-purpose equalizers, amplifiers in successive production lots must have the same average gain. Requirements on the stability of gain as vacuum tubes age, and on the allowable distortion of the amplified signals, dictate the use of as much negative feedback as can be realized over the wide band of the system. In addition to all these performance requirements, the amplifier must be economical to manufacture, and free from costly adjusting procedures. Moreover, maintenance costs must be made as low as possible through an initial design that is reliable, and has provision for the detection and easy replacement of defective elements.

To meet these objectives, intensive development work was required for many basic parts of the amplifier – especially electron tubes and transformers. Three new electron tubes were designed specifically for this service. They combine high gain over a broad frequency band with a reduction in initial variability and a design for long life. New transformers with windings that are produced by plating accurately machined quartz forms provide reproducibility and freedom from temperature effects not possible with conventional wire windings.* Still other examples of new materials and techniques can be found in many resistors, capacitors, and inductors used throughout the amplifier. Some of these elements are visible in the headpiece.

All the elements in the amplifier transmission path are subject to quality control requirements. Through the use of such methods, element deviations that lead to systematic gain deviations are minimized. This control of the average, and the distribution around the average, also minimizes the deviations of individual amplifiers from the desired characteristic. Both objectives are achieved without using adjustable elements or trimmers. A single capacitor, however, is selected from one of three values at the final amplifier test to minimize gain variations at the highest transmitted frequency.

The view of the amplifier with its cover removed, headpiece, shows the three major subassemblies corresponding to the main divisions of the block schematic in Figure 1. These consist of an input amplifier, an output amplifier, and a regulating network connecting them. The input and output amplifiers are each two-stage units with indepen-

* Record, *September*, 1953, *page* 366.

dent feedback loops. These two amplifiers provide the gain required to overcome the average cable attenuation, and the regulating network compensates for variations in the desired gain caused by either temperature changes or a repeater spacing different from 4.0 miles. A thermistor in this network responds to signals from an associated regulator, and automatically changes the amplifier gain by the necessary amount. In addition to the input amplifiers, output amplifiers, and regulating networks, input and output coupling networks are indicated in Figure 1. These networks include the new type transformers and other elements which make the input and output impedances of the amplifier equal to the impedance of the cable. By terminating each cable section in its own impedance in this way, echoes or ghosts that may occur in television pictures are minimized.

The two coupling networks and the feedback circuit of the input amplifier provide the required gain versus frequency characteristic, and the output amplifier, with a flat frequency characteristic, provides the power gain. This required gain, equal to the cable loss, is given by the graph in Figure 2. The difference between this objective and the actual gain provided by average amplifiers is illustrated in Figure 3.

A special feature of this amplifier is the dc circuit associated with each tube. The grids of all tubes are returned, not to ground potential, but to a positive bias source. The cathode resistors are then made sufficiently large so that the usual negative grid-to-cathode voltage is developed. These large resistors, corresponding to a large dc feedback, aid in stabilizing the plate current, and maintaining a constant gain in each tube for long time intervals.

Another innovation is that the output section of the amplifier uses two triodes connected in series with a single plate supply so that they operate as a single stage. The output is taken from the plate of the 347A tube on the right triode while the signal is impressed on the grid of the second or other triode as shown in Figure 1. This circuit has the advantages of the high gain produced by a triode stage, combined with the high input and output impedance characteristic of a pentode. As an output stage, its signal-to-noise ratio is considerably better than the more usual pentode stage.

The outer housing of the amplifier consists of a die-cast cover and base. The cover slips in place over the base and is bolted down to form an air and water tight seal. (In locations with high humidity, this seal prevents the entrance of moisture.)

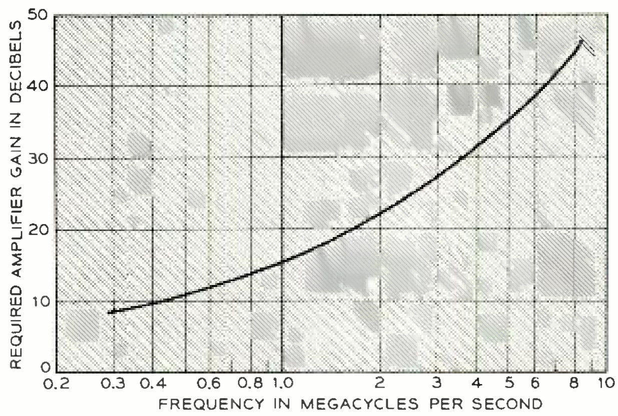


Fig. 2 — Graph depicting amplifier gain versus transmitted signal frequency

Slides on the cover engage in a bracket on a repeater bay to mount the assembled unit, as shown in Figure 4. Water tight power and signal jacks are included on the base of the amplifier, and flexible cords in the repeater bay connect to these jacks.

Since the huts that contain these amplifiers are left unattended for periods up to three months, some method of detecting incipient failures during routine visits is important. The principal cause of such failures is the slow deterioration of electron tubes; though designed for long life, they age slowly until replacement is required. To assist in finding those tubes that are near the end of their useful life, test points are provided external to the amplifier to permit in-service tests. Suspected amplifiers are replaced, and taken to maintenance centers for test and tube replacement. It is not feasible to change tubes in the huts since most of them are not equipped with heat, light, or power.

Considerable ingenuity was required to translate the L3 amplifier circuits to a physical reality since a number of conflicting requirements had to be met by the mechanical design. One of these is ease

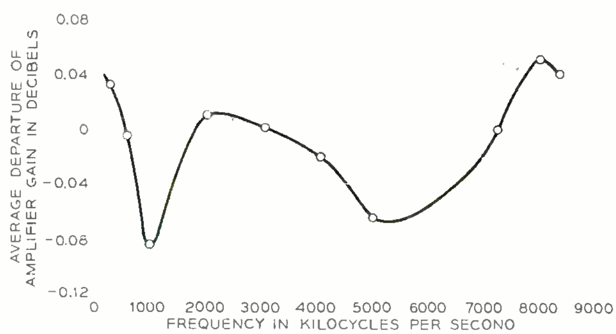


Fig. 3 — Difference between cable loss and actual gain provided by an average L3 repeater.

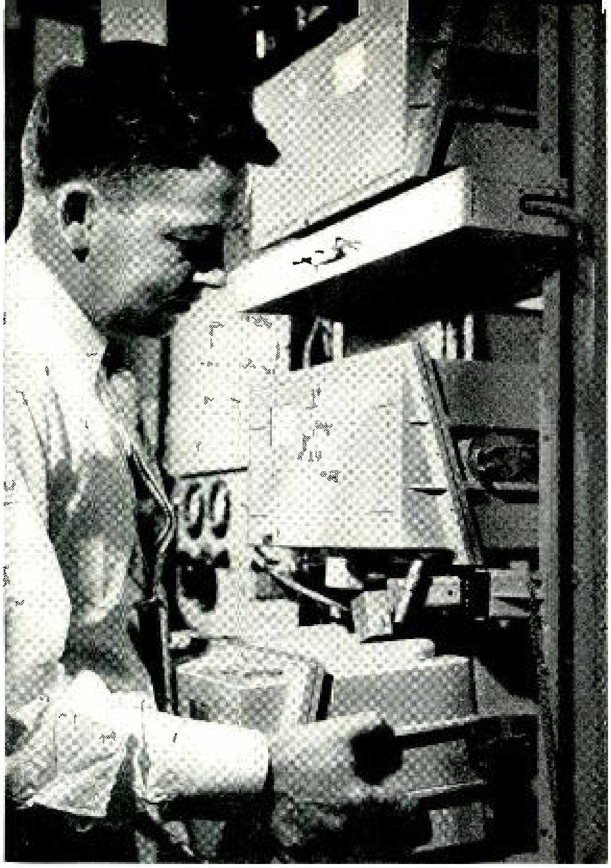


Fig. 4 — G. W. Eftang replacing an amplifier in a test panel at Bell Telephone Laboratories.

of manufacture, but this is complicated by the fact that, in a broadband feedback amplifier, many parts of the mechanical design cannot be separated from the arrangement of the electric circuit. For example, transmission down to 300 kilocycles requires the use of relatively bulky components. Controlled transmission up to 200 megacycles around the feedback loops, on the other hand, calls for physically short leads, and close spacing of critical elements. In the completed amplifier, unwanted couplings are minimized by inserting shields. A by-product of the resulting compact structure is the large amount of heat produced in a small volume; about 40 watts are dissipated in the amplifier. To conduct this heat to the outer case, special heavy shields that make good thermal contact with both the tube envelope and the amplifier chassis were developed.

Reproducibility, another design problem, cannot be completely solved by the use of precision elements. In addition, mechanical and electrical design must come together again to control the location of sensitive elements, and the length and position of interconnecting leads. In this way, full benefit may be obtained from the inherent accuracy built into the new resistors, capacitors, and other circuit elements. Most of these elements are first assembled into networks which are then tested as subassemblies. Strict tolerances must be placed on the relative position of these networks when they are combined in assembling the amplifier.

The method of mounting electron tubes in this amplifier is a departure from the previous practice as used in the L1 system. In the L3 amplifier, the tubes plug into conventional sockets, and no parallel tubes are provided. Any resulting loss of reliability or slight increase in parasitic capacity is offset by the greater ease of manufacture, reduction in components, and simplicity of tube replacement.

The L3 line amplifier is now in volume production. Two years of field trial and commercial operation of a short system have led to the usual number of design changes and adjustments in manufacturing techniques. Over a thousand amplifiers are now in service on the New York-Philadelphia-Chicago coaxial cables. Tripling the message capacity of such cables by conversions from the existing coaxial system and planned new installations will provide millions of channel-miles of economical high quality telephone and television service in the coming years.

THE AUTHOR

Owen L. Williams spent a summer with a transmission measurement group at the Laboratories prior to receiving his B.E.E. degree from Rensselaer Polytechnic Institute in 1949. Returning in February of that year, he participated in the Communications Development Training Program and in 1950 was assigned to development work on coaxial cable systems. Until recently he was concerned with the L3 line and flat-gain amplifier and is currently working on the equalizing equipment for the L3 system. He is a member of Eta Kappa Nu and Tau Beta Pi, and an associate member of Sigma Xi.

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

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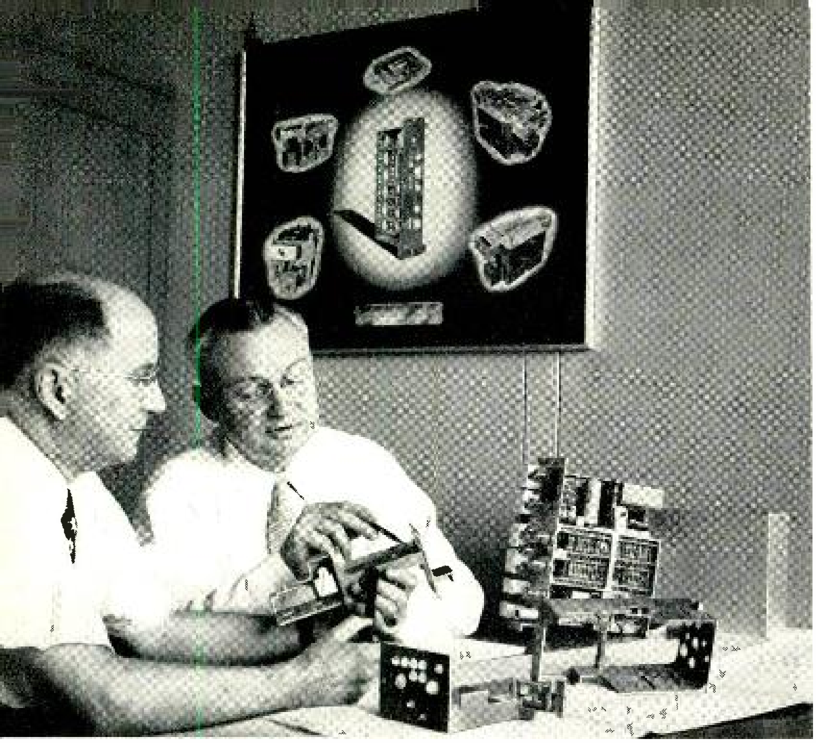


For the N1 short-haul cable carrier system, aluminum die-castings are being used extensively. Such castings are an important part of Bell Laboratories development work, since circuits must be mounted in durable, inexpensive, and easily maintained frames that are as physically compact as possible. Economics, engineering, and production problems must all be considered before a choice is made between a die casting and a fabricated unit.

Aluminum Die-Castings for N1 Carrier

L. PEDERSEN *Transmission Systems Development*

The art of aluminum die-casting is receiving ever-increasing attention in Bell System applications. With the present emphasis on miniaturization, both in individual components and over-all equipment assemblies, the design engineer is finding die-casting a valuable aid. Die-casting is an *art*, and it is one that must be thoroughly understood in order that the designer can realize a substantial part of its possibilities. These possibilities are practically unlimited in scope.

A recent development in which such die-castings have had an important part is the N1 carrier telephone system.* Size and weight of the equipment have been minimized by arranging the miniaturized components compactly in die-cast aluminum frames. These are of a size and shape to utilize fully the rack space available in depth as well as in breadth and height. It is in this type of design, usually referred to as "cubic" construction, as contrasting with "planar" construction of conventional panels, that the design engineer benefits from the use of die-castings. The various mounting surfaces, as well as pockets or compartments for a variety of components, are easily obtained by means of the die-casting process.

Above, J. A. Coy (left) and the author discussing a feature of one of the aluminum die-castings used in N1 carrier equipment. A completely assembled N1 carrier channel unit is seen to the right.

* RECORD, *July*, 1952, *page* 277; *August*, 1952, *page* 333; *October*, 1952, *page* 381; *February*, 1953, *page* 48; *April*, 1953, *page* 136; *July*, 1953, *page* 251; *September*, 1953, *page* 347.

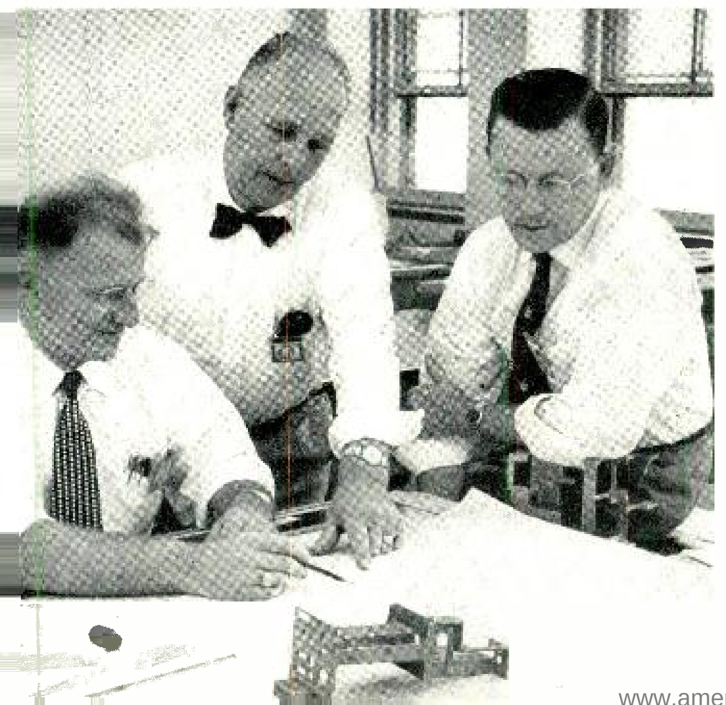
Aluminum was chosen for this application because of its light weight (approximately 40 per cent of that of zinc die-castings), low cost, dimensional stability, good electrical shielding properties in the carrier frequency range, and the rather pleasing appearance of the natural aluminum finish. The aluminum alloy that is used in this process contains 87.5 per cent aluminum, 9 per cent silicon, and 3.5 per cent copper. It has a tensile strength of 40,000 pounds per square inch, a yield strength of 25,000 pounds per square inch, and an impact strength of 3 foot-pounds.

Aluminum alloys form and maintain a thin transparent oxide film which, for many uses, is sufficient protection for the die-casting, and no further finishing is necessary. This is an item of importance when cost is a design consideration. A variety of finishes, however, may be applied. These may be organic, electrolytic oxide, electroplating, chemical or mechanical treatments. One rather effective finish is a light sandblasting followed by a mineral oil dip. The oil treatment does not leave the surface noticeably oily, but does prevent fingerprints from smudging the surfaces.

Die-castings can be machined readily when this is required, and are uniform in dimensions, thus facilitating assembly and aiding the interchangeability of parts. Temperature variations do not appear to cause any permanent dimensional changes or loss of physical properties.

In evaluating some of the experiences gained during the design period of the N1 carrier equipment, it is interesting to note that Lesson No. 1 for the design engineer is to "Think Die-casting." This ability comes only with experience and is absolutely necessary to take the best advantage of the die-casting art. The designer should be able to build into the casting the many possible advantageous features, and the art provides him with wide latitude to accomplish this objective. In the early design stages, close cooperation between the design engineer and die designer is a must. Another lesson is the fact that "Unnecessary Accuracy Means Added Tool Expense." It is good engineering to limit the use of close tolerances to the really important dimensions. Also the design engineer must dimension from a common reference, rather than build one dimension upon another. The minimum tolerances specified for the N1 carrier die-castings were held to ±0.004 inch on any dimension, although ±0.002 is a tolerance common in die-casting practice.

Fig. 1 — A. H. Wagner (left), T. Logan, and R. T. Monahan at work on the design drawings for aluminum die-castings.



Concerning wall thickness, it is good practice to use thin walls and obtain required strength by the use of ribs. There is, of course, a practical minimum to the thickness of wall specified. One governing factor is the necessity of filling the die properly. The minimum wall thickness specified for the castings referred to here is 7/64 inch. However, it is well to remember that each design should be treated as an individual problem. This important rule applies equally to such items as size and weight of a casting, tapers and hole diameters. The word "taper" is one to be treated with considerable respect. This is what the die designer evidently never gets enough of. "Taper" or "draft" is the name given to the slopes of the walls of sections and sides of holes to facilitate withdrawing the casting from the die without tearing, sticking and distortion.

One of the eleven die-castings used in the N1 carrier is shown in the background of the photograph on page 144. This casting is used for the group transmitting unit, and is typical of the complex structures that can be made by die-casting.

Surrounding the center photograph are several views of the large steel die used in producing the casting. When ready for the casting machine, this die weighs approximately 3,000 pounds and consists of a number of precisely made parts expertly fitted together. The die is made in two halves, which are brought together in the die-casting machine, and the molten metal is injected under pressure into the cavity between the halves. After the metal solidifies, the machine opens the die and the completed casting is ejected. The top view illustrates the cover half of the die and contains an impression block; the other views show, from various angles, the die base assembly with the ejector die-half in place. This half contains the main parts of the die, including the movable cores or slides for making the holes or slots in the casting.

Some of the dies used for the N1 carrier castings can be employed for several castings simply by changing one or more of the movable cores or slides. The die illustrated is such a combination die, having two slides available for producing two different front surfaces, leaving all other parts of the die the same. Obviously, this feature reduces tool costs an appreciable amount. The tooling in-

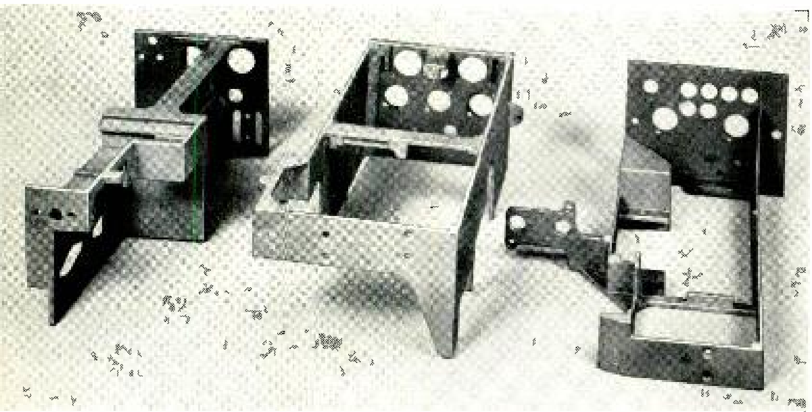


Fig. 2 — The three aluminum die-castings used for an N1 carrier channel unit.

terval that was involved for this rather complex die was fourteen weeks.

Since the greater percentage of the die cost is in labor, it is important that the steel be adaptable to machine processes. Fully annealed high quality steel is used, with full heat treatment following the completion of the die. From here on, there are a number of problems such as heat treating characteristics, heat checking, cracking, distortion, and resistance to deformation, which, for the purpose of this article, we leave to the die designer.

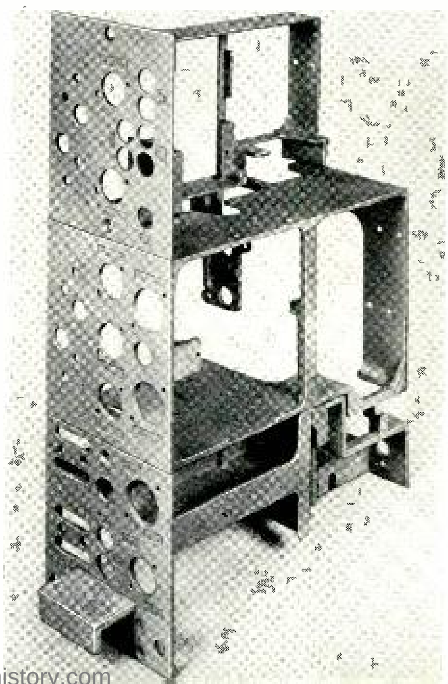
The total number of castings that may be produced from one die depends upon the type of castings. The die shown here is expected to produce up to 200,000 castings. Design changes affecting the completed die are not desirable, but if made are usually expensive as well as risky, since the die may be distorted to the extent that an entirely new die must be made.

There are two basic classifications of die-casting machines in use today: (1) the "submerged-plunger" type, used for casting tin, lead, and zinc; and (2) the "cold-chamber" machine, used for aluminum, magnesium, and copper. The aluminum alloy castings for the N1 carrier are produced on a "cold-chamber" machine. This type of machine requires that prior to each casting the molten metal be ladled, either manually or automatically, into the injection cylinder. From there it is forced into the die by a hydraulically operated plunger. In the "submerged-plunger" type machine, on the other hand, the plunger and cylinder are always submerged in the molten metal in the furnace. At the end of each "shot," metal flows into the cylinder, and, at the start of the next cycle, it is forced by the plunger into the die. Because of the likelihood of the alloy being contaminated by the steel or cast iron surfaces of the plunger and cylinder, high melting point alloys, such as those used for the N1 carrier castings, cannot be used in this machine. The metal pressure used for the casting shown on page 144 starts at 4,500 pounds per square inch and reaches a peak of 9,000 pounds per square inch. The capacity of the casting machine of course varies with a number of factors such as size and complexity of the casting. The pictured casting is produced at a maximum rate of 75 to 77 per hour.

The casting cycle having been completed, the casting will require removal of excess metal. The usual way of removing the excess, or flash, is by shearing in a punch press. For large demand items, special jigs are constructed for this purpose. In a number of instances a heavy file serves the purpose. Machining of the castings, where required, is usually limited to drilling of holes too small to be cored economically (less than 1/8 inch diameter), tapping, and squaring surfaces where taper required in casting cannot be tolerated. Where the dimensional accuracy required is such that it cannot readily be provided by the die, a machining operation may be indicated.

Many questions usually confront the design engineer when he attempts to decide between the use of die-castings and fabricated structures. The all-important question of cost is primarily one of comparison — that is, what will be the unit cost of a die-casting versus a fabricated structure? Large demands are not necessarily the criterion for justi-

Fig. 3 — The three castings of Figure 2 assembled as they appear in the channel unit.



fying a die-casting economically; complexity of design is also an important factor. A simple shape that can be punched or extruded would not, as a rule, be a good candidate for the die-casting technique. It may sometimes prove advisable to use another method like sand or permanent-mold casting, particularly for low-demand items. As a rough guide to the designer, however, it may be stated than an item of fair complexity and with an annual demand of around 5,000 would probably justify die-casting.

Usually we find that the die cost is relatively high but that the unit cost is low. Consideration must also be given to other factors besides cost, such as uniformity and appearance.

In the case of the N1 carrier development, the problem of introducing eleven different die-castings, with a relatively high tool cost for each, required rather careful planning. In view of the fact that this project contained many novel features, possible changes in design might well have been expected even after the equipment was in production. If such changes affected the dies, fabrication might have been less expensive than die-casting until the design was more stable. The annual demand for the N1 carrier equipment was estimated in the early design stages to be 1,000 systems a year (actual production is now 1,200 systems a year), each system requiring a number of die-castings varying from two to as high as twenty-four castings of one kind. On this basis, and assuming only minor casting changes, it was found that the savings obtained with the use of die-castings would permit complete retooling after completion of the first 100 systems. This study dictated the use of die-castings from the start of production of the N1 carrier units.

The die-casting for the group transmitting unit is a small demand item, numbering about 1,000 units a year. Even with this relatively small demand it was found that the unit cost, including some machining – consisting of drilling and tapping a number of holes and its share of the die cost amortized over a four-year period – was only half the cost of a fabricated unit.

The three die-castings shown in Figure 2 are of similar complexity to the one discussed above, but the annual demand was 24,000 of each. The cost estimates in this case showed the die-castings to be only about one-fourth that of a fabricated unit. These castings are used for the N1 carrier channel unit, which consists of three separate subassemblies mounted together to form a complete plug-in unit. Figure 3 shows the three castings assembled as they appear in the unit.

In addition to the differences in the cost of producing these castings, there are other cost differences favoring the die-castings. If properly designed, the die-casting will incorporate details that otherwise need to be mechanically fastened to the fabricated framework, and such items as equipment designations used to identify components may be incorporated in the die by the use of raised characters in a recessed area, instead of being applied by various printing methods.

The uniformity of die-castings shows to great advantage on the assembly line of high production equipment. The time-consuming annoyances of misalignments and necessary adjustments usually present with fabricated chassis are nonexistent with properly designed castings.

THE AUTHOR

LUDWIG PEDERSEN was educated in Norway, graduating from Cristiania Technical School in 1919. After a year at the Western Electric International Company in Oslo, he transferred to the Engineering Department of Western Electric in New York City, joining the Laboratories in 1925. His early work was in machine switching systems and telegraph equipment. During World War II he was engaged in the design of carrier equipment for the armed forces and served as a technical observer with the U. S. Army in the European Theater, later receiving the Bronze Star. Since the war he has been associated with the development of equipment for toll transmission systems, including voice-frequency, cable and open-wire carrier systems, and overseas radio control terminals. Until recently he headed a group engaged in voice-frequency development but in January, 1954 was transferred to take charge of a new group planning the production program of the rural carrier. Mr. Pedersen is a member of the A.I.E.E. and the Armed Forces Communication Association.

The author removes the cords from the cover of the test set.

Electronic Test Set for Signaling Systems

W. W. FRITSCHI *Switching Systems Development III*

Nationwide toll dialing brought forth a host of problems, including those involved with signaling. Dial pulses and flashing supervisory signals required faster-operating devices than previously, and single-frequency signaling systems were developed for this purpose. Improvements in apparatus and techniques in recent years have permitted the development of a new electronic test set that may be used to test single-frequency and other toll signaling systems, such as the "built-in" signaling of Type-N and Type-O carrier.

Nationwide dialing, introduced several years ago, requires the use of new signaling systems capable of transmitting dial pulses and flashing supervisory signals over long toll trunks. In "ringdown" signaling used previously, each operator connected an incoming call to an outgoing trunk and rang the distant operator. Manual switching systems of this type, involving long toll trunks, employed comparatively slow-acting signal receivers. For the longer toll lines, more recent plans for automatic intertoll switching have required faster acting signaling systems, capable of transmitting and receiving dial pulses in addition to flashing supervisory pulses. These more recent systems include single-frequency signaling systems (SF)* and the "built-in" signaling arrangements of N and O carrier.† For the shorter toll trunks, direct-current signaling methods commonly referred to as "CX" systems, are still employed.

CX systems are inherently fast-acting, so that integrating such systems into the nationwide switching program offered no seriously new testing problem, and the well established maintenance

* RECORD, *July*, 1940, *page* 337; *February*, 1954, *page* 62.
† RECORD, *April*, 1953, *page* 136.

procedures for CX systems are being continued. Some tests normally made at toll test boards on CX systems are directly applicable to the more recently developed signaling systems, but tests normally made at the SF or "built-in" signaling equipment require new procedures and test equipment. Since single-frequency and "built-in" signaling systems are electronic in nature, a new test set using electronic apparatus was tailored to fit the requirements of such systems.

As may be seen from the headpiece, the new test set is fully portable, and is housed in an aluminum case with a removable cover. The hinged metal plate inside the cover keeps the circuit schematic handy, and the cover permits cord storage. Cords and jacks on the left edge of the panel, as shown in Figure 1, provide power to the test set and access to equipment under test. The set is used to test apparatus operated by pulses, and therefore provides a wide range of output pulses. These may be a continuous train of dial pulses, or may be trains of pulses controlled by a test dial on the panel. Low rate pulses may be internally produced, adjustable in both repetition rate and per cent break. Flashing supervisory pulses may be externally supplied by connecting a 60 or 120 interruptions per minute (IPM) office interrupter to the P jack on the panel (Figure 1). Two meters are provided, one measuring per cent break, and the other measuring volts, milliamperes, or pulses per second, as desired. Lever-type keys control the type of pulses sent out and the direction in which they are sent. Monitoring is available through two lamps marked D and L.

Fig. 1 — A front view of the test set panel.

These designations, D and L, are used throughout the test set in carrying out the idea of functional markings. Early magnetic "drop"-type indicators gave rise to the designation D, representing apparatus associated with the switchboard termination

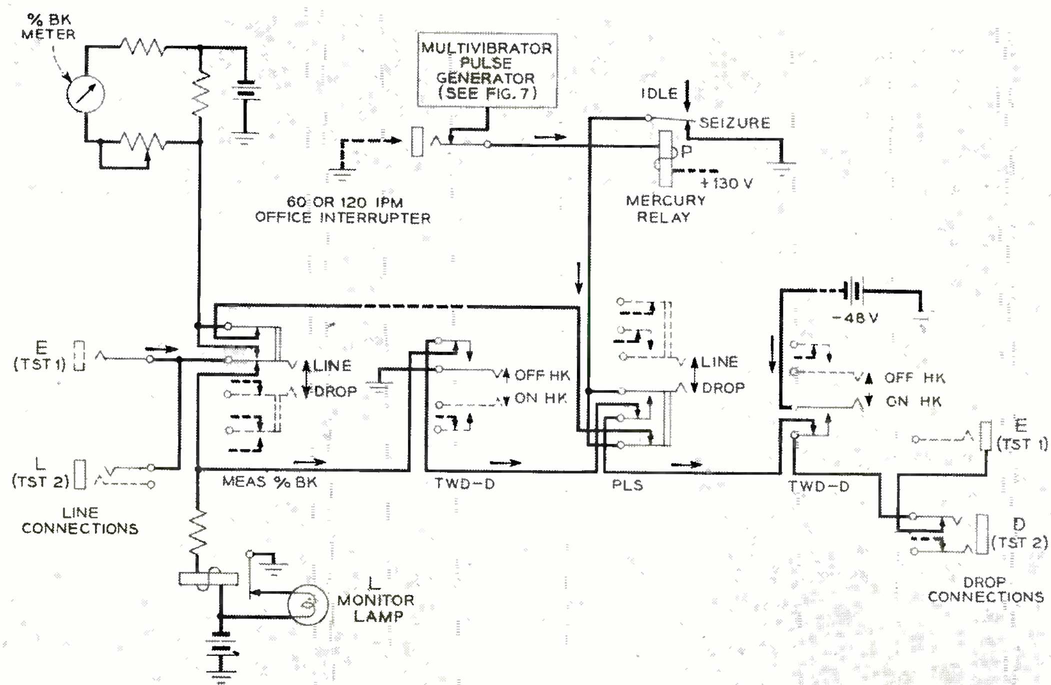


Fig. 2 — A detached contact schematic of the E lead as it goes through the test set.

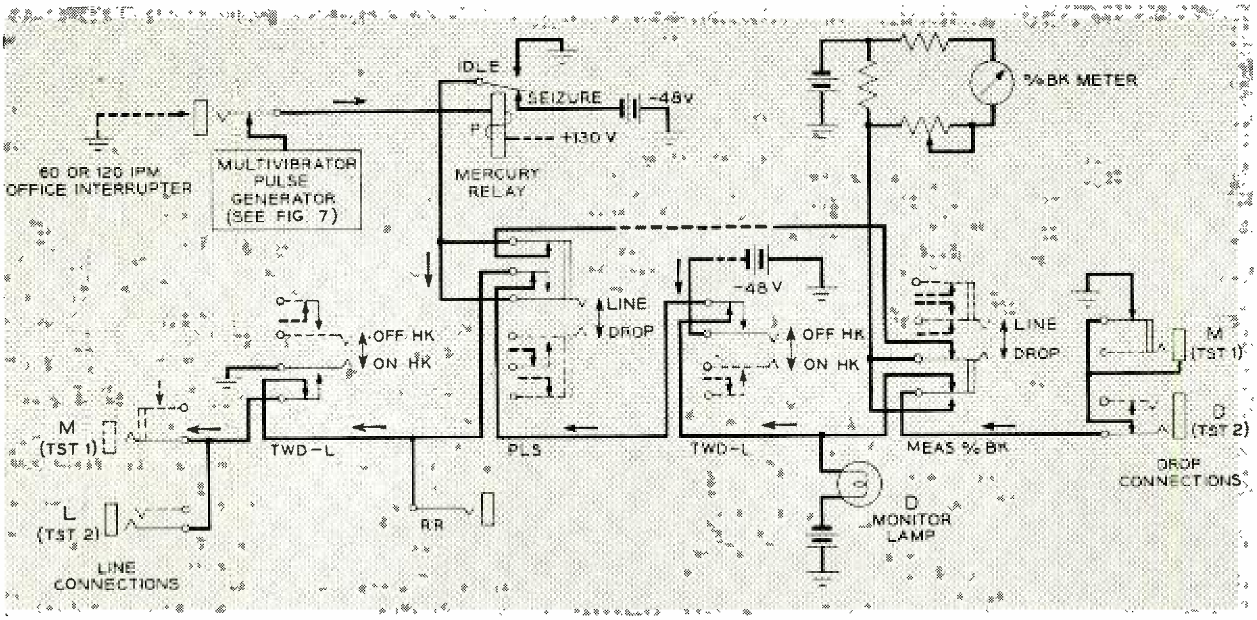


Fig 3 — A detached contact schematic of the M lead as it goes through the test set.

of a line, and this designation has been maintained in telephone terminology. Line equipment is similarly indicated by the designation L. The markings ON HK and OFF HK indicate signaling conditions corresponding to the "on-hook" and "off-hook" switchhook positions of a customer's telephone set. With the lever-type keys in their normal vertical position, the test set is effectively out of the circuit, except for monitoring by the two lamps.

In testing signaling equipment, the test set must pick up two direct-current signaling leads between two different types of central office equipment. The test set is inserted in both of these leads, between switchboard trunk relay (DROP) equipment and the SF or CX signaling (LINE) equipment. Incoming signals to the drop equipment are on the E lead and outgoing signals to the line are on the M lead. The pair of jacks labeled TST1, are used at locations where SF equipment is installed, with all incoming signals entering and leaving the test set through the E jack and all outgoing signals through the M jack. In the older CX locations, both leads appear together on D and L cut-off jacks arranged on a directional basis. A second pair of jacks labeled TST2 are used at these locations, to permit the use of standard patch cords available at toll test boards. Figure 2 is a detached contact schematic of the E lead as it goes through the test set, and Figure 3 is a similar diagram for the M lead.

When the functionally designated lever-type keys are operated in accordance with the panel markings, steady-state "idle" or "seizure" signals may be sent simultaneously toward line and drop equipment. Alternations between idle and seizure signals

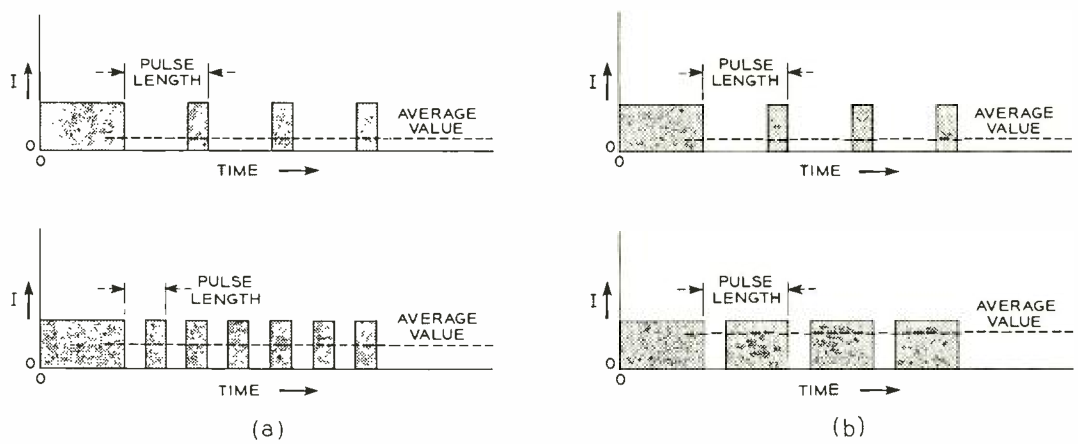


Fig. 4 — Pulse length and per cent break both have an effect on the average value of the dc component.

may be sent in either direction, but not simultaneously. The rate of alternation, or pulse rate, may be varied from about three pulses per second (PPS) to about 15 PPS, using the internal electronic interrupter. Also, trains of accurately timed pulses may be produced from the interrupter, controlled by the test dial. In both cases, the per cent break may be adjusted over a wide range. All pulses sent out from the test set result from the fast-acting mercury relay P, which is rapidly switched between appropriate idle and seizure signals. As may be seen in Figures 2 and 3, connecting a 60 or 120 IPM office interrupter to the P jack will disconnect the internal multivibrator pulse-generator, and take over the pulsing of relay P.

Signals in a system restricted to "on" and "off" conditions of signal energy are usually measured in pulse repetition rate (PPS) and in per cent break. This latter is the ratio of the "break," or open, interval of the signal to the total time of one pulse,

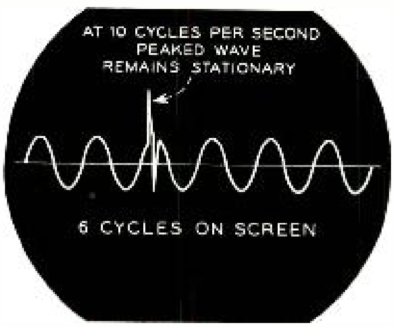


Fig. 5 — To calibrate the pulse-rate meter, the oscilloscope should look like this.

expressed as a percentage. The two meters in the test set are used to measure these two characteristics of pulse signals. Both meters are milliameters connected to receive essentially rectangular pulses of energy, and they therefore indicate the average value of the pulses. During the current-on period, the meter reads full scale; during the current-off period, it drops to zero. If the pulses are fast enough, the meter pointer cannot follow the rapid change in current, and will oscillate about an average value on the scale. The longer the current is on, the greater this average will be.

In the pulse-rate meter, short pulses of fixed duration are fed to the meter circuit. Changing the rate of pulsing changes the effective percentage of time the current is on, and therefore changes the average value. Figure 4(a) shows how this occurs. The pulse-rate meter reads directly in pulses per second, and may be conveniently calibrated with the aid of an oscilloscope. A small 60-cycle signal is fed to the vertical input of the oscilloscope and the sweep circuit is adjusted until six complete cycles of the sine-wave appear stationary on the screen, as shown in Figure 5. A lead connected to the SYNC jack of the test set will pick up a portion of the signal going to the pulse-rate meter circuit, and this is also fed to the vertical input of the oscilloscope.

A peaked wave will be seen to move across the screen, superimposed on the sine-wave. When the internal pulsing rate is exactly 10 PPS, the peaked wave will become stationary and the pulse-rate meter is then adjusted to read correctly. Using the appropriate jacks and the switch on the panel also permits this meter to be used as a voltmeter or as a milliammeter when desired.

Although pulses fed to the per cent break meter will vary in both repetition rate and per cent break, it nevertheless will indicate correctly. Since per cent break is the ratio of current-off time to current-on time for each pulse, it is not affected by the repetition rate. Figure 4(b) shows how the average value depends on the per cent break. This meter is used for only the one purpose, and is highly damped internally to reduce pointer vibration. To permit reading per cent break of signals in either direction, a reversed red scale is also provided.

The internal pulse-generating circuit consists of

Fig. 6 — P. P. Crowe adjusts the internal pulse-generator until the oscilloscope looks like Figure 5.

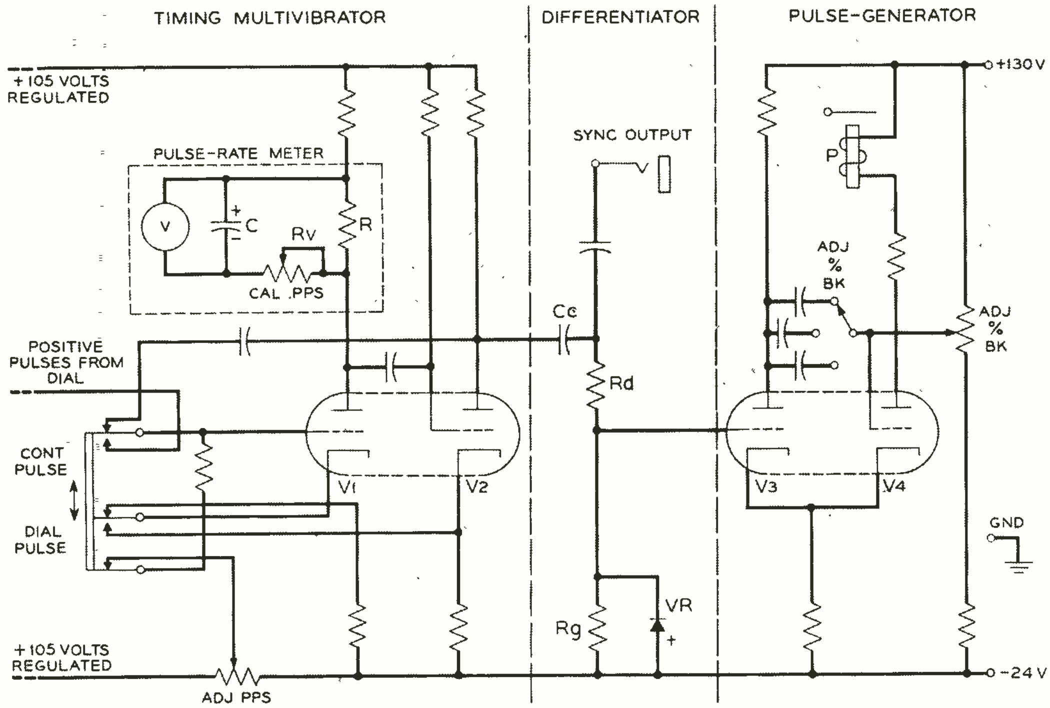


Fig. 7 — A simplified diagram of the pulse-generator, differentiating circuit, and timing multivibrator.

two multivibrators* – one producing the pulses and determining the per cent break and the other determining the repetition rate. The actual pulse-generator (see Figure 7) is a cathode-coupled multivibrator that produces one pulse each time it is triggered and then remains inactive until triggered again. A switch marked ADJ % BK gives rough control over duration of the single pulse, and an ADJ % BK potentiometer gives fine control. Accurately timed pulses from a timing multivibrator, V1 and V2, are used to trigger the pulse-generator. Once the timing multivibrator has been adjusted to the desired rate, it determines when each pulse of the pulse-generator will start. Adjusting the per cent break controls will then lengthen or shorten the duration of the generated pulse, controlling the per cent break. The mercury relay P then does the actual pulsing on the E or M lead, or to the per cent break meter.

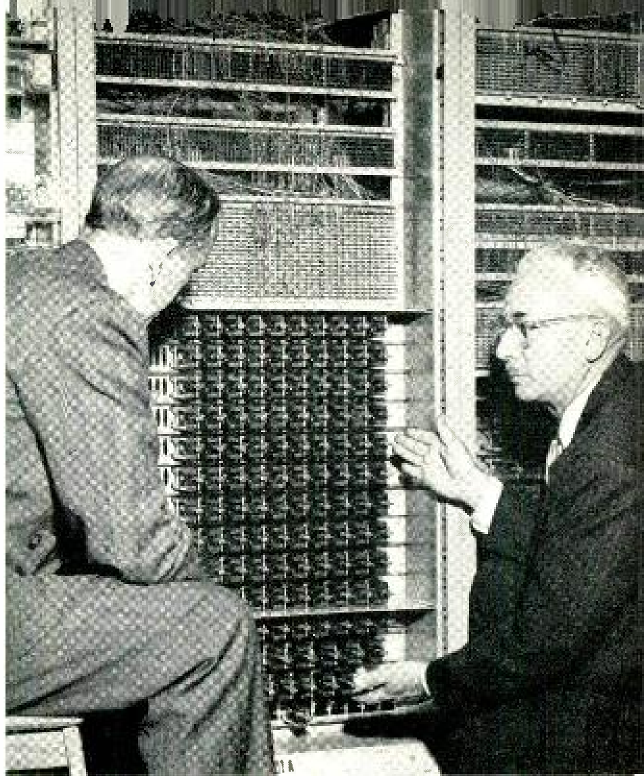
Output from the timing multivibrator is similar to the wave forms shown in Figures 4(a) and (b). The rectangular pulses are fed to the pulse-generator through a differentiating circuit consisting of C_e, R_d, and R_g. The resultant differentiated wave is a series of sharp positive and negative peaks. A small portion of the triggering pulses is also fed to the SYNC jack for use in calibrating the pulse-rate meter. Since only the positive peaks are desired for triggering the pulse-generator, varistor VR eliminates the negative peaks by effectively short circuiting R_g when it conducts. If it is desired to use the accurately timed test dial as a source of pulses, the CONT PLS key is thrown to DIAL PLS, and the timing multivibrator is then no longer free running. It is changed to a cathode-coupled, single-pulse generator. Each pulse from the dial triggers the timing multivibrator, which in turn triggers the pulse-generator. This permits adjusting the average per cent break of pulses controlled by the test dial.

* Record, *September,* 1943, *page* 17.

THE AUTHOR

Walter W. Fritschi, joined the Laboratories via Western Electric Company's Engineering Department in 1923. After three years in the drafting department, he was assigned to design and testing of the toll systems switchboard and voice-frequency signaling studies. During World War II he was associated with radar design and testing, including work on a radar trainer, and following the war turned his attention to the development of voice-frequency signaling for nationwide dialing. He is currently engaged in electronic exploratory development. Mr. Fritschi received the B.S. degree in E.E. from Cooper Union in 1928.

The inherent adaptability of the No. 5 crossbar system made it comparatively easy to arrange for nationwide customer dialing at Englewood, New Jersey. As a result, the dialing of toll and long distance calls to approximately one-fourth of the nation's telephones became an everyday event to people in Englewood, and provided the springboard from which nationwide dialing will become universal.



No. 5 Crossbar Opens the Door to Nationwide Customer Dialing

R. E. HERSEY *Switching Systems Development*

As a result of a customer dialing just three more digits than usual into No. 5 crossbar central office equipment* located at Englewood, New Jersey, vast sets of relays, switches, batteries, wires, electron tubes, and other equipment spring to attention quickly to guide the call, without the direct aid of human hands, to one of over 11,000,000 telephone customers throughout the United States. There the call is completed in about 10 seconds, and rings the bell perhaps 3,000 miles away. Small beginnings but large endings!

What makes it all tick? Careful long range planning and cooperative effort within the A T & T Co., Operating Companies, Western Electric Company, and the Laboratories; hundreds of engineers with their vast fund of experience, collective knowledge and individual ingenuity and resourcefulness; expert draftsmen, craftsmen and machinists; careful installers who erect frames, connect millions of wires and condition the equipment; alert, trained telephone personnel to keep the equipment working.

Let's step behind the scenes. Switching systems are carefully planned electromechanical (in the future perhaps electronic) relay races – yes literally! Each different part of the system receives the baton and runs its course, deposits the baton with the next part which in turn runs its course, deposits the baton, and so on, until the last "runner" reaches the finish line. In Englewood, the dial pulses at the customer's telephone station are received in the central office where they are rapidly counted and passed along to a register. After the completely dialed number is recorded in the register, it is passed along to a marker which quickly connects the line to an outgoing trunk and passes the dialed number to an outgoing sender. The outgoing sender likewise passes the dialed digits out over the trunk to a tandem or toll switching office. This is indeed a relay

The illustration at the top of the page shows W. J. Scully (left) and the author at the office-code translator of the marker in the No. 5 crossbar laboratory. This translator handles both "local" and "area" codes.

* RECORD, *March*, 1949, *page* 85.

race – passing the called number along toward the goal. At the tandem or toll office, similar dial switching equipment takes the call and races on toward the goal. Finally the call reaches the called customer's switching office and his bell is rung.

For ordinary local area dialing, the first three digits, which in our telephone language are called the "ABX code," represent the first two letters of any called office name plus a numerical digit X having any value from zero to nine. There are no letters, however, associated with "one" and "zero" on the dial. ("One" is never used singly as an initial digit because occasionally the act of picking up the handset to start a call creates a single pulse which is purposely ignored by the switching equipment. "Zero" is reserved to reach an operator.) This leaves just eight useful dial positions for the "lettered" parts of the office name and 10 for the numerical. A little arithmetic shows that 8 x 8 x 10 gives 640 possible ABX or office name codes for any given local dialing area.

By making use of the other two dial positions (0 and 1) as the "B" digit, we provide additional three-digit area codes which do not conflict with any of the office name codes. This permits the equipment to readily recognize an area code and await the dialing of an office name and number. Again arithmetic gives 8 x 2 x 10 = 160 combinations. Except for the eight codes ending in "one-one," which are reserved for service calls (as an example, 411 for Information), the remaining 152 special codes may be used as area codes. This is ample for the necessary areas of the United States and Canada. About 95 of these codes are presently in use.

Operator-handled calls already make use of these codes for long distance calls.* For such calls, however, the customer dials only zero or 211 and reaches an operator, who then completes the connection by dialing or keying into the No. 4A toll switching systems.†

For local area calls the customer dials one of the ABX codes followed by four numerical digits – seven in all – and the call will be completed to that particular office, perhaps via a tandem or even two tandem offices. However, with the No. 5 crossbar system, arrangements are provided so that for a call to one of the areas other than his local area, the customer first dials one of the A0X or A1X codes followed by the ABX code and the number the customer wanted. As an example, for a call to a suburb of San Francisco, California, the area code is 318, the office code is OX (ford) 7, and the customer's number is 3354. The No. 5 crossbar switching equipment considers the first three digits and routes the call to a trunk directed toward the called office. The only difference in this case is that the No. 5 crossbar equipment, because of the "zero" or "one" as the second digit, recognizes the code as an area code and waits for the customer to dial seven additional digits. In addition to routing the call to a trunk directed toward the called area, the No. 5 crossbar equipment repeats all the ten digits over the trunk to the next link in the chain, usually a No. 4-type toll office.

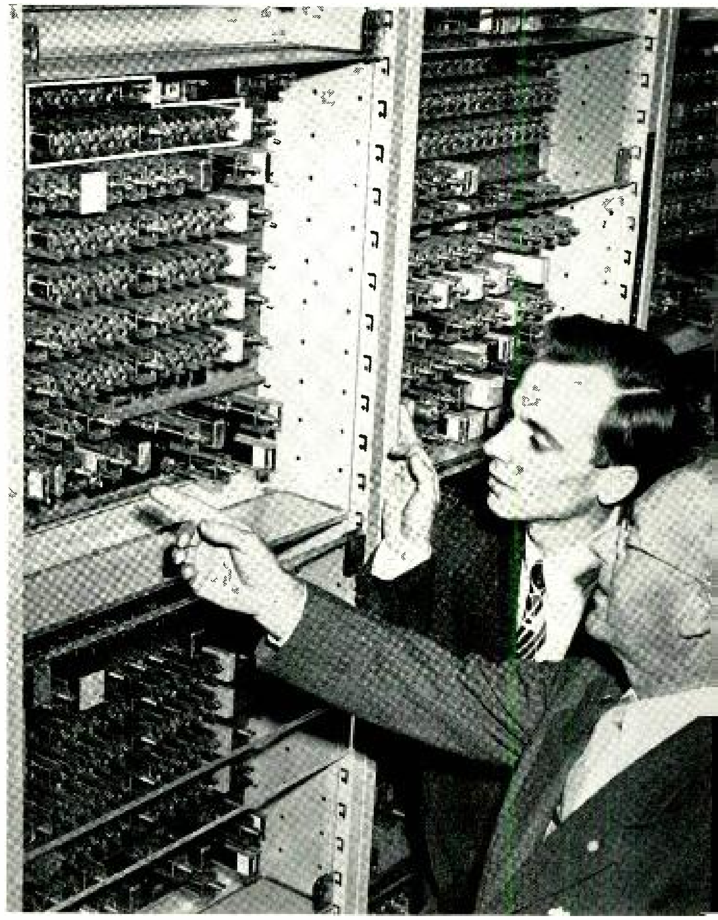


Fig. 1 — W. A. Frylinck, Wire Chief at Englewood (right), and A. F. Bickhardt, Chief Switchman, inspecting an originating register. The three extra digit registers required for customer toll dialing are outlined at the top left.

There are instances, however, where not all the dialed digits are repeated. As a call proceeds along the switching path, area and office digits can be omitted when no longer needed for further routing

* Record, *October*, 1945, *page* 368. †Record, *October*, 1953, *page* 369.

of the call. But, where conflicting codes are encountered in an adjacent area, the area code must be dialed even though the called office is nearby. In this case the No. 5 crossbar equipment is also unique among local switching systems, since it may route the call to a tandem office in that adjacent area and pass along only the ABX code and numericals. The call then will be completed from the tandem office back to the nearby office. However, the originating No. 5 crossbar office may choose to avoid this "back-haul" and route the call over a direct trunk to the called office. In this case, it will pass along only the numericals. This direct routing feature of No. 5 crossbar requires what is called "Foreign Area Translation," not presently applicable to other local switching systems. The Foreign Area Translator will be the subject of a future article.

These are some of the chief technical features of the No. 5 crossbar system as it will be used to serve nationwide customer dialing, but perhaps a few words of historical background will set them into a better perspective.

As dial exchanges became more and more numerous, there appeared certain areas where the geographic boundaries separating telephone areas did not represent the boundaries of telephone interest. One of the first of these fell between New York and New Jersey. Here there was much cross-boundary telephone traffic handled by operators. No. 1 crossbar exchanges were then in the ascendancy. No. 5 crossbar was not even conceived.

Earlier in this article it was stated that the digit "one" is never dialed singly as an initial digit because of its confusion with an accidental pulse created with the switchhook. Studies showed, however, that the occurrence of two accidental initial "ones" was almost nonexistent. As a result, circuitry for detecting two initial "ones" was built into both No. 1 crossbar and No. 5 crossbar equipment and thus when deliberately dialed could distinguish one particular adjacent area. This was made available in the Jersey City No. 1 crossbar office for dialing New York City offices as early as 1940, but was confined to operator use.

The historic first for customer use of the "one-one" feature was Camden, New Jersey, to Philadelphia, Pennsylvania, November 27, 1949, with No. 1 crossbar equipment. The No. 5 crossbar installation at Cranford, New Jersey, permitted its customers to dial New York City directly on February 19, 1950. A little later that year the New York City service was extended to Caldwell customers with No. 1 crossbar equipment. Then, on November 10, 1951 the No. 5 crossbar equipment at Englewood, New Jersey, which was already permitting the "one-one" service to New York City, opened the door to Englewood customers for nationwide dialing, reaching over 11,000,000 customers in thirteen of the national areas. Other No. 5 crossbar offices currently providing this service are in Birmingham near Detroit and Turtle Creek in the vicinity of Pittsburgh. In addition there are a number of other offices being engineered which will permit customer nationwide dialing initially and several already in service with nationwide dialing features operating on a limited basis to nearby areas.

Since the No. 5 crossbar system was designed to provide tandem and toll switching facilities for local and operator use, many of the features required for nationwide customer dialing were already built into the system. One of these features provided for receiving ten and eleven digits over intertoll trunks from distant operators. These digits are received in the incoming register and passed along to the marker for appropriate action in setting up the connection to an outgoing intertoll or to a toll completing trunk as the case may be. The marker asso-

Fig. 2 — F. J. Rizzo (right) and the author using a reel of AMA tape from the Englewood office for test purposes at Bell Telephone Laboratories.

ciates an outgoing sender with the outgoing toll trunk circuit and in turn passes along all ten or eleven digits to it for controlling the switching equipment further along the line. For customer dialing of nationwide calls, it is necessary merely to add three extra digit registers (making ten or eleven total) in the originating register circuit and make minor changes in other circuits. The total added apparatus in the Englewood office, listed in Table I, represents only approximately one-tenth of a relay per customer's line. Table I also lists the circuits requiring modification and the added relays for each.

A final important part of nationwide customer dialing is the ability to charge properly for each call without the aid of an operator. Automatic message accounting (AMA), described in other RECORD articles,* was first put to use in the initial No. 5 crossbar installation at Media, Pennsylvania, for local area calls. In order to extend AMA to nationwide application, it was therefore necessary only to associate the AMA recording tape with the outgoing toll or tandem trunks and provide for recording the additional area code when dialed. The AMA accounting center is also similarly arranged to use this additional information.

Thus, as a result of the features already provided in the No. 5 crossbar system, few additional modifications are required to provide full nationwide customer dialing. These modifications, though relatively few in number, nevertheless represent a tremendous achievement on the part of the design engineers who through years of research and development have made them possible. The success of the Englewood experiment means that a long step has been taken toward the ultimate goal of nationwide customer dialing.

* An AMA bibliography appears in the RECORD, *November, 1952, page* 428.

Table I — Tabulation of added apparatus required in various circuits to provide nationwide customer dialing in No. 5 crossbar offices. Where the No. 5 crossbar office is required to provide tandem or toll service, some of this apparatus is already provided.

CIRCUIT	ADDED APPARATUS	NUMBER OF CIRCUITS AT ENGLEWOOD
Originating Register	19 relays ½ multi-contact relay	80
Pretranslator Frame	8 relays	2
Marker Connector	½ multi-contact relay per marker	10
Marker	15 relays	6
Foreign Area Translator	1 two-bay frame	Not provided at Englewood
Out Sender	18 relays	9
Transverter	14 relays	3
Automatic Monitor, Register, and Sender Test Circuit	36 relays	1
Master Test Control Circuit	3 relays	1
Trunks	*	25

* Toll traffic would normally require trunks to the "zero operator" or the "toll operator." Trunks from these boards would extend the calls to the various areas. With nationwide dialing, the customer is routed over trunks direct to various terminating offices or via toll and tandem centers.

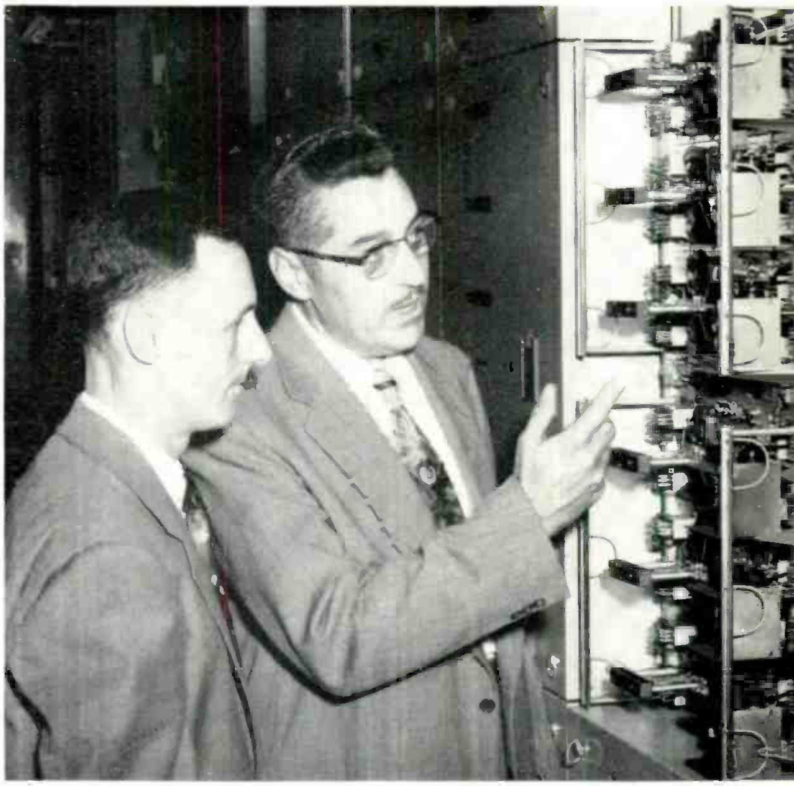
THE AUTHOR

RALPH E. HERSEY joined the Western Electric Company's Engineering Department in 1922 with a B.S. (1918) degree in Physics and Mathematics from Beloit College, and a background of graduate studies at Sorbonne University and at Harvard Engineering School. With Western Electric and later with the Laboratories he was concerned with panel dial systems, development of the automatic call distributing "B" switchboard, the first application of ten-button keysets instead of dials on DSA and toll switchboards, and studies for the No. 1 crossbar system. Since 1941 he has supervised work on senders, decoders and markers for all systems. Recently this responsibility has included supervision of common control circuits of the No. 5 crossbar system, including circuit development leading to the first application of Full Automatic Customer Dialing at Englewood, N. J.

New 12-Channel Bank for Broadband Carrier

A new 12-channel bank – the A4 – has made its appearance in the field replacing the A2B channel bank in broadband carrier telephone systems. The new assembly is approximately two-thirds the size of the old, so that now 36 instead of 24 channel terminals are mounted in one 10-foot 6-inch or 11-foot 6-inch bay. Most of the size reduction was made possible by a new design of the channel filters. Since approximately 2,500 banks are produced yearly, the new banks will save about 400 bays of equipment – a considerable saving in first cost, handling and installation. In addition, the reduction in floor space requirements is especially welcome to the Telephone Companies, with the continually increasing demand for carrier telephone systems.

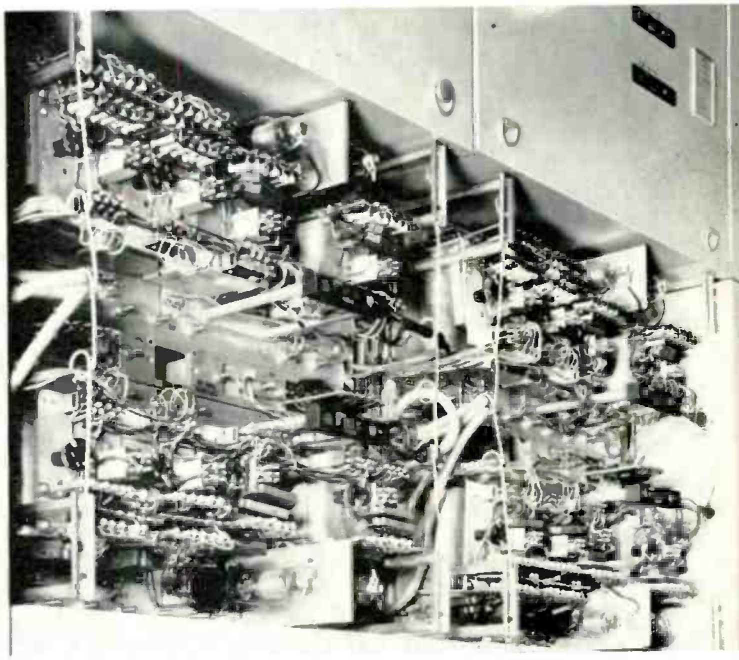
To expedite introduction of the new channel bank, the development was carried on concurrently with the Western Electric Company at Kearny through J. Cisar of the Equipment Standard Engineering Organization. Collaborating on the design at the Laboratories were A. J. Wier and D. B. Penick, Transmission System Development, and E. S. Willis, Transmission Apparatus Development.

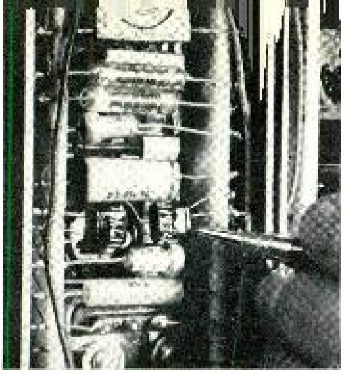


J. A. Cisar (right) Western Electric Standards Engineer on channel banks, discusses the A4 channel bank with W. G. Albert. Additional channel banks, with covers in place, are shown in the background.

Right — A2 channel banks installed at 32 Avenue of the Americas.

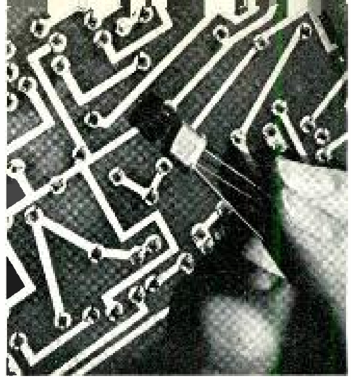
Left — Rear view of the A4 channel bank for broadband carrier telephone systems.





Left — Location of the transistors in the rural carrier oscillator sub-assembly for outlying terminals.

Right — The size of one of the rural carrier transistors in relation to the printed circuit employed.



Transistorized Rural Carrier Trial Starts

The transistor, the revolutionary electronic device invented at the Laboratories, is the heart of a new telephone system which promises to bring more and better telephone service to the nation's rural areas— without adding more telephone lines.

The new system permits many conversations to share a pair of telephone wires without interfering with each other and can operate economically over distances as short as five miles. Other systems not using the transistor have been able to do this economically only over much longer distances.

An experimental model of the new system is now being installed for a trial in a typical farming community near Americus, Georgia, about 135 miles south of Atlanta. The Southern Bell Telephone Company is participating in the trial.

The transistor — a tiny rugged device which can do most of the things an electron tube can do but requires only minute amounts of power — has previously been used in some telephone apparatus. This is the first complete system of telephone equipment, however, which will use them.

More than 300 transistors will be used in the equipment on trial in Americus. Advantage will be taken of the lower power requirements and the reduction in size of various parts which the transistor affords. This is expected to result in cutting the over-all size of the equipment to about one-tenth of what it would be if electron tubes and their related equipment were used.

It is this reduction in size and power requirements made possible by the transistor that has enabled engineers to design a system economical for such short distances. In this system, the transistors will require so little electric power that the batteries needed to supply it will be hung on the telephone poles with the transistors.

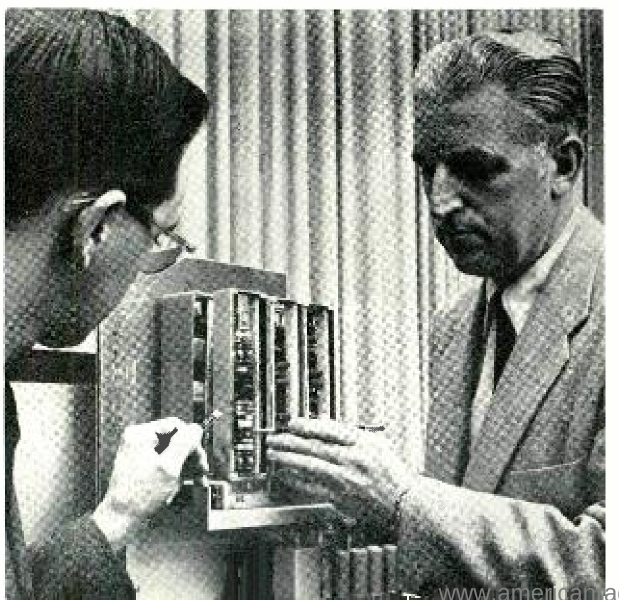
The experimental system is being tried over one line 11½ miles in length and a second line 15 miles in length, both extending from the central office in Americus. The new system uses the "carrier" principle which permits many conversations to share a pair of wires.

The carrier equipment on each of the lines being tested will consist of a terminal in the central office at Americus and another mounted on a pole farther out along the line. Between each of the pole-mounted terminals and the central office terminal, a number of conversations will share the use of the wire by using different frequencies. Beyond each of the terminals, the conversations which have been riding together between the carrier terminals will reach customers directly over the circuit in the ordinary way.

As an example of the small power requirements of the transistor, the carrier equipment in the trial at Americus will require for each terminal only a twentieth of an ampere or less, at 20 volts, in comparison with a power requirement 20 to 30 times as great, that would be necessary if electron tubes were used to perform similar functions.

Equipment being used for the trial consists entirely of laboratory models and will be used to obtain experience in actual service. In the final design the parts will be much more compactly packaged and they will look considerably different.

R. C. Boyd, left, shows P. G. Edwards a transistor used in a model of an oscillator sub-assembly.



Patents Issued to Members of Bell Telephone Laboratories During January

Bachelet, A. E., and Pitlik, H. – *Sequential Circuits* – 2,666,195.

Bonner, A. L. – *Loss Measurement in Two-Way Electrical Transmission Systems* – 2,666,099.

Breivogel, W. G. – *Calling Dial Device* – 2,666,097.

Clogston, A. M. – *Electron Device with Long Electron Path* – 2,666,163.

Cornell, W. A., Hall, N. I., Hecht, G., Koechling, C. D., Korn, F. A., and Powell, H. E. – *Electronic Discharge-Tube Controlled Telephone Switching System* – 2,666,096.

Gardner, L. A., and Hysko, J. L. – *Carrier Telegraph System* – 2,667,536.

Graham, R. E. and Mattke, C. F. – *Servo System for Non-intermittent Film Projector* – 2,666,356.

Graham, R. E. and Mattke, C. F. – *Optical System for Non-intermittent Film Projector* – 2,666,357.

Hall, N. I., see Cornell, W. A.

Hecht, G., see Cornell, W. A.

Hysko, J. L., see Gardner, L. A.

Juley, J. P. – *Switching Control System* – 2,666,578.

Kinsley, T. G. and Mason, W. P. – *Frequency Station Calling System Using Bifurcated Piezoelectric Elements* – 2,666,196.

Kircher, R. J. – *Telephone Signaling System* – 2,666,812.

Koechling, C. D., see Cornell, W. A.

Korn, F. A., see Cornell, W. A.

Mahoney, J. A., Rea, W. T. and Sutliff, C. B. – *Telegraph Repeater* – 2,667,537.

Mason, W. P., see Kinsley, T. G.

Mattke, C. F., see Graham, R. E.

Pfann, W. G. – *Reversible Semi-conductor and Method of Making It* – 2,666,977.

Pitlik, H., see Bachelet, A. E.

Powell, H. E., see Cornell, W. A.

Raisbeck, G. – *Balanced Amplifier Employing Transistors of Complementary Characteristics* – 2,666,819.

Raisbeck, G. and Wallace, R. L., Jr. – *Transistor Amplifier and Power Supply Therefor* – 2,666,817.

Rea, W. T., see Mahoney, J. A.

Robinson, A. L. – *Semiconductor Circuit Elements* – 2,667,607.

Shockley, W. – *Semiconductor Translating Devices* – 2,666,814.

Shockley, W. – *Transistor Amplifiers* – 2,666,818.

Slonczewski, T. – *Measuring Apparatus* – 2,666,100.

Stibitz, G. R. – *Automatic Calculator* – 2,666,579.

Sutliff, C. B., see J. A. Mahoney.

Trent, R. L. – *Transistor Trigger Circuit for Operating a Relay* – 2,665,845.

Wallace, R. L., Jr., see Raisbeck, G.

Talks by Members of the Laboratories

During February, a number of Laboratories people gave talks before professional and educational groups. Following is a list of the speakers, titles, and places of presentation:

A.I.E.E.-I.R.E. Conference on Transistors – Philadelphia

Blecher, F. H., Summing and Integrating Amplifiers.

Early, J. M., An Engineering View of Transistor Physics.

Ebers, J. J., Large Signal Transient Behavior of Junction Transistors.

Ebers, J. J. and Moll, J. L., Large Signal DC behavior of Junction Transistors.

Kretzmer, E. R., Compensation Technique in Transistor Circuit Design.

Moll, J. L., see Ebers, J. J.

Schimpf, L. G., Junction Tetrode IF Amplifier.

Yaeger, R. E., A Carrier-frequency Feedback Amplifier.

Other Talks

Anderson, A. E., The Present Status of Transistors, Sixth Southwestern I.R.E. Conference, Tulsa, Okla.

Anderson, J. Reid, Ferroelectric Storage Devices, Symposium on Digital Storage Devices, Sponsored by Philadelphia Section of I.R.E., Philadelphia.

Becker, J. A., Can We See Atoms and Molecules in the Field Emission Microscope?, Rawlins College, Orlando, Fla. and Stetson College, Deland, Fla.

Brattain, W. H., Surface Properties of Semiconductors, Physics Journal Club, Bryn Mawr College, Byrn Mawr, Penn.

Calbick, C. J., Electron Optics in Electron Microscopy, American Museum of Natural History, New York.

Campbell, W. E., Coulometric Analysis of Surface Films on Metals, Metropolitan Microchemical Society, American Museum of Natural History, New York City; and Boundary

Lubrication, Lecture Sponsored by American Society of Lubrication Engineers, Philadelphia, and Student Group, sponsored by American Society of Lubrication Engineers, New York City.

Coutlee, K. G., Electrical Measurements of Ceramics, Metropolitan Section, American Ceramic Society, New York City.

Dodge, H. F., Chain Sampling Inspection Plan, American Society for Quality Control, Baltimore; and Experiences in Sampling, New Mexico Section of American Society for Quality Control, Albuquerque.

Ellis, W. C. and Fageant, Miss J., Orientation Relationships in Cast Germanium, American Institute of Mining and Metallurgical Engineers, New York City.

Fageant, Miss J., see Ellis, W. C.

Finch, T. R., Circuit Applications of Transistors, Student and Professional Groups, Colorado Agricultural and Mechanical College, Fort Collins, Colo., University of Colorado, Denver and Boulder, Colo., University of Utah, Salt Lake City, and University of Arizona, Tucson, Ariz.

Gohn, G. R., Guerard, J. P. and Herbert, G. J., The Mechanical Properties of Some Nickel Silver Alloy Strips, American Society for Testing Materials, Washington, D. C.

Greenidge, R. M. C., Component Reliability, Seminar on Systems Engineering, University of Pennsylvania, Philadelphia.

Guerard, J. P., see Gohn, G. R.

Hagstrum, H. D., Auger Electrons Excited from Metals by Ions, Physics Colloquium, University of Minnesota, Minneapolis.

Herbert, G. J., see Gohn, G. R.

Jensen, A. G., Color Television, Joint Meeting of Society of Motion Picture and Television Engineers, A.I.E.E., and I.R.E., Dallas; and Personnel of Southwestern Bell Telephone Company, Dallas.

Keister, W., Can Machines Think? Council of Engineering Societies, Rutgers University, New Brunswick, N. J.

Kisliuk P., The Mechanism of Extremely Short Arcs, New York University, New York City.

Knowlton, A. D., The New Telephone Answering Set, I.R.E. Minneapolis Section, Minneapolis.

Lander, J. J., Behavior of Non-stoichiometric Zinc Oxide, American Physical Society, Austin, Tex.

Lewis, H. W., The Hall Effect in a Superconductor, Physics Colloquium, Columbia University, New York City.

Mason, W. P., Stress and Connection Systems in the Solderless Wrapped Connection, Mechanics Colloquium, Cornell University, New York City.

McKay, K. G., Avalanche Breakdown in Silicon, Edison Laboratory, West Orange, N. J. and University of Toronto, Canada.

Mealy, G. H., Digital Computers, City College of New York, New York City.

Moore, Mrs. M. L., Semiconductor Devices, Chestnut Hill College, Philadelphia.

Myers, P. B., A Note on Problem Solving, American Optical Society, Rochester, N. Y.

Pederson, D. O., Network Analysis, Graduate Course in Network Theory, and Introductory Circuits, Undergraduate Course in Elementary AC Circuits, Newark College of Engineering, Newark.

Pfann, W. G., Metallurgy of Semiconductors, Semiconductor Symposium, American Institute of Mining and Metallurgical Engineers, New York City.

Schawlow, A. L., Nuclear Quadripole Resonances in Halogen Compounds, Watson Laboratory, Columbia University, New York City.

Shannon, C. E., Information Theory, Symposium on Recent Advances in Science, New York University, New York City; and Computers and Automata, Summit Association of Scientists, Summit, N. J.

Shockley, W., The Present and Future of Transistor Research, The Thomas A. Edison Memorial Lecture, Naval Research Laboratory, Washington, D. C.

Sparks, M., Transistor Electronics, Chemical Department Colloquium, New York University, New York City.

Thomas, D. E., The Transistor from an Engineering Point of View, Niagara Frontier Section, A.I.E.E., Buffalo, N. Y., and Ohio Subsection, I.R.E., Dayton, Ohio.

Wallace, R. L., Jr., Junction Tetrode Transistors, Symposium on Current Trends in Semiconductor Research, Naval Research Laboratory, Washington, D. C.

Weinreich, G., The Hyperfine Structure of He^3, Physics Department Colloquium, Columbia University, New York City.