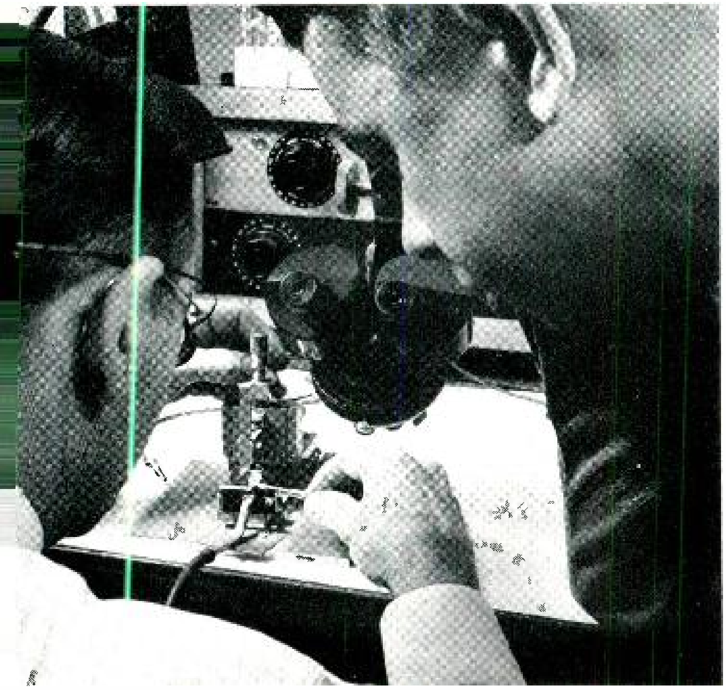


Junction Tetrode Transistor

R. L. WALLACE, JR.
Transmission Research

High-frequency performance of transistors has been greatly improved by several modifications of the basic n-p-n junction transistor. External dimensions have been decreased, the p-layer made very thin, and a fourth lead attached. The resulting tetrode transistor is expected to have important applications in high-frequency, broadband transmission systems.

The objectives of transmission research have been profoundly influenced by two new factors within the last decade. One of these is a very rapid increase in the demand for broadband transmission circuits and the other is the advent of the transistor. Within the last ten years, for example, the total bandwidth of the circuits linking New York with Boston has been increased from 5 to 25 megacycles, thus making possible a five-fold increase in the number of simultaneous telephone conversations over these circuits. This trend emphasizes the need for finding better and more economical broadband transmission methods to meet demands of the future. And in the new systems we can expect the transistor to play an important role.

Broadband transmission systems require transistors especially designed for good high-frequency performance. Several kinds of transistors, potentially useful for performing different functions in such systems, are being studied at the Laboratories. Among them are the recently announced p-n-i-p* in addition to the junction tetrode transistor.

The junction tetrode transistor is a close relative of the junction transistor recently described in a Record article† by M. Sparks. It differs from the earlier transistor in two respects: first, some of the mechanical dimensions have been made smaller, and second, a fourth electrode has been added.

Consider first the dimensional changes. It is found that high-frequency performance is improved as the germanium bar is made smaller in cross section. Only that part of the bar near the p-layer needs to be made small, however, and in the tetrode this is accomplished by a chemical etch. Figure 2(a) shows a junction triode transistor, and Figure 2(b) represents the same transistor with the center section reduced by etching. In this central part, the transistor measures only about

* Record, *October,* 1954, *page* 384.
† Record, *June,* 1954, *page* 203.

Above — The author (right) observing bonding operation. E. Dickten is clamping base wire in micromanipulator.

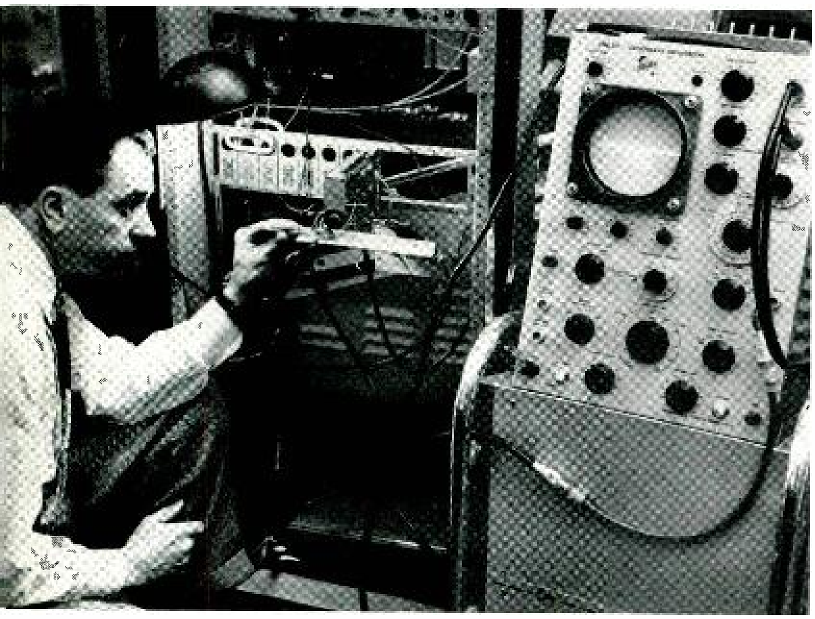


Fig. 1 — R. L. Carbrey adjusting transformer in junction tetrode pulse generator. The oscilloscope at the left displays 0.050 microsecond pulses.

0.01 inch on a side. The electrical effect of this etching process is a decrease in the output capacitance, which is typically reduced to about one micro-microfarad.

Another dimension of the junction transistor that is very important to high-frequency performance is the thickness of the central p-type layer. The signal current is carried across this layer by the diffusion of electrons. If the frequency of the signal is too high, the electrons tend to arrive at the output side of the layer out of step with each other. As a result, the signal current is not properly transmitted at high frequencies. This aspect of transistor performance is improved by making the p-layer thin. New techniques recently worked out in the transistor development and transistor research areas of the Laboratories have produced p-layers about two ten-thousandths of an inch thick. When the best of this material is used to make transistors, as much as 85 per cent of the signal current is transmitted across the p-layer, even when the frequency is as high as one hundred million cycles.

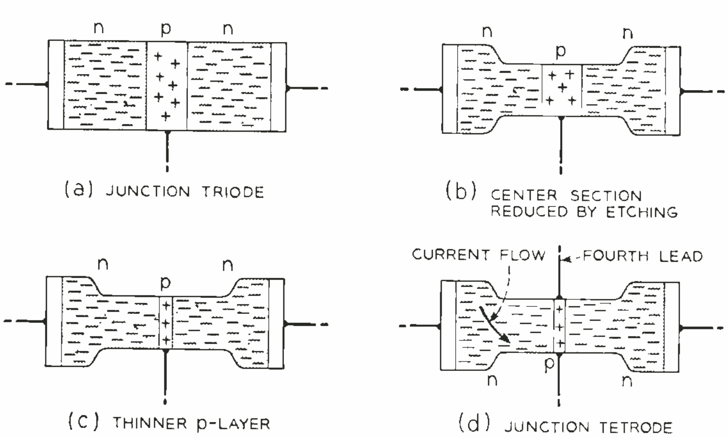


Fig. 2 — Evolution of junction tetrode by process of narrowing center section, making p-layer thinner, and attaching extra base lead.

Figure 2(c) shows a junction transistor made with a thin p-layer and with a small junction area. In spite of the low collector capacitance and good diffusion properties of such a transistor, it does not amplify at high frequencies. The difficulty comes from internal feedback within the transistor. Signals in the output circuit are fed back into the input circuit through a resistive element which is effectively in series with the connection made to the p-layer. Current that enters the transistor through this connection and flows vertically through the thin p-layer encounters a resistance which increases when the path is constricted by making the p-layer thin. A way of reducing this internal feedback had to be found before thin p-layers could be used to advantage.

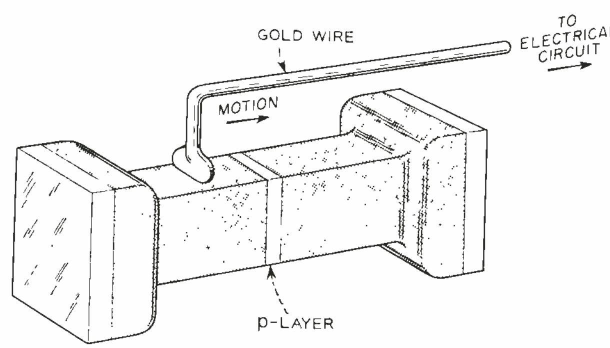


Fig. 3 — Method of finding correct position for bonding gold wire to very thin p-layer.

In the junction tetrode shown in Figure 2(d), internal feedback is very greatly reduced by making two connections to the p-layer and by applying a few volts of bias between the two. The effect of this is to cause the signal current to flow in a constricted path very near one side of the bar as illustrated. All of the transistor action takes place within a fraction of a thousandth of an inch of the bottom base contact. Current entering the base contact in this case has a very short distance to flow (vertically) in the p-layer, and for this reason encounters very little feedback resistance.

Making connection to a p-layer that is only a few ten thousandths of an inch wide presents some interesting mechanical and electrical problems. Techniques for making this connection, however, have been simplified to such an extent that it seems feasible to do the job quickly and accurately with automatic machinery. Actually a number of transistors have been made on an experimental model of such an automatic machine (Figure 5).

In either the manual or automatic process the connection is made by welding on a carefully formed gold wire. The end of this wire is formed into a "paddle" as shown in Figure 3. The paddle is placed in contact with the germanium bar, and with the thin edge parallel with the junction, it is dragged along the bar until the proper position for bonding is found. A carefully controlled pulse of current is then passed between the gold wire and the germanium. The resulting bond makes a long, thin contact with the p-layer.

The most significant electrical property of tetrode transistors is their ability to amplify broad-

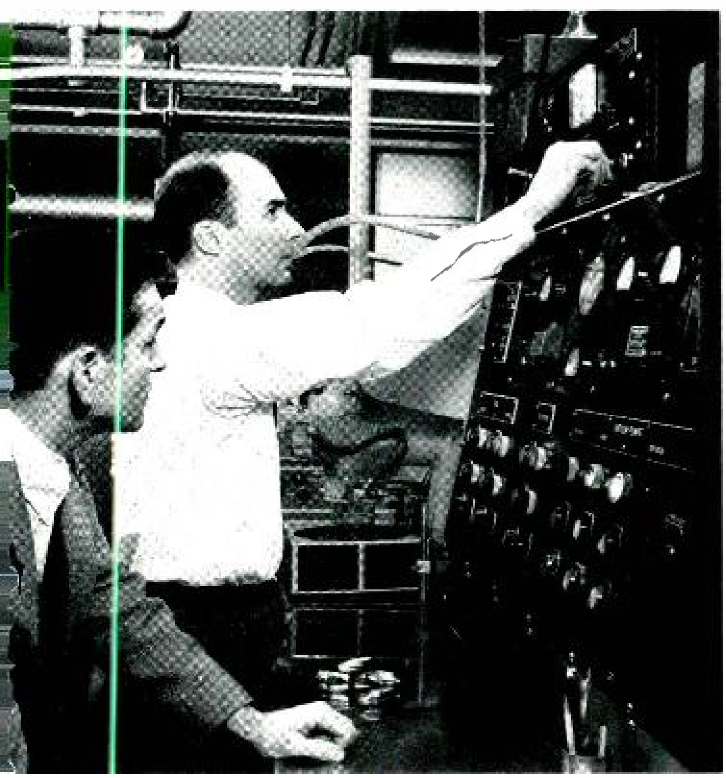


Fig. 4 — H. E. Bridgers (left) and E. D. Kolb operating crystal-growing machine used in making germanium crystals for tetrode transistor research.

Fig. 5 — The experimental automatic bonding machine: L. G. Schimpf (left) and E. Dickten are loading machine with a "header," in which is mounted the junction bar.

band signals and to operate at very high frequencies. Experimental transistors have been used as amplifiers at frequencies as high as 150 mc and have been made to oscillate at frequencies above 1000 megacycles. They have been used to amplify a 20-mc band of frequencies centered at 70 mc, and in this application they can produce about 9 db of gain per stage.

Aside from improved performance at high frequencies, junction tetrode transistors are electrically rather similar to the familiar junction triode transistor. A feature which is important in many applications is the ability to operate on low values of voltage and current from the power supply. Typical power requirements for producing maximum gain are of the order of 10 volts and one milliampere, but values several times higher or lower than this may be used. As an example of the power used in experimental operating circuits, a 100-mc FM receiver in which there are 6 tetrode transistors requires a total of 10 milliamperes at 12 volts. Less than half of this power is consumed by the transistors. In another application, a 5-mc crystal oscillator in which there is one tetrode transistor requires one-tenth of a milliampere at 3 volts.

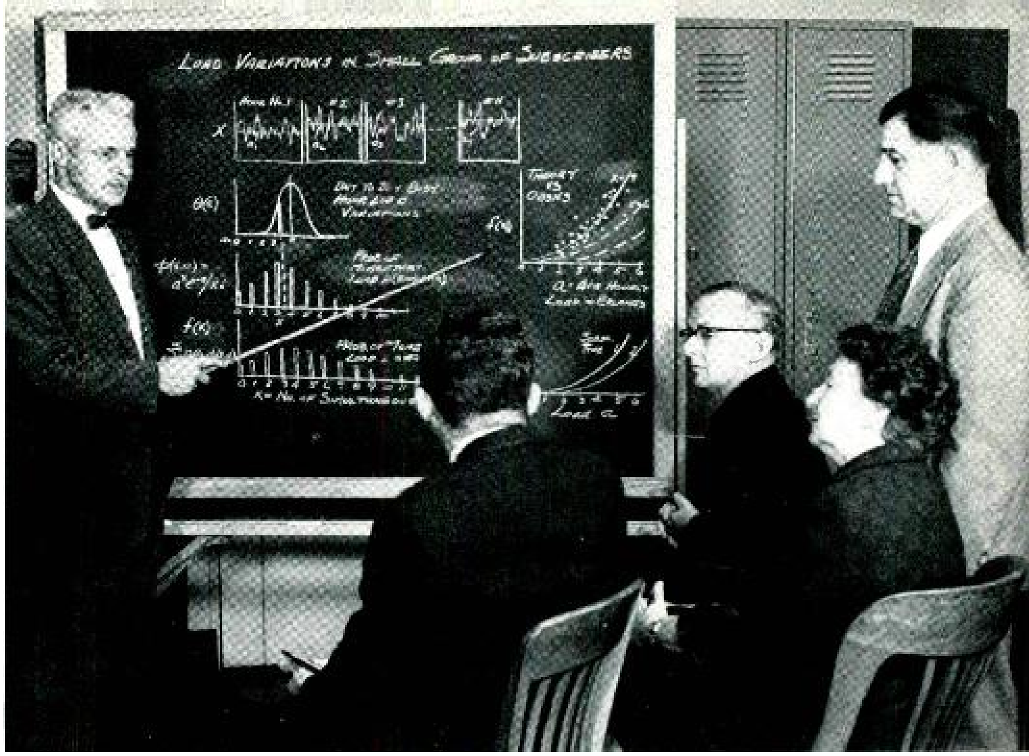
The noise generated in junction tetrode transistors is little enough to be acceptable in all but the most critical applications. Typical measured noise figures are, for example, 3 db at 10 mc and 10 db at 70 mc.

Among possible telephone applications of the junction tetrode transistor being studied in the Transmission Research Department, three are of special interest. The first of these is an experimental broadband carrier system that could be used in conjunction with a miniature cable. In this application the transistor has been used experimentally as an amplifier for a band of frequencies extending from 5 to 15 mc and as a crystal oscillator at 10 mc. A second experimental application has been in a pulse-code transmission system in which (See Figure 1) the transistor has been used to produce and amplify pulses only one-twentieth of a microsecond long and to manipulate these pulses at a rate as high as ten million pulses per second. Peak pulse power output as high as 500 milliwatts has been obtained without excessive heating of the transistor. A third telephone application has been in an experimental very-high-frequency radio receiver. In this case, small size and low power drain are of great importance.

The results described in this article have been obtained with experimental models of junction tetrode transistors made in the laboratory. The Transistor Development Department, however, has made great progress in learning to control the processes involved in making these transistors. Production by the Western Electric Company is scheduled to begin this year, with initial production directed toward meeting government needs.

THE AUTHOR

R. L. Wallace, Jr., received his B.A. and M.A. degrees in Physics at the University of Texas. From 1937 until 1941 he was a graduate student and instructor at Harvard University. During the war years, he was engaged in communications research for the O.S.R.D. at Harvard University. He joined the Technical Staff of Bell Telephone Laboratories in 1946 and has since been concerned with problems in sound spectrograph studies, magnetic recordings and more recently with the circuit applications of transistors, particularly in their broadband applications. Mr. Wallace is a member of the Acoustical Society of America, The Institute of Radio Engineers, Phi Beta Kappa, and Sigma Xi.



To provide the optimum quantities of central office facilities, a good understanding of expected traffic variations is required. A comparison of tentative theoretical variations with actual data obtained in central offices is being discussed by (left to right) R. I. Wilkinson, P. J. Burke, J. W. Gibson, Sallie P. Mead, and W. O. Turner.

W. O. TURNER
Systems Engineering

Traffic Engineering in Bell Telephone Laboratories

The Bell System was a pioneer in the application of probability theory to telephone trunking problems. Out of the early work of E. C. Molina and others in this field have evolved sampling techniques and probability engineering methods of basic importance to modern industry. At Bell Telephone Laboratories the original work on trunking problems has expanded into a broad program of aid to the telephone companies in problems of traffic engineering and administration. This is the first of several articles describing these activities.

When the writer's wife was a little girl in Van Wert, Ohio, her father owned the local telephone company. Her mother, besides keeping house and tending the baby, operated the switchboard. In this capacity she was the whole Traffic Department. Her switchboard was crude by today's standards, yet the telephone service in Van Wert then was as good as you can get anywhere in the world today. It was good because the one-woman Traffic Department knew the telephone needs of her customers, and made sure that they got the kind of service they needed.

To give good dial telephone service today (and four out of five Bell System telephones are dial), traffic people have a problem whose complexity could not have been dreamed of by the young woman in the small Ohio town. They must know the kind of telephone service their customers want; they must know the volume and distribution of the telephone traffic in their offices; and they must know how to use this knowledge in estimating equipment quantities and adjusting traffic loads to the available equipment. Finally, they must keep track of the grade of service being given as a check on the kind of job they are doing.

Probably few traffic people have ever stopped to think that Bell Laboratories is an important behind-the-scenes partner of theirs, both by making fundamental studies whose results are used by telephone folks, and in designing the tools by which telephone people can collect their own information. This article is the story of the group of people in the Systems Engineering Department who devote themselves to this work.

Fig. 1 — Mrs. Marilyn Cusick, of the New York Telephone Company, operates the Laboratories' dial tone speed measuring set while W. G. Barrett looks on.

Take the problem of finding out what is the right speed of dial tone to give customers. ("Speed of dial tone" is a term used to describe the length of time customers wait for dial tone, and thus is one measure of grade of service). You could go out and ask people, but their answers would be only guesses — perhaps not based on any actual experience with slow dial tone service. You could give them progressively slower service and wait for them to come to you and complain, but besides being hard on the customers, this wouldn't give you any very definite relationship between dial tone speed and customer satisfaction. A useful way to approach this problem is to study the normal dialing pattern of customers to see just how soon after removing the receiver they start to dial. Then you can make your decision on the basis of what customers really do, not just what they think. This kind of study is made by the Laboratories for the benefit of those who have the responsibility of determining the service requirements of dial telephone switching systems.

Figure 2 is the result of one such series of studies, and shows the elapsed time from lifting the receiver to start of dialing for thousands of calls made in different cities over a period of many years. Obviously, a great many people, by habit, start dialing in less than two seconds. If dial tone is delayed by even this brief interval, these people are going to be affected in one way or another. They may delay their dialing until dial tone comes on; they

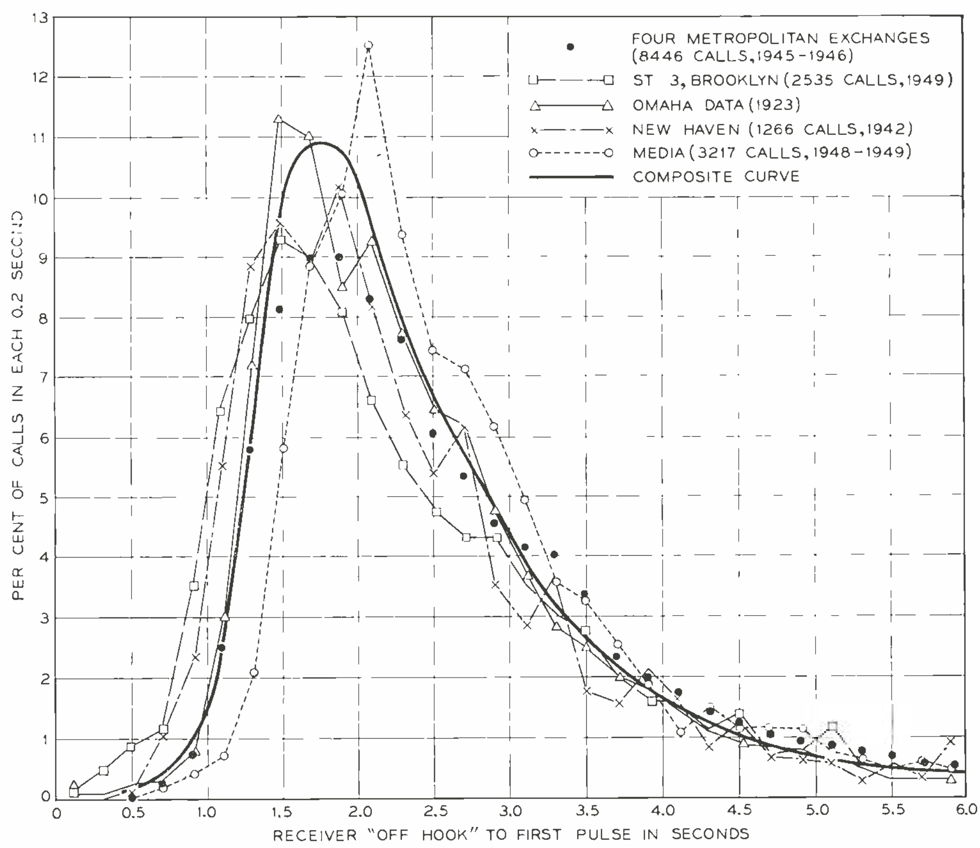


Fig. 2 — Distribution of time normally taken by customers from lifting of receiver to arrival of first dial pulse at a central office.

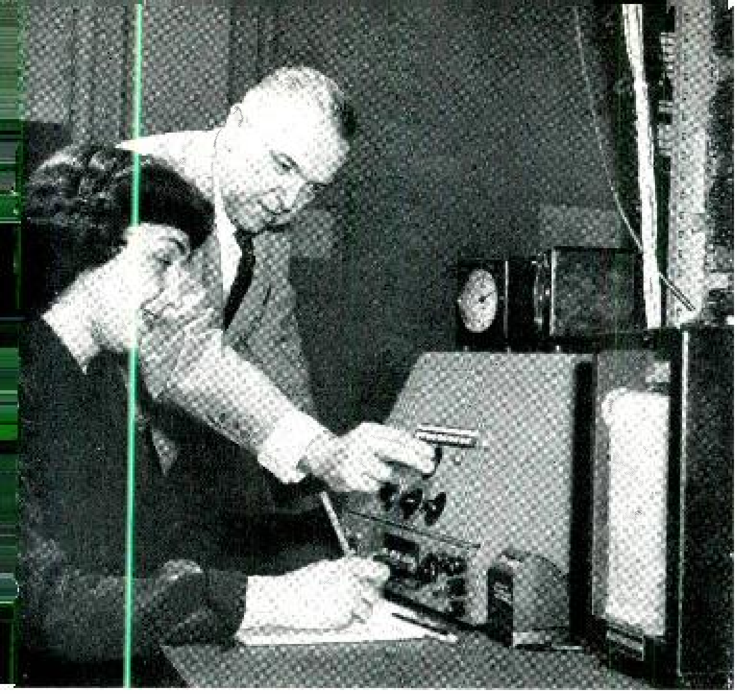


Fig. 3 — C. F. Bischoff instructs Jean Rock, of the Chesapeake and Potomac Telephone Company of Baltimore City in the operation of a special device used to monitor the performance of customer dialing at the Towson, Maryland, central office.

may hang up without dialing, or they may dial before they hear the tone.

To find out what customers actually do when dial tone is delayed, Bell Laboratories engineers have made a number of studies of groups of customers. The results of one such study are shown by the curves in Figure 4. These people were used to very fast dial tone service, and when they met delays of 2 seconds or more, about 40 per cent started to dial without waiting for the tone. Thus, they spoiled their chances of successfully completing their calls, and meanwhile tied up expensive dial switching equipment that should have been handling properly dialed calls. More studies are under way right now to see how customers react to dial tone delays under various conditions.

As mentioned previously, another problem traffic people face is to know the volume and distribution of the telephone traffic in their offices. Knowledge of traffic volume comes from devices designed by the Laboratories and installed in the telephone offices, which count calls and measure equipment usage. A recent development of this type is the Traffic Usage Recorder.*

Knowledge of traffic distribution is needed in two forms—distribution by equipment groups and by time intervals. With the devices provided in the telephone offices, telephone people can get all the data they need as to distibution by equipment groups, and by the larger intervals of time, such as the day and the busy hour of the day. They rarely record volume by smaller time intervals than an hour yet, as we shall see, distribution within the hour is of great importance in the traffic engineering process.

In order to estimate the number of switches or of trunks required to give a desired grade of service, traffic engineers arrive at estimates of the average traffic usage per group and refer this figure to Traffic Capacity Tables, published by the Operating and Engineering Department of the American Telephone and Telegraph Company, which show the number of switches or trunks required. These tables are based on mathematical formulas which predict the probability of any number of simultaneous calls existing at any random instant during a period when the average traffic is known. Practically all such formulas used in the telephone industry assume that, during the period of interest, calls occur at random. This assumption has given satisfactory results over the years, but as the Bell System has designed new dial systems that use common-control circuits (such as markers) very efficiently, even a relatively small departure from randomness might result in considerable error.

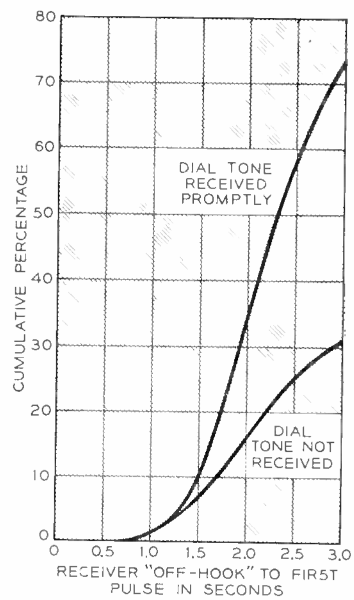


Fig. 4 — Cumulative distribution, in a typical central office, of intervals from removal of receiver to first dial pulse, with prompt dial tone and with delayed dial tone.

Accordingly, the Laboratories recently designed a special recorder that counts the calls flowing through an office and records them at the end of each minute. Figure 6 shows the minute-by-minute

* Record, *September*, 1954, *page* 326.

traffic distribution during one busy period in one office studied. It was found that if trends in traffic volume are identified by using a moving average, as indicated on the figure, the minute-by-minute flow does in fact, vary at random around the average in the busy hours. In this respect, therefore, the probability formulas now in use appear satisfactory, provided the trend in traffic volume during the busy hours is not significant. Trends can be detected by counting calls by half-hour or quarter-hour periods. Significant trends can be compensated for by selecting the high half-hour or quarter-hour for the engineering basis.

The third problem Traffic people face in giving

Fig. 5 — W. S. Hayward, Jr., connects a call-counting and automatic printing device to a group of markers in a Laboratories' test installation.

good dial service is how to use their knowledge of traffic volume and distribution in estimating equipment quantities and adjusting traffic loads. By far the most important tools used in this process are the Traffic Capacity Tables mentioned previously. To publish all these tables in use in specialized forms in the Bell System would take all the pages in three editions of the RECORD. The theoretical work on which these tables are based is the responsibility of the Laboratories.

Sometimes reliable estimates of traffic capacity can be furnished by the Laboratories on short notice; but where new switching principles are involved, years of work may be required. Such has proved to be the case in preparing traffic capacity estimates for crossbar link frames.

On these frames are located the switches by which talking connections are established. The connection is made up of three circuit elements which, in the No. 5 crossbar system, are named the line link, junctor, and trunk link. In the simplest case there are ten of each of these circuit elements available between each line and each trunk as illustrated by Figure 7. A complete channel always consists of a like-numbered line link, junctor and trunk link. Since each group of links and junctors also complete line-to-trunk connections for other channel groups, the heavier the traffic the greater the probability of failure to find an available channel for the particular connection we are concerned with. Such failures result in the return of the "overflow," or "all trunks busy" signal to the calling customer, who then must hang up and dial the call over. The problem, then, is to determine the relationship between traffic per 10 links and the probability of failing to find the three elements of one of the channels simultaneously idle when the call is made.

When this problem was first presented by the No. 1 crossbar system in the early 1930's there was no background of probability literature on the subject. After study of the operation of the proposed system, several mathematical formulas were worked out which took into account, in varying degree, the important factors in determining the probability of a connection failing to be established. The more complex formulas were difficult to compute for different ranges of the variables included, so it was obviously desirable to select for practical engineering use the simplest formula that would yield results of adequate accuracy. The curve on Figure 8 is plotted from one such formula, adapted to the particular conditions involved in a connection between incoming trunk and called line in a No. 5 crossbar office of 20 line link frames and 10 trunk link frames.

Much study and engineering had to be done by the telephone companies before a real office could be placed in service and used to check the formula. In this early work, the capacity estimates used of necessity depended upon the reasonable accuracy of the formula chosen. However, to obtain the earliest possible practical check, traffic simulation methods were used. The traffic simulation method, usually called the "throwdown" method in the Bell

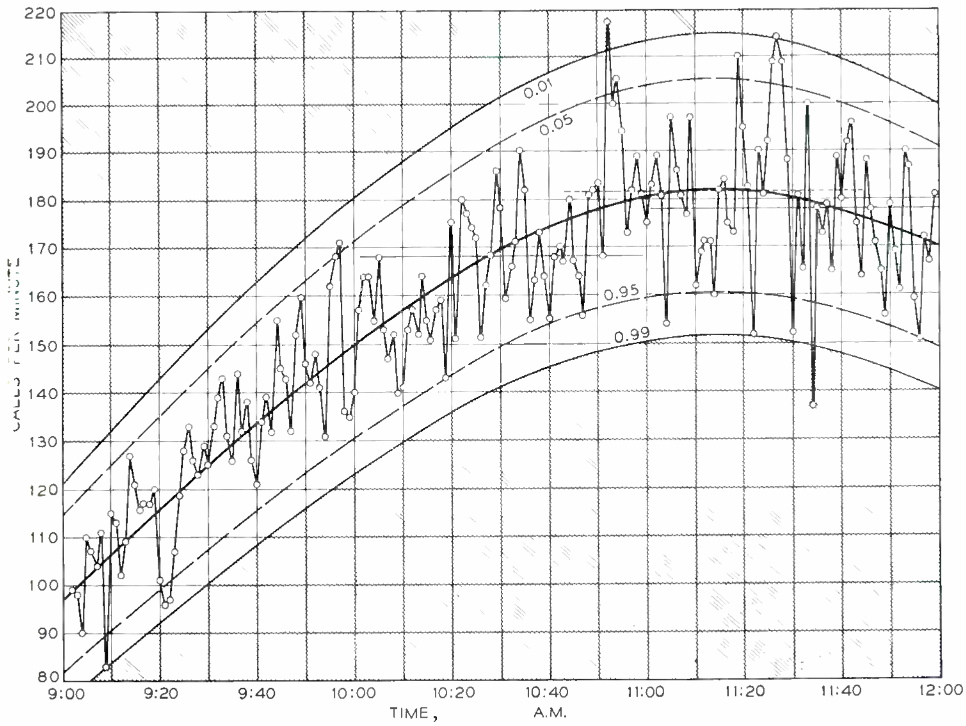


Fig. 6 — A check of the time distribution of calls originating in a typical central office. The observed points conform closely with a random distribution about the central trend line, in which one percent of the points should fall outside of the 0.01 and the 0.99 lines, and five percent outside the 0.05 and the 0.95 lines.

system, consists of constructing a model of the system to be studied, submitting a measured amount of "traffic" to the model, and recording the grade of service observed. In the early throwdown studies of the No. 1 crossbar system the "model" was actually a system of bookkeeping to keep track of the calls, supplemented by mechanical aids to control exactly the timing of various operations. For later studies of the No. 5 crossbar system a device known as the "No. 5 Crossbar Throwdown Machine"* was constructed. This machine reproduced and displayed functions of a modern automatic telephone office, so that the passage of "calls" through the machine could be observed and recorded. This partial mechanization of the process greatly reduced clerical effort and speeded up the studies. The points plotted on Figure 8 show the results of several test runs with this machine. The curve drawn from the formula fits the throwdown results satisfactorily. This demonstrated that the formula adequately described results under the artificial conditions of the throwdown, but there was still the possibility that the laboratory tests might not truly reproduce conditions in a working office.

For the final test of the theory, actual field data were required. And because of differences in operation between the No. 1, No. 4 and No. 5 crossbar systems field studies had to be made in each type of office. The results of one of these studies are plotted on Figure 9, where the theoretical curve has been modified to describe No. 4 toll crossbar office conditions. The probability indicated is that of failure to match the like-numbered junctor and links on the first matching attempt and does not indicate the chance of failing to complete a connection. This is because a second attempt is made, usually using different channels, if the first attempt fails.

The problems of the Traffic people in the telephone companies have only started when they

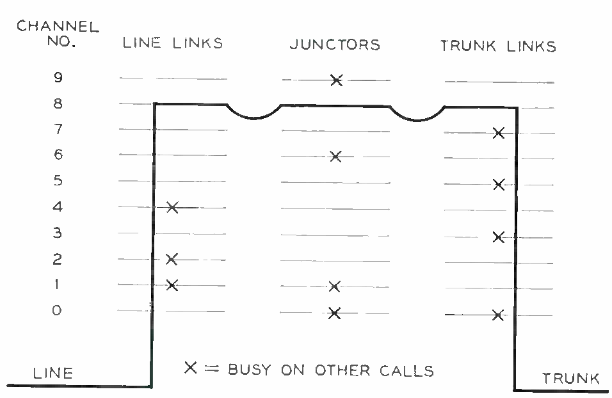


Fig. 7 — Schematic representation of a connection from line to trunk by matching an idle line link, a junctor, and a trunk link in a No. 5 office.

* RECORD, *January*, 1953, *page* 2.

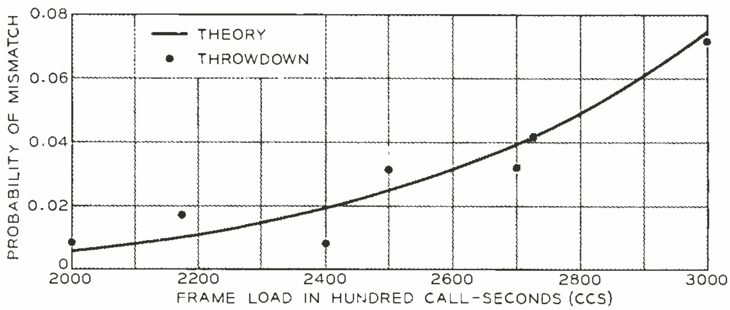


Fig. 8 — Theoretical probability of failure to match on first matching attempt in a No. 5 crossbar office of 20 line link frames and 10 trunk link frames, compared with results from a "throwdown" machine.

have decided how much equipment will be needed to give their customers satisfactory service. Once the equipment has been installed and traffic starts flowing through the office, they must keep continuous watch to see that service stays up to standard. The instruments they use are designed by the Laboratories to meet telephone company requirements as determined by the Operating and Engineering Department.

In dial offices, the over-all grade of service, measured in terms of human and machine errors, speed of answer by operators, charging accuracy on toll calls, wrong numbers reached, and so on, is determined by a process known as "service observing." This is done by girls seated at specially designed desk positions* where they can observe all the essential details of the progress of a sample of the calls placed by the customers. The service observing desks and associated connecting circuits are also designed by the Laboratories.

Before the advent of direct distance dialing,† a complete picture of dial service could be obtained by customer line observing to sample local service, and at toll switchboards to sample toll service. But customer dialed toll calls by-pass all switchboards, so toll observing methods must be changed to meet the new conditions. It is true that routine line observing would pick up a customer dialed toll call now and then, but these calls are a tiny fraction of the total calls dialed by customers. If line observations were relied on to measure the service on these toll calls, the total number of observations would have to be increased many times, and at great expense, to obtain a reliable sample of calls.

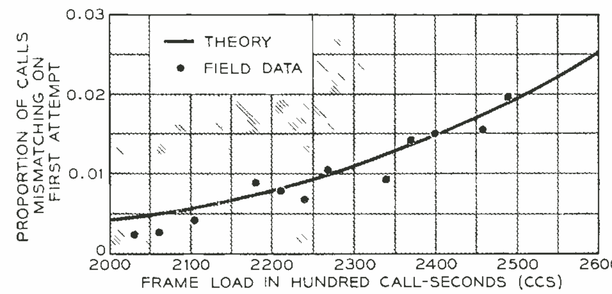


Fig. 9 — Theoretical probability of failure to match on first matching attempt in a No. 4 toll crossbar office of 20 "toll completing" frames, compared with actual observed data.

It is obvious that new service observing facilities are needed to permit the telephone companies to measure this new type of service adequately and economically. To meet these objectives the service observing connections must be made at a point in the switching network where the toll calls to be observed are not diluted by a quantity of local calls or toll calls handled by operators. Where operators are brought in on the connection to obtain the calling number, their speed and accuracy must

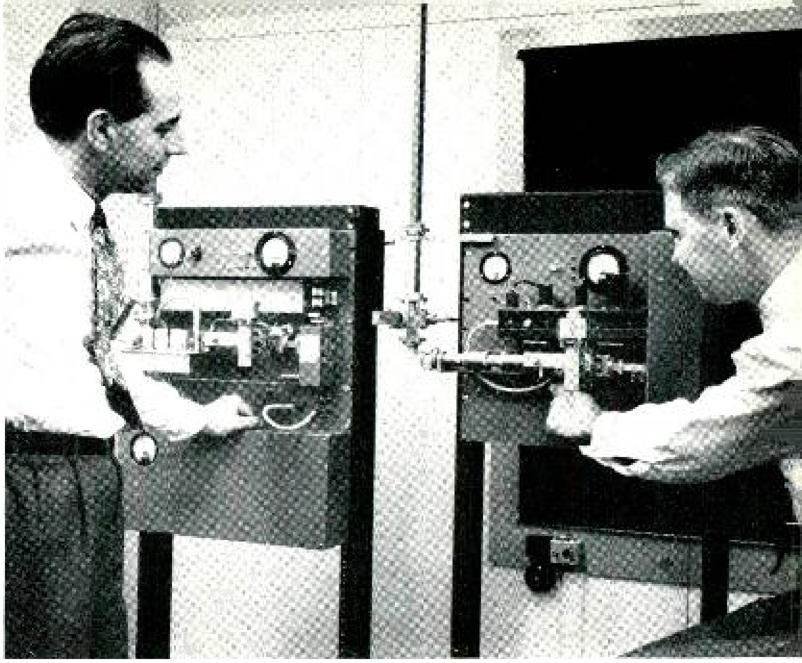
(Continued on page 140)

* RECORD, *November*, 1953, *page* 445. † RECORD, *January*, 1954, *page* 11.

THE AUTHOR

Shortly after receiving the A.B. degree from Darthmouth in 1920, W. O. TURNER joined the New England Telephone and Telegraph Company in Boston, where he became engaged in traffic engineering. In fact, his entire Bell System career has been in the traffic engineering field. In 1927, he transferred to the American Telephone and Telegraph Company, Operation and Engineering Department, where, in 1940 he became Traffic Dial Equipment Engineer. In 1951, he came to Bell Laboratories where he is Systems Studies Engineer, in charge of five groups: traffic analysis of systems, probability studies and traffic research, traffic measuring and service observing, traffic problems in electronic central offices, and mathematical consultants on transmission and probability studies.

A Short-Haul Microwave Transmitter



L. C. TILLOTSON *Radio Research*

For most efficient and economical communication, different lengths of circuits generally require different transmission systems. In particular, short-haul systems require simple but efficient apparatus if their full possibilities are to be realized. Recent advances in microwave electronics, antennas, and ferrites have made possible a frequency-modulated microwave radio transmitter which, though very simple, provides a high order of performance. An experimental 10.7- to 11.7-kilomegacycle model has been built to meet the requirements imposed on a broadband, short-haul type of system for multiple telephone conversations and television signals.

Bell System requirements for long-haul circuits suitable for television programs or several hundred telephone messages are being met by microwave radio and coaxial cable installations. In addition there is a growing need for short-haul circuits to build out branches from these main trunks to serve the smaller cities and towns. A simpler and therefore less costly radio repeater would make it possible to serve areas where the installation of equipment designed for long-haul service could not be justified because of cost. A microwave transmitter-receiver combination makes a good repeater for short-haul use because it permits simple dropping and adding of message circuits and order wire and alarm information for maintenance at repeaters between terminals. To be successful, however, considerable care must be exercised to make the modulation and demodulation process very linear if several links are to be operated in tandem. An experimental microwave radio transmitter employing frequency modulation has been designed with these needs in mind.

It is now well known that a reflex klystron* is a good source of frequency modulated microwave carrier. A reflex klystron consists, essentially, of an electron gun which projects a beam of electrons through a cavity resonator. Upon emerging from the cavity the electrons are slowed down, stopped, and then returned through the cavity by means of a negative electrode called the repeller. If the strength of the retarding field is properly adjusted, the returning electrons can be timed to give up energy to the cavity and thus to cause sustained oscillations. The microwave carrier generated by the klystron oscillator is frequency modulated by changing the voltage on the repeller electrode.

The reflex klystron is a simple and rugged device which has been highly developed, is reasonably low in cost, has adequate power output, and is very easy to frequency modulate. Like other oscillators, however, the frequency of oscillation is deter-

* RECORD, *August*, 1945, *page* 287.

Above — An experimental short-haul system using the transmitter and a microwave receiver. The author (right) turns on the automatic frequency control while A. F. Dietrich observes the effect on the performance of the companion receiver.

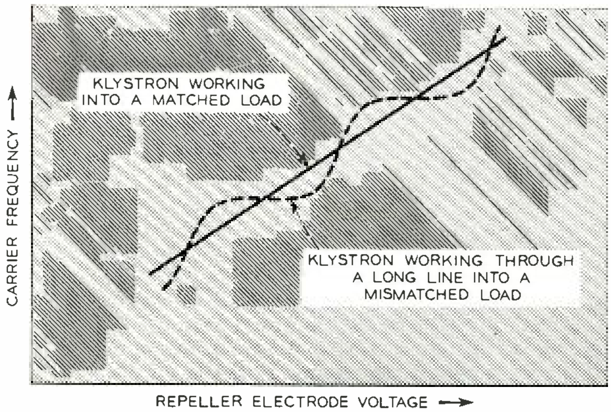


Fig. 1 — Curves showing effect of "frequency pulling" when reflex klystron works into mismatched load caused by imperfection.

mined in part by the load into which the klystron is worked. We say that the carrier frequency is "pulled" by a reactive load, the amount of pulling being determined by the magnitude of the reactive component of the load impedance; the direction of pulling by its sign. These facts make a klystron transmitter sensitive to its environment and complicate its installation and adjustment. This sensitivity can be tolerated when the tube is located very near to its final load — in this case the transmitting antenna — but it rapidly becomes intolerable as the distance is increased. And in radio relay applications it is frequently desirable to use long waveguide runs to connect the repeater apparatus on the ground or in central office equipment rooms with antennas on elevated structures. Under these conditions, the frequency pulling of an unprotected klystron oscillator can become very severe; in some situations encountered in the field, oscillations cease altogether.

We can understand this better if we visualize a wave emitted by the klystron as traveling along the waveguide until it encounters a bend, a joint, or an imperfection in the antenna-waveguide system. Here it will be partially transmitted onward and partially reflected. The reflected component will travel along the waveguide and eventually arrive back at the klystron. It is this reflected wave which causes the klystron to see a reactive load. In fact, the amplitude and phase of the reflected wave determine the magnitude and sign of the reactive component of the load impedance. Since the distance to the point of reflection and return may be many thousands of wavelengths, a slight change in transmitter frequency will cause a large change in the phase delay to the point of reflection and thus a large change in the phase of the reflected wave. Hence, the load impedance as seen by the klystron changes very rapidly with carrier frequency. The effect of this varying load impedance is illustrated in Figure 1 where the straight line is the modulation characteristic of a klystron transmitter working into a matched load, and the wavy line is the characteristic obtained when the antenna-waveguide system contains a single small discontinuity or point of reflection. The number of these ripples occurring within a given frequency range is determined by the round-trip delay to the point of reflection; their amplitude by the portion of incident energy which is reflected.

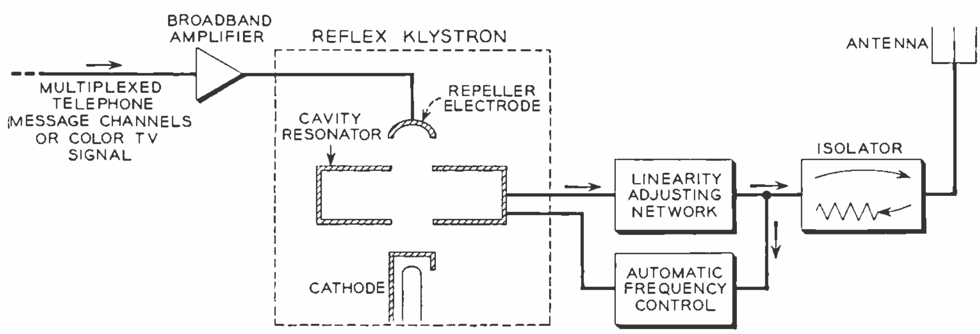


Fig. 2 — Simplified schematic of frequency-modulated microwave klystron transmitter.

Recent progress in the use of ferrites has made it possible to build a one-way transmission device called an "isolator*" having a low forward loss together with a very high reverse loss. Insertion of this device between the klystron and the antenna system has solved the pulling problem in a very satisfactory manner. The arrangement of such a transmitter is shown in Figure 2. After suitable amplification, the broadband signal being transmitted is applied to the repeller electrode of the reflex klystron. This produces frequency modulation of the microwave carrier. While the relation between

* Such isolators will be the subject of a future Record article.

repeller voltage and oscillator frequency is reasonably linear under matched load conditions, it can be straightened still further by using a linearity adjusting network as shown. An automatic frequency control circuit, described below, is provided to keep the oscillator on frequency. The isolator protects the klystron oscillator from variations in load impedance much as a buffer amplifier would. Compared to an amplifier, an isolator is simpler to build and requires no maintenance; it takes no power to operate, and does not introduce phase distortion inherent in any tuned amplifier. The isolator does not provide gain as would an amplifier, but this is no handicap since klystrons of adequate power output are available or can be designed. An isolator will be satisfactory for this application if it provides sufficient protection against frequency pulling and introduces negligible loss.

An experimental transmitter designed by C. L. Ruthroff to incorporate the ideas outlined above has been built and tested. This model operates in the 10.7- to 11.7-kilomegacycle common carrier band. Although it is small in size and of simple construction, its performance is of high order. By correct choice of klystron operating potentials and proper adjustment of the linearity adjusting network, the frequency modulation process can be made linear enough to accommodate well over a hundred message channels multiplexed by frequency division. The useful band of modulation frequencies extends from a few cycles to about 10 megacycles, and is limited primarily by the characteristics of the broadband amplifier. Measurements on this transmitter have shown that control of the phase of the color subcarrier for TV transmission* is also largely a matter of correct design of this amplifier.

* Record *March*, 1954, *page* 81.

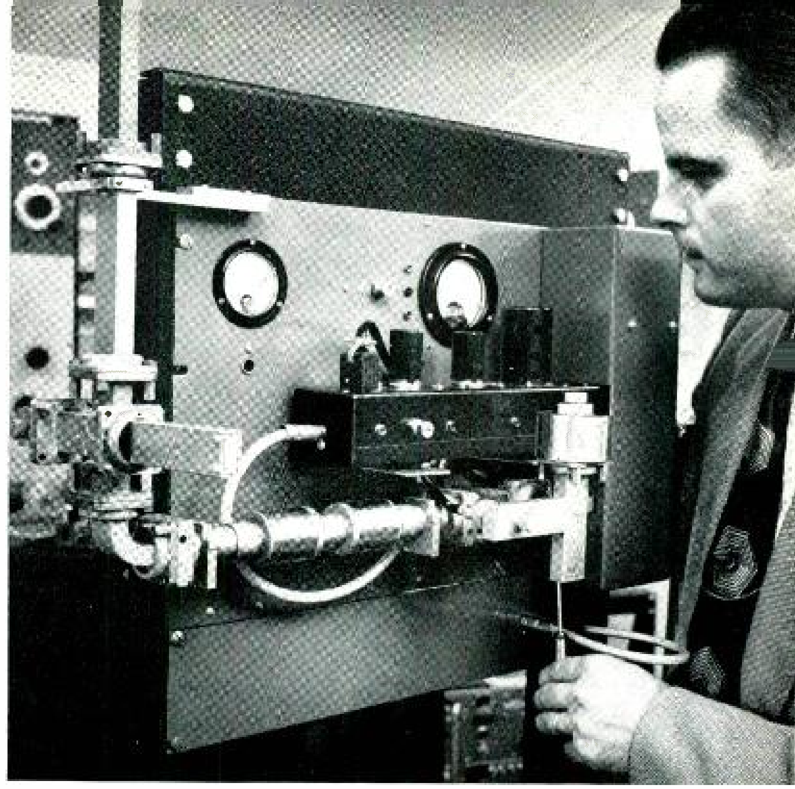
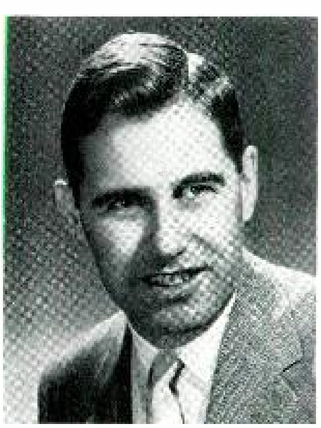


Fig. 3 — C. L. Ruthroff adjusting linearity characteristic of short-haul transmitter. The isolator with its two cylindrical magnets can be seen on the left side of the panel.

Since no microwave amplifier is used following the klystron, no delay distortion or bandwidth restrictions arise from this source.

An extremely simple automatic frequency control (AFC) circuit is used. It consists of a microwave frequency discriminator including a cavity resonator and two point-contact silicon rectifiers which convert the discriminator microwave output to dc. The magnitude of this direct current is proportional to the difference between the average transmitter frequency and the resonant frequency of the cavity; its sense is determined by the sign of the frequency difference. A low-energy polarized relay which responds to 10^{-8} watts is operated di-

THE AUTHOR



Leroy C. Tillotson received his B.S. degree in electrical engineering in 1938 from the University of Idaho and his M.S. degree in electrical engineering from the University of Missouri in 1940. He joined the Laboratories in 1941 and worked for five years on the design and development of filters and networks in the Apparatus Development Department. In 1946 Mr. Tillotson was transferred to Radio Research at Holmdel, where he has been primarily concerned with microwave filters and radio relay systems. More recently, he has been in charge of a group studying microwave applications. He is a senior member of the Institute of Radio Engineers and a member of Sigma Xi.

rectly by this rectified output. This sensitive relay actuates a reversible motor which mechanically tunes the klystron resonator to the reference cavity. The AFC used in the transmitter is precise enough that the frequency stability of the transmitted carrier is limited mostly by the effects of temperature on the reference cavity. An experimental short-haul repeater using the transmitter is shown in the headpiece. The transmitter is on the right, and an experimental microwave receiver designed to be used with the transmitter is on the left.

A simple frequency-modulated microwave transmitter such as this should be low in cost and insensitive to its environment, and yet provide a high order of performance. This should help make it possible to extend broadband circuits by microwave radio into areas which could not previously be served because of cost considerations.

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A New High-Speed Recording System

The author adjusts the external mirrors of the high-speed recorder to properly align the reflected beams on the film.

For switching apparatus to give the utmost in performance, it must be carefully studied in actual operation. Measurements of the mechanical motions involved are essential, and it is often necessary also to determine the relation between motions and associated electrical events. For example, one important relation is that between the current build-up in a relay coil and the opening and closing of the relay contacts. In the Laboratories, the rapid record oscillograph* is used extensively for such studies. This device combines two independent optical systems, a moving paper photographic film, and a rapid automatic developing arrangement. The events being recorded are available for study almost immediately, and the paper film strip provides a permanent record.

One of the two optical systems, built-in as part of the oscillograph, casts shadows of oscillograph strings actuated by the electrical conditions existing in the apparatus under study, and of timing lines at one-millisecond intervals. The second optical system, separate from the oscillograph, casts a shadow of the moving parts – relay armatures, for example – to show the mechanical conditions existing. All shadows appear side-by-side on the film strip, and the resulting permanent record is useful for studies of actions at low and medium relay operating speeds.

Because of the increasing emphasis on faster operating speeds for switching apparatus, a new recording system was needed. The one-millisecond timing lines, at the maximum film speeds available in the older system, are slightly less than $\frac{1}{10}$ inch apart; measurement of time intervals less than $\frac{1}{4}$ millisecond is impractical. The new high-speed recording system covers an interval of eight milliseconds, with the 1-millisecond timing lines two inches apart on a 16-inch film strip, Figure 1. Since this spacing is 20 times that of the older system, studies are possible of motions occurring within much shorter intervals.

Normally, the new recording system takes the place of the moving film strip of a rapid record oscillograph. The same optical systems and mechanical and electrical arrangements are used, with the new recorder being equivalent to a film strip moving at extremely high speed. Actually, the film does not move. Horizontal beams of light from the optical systems are intercepted by fixed mirrors attached to the recorder housing. These in turn direct the beams of light into the housing and through a pair of lenses onto a moving mirror. This third

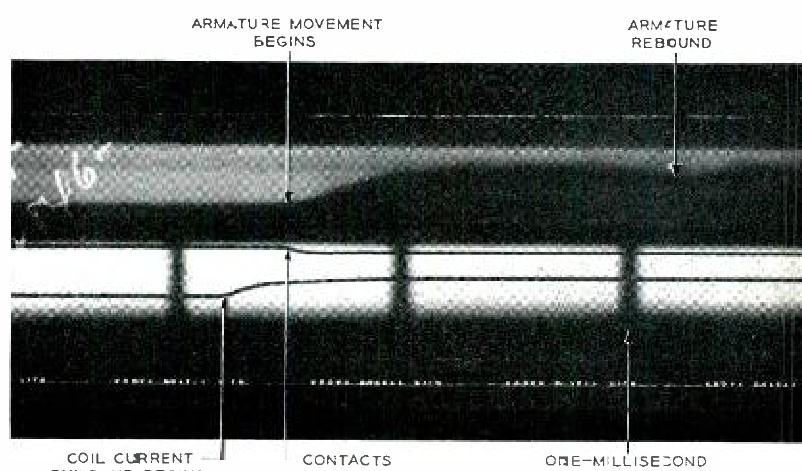


Fig. 1—A portion of a film strip showing the mechanical and electrical conditions occurring when a relay operates.

* Record, *September,* 1937, *page* 27 *and May,* 1952, *page* 233.

mirror rotates about an axis, directing the beams downward to traverse a stationary film strip. The mass of the mirror-moving mechanism is so small compared to that of a moving film that extreme speed is possible. If desired, and after proper calibration, the recorder may be used independently from the oscillograph to record and time mechanical motions alone.

In the actual high-speed recorder, most of the components are contained in a metal housing, including a semicircular film holder. A roll of commercial film is inserted at one end of the holder; the film is then guided along the semicircular holder to a take-up spool. Since there is no shutter, a rectangular entrance tube and non-reflecting baffles are built into the cabinet to prevent unwanted light from reaching the film. Only the reflected light beams from above can reach the film, and rotation of the mirror causes them to traverse the film strip. The back of the moving mirror, which normally would also reflect to the film, is covered with black velvet and, except for the active exposure time, even the incoming light beams are effectively absorbed.

As may be seen from Figure 2, the unusual feature of the recorder is the mirror-rotating mechanism. This consists of two electromagnets, a rotatable mirror, a spiral drive-spring, and a weighted pendulum. Before exposure of the film, the spring is partially wound up and the mirror is held at rest by latching the end of the pendulum shaft under a magnet armature. When the magnet is energized, the armature latch is released and the mirror rotates through about 300 degrees under the driving power of the spring, Figure 3. At the end of its travel, the mirror is caught and again held at rest by a second electromagnet. Here, the pendulum shaft is held fast by magnetic attraction instead of a latch.

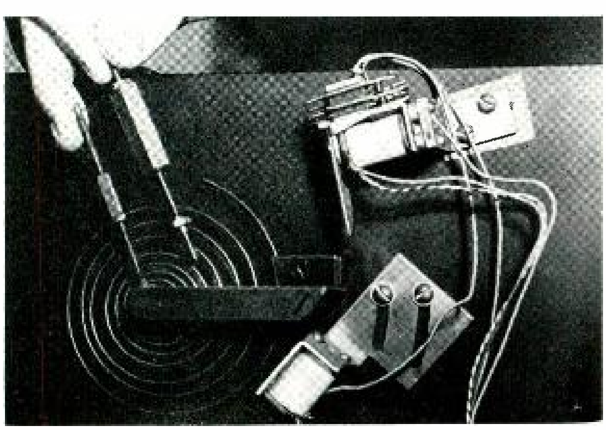


Fig. 2 — The pendulum weight for one-inch spacing of timing lines is compared with the one for two-inch spacing used to obtain Figure 1.

To be useful for the exposure, the angular velocity of the mirror must be practically constant. This condition exists near the middle of the mirror's rotation, after the initial acceleration from

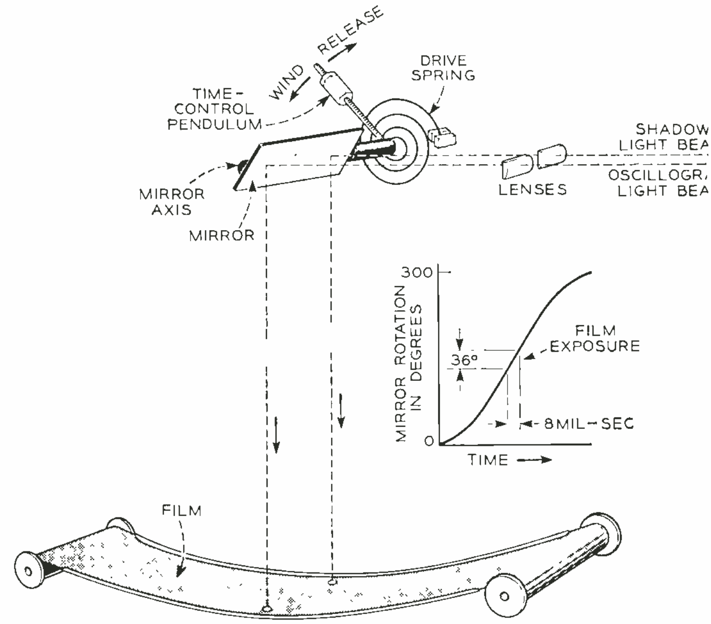


Fig. 3 — Only the middle 36 degrees of mirror rotation is used for exposure of the film.

rest and before deceleration begins. Only the middle 36 degrees of rotation is used for the exposure, assuring a linear time scale on the film. The torsion exerted by the spring and the effective mass of the weighted pendulum control the speed of the mirror, and different exposure times are possible by simply changing the weight on the pendulum. Since, as the mirror moves, the angle through which the light beams are reflected is the sum of the incident and reflected beam angles, the light moves along the film strip at twice the angular velocity of the rotating mirror.

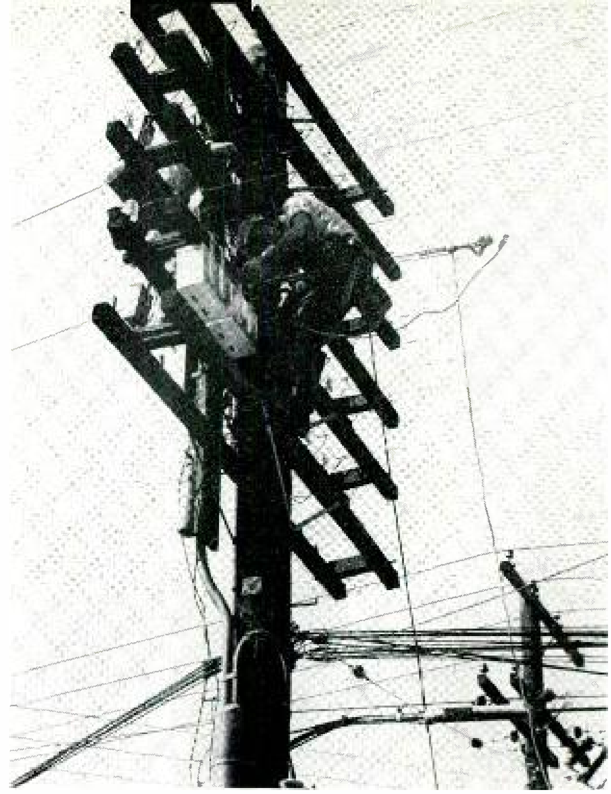
With only the middle portion of the mirror rotation being used, there is a time lag between mirror release and the beginning of an exposure. For a two-inch spacing on the film between timing marks (one-half millisecond per inch), this time lag is 51½ milliseconds. Synchronization is accomplished by a timing circuit connected to the apparatus under study, to delay its operation the proper amount. Means are also provided to increase the brilliance of the projection lights during the eight-millisecond exposure.

G. E. Atkins

Switching Apparatus Development

Filters for Type-O Carrier

F. S. WILLIS
Transmission Apparatus Development



All carrier systems are based on the principle that two or more message channels can be superimposed on a wider band of frequencies for more efficient use of facilities. For such operation, filters are necessary to separate the various channels. The filters used in type-O carrier are unique in several ways. They are the first extensive Bell System use of new adjustable ferrite inductors, plug-in reversible filters, and printed wiring in filter networks, and are in great measure responsible for the economies possible with type-O carrier.

Four "historic firsts" in Bell System equipment are credited to the filter development of type-O carrier. Systemwise, type-O was the first: (1) major use of adjustable high-Q ferrite inductors,* (2) extensive use of plug-in filters, (3) use of an assembly of two filters in one reversible plug-in package, and (4) extensive use of printed wiring in network assemblies. Considerable reduction in the size, complexity, and cost of the carrier system was made possible by the filter design and construction.

During the development of type-O, decisions as to the number of channels, their location and spacing, and the use of single-sideband transmission, were strongly influenced by the ferrite inductor development. The system as it finally evolved was made economically attractive by this development. Prior to the ferrite inductor, a Q (figure of merit) of 250 was about the maximum that was commercially feasible for wire-wound inductors. With piezoelectric crystal units, of course, Q's of 10,000 or better are realizable; however, the limitation of crystal filter bandwidth prevented their use in most of the type-O filters. The adjustable ferrite inductor, with its Q of 500 to 600, fills a need in network design for an inductance whose performance falls between that of previously available wire-wound inductors and the crystal units. The ferrite inductor is made to wide inductance tolerances, yet because of the adjustable feature it can be set to a precise value. This results in a definite improvement in network performance in addition to a general reduction in size of network assemblies.

A continued effort was made throughout the type-O development to coordinate the various circuit and equipment design features to realize the most economical and efficient over-all design. Ordinarily, filters are connected in circuits by soldered elec-

Above — A lineman installs two type-O line filters on a terminal pole in Georgia.

* RECORD, *May*, 1953, *page* 180.

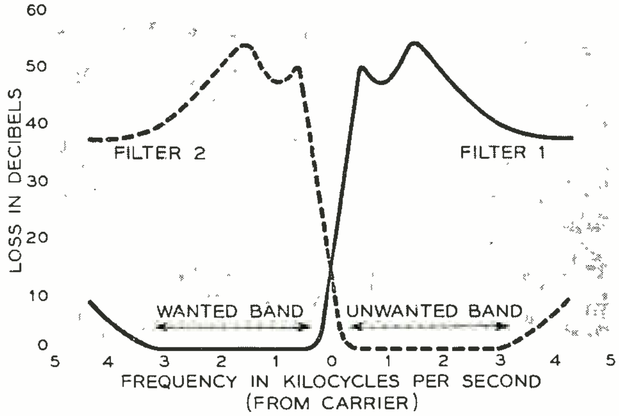


Fig. 1 — A channel filter passes only the wanted band and removes the unwanted sideband.

trical connections. However, it appeared that the use of plug-in filters would reduce the total number of equipment units and the handling and stocking of spare parts, and would add greatly to the flexibility of the equipment. For example, there are four types of channel units differing only in the channel filters they contain. By making the channel filter a plug-in equipment item, one basic channel unit design would suffice. This filter design feature has been used throughout the entire type-O system, resulting in basic equipment designs for all group receiving units, repeater amplifier units, channel units, and others.

Still further savings in space and manufacturing cost are realized by packaging two filters in one unit. The transmitting and receiving channel filters for each channel terminal are packaged together. The basic channel frequency assignments are so paired that the lowest-frequency band is always paired with the highest-frequency band, whether transmission is on the low or high band. Similarly, the two middle channel bands always work together. Hence, filters for the lowest and highest frequency bands are packaged together as the 529A filter, and for the two middle bands as the 529B. Rotating a filter package 180 degrees in its plug-in socket interchanges the two pass bands. Consequently, filter arrangements required for the four channel units of a type-O system are provided by the two filter codes. The usefulness of this feature is still more dramatically illustrated in the case

Fig. 2 — The author plugs a channel filter into a carrier-frequency subassembly of a channel unit.

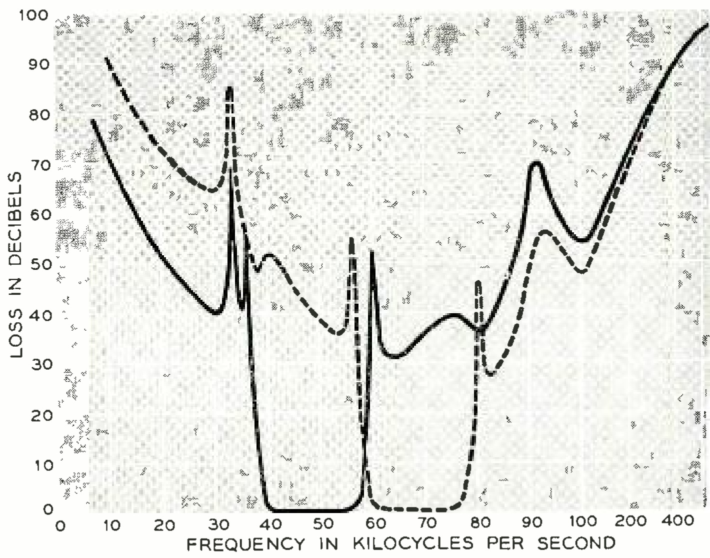


Fig. 3 — A directional filter passes one sixteen-kilocycle group band in one direction and another in the opposite direction.

of the repeater amplifier. One type repeater H-L (high-low) may be changed to the other type L-H (low-high) simply by rotating the directional filters and the auxiliary filter.

Filters in type-O may be classified according to their function as channel, group, modulator, and line filters. The transmitting channel filter selects one of the two sidebands produced by the channel modulator for transmission over the line; the receiving channel filter selects the desired channel from among the received signals. There are four channels to a system, occupying the upper and lower sidebands of two carriers located at 184 and 192 kc. The channel filter, with a characteristic such as shown in Figure 1, passes only the wanted channel and removes the unwanted sideband. Such channel filters use both quartz crystal units and ferrite inductors. In Figure 2, the author shows how a channel filter plugs into the carrier-frequency subassembly of a channel unit. Other plug-in channel filters are on the table.

Group filters accept groups of four channels and place them side by side for transmission over the line with only a 4-kc space between groups. This close spacing of group bands, made possible by the use of the high-Q ferrite inductors, contributes greatly to the economy of type-O systems. The group filters determine the direction of transmission, direct the channels through the proper repeaters and, at branch points, direct the groups

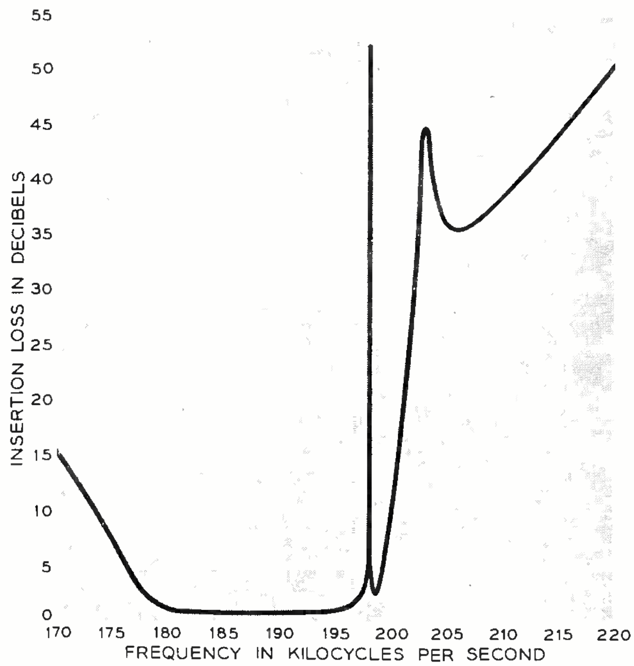
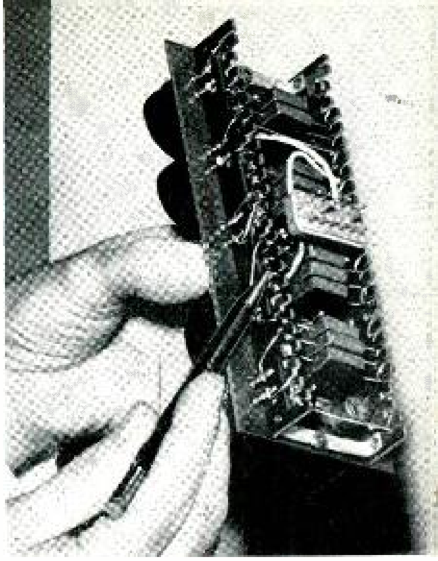


Fig. 5 — The sharp spike in the OA modulator filter characteristic is provided by two crystal units.

along different paths. The directional filters, Figure 3, are typical of this class of filters. The internal construction may be seen in Figure 4. Printed wiring strips are used in these filters, not only to provide electrical connections for the inductors and capacitors, but to position the capacitors securely. Circuit connection is made by plugging the filter into the chassis of a group-receiving or repeater amplifier unit.

Modulator filters have the same construction features and the same appearance as group filters. In the receiving circuit, the group band at line frequencies is modulated by a group carrier frequency to the "basic" channel bands between 180 and 196 kc. The output of this modulator passes through

Fig. 4 — The printed wiring used in the construction of a directional filter is pointed out.



a modulator band filter to remove the carrier and unwanted sideband before continuing with the separation of channels.

In most cases, bandpass filter designs similar to the group filters were satisfactory for modulator filter requirements. In the OA system, however, one carrier located at 198 kc — one per cent away from the edge of the pass band — is too close to be removed by this type of filter. To suppress this carrier, two quartz crystal units resonating at the carrier frequency are shunted across the line at two high-impedance points in the filter circuit. The crystal units provide more than 50 db suppression to the carrier, as shown by Figure 5. The carrier oscillator frequency is adjusted, at time of line-up of the system, to coincide with the sharp "spike" of discrimination in the modulator filter. To assure that these two stay in alignment, the crystal plates used in the filter have the same temperature coefficient as the plates that control the

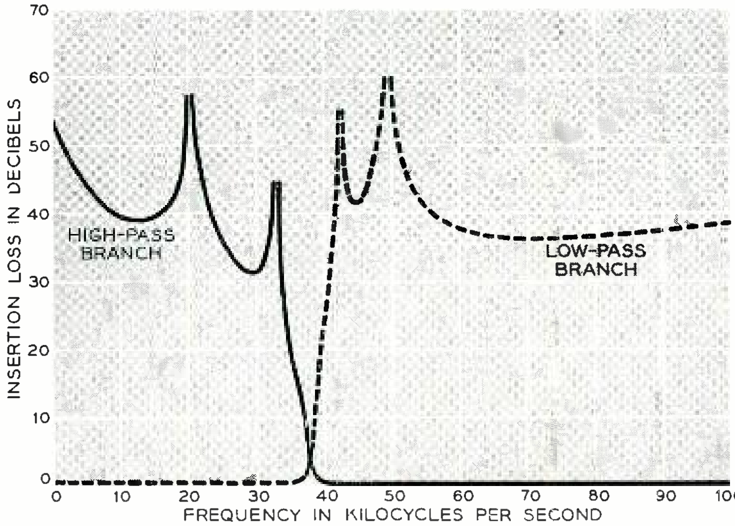


Fig. 6 — At terminals and repeaters, line frequencies are split by a line filter into high and low branches.

oscillator. This filter is mounted adjacent to the oscillator unit so that both sets of crystal plates are subjected to the same ambient temperature.

Line filters are used at terminals and repeaters to connect type-O systems to the line, yet at the same time keep these systems separate from other carrier systems on the same pair of wires. Line filters are also used to separate one type-O system from others on the same line. Since line filters may be subjected to voltage surges caused by lightning, high-voltage capacitors are used to prevent damage. Lightning protector blocks are connected in parallel with the filters.

The 219S line filter, Figure 6, separates line frequencies above forty kilocycles from those below thirty-six kilocycles. That is, the OB, OC and OD currents are separated from OA or any other currents of frequencies below thirty-six kilocycles that may be present on the line. This filter may be mounted at the terminal or repeater, along with other type-O equipment. When a long entrance cable is used between the open-wire line and the terminal, the line filter is mounted on the terminal pole and connected between the line and the entrance cable. In this case, the filter is assembled with its associated lightning protector blocks in a container and is coded as the 538D filter. The headpiece shows two such filters being installed.

Field experience, together with manufacturing economies being realized, point to the continued use of such network features as the adjustable ferrite inductor, printed wiring and plug-in connectors.

THE AUTHOR

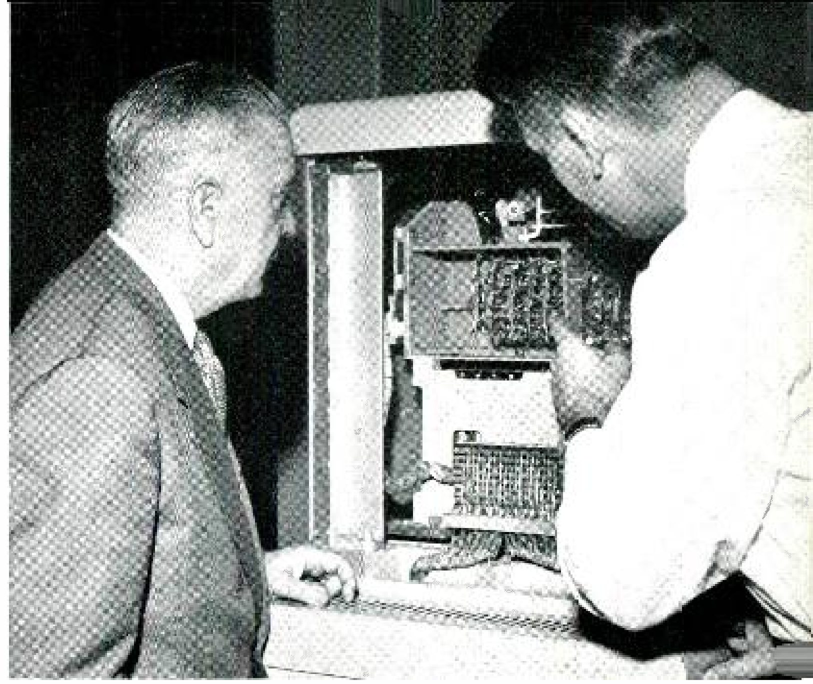
E. S. WILLIS joined the technical staff of the Laboratories in July, 1927 after receiving the degree of M.A. in Physics from the University of Missouri the same year. Since then he has been engaged in the development of various types of transmission networks, such as electric wave filters and equalizers. He had an active part in the first use of quartz crystal elements as applied to various types of filter circuits. Later he was engaged with problems associated with the crystal channel filter for broadband carrier systems. He is presently responsible for the design of filters and networks in the type-O carrier system.

(Concluded from page 130)

be noted. And the conversation time and other billing information recorded by the AMA equipment must be compared with the record of the service observer. The complexity of the job of planning and designing the new circuits and equipment required can best be appreciated by remembering that, in the future, direct distance dialed calls may originate in step-by-step, panel or crossbar offices; the AMA equipment may be located in the local office, at a crossbar tandem, step-by-step tandem or toll crossbar office; and the calling number may be identified automatically or by an operator located either at the tandem switching office or in an entirely different building. And pertinent information from all these points must be fed in proper sequence to a service observer whose desk may be located at some distance from the equipment.

In addition to observing the overall grade of service in dial offices, the Traffic people must record and summarize data showing the volume and distribution of the traffic being carried by the many different channels within and between central offices. These data guide the line assignment activities and form the basis for administration of the local and toll trunk plant. The clerical work involved in handling this mass of service observing and traffic data has come to be a serious burden on the Companies. In line with the Bell System program of mechanizing clerical operations, the Laboratories are studying methods for complete automation of the recording and processing of all traffic data.

A wealth of new devices is now emerging from the research laboratories and being studied for switching telephone traffic and for automation of data processing. Each advance in these fields will bring a new challenge to the Laboratories Systems engineers to provide for the telephone company Traffic people the devices and the fundamental data needed for the efficient engineering and administration of the telephone plant of the future.



Alternate routing is highly desirable for long-distance telephone calls, to use trunking and switching facilities more economically and to give faster service. Its application to automatic switching systems however, presents many problems. In the 4A toll crossbar switching system, these problems are solved by the versatility of the card translator-decoder combination in conjunction with the universal numbering plan.

Automatic Alternate Routing in the 4A Crossbar System

E. JACOBITTI *Switching Systems Development*

When a telephone customer makes a long-distance call, the major problem facing the operator is how to get the call to its destination. In some cases, each toll operator has two main routes by which the call can be started toward this destination. The first-choice route, of course, is the most direct route. If this is busy, the second choice is made, followed by other available choices at the operator's discretion. When telephone operators are concerned with such a call, they can exercise choice between alternate routes. But when operator or customer toll dialing is considered, the choice of routes has to be left to a machine. Since the "intelligence" of a machine is limited to previously "programmed" operations, the choice of routes has to be decided upon, and incorporated in, an automatic alternate routing arrangement.

Studies have indicated the efficacy of alternate routing as well as some of the difficulties to be avoided.* Automatic multi-alternate routing in the 4A system was a major objective in the minds of the designers. This required destination-type codes, and a national numbering and trunking plan. Figure 1 illustrates a portion of this trunking plan. A national center (NC) at St. Louis connects with eight regional centers (RC) throughout the country by direct trunks. St. Louis is also the RC for its own region, making a total of nine regional centers in the country.

In addition to the regional center, each region contains other control switching points (CSP's) of varying ranks. Figure 2 is an enlarged drawing of the darkened portion of Figure 1, representing a call from a local office in Beaumont, Texas, to one in Alexandria, Louisiana. It also illustrates the switching plan for automatic multi-alternate routing. The top-ranking CSP is the NC at St. Louis. Next in rank are the RC's. Sectional centers (SC) follow next, with many primary centers (PC) as

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Above — Ken Southard (right) of the New Jersey Bell Telephone Company discusses with the author a feature of the photo-transistors in a card translator.

the lowest rank. Certain SC and PC offices do not have sufficient traffic to warrant a 4A system, and other types of switching systems having only limited CSP features are used in these offices. The four ranks of CSP's make the switching plan possible. In addition, two other ranks of telephone offices are involved, but are *not* CSP's. One is known as a toll center (TC), and the other is of course the end office. End offices and toll centers can connect to any rank of CSP, depending on which particular one happens to be most convenient. For any given call, the region in which it originates is known as the "home" region, with all other regions being known as "distant" for that call.

In Figure 2 assume that a customer at Vidor 9 in Beaumont, Texas originates a call to a customer at Alexandria 2, in Louisiana. The toll operator at the Beaumont TC dials or pulses this call to the 4A toll crossbar office (PC) at Houston. In this 4A equipment at Houston, a sender, decoder, marker and card translator combine to select the most direct available route from the routes shown. As indicated, the most direct, and therefore the "first-choice," route from Houston to Alexandria (TC) is trunk-group 1. The second choice is trunk-group 2 to Shreveport. Less preferred routes are trunk-group 3 to Jackson, 4 to Atlanta, 5 to Dallas, and 6 to San Antonio. This last route to San Antonio is part of the "backbone" or final route; no further alternate routing is permissible at Houston once this backbone route has been reached.

Assuming the call has been routed to San Antonio,

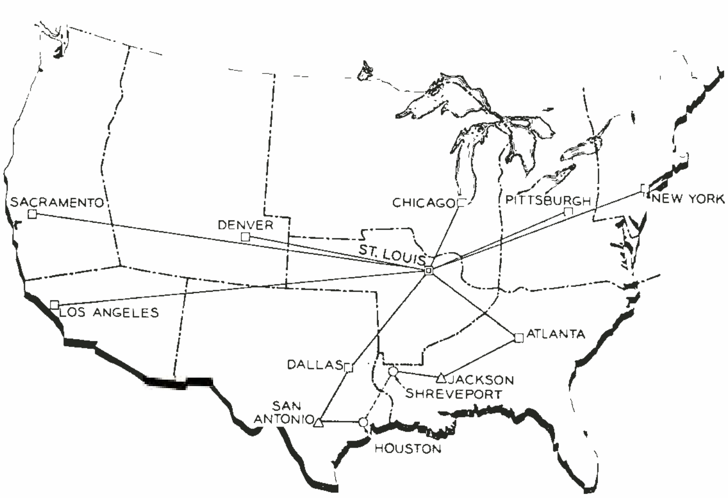


Fig. 1 — The eight regional centers connect to the national center at St. Louis over "backbone" routes. Routes in the shaded area are shown in Figure 2.

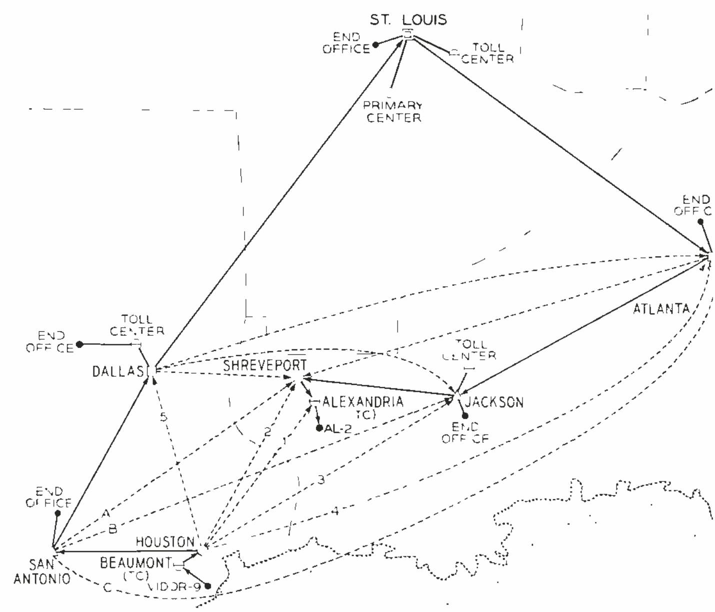


Fig. 2 — Possible routes from the PC at Houston to the PC at Shreveport show how the various levels of CSP's are interconnected in the basic switching plan.

then the call may be alternate routed at San Antonio over routes A to Shreveport, B to Jackson, C to Atlanta, and last to Dallas – again choosing the most direct route first, followed by alternates in this example to CSP's equal or next higher in rank. At Dallas, the call may again take a similar order of routing; first to Shreveport, to Jackson, to Atlanta and finally to St. Louis. At St. Louis the call, in the example of Figure 1, is completed over the nationwide backbone route, having used CSP's at Houston, San Antonio, Dallas and St. Louis (in an ascending order of rank), and then CSP's at Atlanta, Jackson and Shreveport (in a descending order of rank). Once a call enters a "distant" region it uses available routes through lower ranking CSP's in that region and in no case can it be routed back to the originating region. This predetermined switching order prevents a call from being alternate routed back and forth between cities, tieing up trunks unnecessarily.

In the 4A switching system a decoder, with the help of a card translator and marker, performs the task of selecting a route and also determines what code information is to be forwarded to the succeeding switching point. Two groups of decoder relays are set up to handle alternate routing. The first group, an array of 100 route relays, is used for the automatic selection of direct and alternate routes. These relays are provided for all PC's, distant SC's, distant RC's, the NC, one for the home RC, and one for the home SC. The second group of relays controls the area code pulsed forward to the next office as determined by the card translator.

A route relay, capable of testing a group of 160 trunks, is furnished for each CSP to which the office has a direct route. Up to four "group-busy" relays, one for each subgroup of forty trunks (all that a marker can test at a time) may be furnished for each route relay. These group-busy relays remain operated as long as an idle trunk is available in their respective trunk sub-groups. The transfer contacts of the group-busy relays are used for idle and busy indications and are connected to the associated route relay in each decoder so that the lowest numbered sub-group is tested first. The route relays are inter-connected in an orderly pattern of progression, corresponding to the fixed order of alternate routing.

When a 4A sender receives a call, it proceeds to connect to a decoder as soon as three digits are registered. The decoder uses these three digits to select a card in its associated decoder translator. If, from this card, three digits are found to be sufficient to determine a route, the decoder proceeds to complete the call. This would be the case, for example, for calls to offices in the same area as the CSP originating the call.

If more than three digits are required to direct the call to another area, as in the case of the call described in Figure 2, and the sender has six digits available, the decoder restores the three-digit card 504 (area code), and selects the appropriate six-digit card 504-AL2 (Alexandria 2). This card may be in the decoder translator along with three-digit cards, in the decoder foreign translator, or in one of two in a common pool of "foreign area" translators. Information determining the first-choice route to Alexandria is read from this six-digit card, first by the decoder and later by a marker. While the marker is searching for an idle trunk in this first-choice route, the decoder is engaged in finding an alternate route with an idle trunk, if there is one, by using its route relays.

Alternate-route holes on the 504-AL2 card indicate an alternate route pattern, and control the connection to the Shreveport route relay representing the first alternate route for the call. Each route relay has a "route-advance" contact that automatically operates the next route relay (Jackson) if all trunks in the first alternate are busy. The alternate routes are thus tested in order – to Atlanta, to Dallas and then the final, or backbone, route to San Antonio. When the marker finds an idle first-choice trunk to Alexandria, it signals the decoder that the call can go through, the decoder releases and the marker completes the call. If, however, the first-choice route is busy, the marker advises the decoder of this fact; the decoder restores the first-choice route six-digit card (504-AL2) and drops an alternate-route card corresponding to the alternate route it has found idle. Information from this card is passed to the same marker, which then selects an idle trunk on that route. When the first-choice and all alternate routes are busy, the call is directed to a "no circuit" (NC) trunk by the route relay for the San Antonio trunks.

When alternate routing is necessary, the area code may be retained, deleted, or in some instances, prefixed. Furthermore, since a given route may serve as a direct route for one call and as part of an alternate route for other calls, the area code treatment must be different. Figure 3 shows how the route between Newark and Philadelphia may serve as a route in three different types of alternate-routed calls.

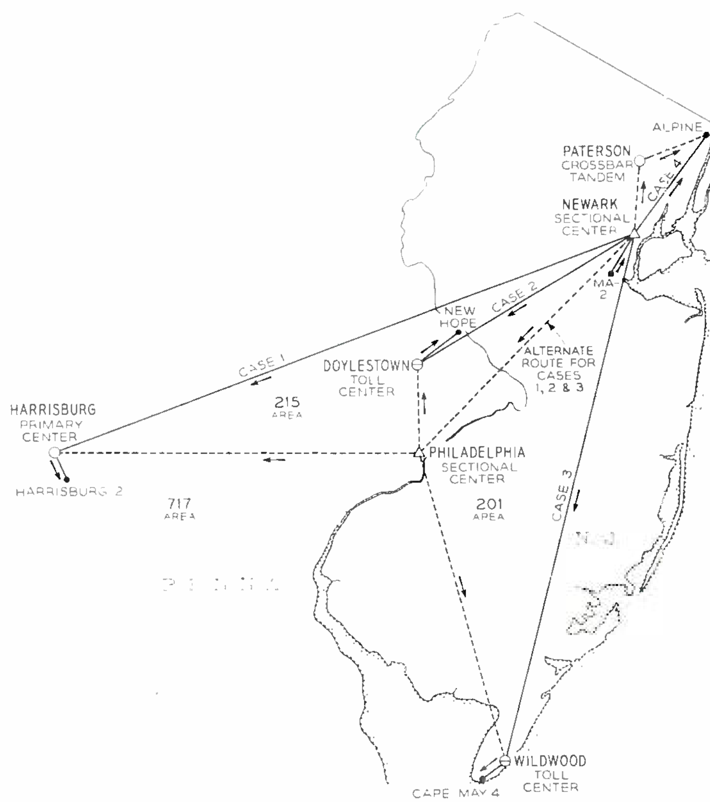


Fig. 3 — The route between Newark and Philadelphia is part of the alternate route for three different calls. Also, the Newark 4A permits an intermediate office to be used in an alternate route to Alpine.

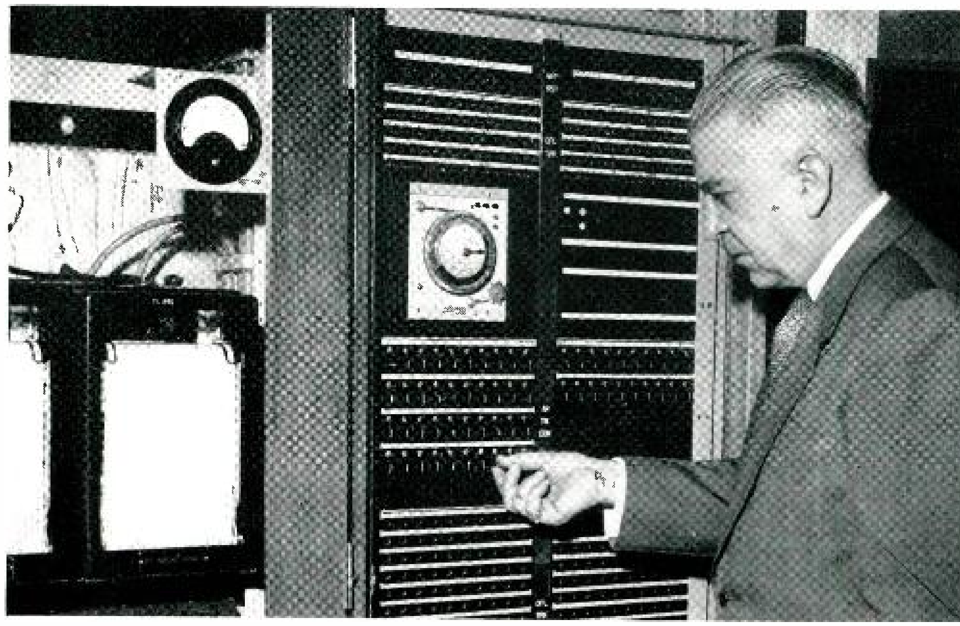


Fig. 4 — The author operates a key on the traffic control panel in the office at Newark.

For the first type of call, from Market 2 through Newark to the Harrisburg 2 local office, the first-choice route is, of course, direct to Harrisburg. If an alternate is necessary, it goes through Philadelphia and then to Harrisburg. This would be case 1, where the alternate route goes through a sectional center in an area (215) different from either the 201 area where the call is originating or 717, the area where the call is terminating. A call made from Newark to New Hope, Pennsylvania would normally route through Doylestown only. The first-choice alternate would be through Philadelphia to Doylestown and again the Newark-Philadelphia portion of the route is an alternate. This would be case 2. A call from Newark addressed to Cape May, New Jersey would normally be directly routed through Wildwood. The first-choice alternate would be through Philadelphia and then to Wildwood. In this instance the call must go outside the original 201 area and then back again. For case 3, then, the Newark-Philadelphia link is again a portion of an alternate route. The same link serves as part of an alternate route for three different types of calls. Another situation out of Newark, that of a crossbar tandem office at Paterson, is also illustrated in Figure 3. A call destined for Alpine is normally routed over direct trunks. Here the local office code AL2 is deleted at the Newark CSP because it is not needed at Alpine. For an alternate route through Paterson crossbar tandem, however, the local code cannot be deleted; the entire original number must be outpulsed. These examples serve only to show the many different conditions that can be handled by the 4A toll crossbar switching system.

The code conversion holes in an alternate-route card are used in determining whether or not an area code must be outpulsed. In Figure 3, the code conversion holes at Newark on the alternate-route card for Philadelphia are punched with the area code 215 (the area in which the Philadelphia CSP is located). For case 1, this 215 code is matched at the Newark CSP with the Harrisburg area code 717. Since they are not the same, the 717 code is outpulsed, together with the office code and numerals, to the CSP in Philadelphia. For case 2, which uses the same alternate route and therefore the same card, the 215 code will match with the New Hope area code and therefore the decoder at Newark deletes the 215 code when outpulsing to the Philadelphia CSP. In case 3, the code conversion holes are not called into play on the same alternate-route card to Philadelphia because no area code is received at Newark on the call to Cape May. Instead, the area code 201 is manufactured and prefixed to the registered number before it is outpulsed to Philadelphia, so that the call will be directed back into the New Jersey area for completion to Cape May. This matching procedure employs three groups of code relays. In cases 1 and 2, the area code 215 is registered on these relays. The decoder matches this code with that received by the sender and determines the disposition of the area code.

Alternate-routing connections for the five CSP offices shown in Figure 2 require five route relays, one for Shreveport, one for Jackson, etc. These are connected in the CSP pattern to succeeding higher-ranking "distant" CSP route relays and then the succeeding lower-ranking CSP route relays in the "home" region. These route relays operate in this order, and are arranged to test their respective trunk-groups with the aid of "group-busy" relays. If a trunk is found idle, further alternate routing is stopped and the information for this trunk-group location is presented to the marker. When the group-busy relays indicate to their associated route relay that all trunks are busy, then the succeeding alternate route relay is operated, and so on.

If alternate routing were permitted without some sort of control, unforeseen difficulties might overload certain offices. Predicted traffic peaks may also result in overloading certain CSP's. For these possibilities, a traffic control panel, Figure 4, is provided at each CSP. An RT key (common to all decoders for each route relay) is provided for each of the 100 route relays. Any alternate route pattern may therefore be broken or terminated by the operation of one of the RT keys associated with that pattern. These keys permit calls to be switched to "no circuit," denying all further alternate routes to the marker for such calls.

Facilities are available at the 4A system's maintenance center for initiating calls with all possible route relay combinations. Alternate routes can be artificially "made busy" to a decoder, either in their entirety or in part. By this means of testing, any alternate-route card can be selected for test and its output information recorded on a trouble record card for verification, at any time after the card has been placed in the translator.

THE AUTHOR

EDWARD JACOBITTI joined the technical staff of the Laboratories in 1919. During his early years he was engaged in the design of local panel and local No. 1 crossbar systems. During World War II, he worked on the fundamental and practical design of relay digital computers and other military projects. Following the War he was engaged in the design of the decoder, marker and translator used in the nationwide dialing toll switching system project. More recently he has been concerned with the design of markers and other common control circuits for a mechanized teletypewriter switching system. He is a graduate of the Newark College of Engineering.

Patents Issued to Members of Bell Telephone Laboratories During the Month of January

Ames, G. W., and Herrington, H. W. – *Electrical Element Mounting Jig* – 2,699,133.

Bachelet, A. E. – *Pulse Counting and Registering System* – 2,700,146.

Edson, W. A. – *Electromagnetic Cavity Resonator* – 2,698,923.

Herrington, H. W., see Ames, G. W.

Logan, R. A., and Sparks, M. – *Method of Treating Germanium for Translating Devices* – 2,698,780.

McGuigan, J. H., Murphy, O. J., and Newby, N. D. – *Magnetic Drum Dial Pulse Recording and Storage Registers* – 2,700,148.

Mendenhall, H. E. – *Secondary Electron Emissive Electrodes* – 2,700,626.

Murphy, O. J., see McGuigan, J. H.

Newby, N. D., see McGuigan, J. H.

Pfleger, K. W. – *Measurement of Relative Delay of Wave Envelopes* – 2,700,133.

Reise, H. A. – *Single-Sided Push-Pull Amplifier* – 2,698,922.

Sparks, M., see Logan, R. A.

Wenk, H. A. – *Electronic Timer* – 2,699,529.

High-Voltage Problems in the L3 System

G. B. ENGELHARDT
Transmission Systems Development

Corona effect, a second cousin of the Aurora Borealis, was one of the problems encountered in converting existing coaxial cable from the L1 to the L3 system. The important economic advantage of using existing cable plant and power stations for the new system was jeopardized when the higher voltages required for L3 introduced a corona effect, or partial ionization of gas, in the cable. To overcome this difficulty, experimental lengths of cable were filled with several different gases of greater dielectric strength than the nitrogen used in L1. One of these gases, sulphur hexafluoride, proved most promising and is now used in the highest voltage portions of the L3 system.

Intolerable noise over the entire 8-mc transmission band of an L3 system is produced when the 60-cps voltage applied to the cable for powering auxiliary repeaters exceeds a critical value. This noise is caused by minute discharge currents, commonly referred to as corona. These currents are associated with the partial ionization of the cable gas. At critical or threshold voltage, the corona is localized; that is, it occurs at a point along the cable where the dielectric stress in the gas is accentuated by a tiny speck of dirt, a sliver or some other minor irregularity in the cable structure.

Corona often occurs when the rms voltage between the center conductor and the grounded outer sheath of a nitrogen filled 0.375-inch coaxial cable exceeds 1,300 volts. There is no serious problem in L1 operation because the maximum cable operating voltage is only about 1,100 volts. L3 operation, however, requires almost double this maximum voltage if the distance between power supply points is to remain the same.

Above — The author, right, and J. C. Melonson, Long Lines Section cable man, at a repeater hut used in the SF_6 gas trial.

It would be possible to operate cable using the L3 system at the present L1 voltages by building new power stations near the half way points in the longer power sections. Since this procedure would be relatively expensive, it was desirable to find a practical method for increasing the dielectric strength of installed cable in areas where the operating voltage exceeds a critical value. This work was undertaken by the Transmission Development, Outside Plant Development and Chemical Departments at Bell Telephone Laboratories.

The most satisfactory and economical method appeared to be to substitute a gas of high dielectric strength for the dry nitrogen normally used in telephone cables. Sulphur hexafluoride (SF_6) was suggested as a suitable gas of this type and early tests on cable stored on reels at Point Breeze in 1949 indicated that it would provide the required two to one dielectric improvement. SF_6 is about five times heavier than nitrogen and, at normal pressure and temperature, is colorless, odorless, noninflammable, nontoxic and chemically inert.

The corona voltage problem was not yet completely solved, however, since the use of a new gas, particularly one containing an element as active as fluorine, raised many questions: Would the gas ever break down and form products that would cause deterioration of the cable or be toxic to personnel? Would the gas increase the high frequency transmission loss of the cable appreciably? These and other questions were studied, and many of the answers were obtained by laboratory tests at Murray Hill and Point Breeze, and in field tests on old cable at Chester. The possible toxic effects of breakdown products were studied by the New York University Institute of Industrial Medicine, with the cooperation of our Medical Department. In addition, the possibility of creating an oxygen deficiency condition in manholes was studied under typical field conditions by the Outside Plant Development Department. In both instances, it was determined that the gas presented no hazard, providing relatively simple safety precautions were observed in practice.

SF_6 looked promising in the light of all these investigations. No detrimental effects on test cables could be detected, and the planned use of the gas was determined to be safe for personnel. High-frequency transmission measurements showed a tolerable increase of only 0.2 per cent in the cable attenuation due to SF_6.

On the basis of these results it was decided to conduct a trial on 48 miles of operating cable in the vicinity of Kingston, New York. This eight-tube coaxial cable had six tubes operating with the L1 system at the time; the two spare tubes were made available for the study of corona when the cable was filled with SF_6 gas. Voltage applied to the coaxials was gradually raised to 2,300 volts – approximately 10 per cent higher than L3 voltages at the extremes of the longest power sections. If corona were completely eliminated and no deleterious effects on the cable or the working voice and TV circuits could be detected in a year's time, it was felt that SF_6 gas could be safely specified for general plant use.

Although the use of SF_6 gas provided the necessary increase in dielectric strength in most coaxials, occasional faults in the cable, which were not serious at 1,100 volts, were found to cause corona or breakdown at L3 voltages, even in the presence of SF_6. Breakdowns were located for repair with a high-voltage bridge following an established fault location procedure developed several years ago by the Outside Plant Development Department.* Faults that appeared only as corona sources, however, without attendant breakdown of the cable, required a new technique for location.

The method developed for locating such faults may be called "pulse-echo timing." It is based on radar principles of echo timing except that the pulse transmission is confined to a cable. The radar principle is used in reverse since the location of the reflecting medium, the unterminated far end of the cable, is known and the location of the pulse source, which is the unwanted corona fault itself, is unknown. It was found that in a cable having a single outstanding fault, corona first appears as one or more sharp pulses on each negative half-cycle of an applied 60-cycle high-voltage wave.

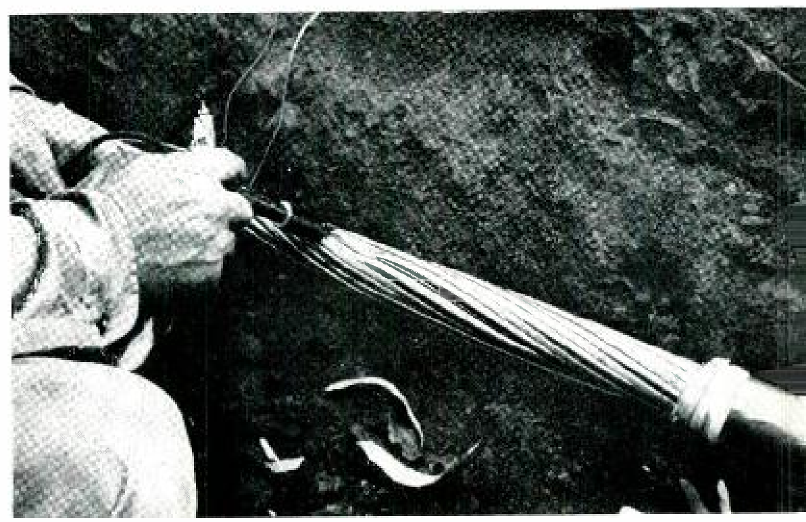


Fig. 1 — Part of a damaged coaxial cable with sheath removed.

A wideband radar test oscilloscope is used as a receiver. This unit provides timing marker dots at 10-microsecond intervals with sweeps triggered by the incoming signal. From the time difference between the direct arrival of a corona pulse originating somewhere along the cable and its echo from the open-circuited far end, the location of the corona fault can be readily determined by using the known rate of pulse propagation.

The experience gained in repairing faults during the trial proved valuable. In each instance, damage was found that eventually would have required attention. It is interesting to note that a cable

* Record, *October*, 1948, *page* 416.

crushed as severely as that shown in Figure 1 was not disabled for L1 service nor was the damage detected until the cable was surveyed for L3 operation. After these faults were repaired, high voltage was maintained in the SF_6-filled cable at Kingston for over a year. No measurable deterioration of the insulation could be found, corona was completely suppressed, and a margin against arc-over was provided. The use of SF_6 gas was established as a means of raising the permissible operating voltage of existing cable where L3 conversions require it.

The Long Lines has since surveyed the Philadelphia-Chicago cable route, located and repaired faults, and installed SF_6 where needed in the conversion to commercial operation of the L3 route.

THE AUTHOR

George B. Engelhardt was graduated from Cornell University in 1930 with the E.E. degree, and shortly thereafter joined the technical staff of the Laboratories, associating himself with the carrier transmission group. In 1939 he completed a series of courses at Columbia University, under the Laboratories part-time post-graduate study plan, leading to the M.A. degree in Physics. His activities at the Laboratories have been concerned chiefly with the design of high-frequency measuring apparatus and with field measurements on the coaxial cable. During World War II, he was concerned with classified projects. From 1946 until the present, he has been engaged in coaxial cable and systems work.

Off-The-Air Pickup Arrangement Proposed by Long Lines Department

The Long Lines Department of the A. T. & T. Co. recently announced an off-the-air pickup arrangement as a major step toward the solution of the problem of extending network programs to television stations in the more remote areas of the nation.

The off-the-air arrangement involves the pickup of audio and video signals broadcast by a station on the regular network facilities and the transmission of these signals to the remote station by channels furnished by the telephone company under contracts covering a minimum period of three years.

Economies would be realized by eliminating the monitoring, supervision and some equipment features now used to protect the quality and continuity of the service on the regular network facilities on which the programs of many TV stations depend.

The proposal was made in a letter to the Federal Communications Commission outlining the results of a detailed study of practical procedures for making network programs available to smaller communities off the main television arteries.

Ralph L. Helmreich, Director of Operations for Long Lines, said, "We are aware of the economic problems of the more remote stations in securing network service. We have had a number of proposals under consideration. We believe the off-the-air arrangement is the most practical means of extending network programs to these areas at the lowest possible cost to the stations. When a request for the off-the-air arrangement is made by a customer, a specific charge for each channel will be developed which will reflect the particular conditions involved."

In its letter to the FCC, Long Lines said further that preliminary estimates indicate that, "The charges in cases involving distances of 100 to 125 miles . . . probably will average about half of those which would apply for direct connections to the network. In individual cases, the differences may vary substantially from this average—tending to be larger for shorter distances."

In any telephone office one problem is the availability of enough equipment of the proper kind to handle all calls through that office. Traffic registration equipment is one source of information that may be used to improve the traffic-handling ability of an office. In the 4A toll crossbar system, new features required for nationwide dialing, such as the trunking plan, automatic alternate routing, and expanded translating ability, must be checked for efficiency. Registration facilities in the 4A system provide a flexible, efficient check on these aspects of the system.

Traffic Registration in 4A Toll Crossbar

W. J. MEYER, Jr. *Switching Systems Development II*

Operator and customer toll dialing will be greatly expanded by the 4A toll crossbar system, with its trunking plan, automatic alternate routing of calls, and translating features. The successful operation, engineering, and administration of such a complex system require certain traffic data on the usage of trunks and various equipment. Such information is employed in assigning trunks so as to use the trunks and the existing equipment more efficiently, and to assure the timely provision of additional equipment of the proper types and in sufficient quantities for future office requirements.

Traffic registration is usually handled by banks of electromechanical counters, or registers, arranged to count the number of operations of some unit or group of equipment. The simplest and most direct method of taking such data would be to provide a register for each trunk, sender, marker, or other equipment unit. Economically, however, such an arrangement is impractical because of the large number of registers that would be required. A preferable arrangement is to provide a sufficient number of registers to give the required information, and some means of distributing them among the various items on which data are desired.

Registration facilities of the 4A system provide a high degree of flexibility and, in addition, include several other electrical recording devices unique to toll registration service. All registers and special recording devices are mounted in several bays of a register rack in the traffic room. Relays, ampere-minute meters, and a distributing frame are mounted out of the way in one of the switching rooms. Registers and other indicating devices may be connected through the distributing frame to any portion of the 4A system. Cut-off keys for the registers permit data to be collected only when desired and thus eliminating unwanted data.

Flexibility of registration facilities, in addition

Above — Recording ammeters are used to give information on load conditions. Associated jacks permit the meters to be patched to various circuit units as required.

to that afforded by the distributing frame, is provided by the register patch bay. Part of the jack field in this bay, Figure 1, serves link frames and trunk-block connectors, and part serves the registers. Double-ended patching cords permit patching any register to any link frame or frame group. Short-circuiting plugs inserted into link-frame jacks will connect those frames into the circuit measuring total load; all links may be connected by using a plug for each jack.

Normally, one thinks of traffic registration as simply a peg-count – from the old practice of counting on peg-boards – of the number of calls on a trunk or a trunk-group, or the number of operations of an equipment unit. In the 4A system, peg-count registers are permanently wired to the distributing frame for such units as senders, decoders, markers, link controllers, and reorder, no-circuit, and outgoing trunk-groups. Peg-counts may also be recorded on incoming and outgoing link frames and trunk-block connectors when desired, using the cords on the register patch bay.

In addition to the usual peg-count facilities, however, it is highly desirable that information be collected on other aspects of the system. Common-control equipment, used for only a short time on each call, is supplied in quantities sufficient for ordinary traffic. When traffic is heavy, this common-control equipment sometimes gets overloaded and some calls are delayed. Traffic studies must certainly include information on overflow (failure to complete) and delayed calls. Overflow calls are normally registered for outgoing, reorder, and no-circuit trunks, and through the register patch bay, for link frames when desired. Delayed calls are registered for sender link frames and sender link frame groups. First and second trial failures of markers and decoders are also registered. In addition to peg-counts of equipment units, then, various overflows, delays, and first and second trials are also registered.

Load conditions on the system, and on various portions of the system, are of major importance in a working toll office. To aid in collecting load information, several other electrical measuring and recording devices are used in the 4A system. In some instances, the number of counts required in a study period will exceed the 9,999 maximum of the standard registers. For these counts, commercially supplied electro-magnetic counters having a maximum of 999,999 are used. Figure 2 shows both

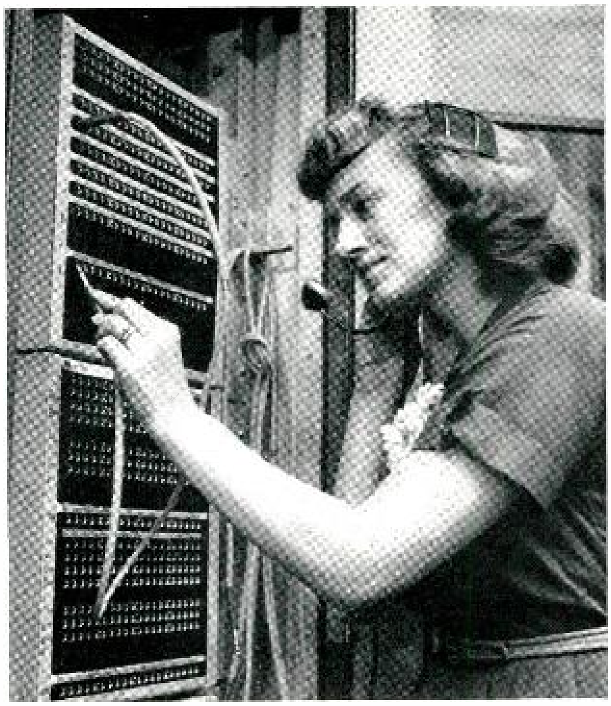


Fig. 1 — The register patch bay provides interconnections between the registers and any desired circuit unit.

Fig. 2 — The 14-type registers at the left and the electromagnetic counters on the right provide counts of equipment and trunk usage. A jack at the bottom of each bay permits the recording desk to be in a different room from the registers, the information being transferred by telephone.

the standard 14-type registers and the larger electromagnetic counters.

Other registration devices provided are dc ammeters, shown in the headpiece, and ampere-minute meters. Except for the two rectangular meters, all are associated with cords and plugs, and may be patched to jacks associated with any or all incoming and outgoing link frames or to the various sender groups. The small meter is an ordinary dc ammeter: the others are recording ammeters. The circular meter gives a 24-hour record of the load on patched equipment. The two rectangular meters provide a graphic record of the percent of the total load that is handled by specific link frame groups. These meters give such an interesting picture of traffic conditions that they are often the first point of call for visitors.

One other recording method is the use of ampere-minute meters. These are physically very similar to the ordinary kilowatt-hour meter, but do not include any registration device. They provide an electrical impulse once each ampere-minute, and these are registered on standard registers in the traffic room. Charts are available to change ampere-minutes to the usual traffic-study units to expedite the determination of traffic data.

THE AUTHOR

W. J. Meyer, of the Illinois Bell Telephone Company, spent two years with the Laboratories from 1951 to 1953 working on development of the 4A toll switching system. Since his return to Illinois Bell he has made up estimates and schedules for manufacturing and installation intervals and has prepared cost estimates for management on dial equipment. A member of Illinois Bell's State Area Engineering Department, Mr. Meyer has concentrated for the last half year on transmission engineering in connection with teletype equipment.

He received a B.S. in E.E. degree from Purdue University in 1947 and began his Bell System career with Illinois Bell the same year. Prior to his two year stint at the Laboratories, Mr. Meyer had written specifications for converting manual type offices to crossbar dial and had supervised field work. This was in addition to a six-month job of writing detailed specifications for crossbar dial equipment while on loan to the Western Electric Company. He served three years in the Army during World War II and saw service in Europe as an artillery observation pilot. Mr. Meyer holds the Distinguished Flying Cross, the Purple Heart and the Air Medal with six clusters.

Rudolph Kompfner to Receive the Duddell Medal

Rudolf Kompfner, a member of the Laboratories' Research in High Frequency and Electronics Department, has been designated by The Physical Society of England as the 1955 recipient of its Duddell Medal.

The Medal, one of the highest honors bestowed by Britain's physicists, is expected to be presented to Mr. Kompfner in London next autumn.

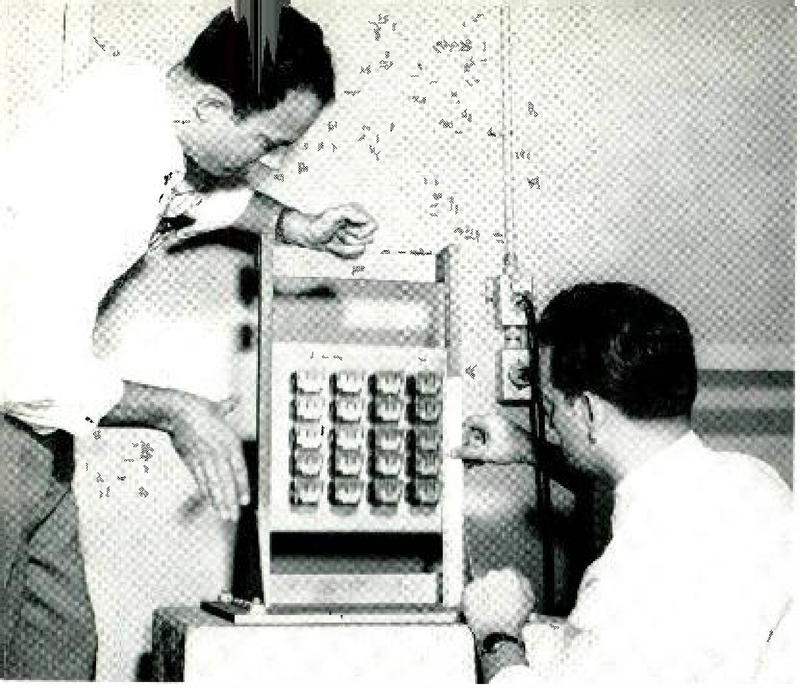
In a letter to Mr. Kompfner, H. S. W. Massey, President of the English society, stated that the Medal "is awarded to persons who have contributed to the advancement of knowledge by the invention of instruments or by discovery of materials used in their construction and is awarded to you for your work on the travelling wave tube."

Born in Vienna, Austria, and trained there as an architect, Mr. Kompfner pursued physics and radio engineering only as a hobby in London until 1941. In that year the British Admiralty offered him a position at Birmingham University in the Royal Naval Scientific Service. From 1944 to 1951 he did further work for the British Government at various institutions, including the University of Oxford, where he received a Ph.D. degree in 1951.

His work on the travelling wave tube was of considerable significance to the field of microwave repeater development and, in December 1951, Mr. Kompfner joined Bell Telephone Laboratories to continue his research on vacuum tubes, particularly those used in the microwave region.

In 1949 Mr. Kompfner was made a Fellow by the Institute of Radio Engineers. He has been a Fellow of London's Physical Society since 1948.

The Duddell Medal was established as a memorial to W. Duddell, a British physicist who contributed to developments in telephony and telegraphy and who died in 1917. Famous recipients have included Hans Geiger, who received the Medal in 1937 for his invention and development of counters, E. O. Lawrence in 1940, for his invention and development of the cyclotron, and F. W. Aston in 1944, for his mass spectrograph.



Stability Evaluation of Switching Apparatus

C. SCHNEIDER *Switching Apparatus Development*

Automatic telephone switching systems are composed primarily of relays and other electromagnetically operated apparatus, and are expected to give good service for many years. Any change in shape or position of mechanical parts, in spring tensions, or in electrical characteristics will have a decided effect on the operating efficiency of the apparatus, and hence of the switching systems. To assure long life and dependable service, switching apparatus continually undergoes tests of many kinds, to permit evaluation of the physical and electrical stability of specific designs. Here are some of the tests conducted to make dependable evaluations.

In an average 10,000-line No. 5 crossbar office, there are approximately 90,000 relays and electromagnets. The total daily operation of relays alone is in the tens of millions. Some electromagnets are required to operate hundreds of millions of times, and frequently as many as one billion times during their lifetimes. Since switching apparatus is expected to function for many years, it is obvious that the highest possible degree of reliability is imperative to assure dependable service and minimum maintenance cost of the apparatus.

Satisfactory performance depends on maintaining, within predetermined design limits, close dimensional relations between actuating and actuated members under various conditions that tend to disturb mechanical adjustment and electrical characteristics. During handling and shipping, electromagnetic apparatus encounters shock, vibration, and temperature and humidity fluctuations. After installation, both seasonal and short-term humidity and temperature variations are experienced. To withstand these conditions, the apparatus must be rugged, dimensionally and electrically stable, and have good wear characteristics. Although fundamental tests offer guidance in the choice of materials for a particular design, extensive testing is required to evaluate probable field performance.

Studies wherein attempts have been made to measure the severity of shock and vibration experienced during shipping have not been completely successful. Therefore, the shock resistance of a new design is evaluated by comparison with an existing design that experience has shown is capable of withstanding shipping conditions. Shock tests are conducted by mounting the apparatus on a simple device, essentially a steel plate that is allowed to fall freely while being guided by two side tracks. Severity of the shock is, of course, a function of the distance through which the plate falls. The effect of single or repeated shocks on adjustment is measured and high-speed photographs are taken to observe transient displacement of various parts of the structure. Occasionally, laboratory tests are supplemented by actually shipping several lots of samples and observing the effects.

Above — Relays are shock tested on a device nicknamed "the Guillotine." A. P. Caruso has just released the sliding plate for a twelve-inch drop, measured by M. Feder.

Electromagnetic apparatus is usually rugged enough to withstand any vibration likely to be imposed during shipping, and will not be affected adversely by vibration at 10-55 cycles per second with an amplitude of 0.030 inch. Thus, shipping vibration seldom presents a problem.

Phenol fiber or phenol plastics are used extensively in electromagnetic apparatus, since other materials that may be less susceptible to dimensional changes at high humidity do not have all the other characteristics required of insulating materials in electromagnets. Some of these properties are low cold-flow at elevated temperatures, good abrasion resistance, high strength, easy machinability for large-scale production, and adaptability to low-cost production methods.

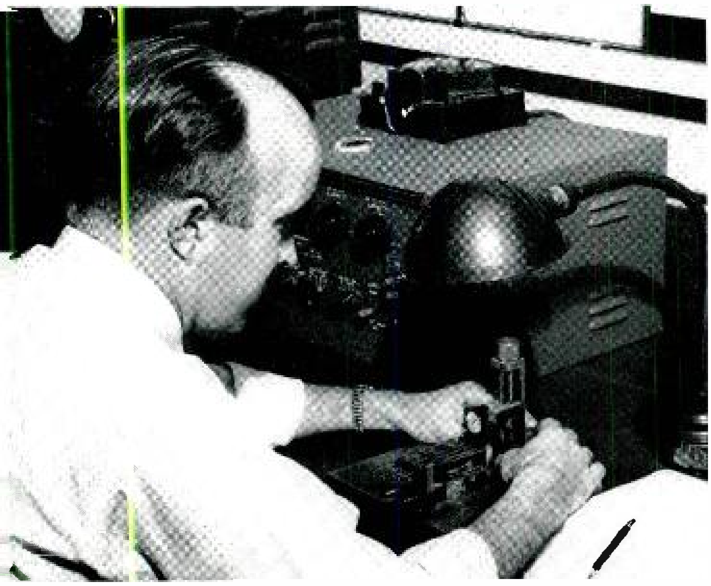
Phenolics swell progressively for weeks during humid seasons; during dry seasons progressive shrinkage occurs. Obviously, tests conducted under actual field conditions would be time-consuming and would retard a development program. Therefore, effects of atmospheric variations are simulated by accelerated test methods. Available data indicate that the cumulative effects of a humid season can be approximated by a brief exposure to 90 per cent relative humidity at 85°F. Electromagnetic apparatus engineered on the basis of a six-day exposure to this condition has been relatively free from dimensional instability.

Other factors to be considered are corrosion of metal surfaces and the tendency for sticking to develop between certain combinations of materials. Zinc-plated parts and many insulating materials are particularly susceptible to sticking.

In determining the effects of prolonged drying in the field it is necessary, as in the humidity tests, to employ accelerated methods. It has been found that humidity exposures followed by drying for six days at 120°F offer a fair evaluation of over-all dimensional or adjustment changes likely to occur in service. The energization of windings, however, sometimes produces higher temperatures. Tests, then, are conducted at temperatures determined from heating studies in which the apparatus is energized under probable circuit conditions.

Exposure to an elevated temperature usually produces two effects, shrinkage and cold-flow of the insulating materials. Hygroscopic materials, such as phenolics, exhibit both of these characteristics; in materials such as hard rubber only cold-flow occurs. Generally, the changes caused by cold-flow are permanent whereas those from shrinkage are recovered with an increase of humidity.

The duration of exposure to elevated temperatures in service may vary from a few hours to hundreds or thousands of hours, depending on usage. Fortunately, for all practical purposes, most materials used in electromagnets tend to stabilize after several days at a particular elevated temperature, and it is possible to appraise a design without resorting to long-term tests. Cold-flow or shrinkage effects can be accelerated by exposure for a short time to temperatures higher than those normally encountered. Raising the temperature, however, may exaggerate



'g. 1 — Ph /sical measurements of a wire-spring relay are ɘing made by G. A. Gawel.

Fig. 2 — The author examines the surface of a wire-spring relay armature for wear, assisted by M. Feder.

as well as accelerate dimensional changes and this type of test is approached with caution.

Of the many types of electromagnets employed in switching systems, the heavy-duty relay, which is required to operate heavy loads at high speed, presents the most complex design and evaluation problems. To evaluate the probable life of such relays, it is again necessary to resort to accelerated operating tests. Even under highly accelerated test conditions – operating relays at 20 pulses per second, for example – one to two years of operation is required to approach service life requirements. Thus, in spite of accelerated tests it is often necessary to estimate probable life from fractional life data.

The possibility must be considered that accelerated test conditions may exaggerate or reduce wear that might occur under normal operating rates. Some indication of the severity of accelerated tests is obtained by pulsing samples at slower rates and comparing trends during the early stages of a test. High-speed photographs and measurements of vibration of critical parts are also used to estimate the severity of a test. The assistance of the statistician has also been sought in interpreting and extrapolating test data. Predictions are based on the assumption that no substantial change in trend will occur during later stages of a test. Unfortunately, this is not always true, and experience and judgment are essential in the evaluation of test results.

Another important factor is the probable degree of deterioration of materials and finishes over a period of many years. When newly developed materials are under consideration, accelerated testing techniques and extrapolation of data are involved. Here again, judgment based on experience is necessary to determine the severity of accelerated tests and to evaluate probable deterioration. These questions are usually referred to the Materials and Chemical Research Staff.

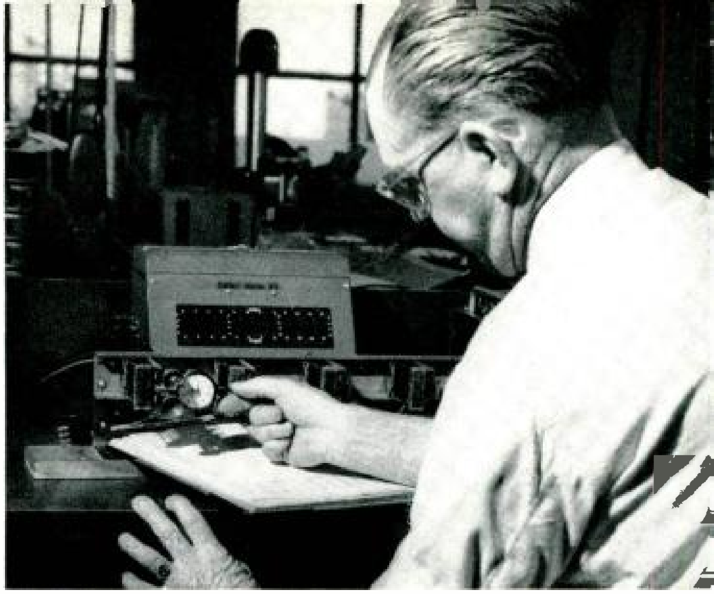


Fig. 3 — Armature travel and contact-operate points are checked by H. V. Farnham.

In addition, electrical stability must be evaluated. Insulation resistance, dielectric strength and winding corrosion are three primary considerations. Some of these effects have been described previously.*

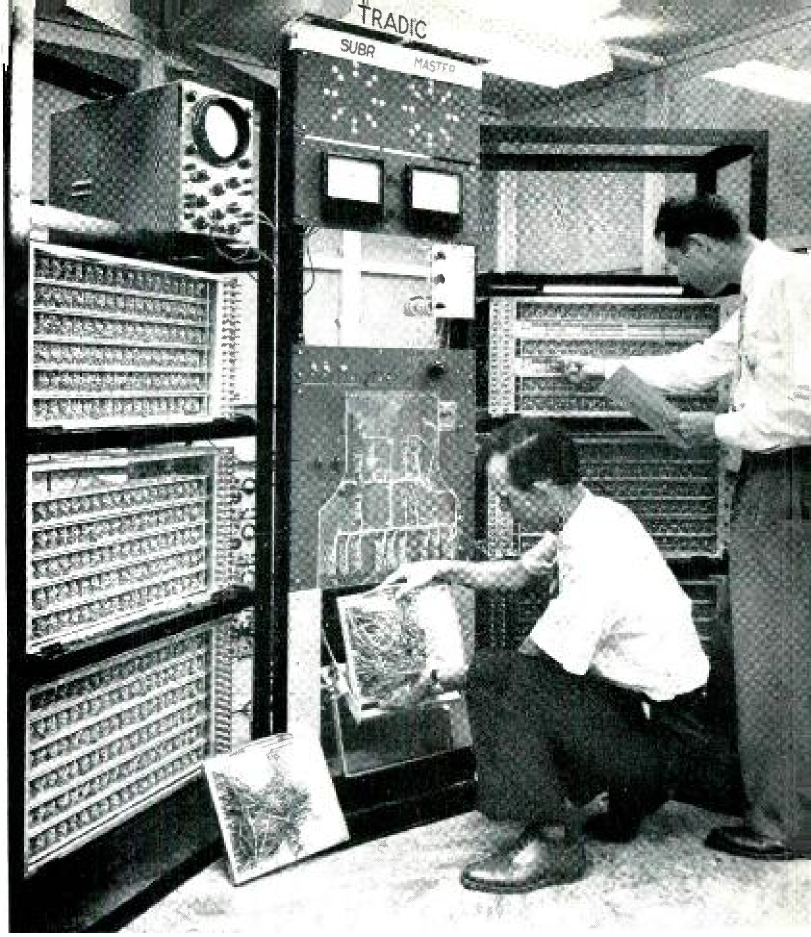
Although changes in adjustment as related to initial and required performance are the final criteria, measurements of these characteristics alone are not sufficient to permit analysis or evaluation of a design. It is necessary to know the causes of any observed changes and the extent to which various parts of the structure contribute to these changes; to this end special measuring instruments and fixtures are designed to measure dimensional changes of critical parts. In this manner, it is possible to establish whether a design is inherently unstable or whether only design modifications or changes in material are required.

*Record, *November*, 1951, *Page* 514.

THE AUTHOR

Charles Schneider began his career with Bell Laboratories in 1923. He received a B.S. degree in electrical engineering from Cooper Union in 1932. Mr. Schneider was concerned then with design analysis and he conducted evaluation studies on general apparatus. After World War II he specialized in testing and analyzing the design of switching apparatus, particularly electromagnets. More recently, he has been in charge of a group concerned with stability studies of switching apparatus.

New Transistor Computer Developed for the Air Force



TRADIC, a new digital computer developed at the Laboratories. J. H. Felker (left) gives instructions to the computer by means of a plug-in unit while J. R. Harris (right) places numbers into the machine by flipping simple switches.

A miniature electronic "brain" that opens a new era in computers and that can operate flawlessly in planes flying at supersonic speed has been developed for the U. S. Air Force by Bell Telephone Laboratories.

The "brain," a digital computer, eliminates vacuum tube failure and heat, jet aircraft's greatest electronic problems, by the use of transistors instead of vacuum tubes. It contains nearly 800 of these tiny, solid devices and is believed to be the first all-transistor computer designed for aircraft. Transistors, invented at Bell Laboratories, are completely cold, highly efficient amplifying devices which use very little power.

The new computer, known as TRADIC (TRAnsistor-DIgital-Computer), requires less than 100 watts to operate. This is one-twentieth of the power needed by comparable vacuum tube computers. Early computers used as many as 18,000 vacuum tubes and frequently required thousands of watts to operate.

The new electronic "brain" contains, in addition to transistors, nearly 11,000 germanium diodes. These serve as the electronic equivalent of tiny one-way switches. Solid, like transistors, they are capable of operating thousands of times faster than their mechanical counterparts.

When design work has been completed, the new transistor computer will probably occupy less than three cubic feet of the critical space in modern military aircraft.

The new general purpose computer was developed at Bell Laboratories under the direction of J. H. Felker, an electrical engineer. Mr. Felker is in charge of a group of electrical and mechanical engineers developing transistor and semiconductor diode circuits for military applications.

Tradic can do sixty thousand additions or subtractions, or three thousand multiplications or divisions a second. A typical problem fed into the machine requires it to go through about 250 different steps of computation. It can run through an entire problem of that complexity and provide an answer in about 15-thousands of a second. The computer can handle, simultaneously, as many as thirteen 16-digit numbers.

Mathematical instructions are placed into Tradic by means of a "plug-in" unit resembling a small breadboard. Plug-in units are set up beforehand with interconnecting wires to represent problems at hand. Numbers to be processed are put into the machine by means of simple switches.

The laboratory model of Tradic provides answers to trigonometric problems with a series of "dots" on an oscilloscope. These dots of light move so rapidly that they actually appear to draw geometric diagrams on the scope.

To handle the successive steps of complex computation, a machine, like a human, must have a means of storing information until it is needed.

When a man works on an involved mathematical problem, he usually jots down on paper the answer to each section as it is solved, then refers back to this frequently as he proceeds. Tradic, however, automatically transfers each sub-answer to built-in "memory" packages while continuing to tackle the remaining sections.

There are two main types of computers, digital and analog. A digital computer, like a desk calculator, is a "counting" machine which clocks off one number after another. Digital computers can actually perform only additions or subtractions but they are able to multiply or divide by a number of successive additions or subtractions.

An analog computer might be likened to a slide rule. This type of computer gives results in terms of voltages, resistances or rotations. It is designed for a specifc task and cannot be easily adapted for other problems of a different type.

Tradic, fundamentally a digital computer, has the additional advantage of being able to operate using translated analog data.

Western Electric Year-End Report for 1954

The Western Electric Company has reported that 1954 was another busy year—much busier than was anticipated when the year began. After midyear the demand for telephone service was growing and that growth increased as the Bell companies moved ahead with an energetic nationwide sales campaign. Their orders to Western Electric were sharply increased. Also, the government's demand for military goods and services was strong and Western was asked to undertake additional work for the armed services. When the figures for the whole year were added up, it was seen that sales had shown a small increase over 1953 instead of being somewhat lower as had been predicted.

Total sales of the Western Electric Company and its subsidiaries were just over 1½ billion dollars of which two-thirds were sales to Bell companies and most of the rest was to the United States Government. New products, particularly new types of telephones, were a feature of Western's busy year. Telephones in color, plus many other types such as a "hands free" set with built-in microphone and loudspeaker, a volume control telephone which benefits users who have difficulty hearing, and a set that is equipped with a light-up dial helped to implement sales programs throughout the Bell System.

Western Electric factories shipped record quantities of exchange cable and large quantities of dial switching and automatic message accounting equipment. Work continued on underwater repeaters for use in the transatlantic telephone cable. Production of broadband carrier equipment increased during the past year to speed the job of equipping coaxial cable routes for color TV.

Western's manufacturing facilities were expanded during the year for greater production: (1) At Winston-Salem, N. C., a new manufacturing building of 625,000 square feet was completed during the year and is now occupied. In it are being made military products for the U. S. Government. (2) Construction of the new Merrimack Valley plant in Massachusetts progressed satisfactorily and should be completed in early 1956. This plant will be devoted to making systems and apparatus for use in long-distance telephony. (3) Arrangements were made for increased manufacturing facilities at Allentown, Indianapolis, Hawthorne, Point Breeze and Kearny.

In both sales of stock items and repair of telephone equipment, 1954 was a record year for Western's distributing houses. Stock volume, or sales from stock of both new and reconditioned items, was almost 14 per cent greater than in 1953. In all, Western's houses delivered 19,866,000 stock items to Bell System customers during the year (an item is one entry on an order—whether the quantity is one or 1,000), and 97.4 per cent of these were delivered on the exact day specified by the telephone company. To keep pace with the increasing workload, Distribution expanded its facilities. Two new distributing houses to replace leased quarters were completed and occupied—one in Milwaukee, and the other in Union, N. J. Modern new houses will replace the present quarters in Pittsburgh, Nashville (replacing Louisville), and San Francisco during 1955. Plans progressed for the building of replacement houses on Long Island, N. Y., and in Kansas City in 1956.

Western Electric's Installation Organization, too, had a busy year. Installers worked on 39,000 jobs in 44 states putting in equipment for the Bell

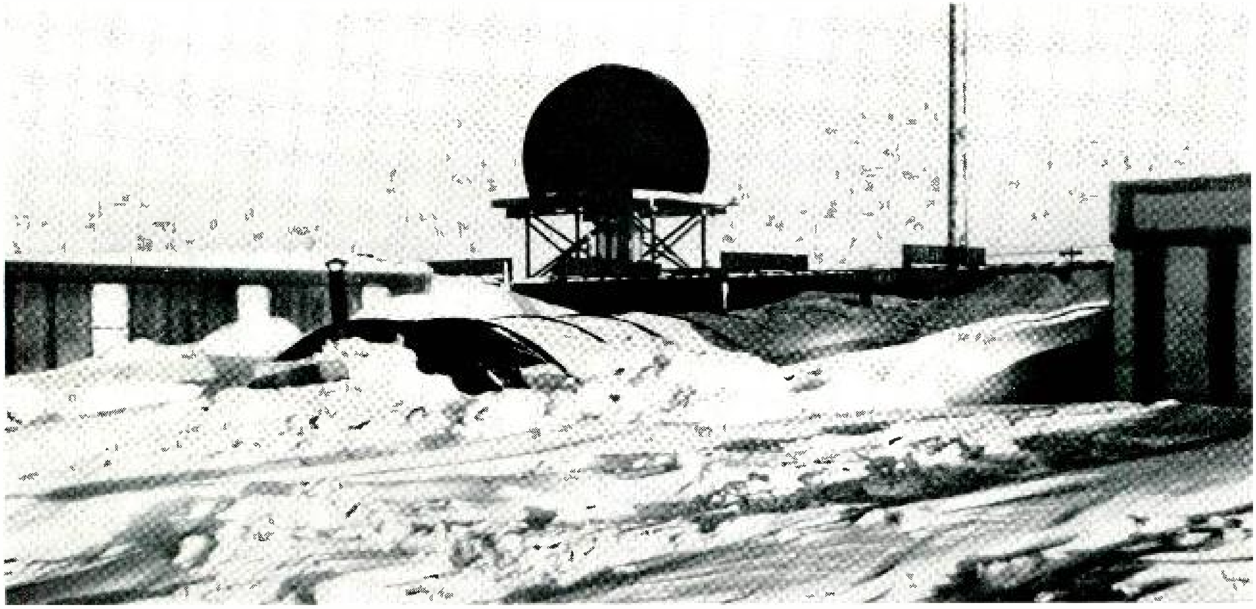
System. A sizable percentage of Installation's work was on 4A crossbar offices. These offices, featuring ingenious card translators, will be the means whereby the Bell System moves forward in its program of Direct Distance Dialing. In 1954, 4A offices went into service in Chicago (its second), Little Rock, Oklahoma City, Los Angeles, Syracuse, Richmond, White Plains, Denver and Charlotte. Western's installers also put in repeater and terminal facilities which enabled the Bell System to add a large number of cities to the nation's TV networks. During the year 102 stations in 75 cities were added to the network carrying black and white programs, bringing the total to 357 stations in 233 cities and the total of stations now broadcasting color programs is 149 located in 109 cities.

To provide the materials and supplies Western Electric needs in performing its dual job for the Bell System and the Government, purchases of supplies and services were made from some 28,000 large and small firms, last year, located in over 3,000 cities and towns in every state and more than a score of foreign countries. Procuring these supplies and services entailed an expenditure of $685 million—the highest annual amount ever.

Western Electric's work on U. S. Government orders continued unabated during 1954. Deliveries of electronic military devices and special communications equipment were at a high rate. A substantial part of this work has to do with systems that will provide a defense against surprise enemy air attacks. During the year, the company received a sizable contract to continue the production of NIKE guided missile systems.

A new organization, the Defense Projects Division, came into being as a result of the Company's expanding responsibility to the Government for defense projects which call chiefly for broad management, engineering and administrative services. This new division is in charge of such important work as construction of the Distant Early Warning Line of radar stations in the Arctic and other major continental defense projects.

Principal Manufacturing, Distribution, and Installation Locations of Western Electric as of December 31, 1954



Inside the mushroom-shaped rubber dome is a radar antenna that is one of the experimental units in the Distant Early Warning Line in the Barter Island area in Alaska.

Western Electric to be Prime Contractor on "DEW" Lines

The United States Air Force recently announced that the Western Electric Company has been selected as the prime contractor for construction of the Distant Early Warning (DEW) Line. Western Electric was also the contractor for the first experimental units of the DEW Line in the Barter Island area in Alaska. These units have now been tested and have resulted in a decision to extend the line of radar stations designed to detect the approach of enemy aircraft from across the Arctic regions.

A recent joint announcement by the governments of Canada and the United States stated that although both countries would participate in the project, responsibility for construction and installation would be vested in the United States.

Several subcontractors, including Canadian companies, will participate in the construction and equipment manufacturing for the project. The United States Air Force will discharge its responsibilities in connection with the project through a joint project office but may perform certain portions of the work through its own resources.

The joint project office which has been set up in New York City is composed of representatives from the United States Air Force's Air Research and Development Command, the Air Materiel Command, the Continental Air Defense Command, the Royal Canadian Air Force, The Canadian Department of Defense Production and the Western Electric Company. The executive management of this office is the responsibility, at the present time, of the Air Research and Development Command of the U. S. Government.

The DEW Line radar network is being designed by Bell Telephone Laboratories to detect enemy aircraft and flash a warning to Defense Command Centers in Canada and the United States seconds after the aircraft come into radar range.

The DEW Line equipment requires far fewer personnel than previously needed to operate radar lines. It was inspired by studies at M.I.T., equipment developments at McGill University for the Mid-Canada Line, and development work at Lincoln Laboratories.

Western Electric Chairman of the Board Retires

Stanley Bracken, chairman of the Board of Directors and former president of the Western Electric Company will retire from the company on March 31 under the age rule. His retirement will culminate 43 years of service which saw him rise from his first position as a student engineer at Hawthorne in 1912 through many responsible posts including Western Electric consultant to the Sumitomo Electric Wire and Cable Works in Japan, president of the Teletype Corporation, vice president and president of Western Electric and his most recent position as chairman of the Board of Directors. As president, Mr. Bracken's administrative ability and leadership were strong factors in steering the company successfully through six important years of the post-war period.

Mr. Bracken graduated from the University of Nebraska in 1912 with a B.S. degree in electrical engineering. In 1944 he received an honorary degree of Doctor of Engineering from that University.

Stanley Bracken, retiring chairman of the Board of Directors of Western Electric Company, has been awarded the Sigma Tau Distinguished Service Award in recognition of his " . . . distinguished role as an engineer and executive and long-time member of the Sigma Tau Fellowship Committee, in appreciation of . . . continuing service throughout the years to the Fraternity and to engineering education." Morris Cook, Vice President of the Laboratories, presents the awards (left to right) to Dr. Walter Wohlenberg, Dean of Engineering, Yale University; Albert N. Gonsior, Director of Engineering, P. Ballantine & Sons; and Stanley Bracken.

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. Winter General Meeting, New York City

Aamodt, N. O., Cable Dancing.

Baker, W. O., see Winslow, F. H.

Blefary, V. F., A Demonstration of Common Control Telephone Switching Principles.

Chapin, D. M., The Theory and Operation of the Bell Solar Battery.

Davey, J. R., see Purvis, M. R.

Emling, J. W., and Huntley, H. R., Problems and Promises of Rural Carrier.

Ferrell, E. B., Statistical Methods in Engineering Design.

Frost, G. R., "Little Audrey" – A Voice-Controlled Logic Machine.

Geballe, T. H., Thermoelectric Properties of Semiconductors.

Gilbert, E. N., and Morgan, S. P., Effects of Random Variations on the Patterns of Discrete Antenna Arrays.

Gilman, G. W., Kelly, M. J., Radley, Sir Gordon, and Halsey, R. J., A Transatlantic Telephone Cable.

Hagelbarger, D. W., The Out-Guesser and Other Semi-Intelligent Machines.

Herbert, N. J., A Reliable Point Contact Transistor for Military Applications.

Kelly, M. J., see Gilman, G. W.

Kinsburg, B. J., see Van Haste, W.

Lumsden, G. Q., The Physical Life of Wood Poles.

Morgan, S. P., see Gilbert, E. N.

Purvis, M. R., Davey, J. R., and Hanley, F. H., A New Telegraph Serviceboard Using Electronic Circuits.

Schelkunoff, S. A., Comments on Definition and Measurement of Physical Quantities with Particular Reference to Rationalized, Non-rationalized, and Gaussian Forms of Maxwell's Equations.

Talks by Members of the Laboratories, Continued

Schelkunoff, S. A., Solution of Field Problems with the Aid of Distributed Circuit Parameter Concepts.

Van Haste, W., and Kinsburg, B. J., The Application of Statistical Techniques to Electron Tubes for Use in a 4,000-Mile Transmission System.

Winslow, F. H., Baker, W. O., and Yager, W. A., Magnetic and Electrical Properties of Polymers Subjected to Thermal Aging.

Yager, W. A., see Winslow, F. H.

Other Talks

Archer, R. J., The Rate of Evaporation of Water Through Monolayers, American Chemical Society, New York Section, New York City.

Barstow, J. M., Color Versus Black-and-White Intercity Television Transmission, I.R.E. Boston Section and Boston Chapter of Professional Group on Broadcast Transmission Systems, Boston.

Beck, A. C., Multimode Waveguides, Millimicrosecond Pulses and Broadband Communication, I.R.E. Boston Chapter of Professional Group on Microwave Theory and Techniques, Boston.

Blecher, F. H., Transistor Circuits for Analog-to-Binary Code Conversion, A.I.E.E.-I.R.E. Conference on Transistor Circuits, Philadelphia.

Downes, G. H., Maintenance Engineering in the Bell Laboratories — Application to Switching Systems, Signal Corps Symposium, Fort Monmouth, N. J.

Finch, T. R., The Future of Communications, Southern Bell Telephone Company, Louisiana Independent Telephone Association, and A.I.E.E. New Orleans Section, New Orleans, and Louisiana State University, Baton Rouge, La., and Semiconductor Junction Devices and Circuits, A.I.E.E.-I.R.E. Student Sections, University of Colorado, Boulder, Colo.

Flaschen, S. S., Crystal Growth, Michigan Mineralogical Society, Detroit.

Fletcher, R. C., Hyperfine Splitting in Electron-Spin Resonances of Donors in Silicon, Physics Seminar, Syracuse University, Syracuse, N. Y.

Fuller, C. S., Bell Solar Battery, Sigma Delta Epsilon, New York Academy of Sciences, New York City.

Gambrill, L. M., Communications for the Nation's Airways, A.I.E.E.-I.R.E. Student Sections, Iowa State College, Ames, Iowa.

Geller, S., Some X-Ray Crystallographic Research at Bell Laboratories, Point Group Seminar, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

Graham, R. E., The Information Aspects of Television, A.I.E.E. Sections, Houston, Freeport, and Corpus Christi.

Greiner, E. S., The Plastic Deformation of Germanium and Silicon by Torsion, A.I.M.E. Annual Meeting, Chicago.

Hagstrum, H. D., Electron Ejection from Metals by Slowly Moving Positive Ions, University of Notre Dame, Physics Department Colloquium, South Bend, Ind., and Experimental Study of Auger Ejection by Ions, University of Minnesota, Physics Department Colloquium.

Hamming, R. W., General Use of Digital Computers, A.I.E.E. Basic Science Division and I.R.E. New York Section Computer Group, New York City.

Hough, R. R., NIKE Project, Lincoln Laboratory, Cambridge, Mass.

Keister, W., Can a Machine Think?, A.I.E.E. North Jersey Section, Newark, and Mechanized Intelligence, I.R.E. Dallas Section, Dallas, and Joint A.I.E.E.-I.R.E. Student Sections, University of Texas, Austin, Texas.

Keyser, C. J., Fundamental Responsibilities of a Quality Engineer, A.S.Q.C. Metropolitan Section, New York City.

Linvill, J. G., The Relationship of Transistor Parameters to Amplifier Performance, A.I.E.E.-I.R.E. Conference on Transistor Circuits, Philadelphia.

MacWilliams, W. H., Jr., Introduction to Control Systems, A.I.E.E. Basic Science Division and I.R.E. New York Section Computer Group, New York City.

McNally, J. O., Basic Problems in Electron Tube Technology, University of Tennessee, Knoxville.

McSkimin, H. J., Ultrasonic Waves and Their Propagation, A.I.E.E. New York Section, Winter Study Group.

Meacham, L. A., The Telecaller, An Exploratory Development Project, A.I.E.E. Student Sections, University of Washington, Seattle, University of Idaho, Moscow, Idaho, and Washington State College, Pullman, Wash.

Olmstead, P. S., Quality Control and Operations Research, American Society for Quality Control, Metropolitan Section, New York City, and Philadelphia Section.

Paul, C. E., Temperature-Compensated Transistor Power Converter, A.I.E.E.-I.R.E. Conference on Transistor Circuits, Philadelphia.

Pearson, G. L., The Bell Solar Battery — A Silicon p-n Junction Photovoltaic Device, Rutgers University, Physics Department, New Brunswick, N. J.

Pederson, D. O., Regeneration Analysis of Junction Transistor Multivibrators, A.I.E.E.-I.R.E. Conference on Transistor Circuits, Philadelphia.

Pfann, W. G., Transistors and Metallurgy, Metal Science Club, New York City.

Pietenpol, W. J., Present Status of Transistor Development, Southwestern I.R.E. Conference, Dallas.

Raisbeck, G., The Bell Solar Battery, Morris County Engineer's Club, Morristown, N. J.

Rose, D. J., Physics of Glow Discharge, University of California Seminar Group, Berkeley, and University of Washington Physics Colloquium, Seattle.

Rowen, J., Ferromagnetism and its Application to Microwave Circuit Techniques, I.R.E. North Jersey Chapter, Montclair, N. J.

Schawlow, A. L., Structure of the Intermediate State in Superconductors, University of Toronto, Physics Department Colloquium, Toronto.

Shulman, R. G., Nuclear Magnetic Resonance in Semiconductors, Microwave Colloquium, Columbia University.

Singer, F. J., Aspects of Continent-Wide Dialing System, Northern Electric Company, Montreal.

Storks, K. H. Instrumental Methods for the Analysis of Ceramics, American Ceramic Society, New York City.

Terry, M. E., Planning and Analyzing the Experiment, Annual Clinic of the Rochester Society for Quality Control, Rochester, N. Y.

Vogel, F. L., Jr., Dislocations in Plastic Bending of Germanium Single Crystals, A.I.M.E. Annual Meeting, Chicago.

Williams, I. V., Metals Engineering for Communications Equipment, American Society for Metals, Winston-Salem, N. C.