Redundancy in Television

E. R. KRETZMER *Television Research*

The theory of communication, born in recent years, has shed new light on the practical aspects of modern communication. One assertion of the theory is that information can be sent more efficiently than heretofore thought possible. This assertion is based on a concept known as redundancy, which has recently been the subject of considerable study in the Laboratories.

Television, like other types of communication, involves the flow of information. Not only is this information broadcast from hundreds of television stations, but it is also relayed from coast to coast over the Bell System's extensive transmission facilities.* Information, whether in pictorial or in other forms, is rarely conveyed in the most efficient way possible. It is generally accompanied by so-called redundancy – a topic that is receiving more and more attention from communication engineers.†

Redundancy is a concept that is not readily described by a simple, all-inclusive definition. In its simplest sense, it implies repetition, which may be wasteful but can also be of value in enhancing the reliability of communication. In its subtler forms, redundancy appears in almost all communication signals – whether they be television, speech, or even written language. It exists largely because most forms of information have certain structural properties which cannot be exploited by the straightforward methods used to "translate" information into communication signals. Redundancy can be reduced through the use of more intricate translation methods, involving "codes" designed to match particular forms of information such as pictorial information.

As long as no effort is made to devise and implement these translation methods, electrical communication signals will require wider channels for transmission than might otherwise be necessary. The engineer is therefore faced with the challenge to minimize redundancy and thus obtain greater economy of communication facilities. This challenge is particularly great in the case of cross-country television transmission.

Television signals are by far the largest of the "vehicles" in today's communication traffic; they use channels up to four megacycles in width – about one thousand times as wide as those used for speech. Because of the great bandwidth and the severe transmission requirements of these signals, the nec-

* Record, *March*, 1954, *page* 81. † Record, *September*, 1953, *page* 326; and B.S.T.J., *July*, 1952, *page* 751, describing in detail the correlation-measuring apparatus being adjusted by the author in the photograph above.

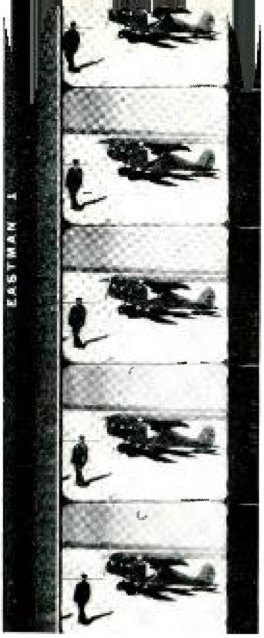


Fig. 1 — Typical motion-picture frame sequence. Since the individual frames recur at the rate of 24 per second, consecutive pictures do not generally differ much from each other. Similarly, television frames, which are scanned at the rate of 30 per second, tend to change little from frame to frame. Knowing a sequence of frames, one can make a good estimate as to the following frame. Yet, each frame is transmitted and received without reference to previous frames — a simple example of redundancy.

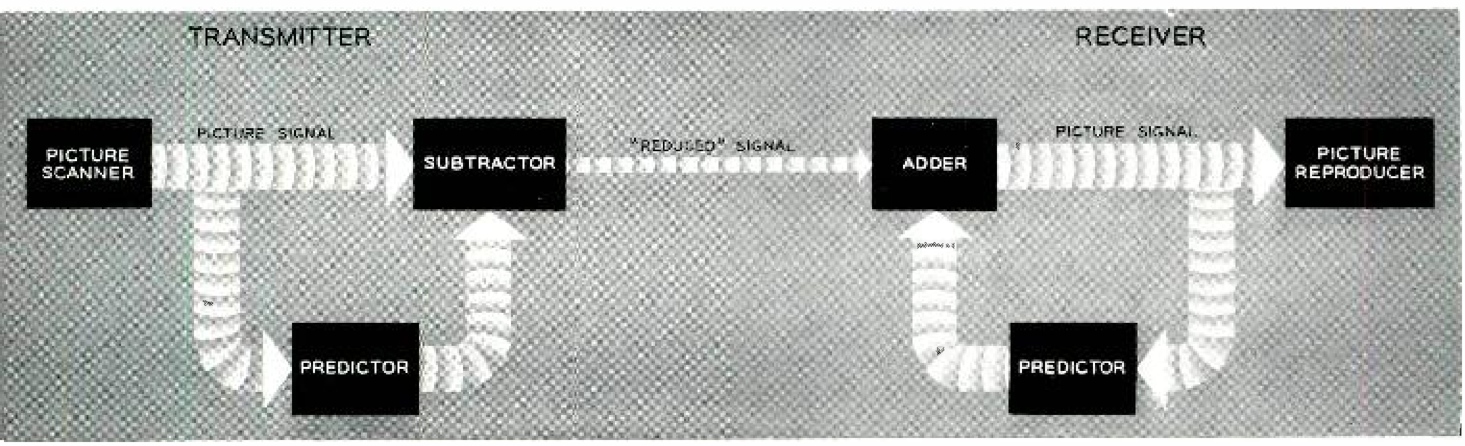
essary long-distance transmission channels are very expensive. It is particularly appropriate, therefore, to explore any possibilities of reducing the redundancy of present-day television signals, in the hope of ultimately achieving a reduction of the bandwidth that is required for their long-distance transmission.

To transmit a television picture, we must translate or convert it into an electrical signal. This signal, in the present-day technique for black-and-white pictures, serves to describe the brightness point by point. For television in the United States, the electrical signal describes the brightness of about 200,000 picture points within 1/30 second. During the next 1/30 second the process is repeated and it continues at the rate of 30 "frames" per second. The large number of picture points is required to obtain a picture that is not objectionably coarse, and the fast "frame" rate ensures a picture that is sufficiently free from flicker. We therefore have to describe thirty times 200,000 or 6,000,000 points per second. Since we must also send so-called blanking and synchronizing signals, the actual picture transmission takes place during hardly more than three quarters of the total time. Consequently, picture transmission is squeezed into about 1/40 second during which the 200,000 points are described at the rate of almost 8,000,000 per second.

One of the fundamental laws of communication theory states that the transmission of n "samples" per second requires at least n/2 cycles per second of channel width, if the samples are all assumed to be independent of each other. Therefore, the nearly eight million picture points per second require a minimum channel width of nearly four megacycles, so long as no use is made of relationships among their brightness values. Actually, the brightness values of the picture points in a single frame or even several successive frames, are generally not independent of each other. They are related in certain statistical ways, imparting a type of redundancy to the point-by-point description that makes up the video signal. By using these statistical relations, we hope, in the future, to devise means of reducing the channel width required for television transmission.

That there is indeed a dependence or so-called "correlation" among the 200,000 picture points can be demonstrated in various ways. For example, given only portions of a picture, we can usually fill in neighboring portions with fair accuracy. This is

Fig. 2 — Prediction system for reducing redundancy in a signal before transmission, and restoring it at the receiver. Reduced signal still occupies full bandwidth but lends itself to encoding in reduced bandwidth.



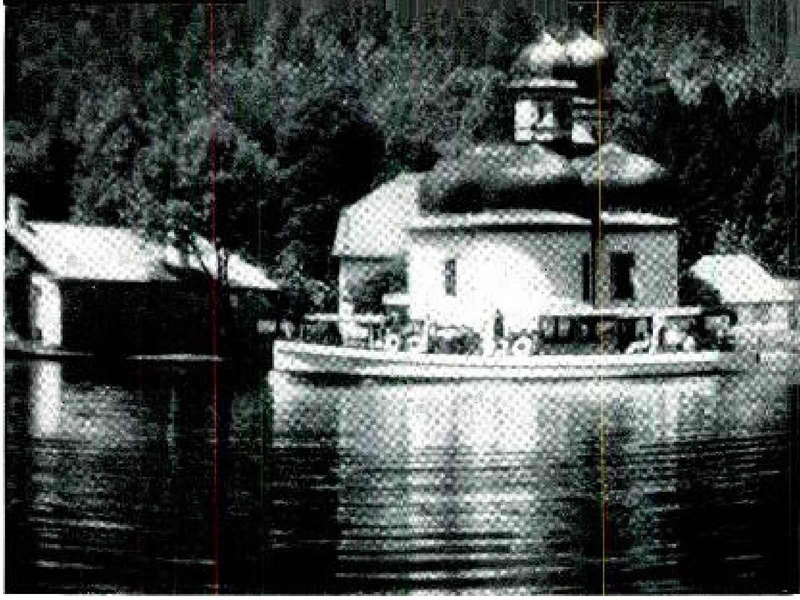
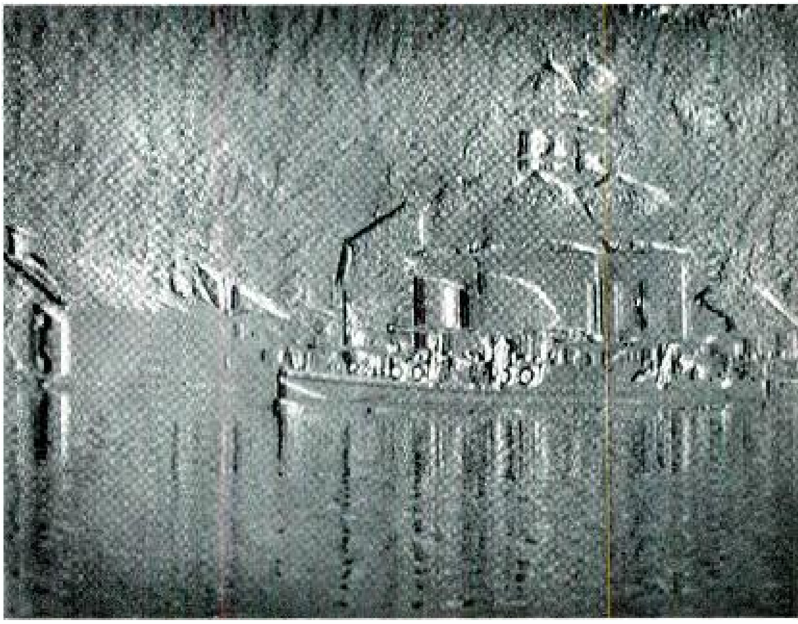


Fig. 3 — When a previous-value prediction error signal is applied to a kinescope, the "picture," below, results. Only changes (contours) of the original picture, above, appear, since the predictor errs whenever there is a brightness change from one picture point to the next. From the error signal the original picture can be correctly reproduced.



analogous to the correlation among the letters of printed text which enables us to fill in the missing vowels in a phrase such as TLVSN BRDCST TRNSMTTR. Not only is there correlation within a given picture, but also among the successive pictures of a typical frame sequence as illustrated by Figure 1.

Another illustration involves some staggering numbers. If we assume that each of the 200,000 picture points can have any one of 100 distinguishable brightness levels, then there are a total of $100^{200,000}$ or $10^{400,000}$ possible combinations. If each combination represents a picture and these pictures are sent at the usual rate of thirty per second, it would take $10^{399,991}$ years to transmit them all — a number totally beyond human imagination. Evidently, the vast majority of dot combinations would not be considered pictures in the usual sense, but our television facilities are prepared to transmit any and all of them.

It is often easy to point out deficiencies, but it may be hard to implement an effective remedy. This is certainly so in the case of redundancy in television transmission. True, much of the data now transmitted could be omitted and successfully reinserted by a human observer — if he were given a chance to study each frame at length. Of course, there is not sufficient time, nor is it feasible to have an observer perform any such task.

One answer to the problem, as the communications engineer sees it today, lies in the design of transmitting and receiving equipment possessing some degree of "intelligence". The equipment will then be called upon to perform, at high speed, some of the tasks which a human observer could perform, if he were given sufficient time. A great deal of such equipment has been conceived in principle, but to construct it is quite another problem.

To date, only the simplest ideas have been investigated in the laboratory; actual reductions in channel width have not yet been achieved. The basic philosophy that underlies past and present work at Bell Telephone Laboratories in this field can be described as follows: The transmitter, instead of sending the brightness of each picture point, has a "brain" that examines the last few picture points scanned, and makes an intelligent prediction of the next picture point. It then compares its prediction with the actual brightness value and sends the difference between the two, as shown in Figure 2. What is sent is an error signal — the amount by which the "brain" errs in its prediction. At the receiving end there is an identical brain that is able to reproduce the actual picture signal from the error signal by means of a feedback system. This much has actually been done, though only with "brains" of limited intelligence. The simplest system, and perhaps the most successful one, merely predicts that each picture point will have the same brightness as its nearest prior neighbor.* This has been called "previous value" prediction. A typical error signal, when applied to a kinescope, appears as shown above.

What has been gained by sending an error signal

* B.S.T.J., *July*, 1952, *page* 764.

instead of the actual picture signal? The answer lies in the statistical structure of the error signal, which is quite different from that of the original picture signal. If the predictor is intelligent, its errors will usually be small; medium and larger errors are progressively less probable. Knowing this, one can devise a code to take advantage of the large incidence of small errors and the small incidence of large errors. A run of many small errors might be "packaged" so as to require less channel width than the corresponding original signal.

Besides this so-called prediction method that requires identical "brains" or computers at transmitter and receiver, there are other conceivable methods of transmitting pictures in a reduced channel width. Instead of examining the picture dot by dot, for example, it might be examined in terms of its contours. If each contour is described as to location, slope, and associated brightness value, and if this description can be handled in an efficient manner, a more economical method of picture transmission might result. Various other schemes have been proposed, but none of these has so far been implemented successfully.

The color television system of the National Television System Committee represents a case in which some channel economy has been achieved through the use of principles quite different from those discussed above. Partly through efficient packaging of brightness and color information, and partly through exploitation of certain properties of the human observer, this system has been made to require a channel width no more than that used for black-and-white transmission.

Studies directed toward compressing transmission frequency bands have not been limited to television. In the field of speech communication, such studies have been carried on for many years. The best known result of this work is an apparatus called the Vocoder* which has some remarkable capabilities. Among the newer speech-band compressing schemes, potential performance ranges from modest band compression, with little loss in quality, to much greater band compression, with considerable loss in quality and voice individuality. In the latter case, not only redundancy, but also some actual information may be lost.

An important fact mentioned previously is that redundancy can often be of great value. In speech, for example, it may serve to reduce misunderstandings; in electrical signals, it may reduce vulnerability to interference. Therefore, redundancy should not be removed indiscriminately from a television signal lest the result be a "frail" signal that is highly sensitive to interference. In fact, so-called error detecting codes† used in electronic computers contain carefully planned redundancy which is introduced deliberately and to great advantage.

Whether television channels will ultimately be compressed is a question of economics, and of technical developments in various directions. It is conceivable that new transmission media will greatly lower the cost of wide transmission channels. It also appears likely that a substantial reduction of redundancy would call for considerable extra terminal equipment. The cost of this extra equipment must be weighed against the savings resulting from the narrower channels.

Redundancy in television is indeed a highly complex subject. Nevertheless, communication engineers are studying this field in the hope of finding profitable applications. Successful efforts in this direction may ultimately lead to a more efficient use of our rapidly expanding communication highways.

* RECORD, *December*, 1939, *page* 122.
† RECORD, *May* 1950, *page* 193.

THE AUTHOR

ERNEST R. KRETZMER received his B.S. degree from Worcester Polytechnic Institute in 1944 and his S.M. and Sc.D. degrees from Massachusetts Institute of Technology in 1946 and 1949. He taught electrical engineering at M.I.T. from 1944 to 1946 and later conducted electronic research there, studying the characteristics of pulse communication systems. Dr. Kretzmer joined the Laboratories in 1949. Except for two years when he was concerned with the application of transistors to military uses, Dr. Kretzmer has been engaged in television research, concentrating on the decorrelation of television signals. He is a member of Sigma Xi and a senior member of the Institute of Radio Engineers, serving on the Information Theory and Modulation Systems Committee and the Administration Committee of the Institute's Professional Group on Information Theory.

A New Cable Splice Closure

W. C. KLEINFELDER *Outside Plant Development*

During the post-war shortage of lead, new alpeth and stalpeth cable, sheathed in polyethylene, have proved excellent substitutes for traditional lead-sheathed cable in meeting urgent demands for new voiceways. But their use has been limited by the difficulty in closing a sheath that cannot be soldered and sealed by the long-established techniques used with lead sheath. This article tells how this difficulty was overcome by using an entirely new procedure, in which a die cast aluminum casing is conveniently bolted to the cable and sealed gas-tight with a special compound.

When two lengths of cable are spliced or a cable comes to an end, the sheath must be thoroughly sealed to protect the paper insulation of the cable conductors against moisture. Where, in addition, cable wires are to be connected to open wire or drop wires to customers' premises, suitable terminating arrangements must also be provided. In the past few years there has been rapid development of greatly improved sheath closing and terminating arrangements; an important part of this development is a new method of sealing which makes water-tight and gas-tight joints with both metals and plastics and permits the design of an economical splice closure for plastic sheath cable.

The traditional way of enclosing splices in lead-covered cable has been to place a lead sleeve over the assembly of conductor joints, then to solder wipe the "beat in" ends of the sleeve to the sheath. This procedure, which was borrowed from the plumber's art, has been standard since lead-covered cable was introduced in the early 1880's. It provides a chamber that is as moisture-tight as the sheath itself.

When World War II ended, it was soon apparent that neither the available lead supply nor the lead sheathing capacity of Western Electric would be adequate to meet the unprecedented demand for the production of cable of standard design. As a result of considerable prewar development work by the Laboratories and Western Electric on alternative types of cable sheath, together with rapid advances in the field of plastics, it became possible to increase cable production early in the post-war period by introducing alpeth* sheath as a supplement to lead sheath. Alpeth sheath comprises an inner layer of thin sheet aluminum and an outer layer of extruded polyethylene compound. A later modification, stalpeth† sheath, has an added layer of corrugated terne-coated steel strip, with its overlapping edge soldered, between the aluminum and polyethylene layers.

When the plastic sheaths entered the picture, the existing methods of enclosing splices were useless since a metal sleeve could not be soldered directly to the sheath. Many suggestions for making a satisfactory splice closure were tried but for one rea-

* RECORD, *November,* 1948, *page* 441. † RECORD, *August,* 1951, *page* 353.

son or another most of these were found to be impractical under the varied and at times extremely adverse conditions in which the splicer must do his work.

The method which was adopted and is presently in use, retains the customary lead sleeve, and requires operations which, in effect, place short sections of lead sheath over the plastic at each end of the main sleeve, so that the usual solder wiped joint can be made. In some situations, the closure can be made directly between the main lead sleeve and the plastic sheath, without the use of the supplementary sections of lead sheath. In either case, the requisite mechanical strength and water tightness for splice protection are provided by wrappings of materials, chiefly tapes, so arranged as to insure reasonably long life under normal field conditions. Where continuous gas pressure is to be maintained in the cable, corrosion resistant clamps are placed over the wrappings to reinforce them.

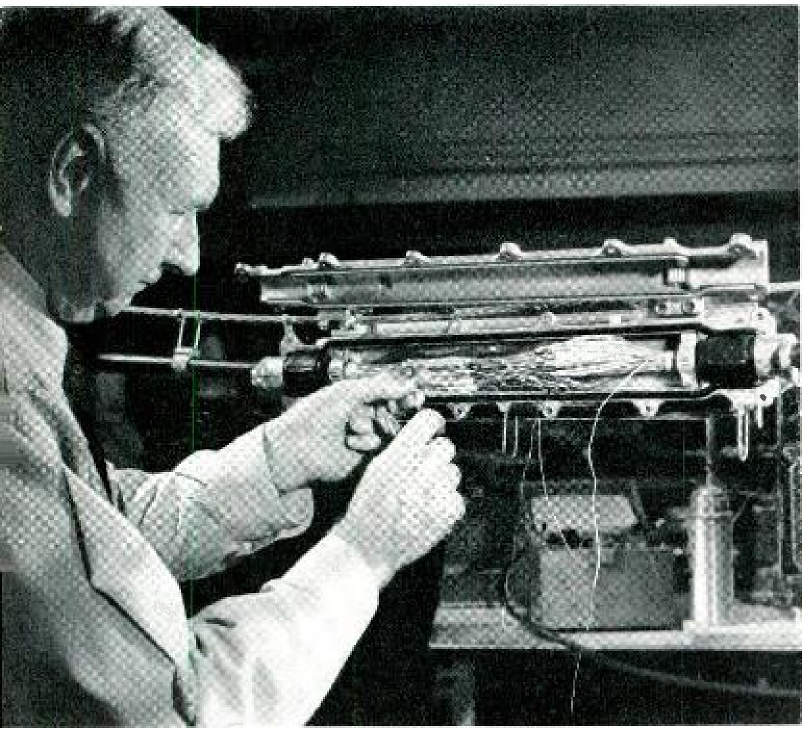


Fig. 1 (above) — D. C. Smith splices a pair in a T-type splice closure for stalpeth cable. View shows splicing chamber, longitudinal joint seal and end seals between aluminum casing and cable sheath.

While the splices made by this method have proven satisfactory, the time and cost penalties involved in making them, in comparison with the simple wiped joint used on lead sheath, have had some restrictive effect on full utilization of the plastic sheath cables. This has been particularly the case in situations where splices must be made solely to provide terminal facilities, as the actual wire splicing work in these situations is not very great and the labor cost of closing the splice is therefore proportionately greater.

An obvious way to simplify the operation would be to use a water-tight and gas-tight housing that could be easily clamped over the splice. The idea of such a clamped housing was not new. Various commercial devices of this type had been investigated over a period of many years but experience indicated that they were deficient in one or more respects or that they possessed no marked advantage over existing designs and methods. Tests had shown that none of these could be relied upon to furnish adequate moisture protection to the cable over the many years required.

It was recognized initially that any splice closure of this type should be light in weight, as the most pressing need was for applications in the aerial distribution plant. It was decided, therefore, that the design should be based on the use of aluminum die castings. It also became apparent early in the development work that the crux of the design problem was to establish a permanent gas-tight and water-tight seal between the cable and the housing. Early designs involved a housing, split in half longitudinally, to be bolted together over the splice, with molded vulcanized rubber gaskets to seal the longitudinal joints and compressed rubber bushings to provide seals at the ends of the housing. Considerable laboratory test work, including the study of

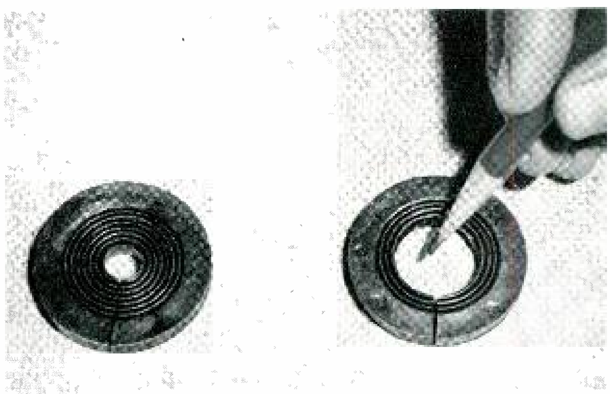


Fig. 2 (right) — Plastic washer at end of stuffing box retains Butyl compound. Concentric grooves guide cutting tool so that inside diameter of washer is readily cut for snug fit on cable.

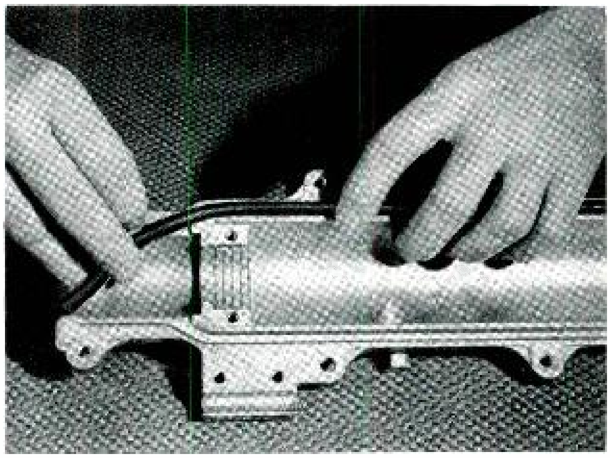


Fig. 3 — Butyl rubber sealing compound is easily handled yet adheres firmly to metal.

various cured rubber compounds, was expended on this basic design, and some closures using this type of seal were placed on field trial.

Experience in the laboratory and in the field made two points clear. First, if live rubber bushings were used to seal the housing to the cable, a very good initial fit would be necessary, and therefore, a considerable number of sizes of rubber bushings would be needed to care for the various sizes of cable used in the field. Secondly, relaxation of the cable sheath and the rubber bushings due to such causes as temperature change or cold flow of materials might eventually result in loss of water-tightness. That this could occur under normal conditions of exposure was disclosed by temperature cycling tests in the laboratory and corroborated by field weathering tests at the Outside Plant Field Laboratory at Chester, New Jersey. It was found that some improvement could be obtained by introducing spring members in the sealing system to maintain the compression on the rubber, but the results did not promise adequate long-term sealing.

Since the general form and arrangement of the metallic parts of the design seemed to be approximately right, it was decided to try a radically different approach to the sealing problem. Instead of relying on continued compression of live rubber compounds for sealing, a search was undertaken for a material that would perform the needed functions by reason of its softness, deadness and ability to adhere to surrounding surfaces. The materials engineers of the Chemical Research Department found that a compound based on uncured Butyl rubber had the desired properties. This compound is non-hardening, adheres to metal and polyethylene, has the requisite somewhat putty-like consistency and can be produced and packaged in the needed forms, in this case flat strip and round cord.

Each casting, shown in Figure 1, has a chamber at the end in which the sealing material, applied in tape form and built up to the required diameter around the cable, is compressed. An "adjustable" plastic washer with concentric grooves extending partly through its thickness has been designed to center the cable and confine the sealing material in the end chamber, Figure 2. The outside diameter of this washer is just slightly less than the inside diameter of the stuffing box housing formed at each end when the two halves of the splice closure are assembled. To fit the inside diameter of the washer to the cable, it is merely necessary to cut along the proper groove with a cutting tool designed for the purpose. Enough material is thus cut away to fit the inside diameter of the washer to the cable size. The washers are slit radially so they can be slipped over the cable. Grooves in the castings extend longitudinally along each of two mating surfaces and into these grooves cords of the sealing material are laid, Figure 3. When the halves are bolted together and the compression glands are assembled and tightened at the two ends of the closure a complete seal is accomplished by the captive material compressed in the longitudinal grooves and the stuffing boxes at the ends, Figure 4.

In addition to excluding moisture, the case must provide a means for gripping the sheaths of the cables to prevent relative motion between cable and case due to tensile or compressive forces, and to maintain across the splice the electrical continuity of the metallic portion of the sheath. The method for doing this consists of slitting the sheaths for a short distance at each side of the splice and gripping the tabs so formed in a clamp secured by screws to the housing.

Fig. 4 — Appearance of the straight splice closure with casing bolted together.

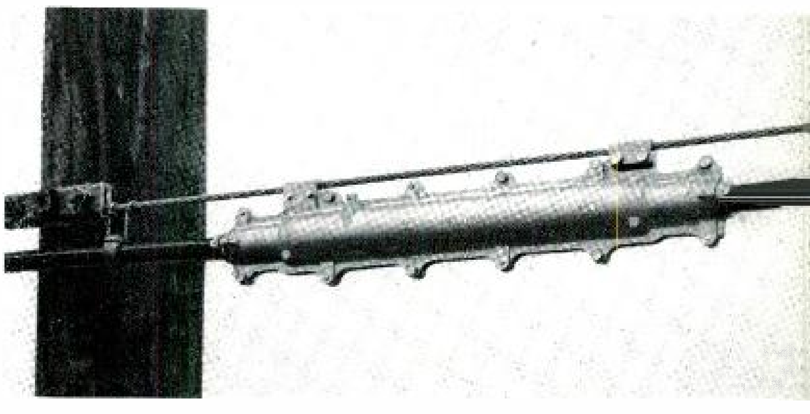


Fig. 5 — Older F-type cable terminal cover raised by John Apgar to show faceplate and binding posts. Protectors are housed in mounting underneath.

While this seal was being developed to solve the alpeth and stalpeth cable splice problem, work was also in progress to improve the terminal facilities. In the past a cable terminal has usually consisted of a faceplate with binding posts for connecting the customers' drop wires, a short length of lead-covered cable whose conductors terminate on the back of the binding posts in a manner which seals the connections and the cable end against moisture, and a housing for the terminal assembly. For many years the terminal was mounted on the pole, Figure 5, and the stub cable was connected to the main cable by a bridge splice. More recently the terminal has been hung from the cable strand, but still connected through a stub cable, as shown in Figure 6. To connect the terminal into the main cable, it is necessary to bring the stub into the splice sleeve, join its conductors to the proper wires in the main cable, and include its sheath in the wiped joint as illustrated on the right of Figure 7. In addition, when terminals of these types are installed where the drop wires or cables connecting to them are exposed to high voltages, electrical protective devices have to be installed to limit the voltage appearing on the drops or cable conductors in the event of a power cross or lightning. With the older types of terminals, protection is provided in separately mounted housings as shown in Figures 5 and 6. In the more modern NC terminal shown in Figure 7, the protectors are mounted inside the terminal. Thus, not only is the separately mounted protector dispensed with, but the wiring between terminal and protector, Figure 6, also is eliminated.

With the development of the mechanical splice closure it has become possible to combine the closure and the terminal shown in the photograph on page 405 and in Figure 8. The terminal portion of this type of assembly is housed in an aluminum

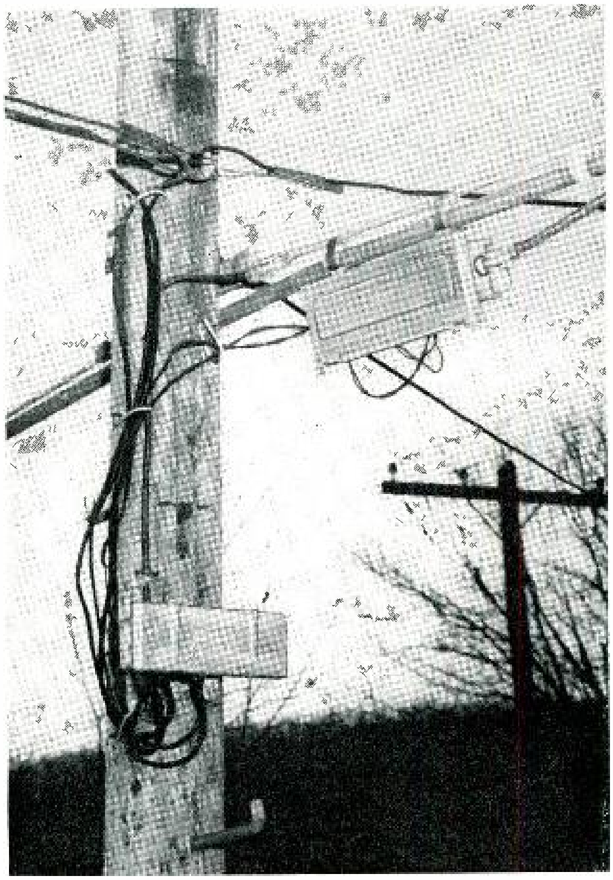


Fig. 6 — More recent NA-type cable terminal is conveniently suspended from cable strand. As with F-type terminal, protectors are mounted on pole.

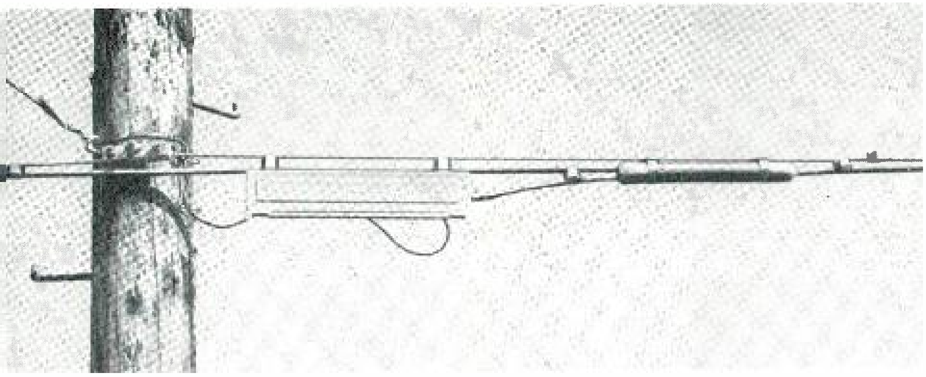


Fig. 7 — An improvement over the NA-type of Figure 6, NC-type cable terminal houses protectors too, thus eliminating separate protector mountings.

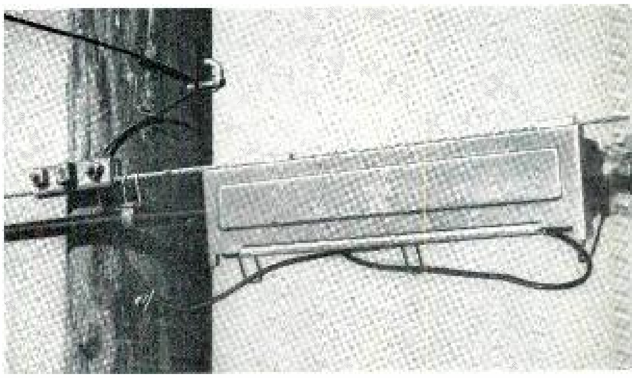


Fig. 8 — New T-type terminal combines terminal, protectors and splice closure.

die casting which mates with a straight splice closure half, and in so doing forms the other half of the splice cover as shown in Figure 1. The terminal half of the unit contains a cast resin block, holding the binding posts and protectors, and the terminations of the plastic-insulated leads to the binding posts are sealed within the resin block. The block and its housing are similar to those used in the present N-type terminals, except that the leads, rather than emerging as a lead sheathed stub cable, go directly from the rear of the resin block into the splicing chamber through a gas-tight bushing in the housing.

The terminal half is made available in both 10- and 16-pair sizes. If more than 16 pairs are required to be terminated, any combination of the 10- or 16-pair terminal halves may be installed back-to-back to make 20, 26, or 32 pairs available. Either type is obtainable with or without built-in electrical protection. The cases and terminals which have been made available initially are suitable for use on cables up to one inch outside diameter. Development work is in progress on sizes suitable for larger cables, and trials have been made on very large cases for use on underground cables.

Although the new cases and terminals are expected to find their principal use on plastic sheathed cables they may also be used on lead sheathed cables with minor changes in the installation procedure. Acceptance of the design has been favorable and the indications are that very substantial over-all savings will be realized.

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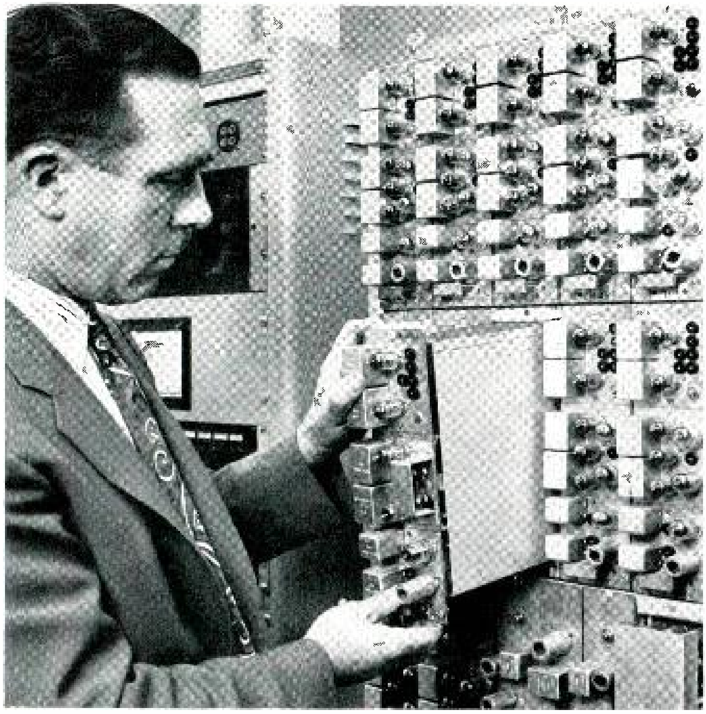
W. C. KLEINFELDER had been engaged in outside plant tool and wire development at the Laboratories for five years when he received the B.S. degree in M.E. from Cooper Union in 1934. In 1939, still a member of Outside Plant, he transferred from projects in wire and wire attachments to cable joining and maintenance, in which he has worked on problems such as the splicing of coaxial cables, splicing methods for cables having new sheath structures, and improved methods for joining cable conductors, particularly those made of aluminum. This work was interrupted during World War II when he spent three years in the development of military equipment. He has recently been in charge of the group working on cable joining methods and in addition has been engaged in military projects.



Radio Programs on N1 Carrier

A. V. WURMSER
Transmission Systems Development

The N1 carrier system ordinarily permits the simultaneous transmission of twelve telephone conversations, and it also can be quickly adapted to provide transmission channels for radio programs. When the N1 system is serving as part of a radio program network, newly developed circuits can be substituted for one or more of the telephone message channels. These program channel units are designed to handle both 100 to 5,000-cycle and 200 to 3,500-cycle service on either a full-time or temporary basis.

Although N1 carrier was initially planned only as a telephone message transmission system, it became evident that its inherent flexibility and economy could be used to advantage for the transmission of radio programs. Somewhat like telephone calls, radio programs that are to be broadcast from individual stations over a wide area of the nation must be switched from a local studio to a toll office, and thence to other toll offices for distribution.

The past history of program networks has dictated four main classes of service, all of which the N1 system will handle efficiently. These four types, or "schedules", of service are designated as A, B, C, and D. Schedules A and B are the higher quality services, designed to handle frequencies from 100 to 5,000 cycles per second. Schedules C and D services handle frequencies from 200 to 3,500 cycles per second, and are used, for example, for programs consisting chiefly of voice broadcasts, where a more restricted frequency range is sufficient. Furthermore, schedules A and C are usually handled by full-time circuits; these are used daily and are leased by the radio networks on a monthly basis. Schedules B and D are handled by temporary circuits. For special events or other programs of a short-term nature, broadcasters ordinarily require these classes of service by the hour, day, or week.

To supply radio network customers with these types of service, it is fairly obvious that a transmission system must be flexible enough to permit the necessary changes. The full-time schedules A and C circuits must occasionally be altered to allow for differing radio program traffic loads. The temporary schedules B and D circuits must be especially flexible. These latter circuits are usually derived by removing telephone message circuits for the time required by the broadcast, after which the message circuits are restored to normal operation. In making these changes, the N1 carrier system is very flexible as a radio program transmission medium. Another advantage is realized when new cables are being installed. If radio program material is transmitted in its natural frequency range (that is, without translation to carrier frequencies), cables must be engineered to provide a sufficient number of special cable pairs for this service. It was therefore advantageous to design radio program transmission circuits that could make use of the normal N1 telephone channel space.

The method used will be illustrated first by considering the less complex schedules C and D services. As described in previous RECORD articles, the N1 system provides twelve telephone message channels. At the terminals in the telephone offices, individual message channel units are mounted for each of the twelve channels. For schedules C or D radio program transmission, a message unit is merely pulled out of the terminal mounting, and the appropriate program unit having a wider transmission frequency band is substituted.

A simplified schematic of such a schedule C program channel unit is shown in the central area of Figure 1. Radio program material from a broadcasting studio is fed from the program room or network to this unit. As seen in Figure 1, the program unit, like the message channel units, uses the familiar compressor-expandor principle* to reduce noise interference and to lessen crosstalk difficulties. Since noise is particularly noticeable when volumes are low, the compressor takes advantage of this fact by automatically amplifying the low volumes and slightly attenuating the high volumes. The more even range of volumes can then be transmitted over the cable at a better signal-to-noise ratio. The original range of volumes is then restored at the receiving end by the action of the expandor.

At the output of the compressor, the low-pass filter attenuates frequencies above 3,500 cycles to prevent interference with other channels of the N1 system. Next, the oscillator and modulator circuits convert the program material to the particular N1 frequency band being used. Since the frequency cutoff of the line repeaters tends to narrow the bandwidth on channel one, this channel is used only for short links. Any of the other eleven N1 channels, however, can be used for regular 3,500 cycle service.

The modulator's double sideband output with its carrier is then amplified by the transmitting group unit, which performs the same amplification for telephone message transmission. Between terminals, repeaters amplify the transmitted frequencies to restore energy lost in transmission over the cable.

Assuming now that the unit shown in Figure 1 is receiving radio broadcast material, the carriers and sidebands, along with the regular message channels, are amplified by the group receiving unit. Receiving band-pass filters separate the spectrum into the twelve individual channels, and the individual sideband levels are automatically adjusted by the channel regulator. The carrier frequency is used to control this adjustment. The signal is then demodulated and passed to the receiving low-pass filter, which suppresses the carrier frequency, the adjacent channel signaling tones, and the eight-kilocycle tones resulting from beats between adjacent channel carriers. The expandor then reverses the action of the compressor, so that when the program is finally broadcast over the air, the radio listener hears the normal volume ranges. After leaving the expandor, however, the program may not go directly to a radio station; it may go on to other links in the network before reaching its destination.

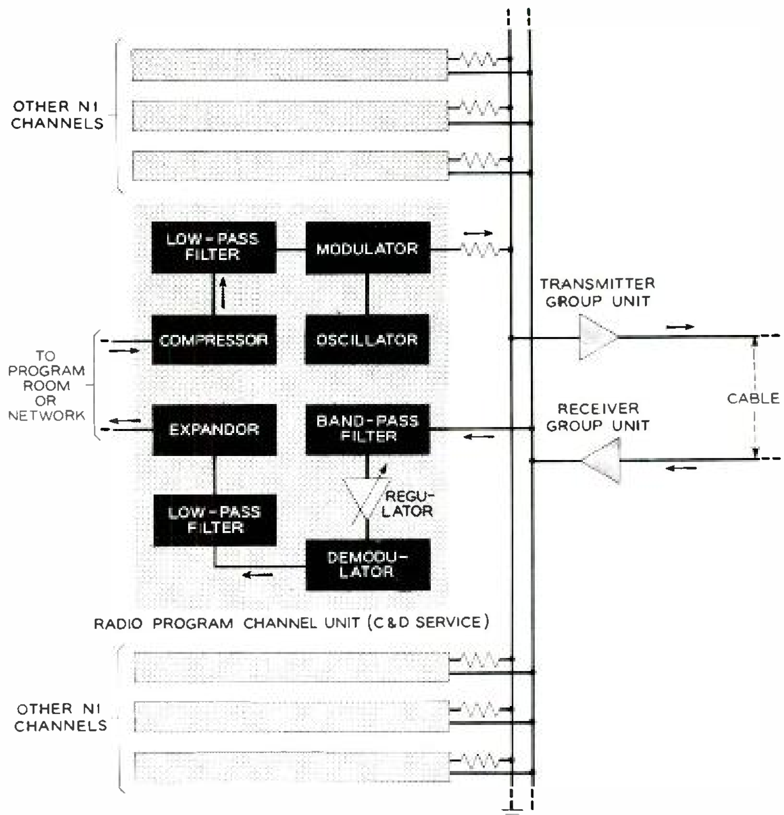


Fig. 1 — Block schematic of radio program channel unit for schedules C and D service. The program unit, like the message channel units, uses the familiar compressor-expandor principle to reduce noise interference and to lessen crosstalk difficulties.

* RECORD, *November*, 1953, *page* 452.

Another feature of the unit, not shown in Figure 1, is the addition of certain adjustable compensating components that extend the frequency range on both the high and low ends. This improvement is shown graphically in Figure 2, where curve A is a typical message channel frequency characteristic. To obtain a frequency characteristic such as curve B for program purposes, a new low-pass filter was designed to extend the frequency range up to 3,500 cycles, and another network was added to boost the low frequency end. Since both of these compensations are accomplished in the compressor subassembly unit before modulation, the program unit can be used in any of the available channel positions.

In radio program transmission work, it is important to make the distinction between "reversing" and "non-reversing" circuits. Some networks are laid out in a more or less circular or "round robin" pattern, so that no matter which station originates the program, this program will be transmitted to the other stations only in one direction around the circle. Service is here supplied on a non-reversing basis. In other networks, however, where the stations are distributed along a main line, the transmission system must permit programs to be sent in either direction along the line, on a reversible basis.

Schedules A and B services can be either reversing or non-reversing, and Figure 4 shows in block schematic form a program unit of the non-reversible type, suitable for either of the two higher quality, 5,000-cycle schedules. The provision for 5,000-cycle service results in a somewhat more complex circuit than that for the schedule C circuit shown in Figure 1. To obtain sufficient bandwidth, three message channel units must be removed from service for the substitution of a single N1 carrier radio program unit.

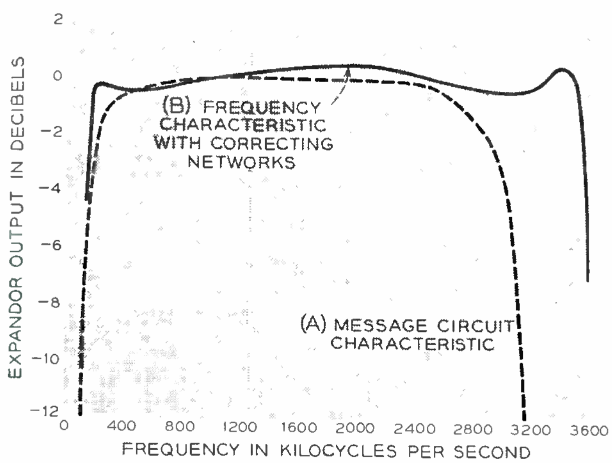


Fig. 2 — Frequency-characteristic curves, showing extension of bandwidth schedule C or D radio program transmission.

In Figure 4, the actual plug-in unit is enclosed in the central area. In this case, units like the filters, predistorter, compressor and expandor shown are external to the N1 carrier terminal. These are usually located in a miscellaneous bay or program room in the telephone office. In the transmitting portion of the circuit, the low-pass filter limits the incoming program to 5,000 cycles. The next unit is a predistortion circuit, similar to those used on other pro-

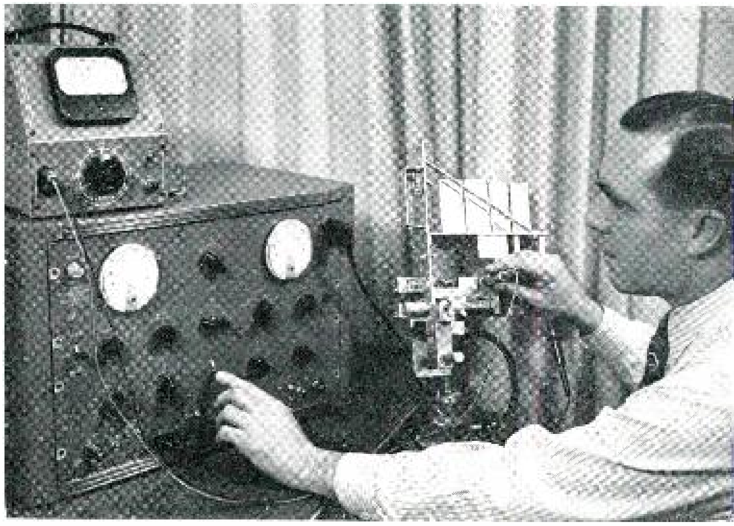


Fig. 3 — The author testing a receiving regulator of a schedule A program unit.

gram-carrying systems. The principle involved is that most of the energy is in the low frequency spectrum and very little in the "high's." If the energy level of the "low's" is decreased slightly, the level of the "high's" can then be increased a considerable amount, leaving the total energy unchanged. The "high's" will therefore have a better signal-to-noise ratio, and over-all transmission performance is improved. This ratio is further improved by the action of the compressor, as described for schedule C service. This compressor, however, is designed to handle the 100 to 5,000-cycle band.

In the program channel unit itself, this compressed program material is accepted by the input circuit, and is converted to the N1 carrier range by the associated oscillator and modulator circuits. The carrier frequency is transmitted along with the sidebands, and is used in conjunction with the other carriers to control automatic gain regulation at the repeaters and at the receiving group unit. The carrier power for the program channel is increased to provide the same total carrier power as for the twelve message carriers of a normal N1 system. As before, the carrier also controls the regulator in the receiving portion of the circuit.

Assume now that the program unit in Figure 4 is receiving radio program material. This material, along with the carriers and the telephone message material, will be amplified by the receiving group unit. The channels are then separated by the individual receiving band-pass filters. The program band-pass filter will pass the 5,000 cycle sidebands and carrier frequency. These pass through the channel regulator, which adjusts them to the proper level for demodulation. The demodulator then restores the program material to its original frequency range, and the output circuit delivers the material to the program room or miscellaneous program bay where the rest of the equipment is located.

Following the output circuit, a 5-kc filter is added to reduce further the interference outside the 5-kc band and to reduce the possible effect of the interference on the operation of the expandor. Some small amount of frequency distortion is usually accumulated during transmission, and this is compensated for by adjustable equalizers. Then the expandor reverses the performance of the compressor, as in schedule C operation, and the program is restored to its normal volume range. Finally, the program passes through the restorer network, whose frequency characteristic is complementary to that of the predistorter at the transmitting end. This network thus restores the energy levels of the different frequencies to their original distribution.

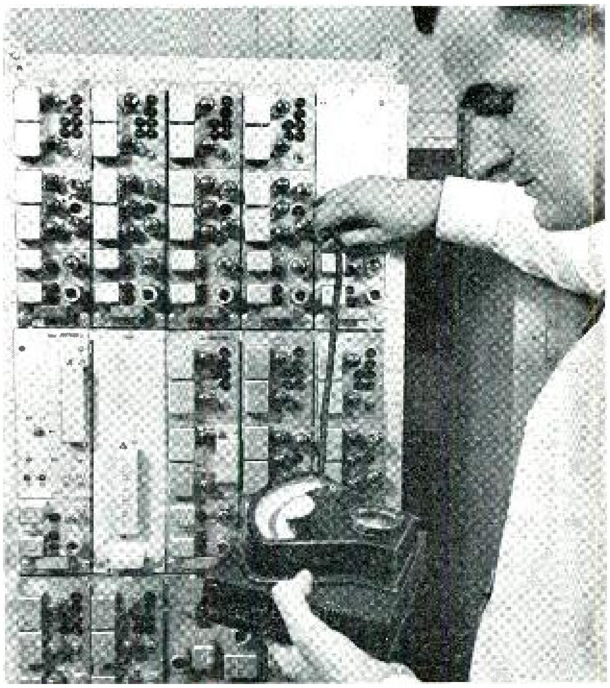


Fig. 5 — G. J. Nixon checking rectified current of received-carrier reversing signal. Schedule A unit is seen on the middle left of the frame.

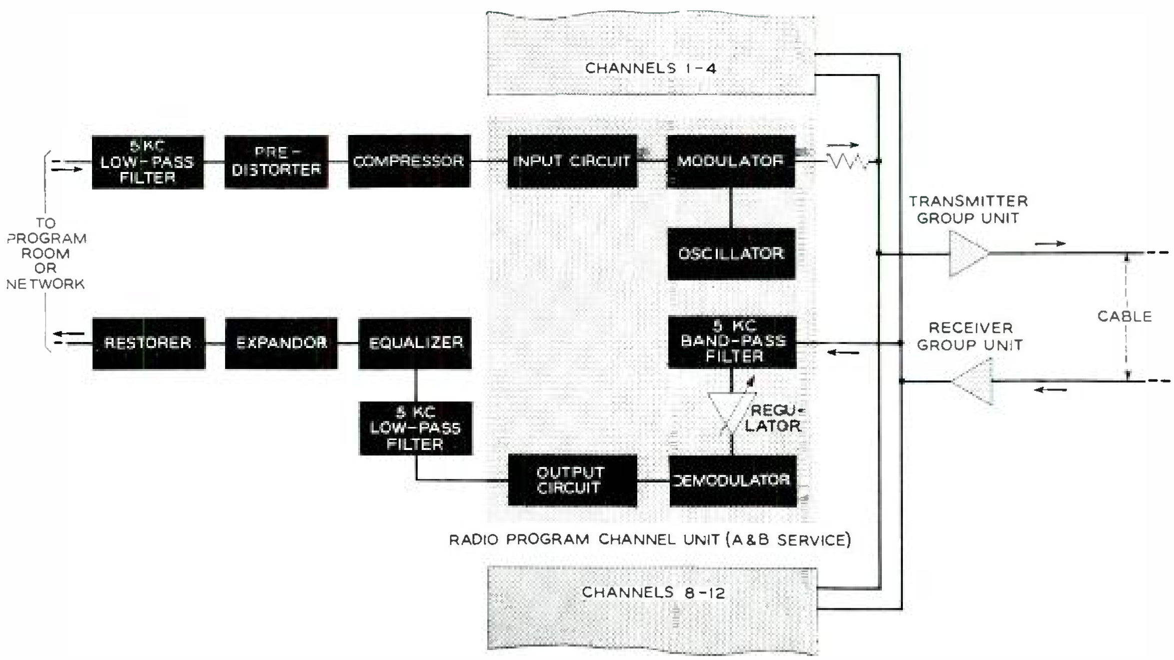


Fig. 4 — Block schematic of non-reversible radio program channel unit for schedules A and B service. The plug-in unit is shown in the central area with other components to the left.

As already noted, schedule A or B service requires that three telephone message channels be removed from service, because of the 5,000-cycle frequency range. This program unit also requires a different carrier subassembly than that used for regular message service. For these reasons, the 5,000-cycle unit is limited in its location in the N1 carrier band. To achieve the best conditions so far as cross-talk, noise, and transmission are concerned, the program unit is "centered" on channel number 6. The double sidebands extend into channels 5 and 7, but leave about three kilocycles on the upper and lower ends of the frequency spectrum. This remaining space in Channels 5 and 7 is used to gain separation between the program and message channels.

In a third type of program unit, part of this extra channel space is also used for a reversing signal. As already explained, the unit represented in Figure 4 is non-reversible. In any given radio network, it can be set up to transmit in one direction or the other, but it will not permit rapid switching between the two directions. This satisfies many network layouts, especially in the eastern part of the country, where the stations are usually "looped", or laid out in a circular manner. In the western section, however, between Chicago and the West Coast, stations are usually laid out along a single line. Since any one of these stations may become the origin of a radio program, it is necessary to provide a program unit that can be quickly changed, so that the program can be transmitted in either direction.

This third program unit will not be described in detail. Briefly, however, a special circuit is inserted in the vacated message channel 5 position for this reversing operation. This special circuit provides a 200-kc carrier frequency and a 200-kc detector for its reception. When personnel at the radio station must reverse the direction of transmission, they operate a key that sends a dc signal to the N1 carrier terminal. This signal operates relays that send out the 200-kc control signal over the system to the remote terminal. The control signal, when rectified, operates "program" relays that perform the necessary reversing action. At the end of the program, the dc signal is removed, and the circuit can then be reversed again by sending dc from the other direction.

In the transmission of a program, many precautions are taken in the circuitry of the system to ensure constant operation. Since a program may involve millions of listeners, great care must be taken to prevent failures and false reversal operations during a broadcast period. The N1 carrier system, with its program circuits, is designed to fulfill these requirements and to work efficiently in conjunction with other program transmission systems.

THE AUTHOR

A. V. Wurmser joined the Laboratories in 1923. His early work was in carrier development and he was also associated with the early experimental work on feedback amplifiers. Most of his Laboratories career has been concerned with circuit development and transmission measuring circuits. During World War II he worked on developments for the armed forces, including test equipment of spiral and cable carrier systems and underwater sound control and testing circuits. He later worked on transatlantic radio systems, the development of electronic circuits for the O carrier test equipment and application of program over the N carrier system. He is currently with a planning goup concerned with the development of new microwave systems for telephone and television. Mr. Wurmser received a B.S. degree from Cooper Union in 1931.

First Transatlantic Telephone Cable Scheduled to Start Operation in 1956

The first submarine telephone cable between the United States and Europe is expected to be in commercial operation by late 1956, four top-ranking British and American communications experts announced last month in a paper presented before the American Institute of Electrical Engineers in Chicago.

The new $35,000,000 transatlantic telephone system will be by far the longest underseas voice cable in the world and the first laid at depths found in mid-ocean. It will supplement radio circuits now in use and will have three times the present circuit capacity.

The paper, given before the international communications section of the Fall Meeting of the A.I.E.E., was authored by Dr. Mervin J. Kelly, President of Bell Telephone Laboratories, who presented the paper; Sir Gordon Radley, Deputy Director General of the British Post Office; George W. Gilman, Bell Laboratories Director of Systems Engineering; and R. J. Halsey, Assistant Engineer in Chief of the British Post Office. The cable will be jointly owned by the American Telephone and Telegraph Company, the Eastern Telephone and Telegraph Company, the British Post Office, and the Canadian Overseas Telecommunications Corporation.

A feature of the meeting was a recorded message from Dr. Oliver E. Buckley, former President and Chairman of the Board of the Bell Laboratories, now retired. Under his leadership, Bell Laboratories began its studies of deep-sea submarine cable shortly after World War I. Dr. Kelly said that "the concept of a transatlantic telephone cable owes its origin to the inspiration of Dr. Buckley's early work. He laid the firm technical foundation for such a project."

The transatlantic portion of the system to provide thirty-six high-grade telephone circuits between the United Kingdom, Canada and the United States, will be 2,000 nautical miles in length. It will be laid in depths up to three miles on the ocean floor between Scotland and Newfoundland and each of the two cables will contain fifty-two submerged repeaters. The longest submarine telephone cable with submerged repeaters now in use is less than 350 miles long and contains only seven repeaters.

The system will contain a group of telephone circuits between New York and London and another group between Montreal and London. At the gateway cities, the circuits will connect with the telephone systems of the respective countries.

Telephone conversations from the United States will be carried overland by microwave radio-relay from Portland, Maine, to Nova Scotia where the radio-relay route will connect with a 300-mile submarine cable to Newfoundland. The transatlantic portion of the cable will stretch from Clarenville, Newfoundland, to Oban, Scotland. The transatlantic circuits will be taken from Oban to London by carrier cable with alternative routes via Glasgow or Inverness and Aberdeen. In London, it will be possible to connect any transatlantic circuit to any one of the existing submarine cable circuits to the continent of Europe.

Development of the technical design for the deep-sea section of the cable project has been under way in Bell Laboratories for a number of years. Research by British telephone engineers has produced the design for the Newfoundland-Nova Scotia section of the submarine cable.

"With the completion of this project," Dr. Kelly said, "telephone service between the two continents should enter into a new era marked by improved quality of service and reliability and a capacity for growth no longer restricted by the limited capacity of the radio spectrum."

Dr. Kelly said that short-wave radio telephone service, first opened in 1927, would remain important and that the advantages of flexibility, the speed with which communications can be established and shifted from route to route, the feature of direct access from one country to another and relatively low cost could not be overlooked.

The new transoceanic cable will be of the coaxial type consisting essentially of a copper tube, through the center of which runs a single copper conductor, properly insulated from the surrounding outer conductor. High-molecular weight polyethylene is used for insulation.

The cables will be not quite two-thirds of an inch in diameter at the outer conductor. They will be protected against the teredo worm, a marine borer, by wrappings of copper tape. Outside this will be wrappings of heavy jute, steel armor wires for mechanical strength and an outer wrapping of jute to prevent corrosion of the armor wires. The deep-sea sections will be about an inch and a quarter in over-all diameter.

Dr. Kelly explained that a submarine cable presented a unique and highly complex problem in that the amplifiers, or repeaters, must lie on the floor of the ocean where they are subjected to pressures of several tons per square inch.

Repeaters, with their electron tubes and many associated parts, must attain an extraordinary degree of reliability and require no maintenance attention. The repeaters, in flexible, pressure-resistant housings shaped like tubes, will appear simply as bulges in the cable. This will permit them to be fed smoothly around the drums and sheaves of the cable ship "Monarch" so that the cable and repeaters can be laid on the ocean floor as a continuous operation.

Repeaters, spaced about forty miles apart, will each consist essentially of a three-stage feed-back amplifier, so that there will be more than 300 long-life electron tubes on the ocean floor with some 6,000 other electrical components, all designed for reliable, trouble-free operation for twenty years or more.

Electron tubes and other components, constructed or selected for reliability in service, have been under life test since 1940.

Electrical power to operate the amplifiers will be fed to them over the central conductor of each cable from the terminal stations on shore. This will require more than 2,000 volts at each end. The design of the terminal power plant will place special emphasis on current regulation, continuity of service and protection against power surges.

Dr. Kelly commented on the difficulties yet to be encountered in actually laying the cable. A period of twelve days with continuously good weather conditions is necessary to carry out the main operation. In the North Atlantic such conditions are unlikely except during the period mid-May to mid-September. One cable will be laid during the summer of 1955 and all cable-laying operations are scheduled to be completed in 1956.

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

Aamodt, T. — *Directional Transducer* — 2,686,847.

Albersheim, W. J. — *Signal Transmission System* — 2,686,256.

Biddulph, R. S., and Davis, K. H. — *Voice-Operated Device* — 2,685,615.

Bomberger, D. C., and Och, H. G. — *Plotting System* — 2,686,099.

Brewer, S. T. — *Telephone Set* — 2,686,844.

Brewer, S. T., and Bruce, E. — *High Speed Electronic Switching System* — 2,686,837.

Bruce, E., see Brewer, S. T.

Davis, K. H., see Biddulph, R. S.

Dehn, J. W. — *Translator* — 2,686,838.

Domaleski, J. V., Gartland, E. L., and Kleimack, J. J. — *Semiconductor Translating Device* — 2,688,110.

Edson, W. A., and Wilson, I. G. — *Constant Q Resonators* — 2,688,122.

Feder, H. S. — *Corona Shielding Insulation* — 2,686,904.

Ferrell, E. B. — *Motor Control Circuit* — 2,686,271.

Fondiller, W. — *Isothermal Electric Cables* — 2,686,215.

Gabel, W., and Weltert, J. — *Paper Sheet Feed and Tensioning System* — 2,686,012.

Gartland, E. L., see Domaleski, J. V.

Holden, W. H. T., and Morton, E. R. — *Fault Signaling System for Counting Chain* — 2,685,683.

Kleimack, J. J., see Domaleski, J. V.

Lakatos, E., and Och, H. G. — *Curved Course Predictor* — 2,686,636.

Morton, E. R., see Holden W. H. T.

Och, H. G., see Bomberger, D. C.

Och, H. G., see Lakatos, E.

Ohl, R. S. — *Translating Material and Method of Manufacture* — 2,685,728.

Pferd, W., and Prescott, R. E. — *Parallel Pivot Type Speed Responsive Brake* — 2,685,946.

Phipps, G. S. — *Wiped Joint* — 2,685,893.

Prescott, R. E., see Pferd, W.

Reichle, W. E. — *Radio Telephone Communication Station* — 2,686,257.

Shafer, W. L., Jr. — *Call Distributing Service Desk* — 2,686,843.

Tillotson, L. C. — *Microwave Branching Arrangement* — 2,686,902.

Weltert, J., see Gabel, W.

Wilson, I. G., see Edson W. A.

Metals with Whiskers

S. M. ARNOLD *Chemical Research*

That telephone research leads to fundamental contributions to science is nicely illustrated by recent work on metals with "whiskers." These tiny metal growths appeared on channel filters, and were studied to eliminate equipment failures. Their use in the investigation of plastic deformation in metals will be the subject of later RECORD articles.

When a single telephone line or coaxial cable is used for several simultaneous talking and video circuits, filter networks are employed to accomplish the necessary separation of channels. In effect, these networks divide the frequency spectrum into bands and maintain each channel within its assigned band.

Because of the vital part played by these channel-frequency filters, extreme care is devoted to their assembly, and any trouble developing in a filter network after installation calls for emergency action. Consequently, a rapid diagnosis was required when trouble of an unknown nature recently developed in filters that had been in service in a broadband carrier system for less than a year.

Examination of one of the filters from the field disclosed no failure of any of the component parts, but it was noted that a number of lint-like particles were lodged on the surface of a small mounting bracket, as shown in Figure 1. The particles were extremely fine and were highly reflective to light. One or two actually spanned a gap of approximately 3/16 inch between the bracket and the post of an air capacitor. Removal of the lint-like filaments restored the filter to operating condition.

There appeared to be three possibilities as to the identity of the filamentary material: lint or fibrous organic matter that had been deposited on the bracket surface despite the precautions taken in the assembly of the filter; a fungus growth that had developed subsequent to sealing the filter container; or a corrosion product of the thread-like type frequently encountered on metal surfaces in the presence of organic finishes.

Further examination quickly ruled out lint or fungus and left a corrosion product as the most likely possibility.

Since the offending material seemed to be associated with the zinc-coated bracket, a number of steel specimens were electroplated with zinc, Figure 3, and exposed to an atmosphere of high relative humidity in the presence of organic material. In six months a number of filamentary protuberances similar to those noticed on the filter brackets were found among the normal corrosion products.

Additional specimens, including the most commonly used electroplated metals, were exposed at various relative humidities and temperatures, both in the presence and in the absence of organic material. Again after some months, the filaments were found not only on zinc but also on cadmium-plated and tin-plated steel. It was observed, however,

Above — The author assembling a rack of metal specimens previous to growth of whiskers.

that neither high relative humidity, elevated temperature, nor the presence of organic matter was necessary to develop the characteristic surface condition. This indicated that corrosion as normally encountered was not the cause of the trouble.

The next step was an attempt to determine the actual composition of the filamentary material. The filaments were so small – most of them in the neighborhood of 80 millionths of an inch in diameter and less than 1/16 inch in length – that chemical analysis could not be applied without the isolation of a large number of filaments.

The spectroscope* gave a partial answer regarding the composition of the material, after a number of filaments were laboriously collected from one of the zinc-plated filter brackets. To avoid contamination, tweezers fashioned from a glass fiber were used to remove the filaments individually.

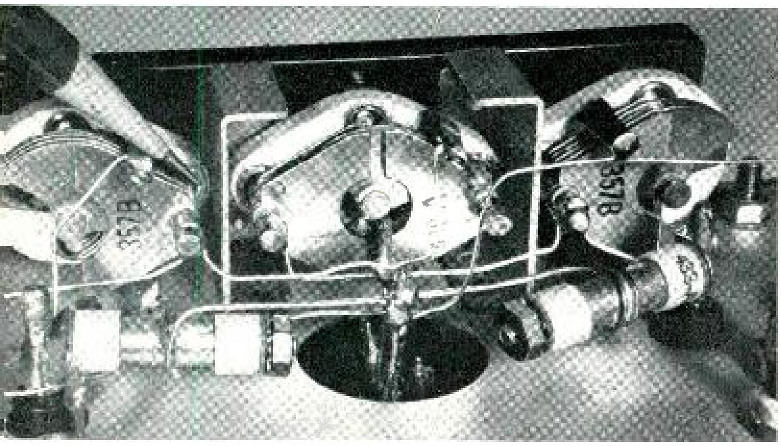


Fig. 2 — Channel filter of sort that encountered trouble because of whisker growth. Pencil shows gap where whisker formed.

The spectroscope indicated that the removed material was mainly zinc. This still left the question whether we were dealing with zinc or one of its compounds. Because of their appearance and electrical conductivity, however, it was suspected that the filaments were actually metallic.

The X-ray diffraction camera* was used to determine this point. One of the filaments that had been removed from the zinc-coated filter bracket was exposed in the camera for a period of some eighteen hours and its diffraction pattern obtained. The pattern indicated that the material causing the trouble consisted of single crystals of metallic zinc. The X-ray study thus explained why the filaments possessed their high reflectivity and low electrical resistance but did not establish their source.

* Record, *December*, 1953, *page* 470.

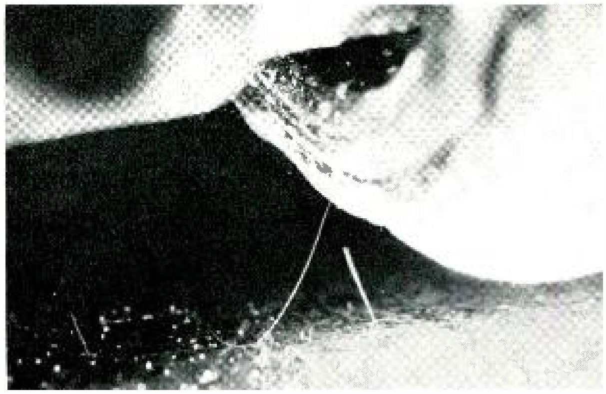


Fig. 1 — Whisker bridging 3/16 inch gap between bracket and capacitor post.

The electron microscope shown in Figure 4 supplied a clue. A plated steel ring with a 20-mil diameter hole was mounted in the microscope, and by making some 160 overlapping electron-micrographs, a complete record of the silhouette of the periphery of the hole was obtained at a magnification of 2,550 diameters. At intervals the ring was re-examined, and finally a change was noted in one area – a tiny (even at the 2,550 diameters magnification) "hair" was found which was not present in the original picture of the area. Subsequent examinations at monthly intervals revealed that the "hair" was actually growing longer. Further, it was noted that the tip

* Record, *November*, 1953, *page* 428.

Fig. 3 — G. Bittrich preparing some of the metal specimens in the electroplating laboratory.

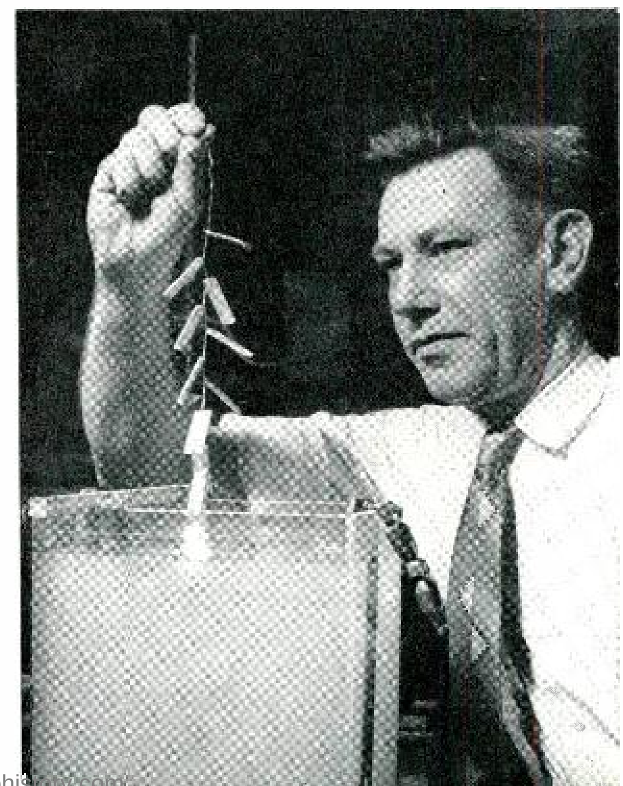


Fig. 4—Miss S. E. Koonce examining whisker growth in electron microscope.

end maintained its initial shape, as shown in Figure 5. New material was evidently accreting at the base. This method of growth thus contrasts with that of a tree, the form of whose top continually changes.

The study was then expanded to determine whether other metals exhibited this tendency to develop filamentary growths or "whiskers", as they were now commonly being called. Some 2,000 specimens, including both solid and plated metals, are under test at present, exposed under various environmental conditions. In this study, the time factor cannot be overlooked. Whiskers have been found on some specimens only after a period of exposure of more than three years; other growths may require even longer periods before they appear.

It is known that metals other than zinc, cadmium, and tin will develop whiskers under certain conditions, but of greatest concern to the Bell System, at the present at least, are the metals zinc and tin. Both of these are used in large quantities in the form of electroplated coatings, either for corrosion protection or for improved solderability.

Methods aimed at prevention of whisker growth on such metals, as well as methods for removal of growths from equipment already in trouble, are under study. Thus, while it is possible to make some of the channel filters operative by application of an electrical potential high enough to burn off the whiskers,* this method cannot be applied in all cases because of danger to circuit elements. Further, only the whiskers actually making contact are affected. Those which have not grown sufficiently to form a short-circuiting bridge between two conductors will not be removed when the voltage is applied, and thus will remain as a potential cause of trouble.

To specify an alternative metal or metallic coating for components to be used in a sensitive electrical circuit, there must be assurance that whiskers will not develop on the metal surfaces even after an extended period of time. To be able to predict with certainty that such growth will not take place, the actual mechanism of whisker growth must be established.

Why the whiskers form at all has yet to be satisfactorily explained. Environment apparently does not play a decisive role, since whiskers recently have been grown in an evacuated container in which the gas pressure was of the order of 10^{-8} mm of mercury. Temperature does have an effect, and the optimum temperature for growth, at least in the case of tin-plated surfaces, is apparently in the neighborhood of 125 degrees F. Unfortunately, because of proximity to electron tubes and other heat-dissipating units, this is in the very temperature region where much communication equipment operates. It is known also that pressure will greatly influence the rate of whisker growth. A pressure of from 2,000 to 3,000 pounds per square inch applied to test specimens has produced, in a matter of seconds, growths equal in length to those normally requiring several months when specimens are exposed under atmospheric pressure. Purity of the metal, the character of the substrate or underlying metal, the thickness of an electroplated coating, and a number of other factors also are known to affect the tendency to develop whiskers, and these must eventually be fitted into a satisfactory picture of what is happening. At present, too many questions remain unanswered to see clearly the mode of whisker formation.

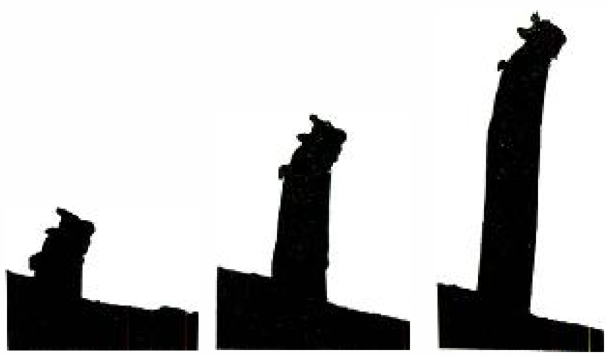


Fig. 5—Stages of growth of whisker, illustrating accretion at base. Tallest stage 0.0012 inch long.

* RECORD, *June*, 1951, *page* 262.

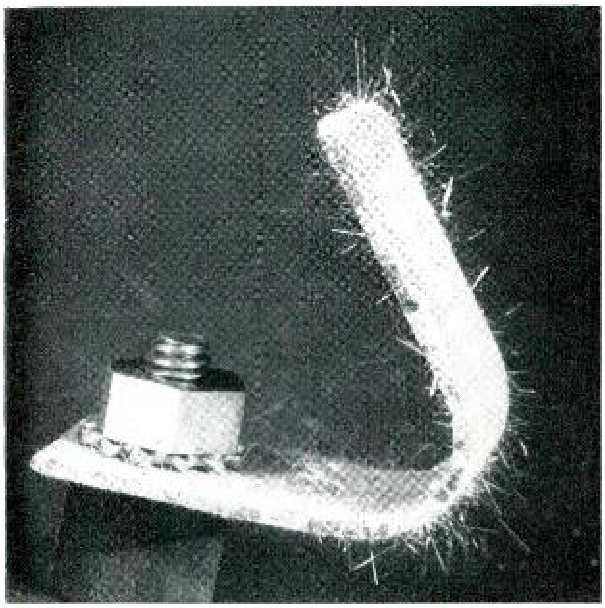


Fig. 6 — Photograph of tin-plated specimen showing whiskers. Magnification about six diameters.

The necessity for a clearer understanding of the conditions conducive to whisker growth is in line with the very practical requirement of closer and closer spacings in miniaturized unit assemblies. A gap of ⅜ inch between parts is not sufficient to insure trouble-free operation, since whiskers have been grown longer than this. Likewise, the mere application of a supplementary coating, such as a lacquer, will not avoid trouble. Whiskers apparently penetrate such a film with ease.

While whiskers have not been recognized as a major problem until rather recently, examination of old undisturbed equipment of Western Electric Company manufacture has disclosed that whiskers are present on many of the zinc-plated parts. Nor are whisker growths unique with the Bell System. Equipment produced by other manufacturers has been examined and found to have whisker complements on the metal surfaces. Many manufacturers may be plagued with this problem but as yet are not aware of its existence.

Thus the presence of a little fuzz on a metal surface turns out to be more than a matter of casual interest. Because of the knowledge of the whisker-growth tendencies of some metals, for instance, the designers of certain components of the new trans-atlantic submarine cable have substituted gold plate for the tin plate originally specified. Other equipment, including assemblies for the armed forces, has been redesigned using alternative materials to avoid the possibility of operational failure at a critical moment due to the presence of a tiny "whisker".

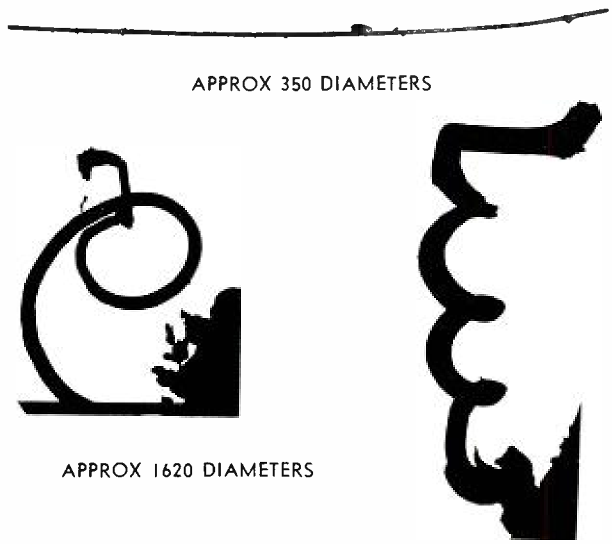
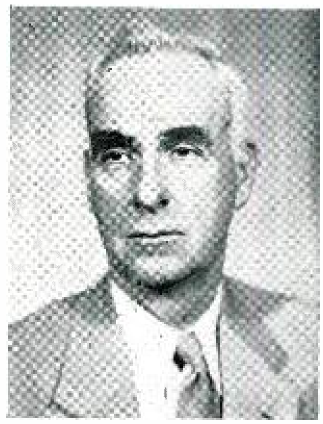
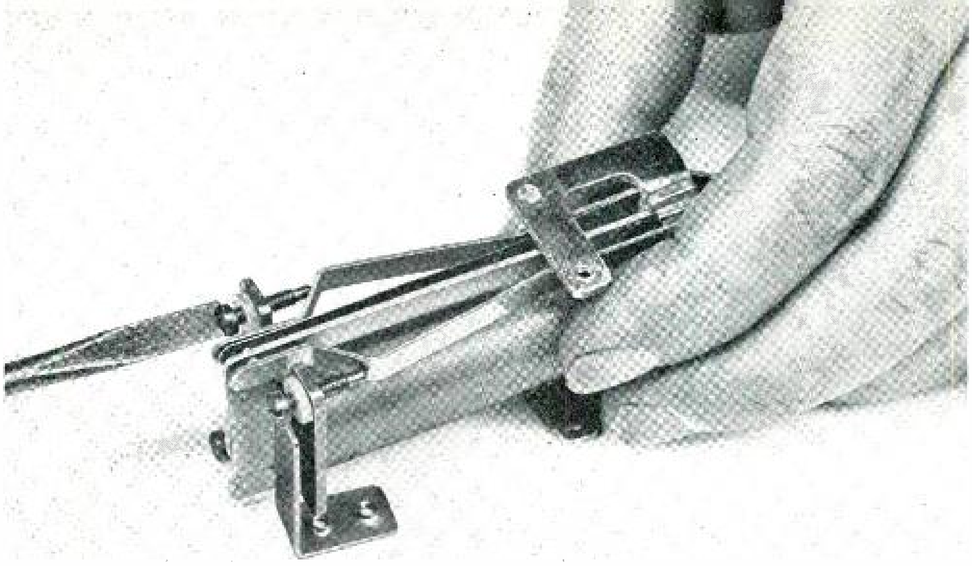


Fig. 7 — Three of many shapes of whiskers discovered, as photographed in electron microscope.

THE AUTHOR



Sydney M. Arnold received a B.S. degree in chemical engineering from Cooper Union in 1925 and his M.A. degree from Columbia University in 1934. He joined the Laboratories in 1928 and until 1941 he was in the analytical and microchemical laboratories. From 1941 to 1947 he was in the apparatus development group, where he was concerned with the use of materials and with lubrication problems. Since then he has been in the corrosion and finish group where he has concentrated on studies relating to the growth of "whiskers" on metal surfaces. Mr. Arnold is a member of the National Association of Corrosion Engineers.



Improved Design of B-Type Relay

F. A. ZUPA *Switching Apparatus Development*

In the early days of common battery telephone systems, supervisory relays were of the tubular magnet type similar to the line relays of that day. When flat, punched-type line relays were introduced, development work began on a similar punched-type design of supervisory relay, resulting in the B-type that has served faithfully for almost half a century. Despite the introduction of many new relay designs, this type continues to resist efforts to replace it, and recent improvements in its design and construction appear to establish even more firmly its place in the Bell System.

As its code letter indicates, the B-type relay is one of the oldest flat-type relay designs in use in the Bell System. It was introduced about forty years ago to fill the need for a low cost sensitive supervisory relay in the manual telephone system. Although telephone systems have grown and expanded, and new relay designs have come into use, the old B-type design has withstood the challenge of new relays to replace it. Its production rate has also increased, and in 1952 exceeded 1,500,000.

This growth in manufacture and use has not been trouble free, however, because the B-type relay structure is quite sensitive to mechanical strain and therefore likely to suffer changes in its adjustment during manufacture and subsequent handling in shipment. The relative frailness of its structure is the underlying cause of its instability, and it was found necessary to counteract this with readjusting procedures before the equipments using these relays could be delivered for installation.

Considerable effort has been applied to improve the design. It is now believed that the structural weakness of this relay has been eliminated, and simple changes are being made which give good promise of obtaining adequate stability of adjustments without affecting its interchangeability in existing equipments. The economic value of maintaining complete interchangeability directed these efforts toward modifying the existing B-type relay design rather than to undertake the more expensive program of developing a new relay to replace it. Figure 1 shows a comparison of the old and new.

The mechanical weakness of the old structure was not the result of an oversight on the part of the original designers. The relay core had to be small in cross-section because, for circuit reasons, the coil inductance and the magnetic residual forces must be small in value. The core had to be made long in order to provide the large space needed for the relay winding to permit it to operate on only a few milliamperes. Besides, the adjustment of the position of the armature relative to the core pole face and the adjustment of the contact spring load acting on the armature, are required to be extremely fine – so much so that, as shown in the headpiece, only the cam action of a screw acting on the inclined surface of a stiff flat spring provided a practical way of making the adjustment. The circuit requirements for a large number of relays of this type are such that a change of only one gram in the load acting on the armature is serious enough to cause failure to meet the operate and release requirements.

A critical analysis of the existing B-type relay design to determine the causes of changes in adjustment disclosed several characteristics which are responsible for changes in adjustment. One of these is illustrated in Figure 2. The distortion that takes place when the screws are tightened to secure the cover affects the alignment of the armature, core,

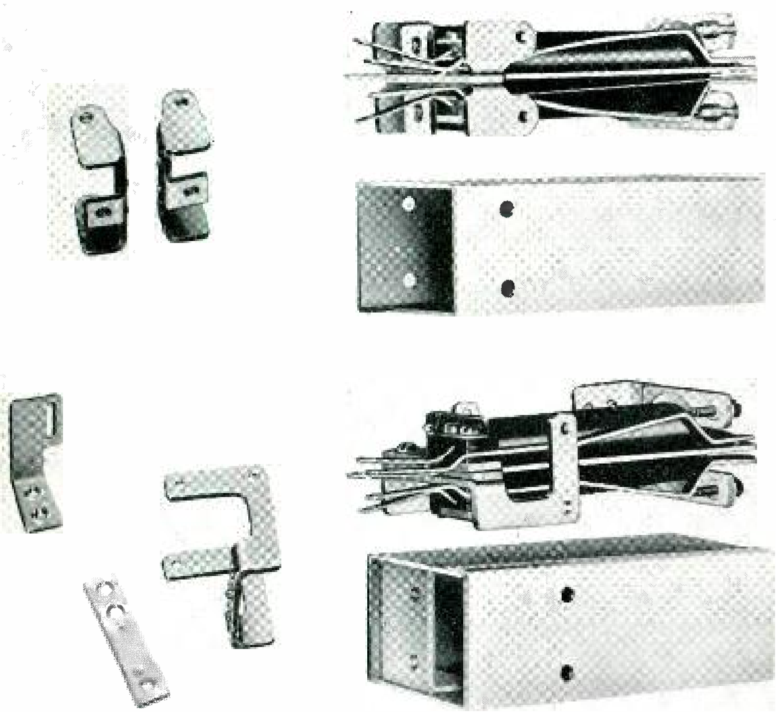


Fig. 1 — Comparison of the old (above) and modified B-type relays. The new comparatively flexible core brackets, shown at the lower left, replace the old rigid type. The right angle bracket is the new support for the front of the core.

and contact springs. Precision fits of the various parts would, of course, avoid the distortion, but the resulting cost would be prohibitive. It became evident, therefore, that the remedial change should be to modify the bracket design. This was accomplished by replacing the two brackets by a single bracket having two flexible L-shaped legs that can conform to the variable size of the cover. The differences between the brackets are shown in Figure 1.

Another modification concerns the method of mounting the relay on the relay rack mounting plate. In the old design, the relay is mounted by two lugs, one on each bracket. These lugs are seldom in exact alignment, and when the relay mounting screws are tightened, the lugs are distorted to conform to the mounting plate, with resulting distortion to the spring pile-up assembly. By replacing the two mounting lugs with a one piece bracket welded to the cover, Figure 1, practically no distortion is transmitted to the relay structure during installation.

The relay core is, in effect, a weak cantilever beam, unsupported at its front end, and the large mass, consisting of the coil and adjusting plate, represents a heavy load upon the core. Calculations and test results proved that the core cannot support this load under the normal shocks encountered during handling of equipment using these relays, without permanent deformation. It has also been observed that even a slight deformation in alignment of the core causes a change in the operation of the relay. Bending of the core results in a displacement of the adjusting screws with respect to the contact springs, and also changes the effective air-gap magnetic reluctance. Shocks resulting from normal handling or in shipment cannot be absorbed or dissipated without costly packaging, so it was deemed expedient to provide a support for the front end of the core.

Several means of supporting the front end of the core were analyzed. Those which rigidly attach the adjusting plate to the cover, or which attach a bracket rigidly between the core and the cover were quickly discarded because these means were found to introduce stresses in the assembly that would be subject to change with shock and vibration. The final choice was the use of a simple motion-limiting bracket as shown in Figure 3. The rectangular slot in this bracket is made slightly larger than the section of the pole face end of the core, this slot permitting slight movements of the core but not enough to result in permanent displacement of the core.

Adjustments of the contact springs are made by the use of special screws having a spherical surface on the end that bears against the inclined plane surface of the contact spring and the armature tension spring. The position of these springs determines the armature travel and armature load, thus making it imperative that these screws maintain their adjusted positions. In the old B-type relay design, slotted tapped holes in the front adjusting plate were used to hold the adjusting screws in their adjusted positions. This design required that each adjusting plate be squeezed to close up the tapped holes sufficiently to obtain a tight fit for each adjusting screw. The resulting alignment and stability of the screws were sometimes questionable. Improved axial stability of these screws has been obtained in the new design by supporting them in molded nylon bushings, in which the screws cut their own threads and thereby obtain a relatively tight fit. In addition, the number of screw threads supporting the screw has been in-

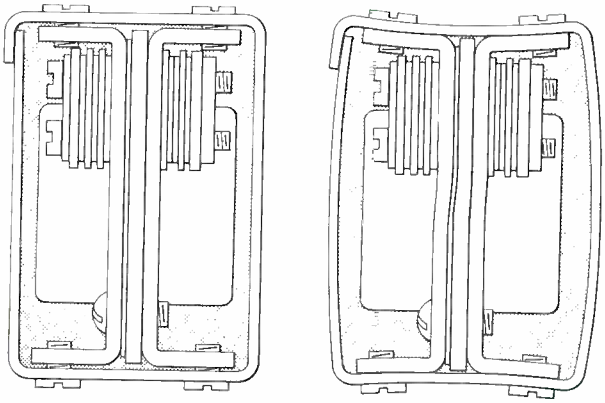


Fig. 2 — Distortion that affects the relay adjustment occurs when the screws are tightened to secure the cover to the old relay.

creased from about 2½ in the old design to about 6 in the new.

Each relay is equipped with two contact springs that have dual purposes — to carry the electrical contacts and to act as front and back position stops for the armature. For stability, therefore, these springs are made of relatively heavy-gauge stock. On some relays, and as illustrated in Figure 1, the front contact is placed on a very flexible spring which can move after the armature makes contact with it. This is done to improve reliability of contact operation.

On the old design, the heavy springs have to be tensioned to bear firmly against the adjusting screws by bending them manually. In so doing, the relay

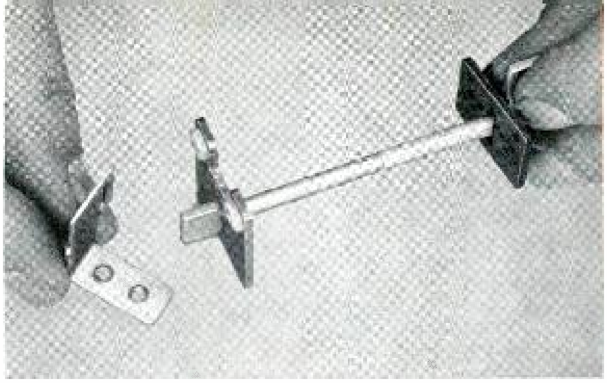


Fig. 3 — The motion limiting bracket on the left fits over the pole face end of the core, and is subsequently fastened to the cover by means of screws.

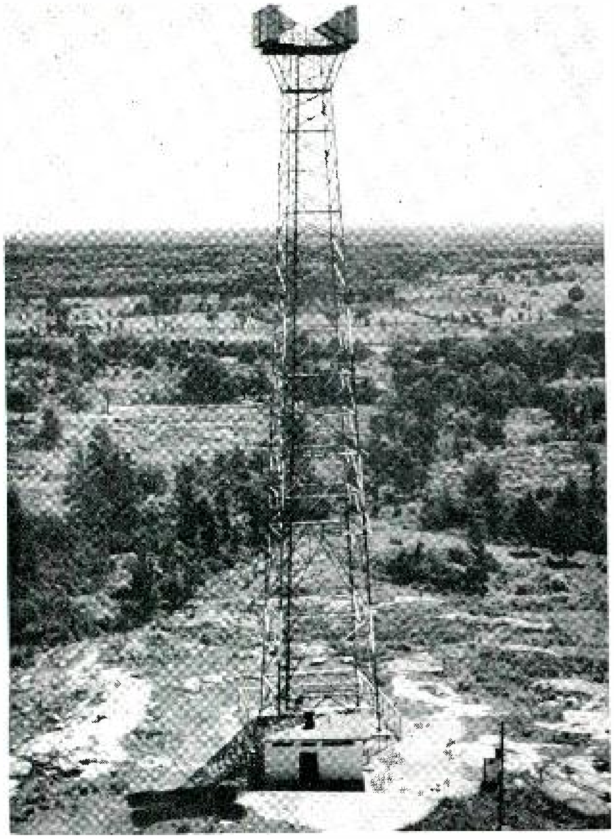
structure is subjected to distorting stresses. On the new design, however, these same springs are preshaped so as to provide the desired tensions without manual bending.

Separate transmission circuits frequently appear on adjacent B-type relays, with the result that protection against crosstalk between these circuits is needed. This protection has been accomplished by means of an iron cover. In this investigation, it was found that the cover, a rather costly rectangular tube, could be replaced by a formed sheet iron cover, annealed when required for better magnetic permeability, at a considerable reduction in cost.

It is too early to evaluate the over-all gains of the modified B-type relay. However, test results have indicated that definite improvements in stability of adjustments have been obtained and that the troubles experienced with the older design will be greatly reduced. These improvements have been gained at little increase in manufacturing cost of the relay assembly; the principal gain has been in the reduction in adjusting costs, so that the increase in manufacturing cost is more than offset by the substantial saving in readjusting effort. Besides, the reduction in maintenance effort by the Telephone Companies is expected to be considerable during the service life of the improved relays.

THE AUTHOR

Frank A. Zupa started in the Physical Laboratory in 1918 while attending C.C.N.Y. at night. He was engaged in the testing of apparatus and materials, including photomicrograph work, for about six years. He then transferred to the Apparatus Department where he was engaged in design and development work on many types of relays, particularly in the design of the U, Y and UA types of relays. During the war, Mr. Zupa carried out the "packaging" and manufacturing information work for the optical proximity fuse and the laboratory testing of the magnetic mine mechanism. Presently he is in charge of the group concerned with message registers and also with relays. Mr. Zupa was graduated from Cooper Union in 1922 with a B.S. degree in E.E.



Growth of TD-2 Radio Relay

This antenna tower in Ontario, Canada, is part of the TD-2 system supplying American network television to several large Canadian cities.

Since its inception, microwave radio relay has been a rapidly expanding part of the long-distance communication network of the Bell System. The first microwave radio relay system installed in the Bell System was between New York and Boston. This experimental TD(X) application consisted of seven repeater stations and two terminals. It was essentially a full-scale field trial to evaluate, under actual operating conditions, the economic and technical aspects of radio relay circuits for broad-band services.

Four channels, two northbound and two southbound, operating in the band between 3,900 and 4,200 mc, were installed between 32 Avenue of the Americas in New York and the Bowdoin Square building of the New England Telephone and Telegraph Company in Boston. This equipment was placed in television program service during November, 1947. During the opening ceremonies the coaxial facilities between New York and Washington, D. C., were added to the microwave circuit between New York and Boston. Officials of the Federal Communications Commission and the Chesapeake and Potomac Telephone Company in Washington conversed with officials of the Long Lines Department of the American Telephone and Telegraph Company in New York and the New England Telephone and Telegraph Company in Boston. These TD(X) installations have since been replaced with TD-2 equipment.

The TD-2 microwave radio relay system operates in the band of frequencies between 3,700 and 4,200 mc and can provide up to twelve channels (six in each direction) along a route, each 20 mc wide, with guard bands of 20 mc between channels. Each channel can accommodate one television program, and two channels (one in each direction) can provide 600 telephone circuits. TD-2 was designed to meet the requirements of a transcontinental radio relay system with repeater stations spaced about 25 or 30 miles apart.

During the ceremonies marking the opening of transcontinental radio relay on August 17, 1951, a telephone call was looped back and forth across the continent so that voices were clearly heard over a distance slightly greater than the earth's circumference at the equator – the longest distance that the human voice has ever traveled by telephone. Television network facilities daily handle programs between the most distant cities in the United

States and Toronto, Ottawa, and Montreal in Canada via radio relay.

Since first placed in service for television program and telephone transmission, TD-2 has expanded at an ever-increasing rate. The accompanying map shows the principal existing routes and those proposed for installation soon. A second transcontinental route is indicated between Oklahoma City and Los Angeles.

While taking its place among modern technical achievements, TD-2 has participated in the televising of many history-making events such as the Japanese Peace Treaty Conference, political conventions and elections, the British Coronation, sports events, the Presidential Inauguration, and other world news events.

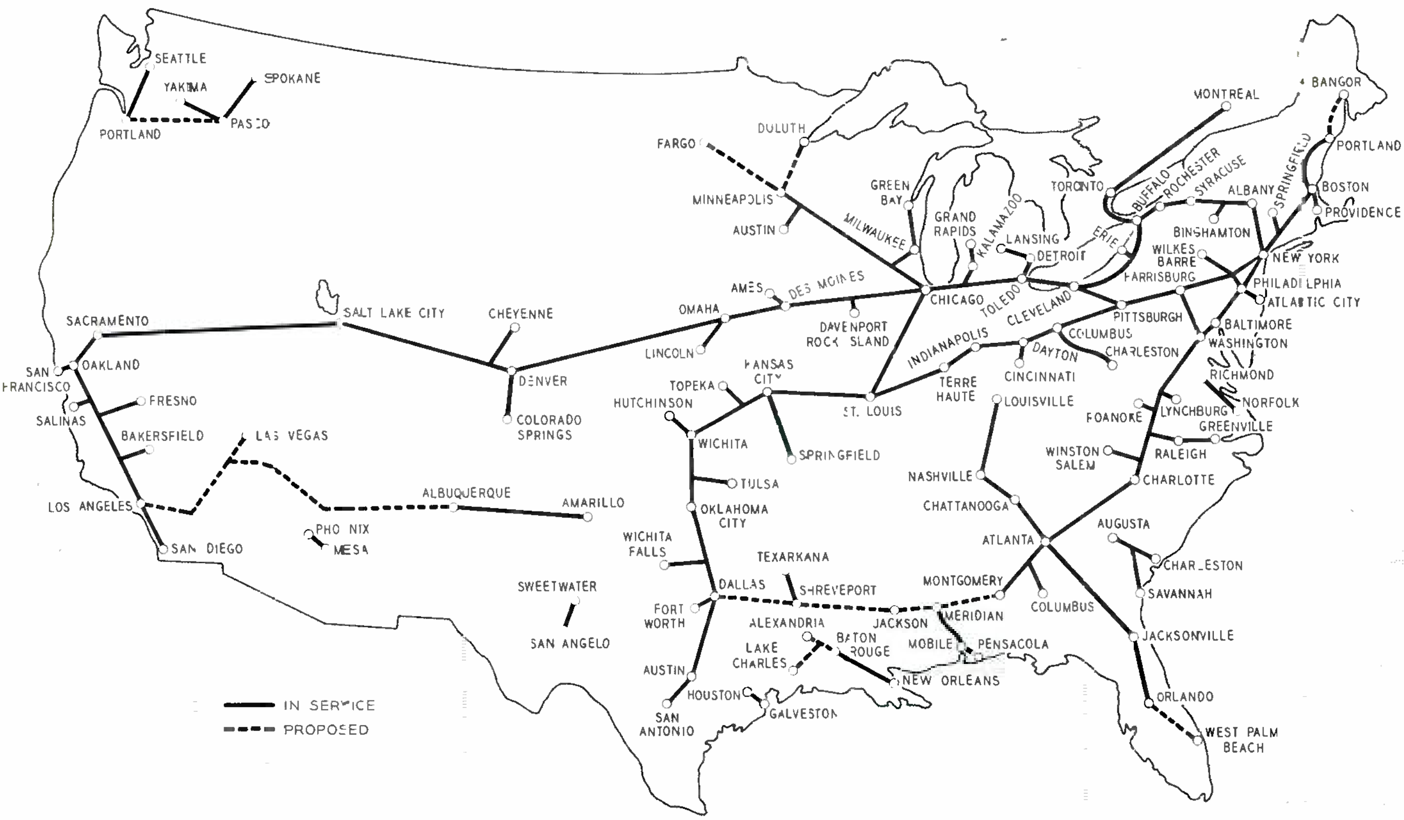
A total of 472 TD-2 radio relay stations were in operation as of September 1, 1954. Through these and other TD-2 facilities added since, television programs are made available to 309 stations in 198 cities with a potential audience of 110,000,000. Some 5 million miles of telephone circuits are now in use on radio relay. This is equivalent to about 13 per cent of the total telephone circuit mileage that is used in the Bell System.

Transmission of color television programs is being handled by TD-2 with suitable modifications. Recent development work has made available automatic switching to substitute a standby channel for one encountering trouble. This feature will further enhance the reliability of service, and provide greater flexibility for maintenance operations.

Additional know-how derived from accumulated operating experience, together with continued development effort on the part of the Laboratories, tends to keep TD-2 abreast of the ever-increasing demands for television program and telephone-circuit transmission via microwave radio relay.

W. L. Tierney

Transmission Systems Development I



TD-2 routes in service and proposed as of September, 1954. Many of these cities are also interconnected by coaxial cables, not shown on this map

Papers Published by Members of the Laboratories

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

Alsberg, D. A., Transistor Metrolog, Trans. I.R.E., Professional Group in Electron Devices, ED-1, **3**, Aug., 1954.

Anderson, P. W., Mathematical Model for the Narrowing of Spectral Lines by Exchange or Motion, Phys. Soc. Japan J., **9**, pp. 316-39, May-June, 1954.

Becker, J. A., The Life History of Adsorbed Atoms, Ions, and Molecules, Annals of the New York Academy of Sciences, **58**, pp. 723-740, Sept. 15, 1954.

Bommel, H. E., Ultrasonic Attenuation in Superconducting Lead, Letter to the Editor, Phys. Rev., **96**, p. 220, Oct. 1, 1954.

Bond, W. L., Notes on Solution of Problems in Odd Job Vapor Coating, J. Opt. Soc. Am., **44**, pp. 429-38, June, 1954.

Bonner, A. L., Servicing Center for Short Haul Carrier Telephone Systems, A.I.E.E. Commun. and Electronics, pp. 388-396, Sept., 1954.

Bozorth, R. M., see Nesbitt, E. A.

Brattain, W. H., and Garrett, C. G. B., Surface Properties of Germanium and Silicon, Annals of the New York Academy of Sciences, **58**, pp. 951-958, Sept. 15, 1954.

Bullard, W. R., Hays, J. B., and Saunders, H. O., Electrical Protection of Telephone Systems A.I.E.E. Commun. and Electronics, pp. 385-388, Sept. 1954.

Calbick, C. J., Surface Studies with the Electron Microscope, Annals of the New York Academy of Sciences, **58**, pp. 873-892, Sept. 15, 1954.

Christensen, H., Surface Conduction Channel Phenomena in Germanium, Proc. I.R.E., **42**, pp. 1371-1376, Sept., 1954.

Danielson, W. E., see Pierce, J. R.

Devlin, G. E., see Schawlow, A. L.

Francois, E. E., see Law, J. T.

Fuller, C. S., Solar Battery, The Indicator, Special Convention Number, Sept., 1954.

Fuller, C. S., and Severiens, J. C., The Mobility of Lithium Ions in Germanium and Silicon, Phys. Rev., **96**, pp. 21-24, Oct. 1, 1954.

Garrett, C. G. B., see Brattain, W. H.

Geballe, T. H., and Morin, F. J., Ionization Energies of Groups III and V Elements in Germanium, Letter to the Editor, Phys. Rev., **95**, pp. 1085-6, Aug. 15, 1954.

Geller, S., and Wood, E. A., Crystal Structure of Rhodium Silicide, RhSi., Acta Cryst., **7**, pp. 441-443, May 20, 1954.

Hays, J. B., see Bullard, W. R.

Haynes, J. R., see Hornbeck, J. A.

Hornbeck, J. A., and Haynes, J. R., Decay in Photoconductivity Associated with Deep Electron Traps in P-Type Silicon, Phys. Rev., **94**, pp. 1437-1438, June 1, 1954.

Howard, R. C., see Savant, C. J.

Jacobs, O. B., Aurora Borealis – A Defense Problem, Wire and Radio Commun., pp. 10-12, Oct., 1954.

Kleinman, D. A., see Ryder, E. J.

Knapp, H. M., Better Designing for Automatic Production. Lower-Cost Telephone Relay Highlights, Automation, **1**, pp. 51-56, Sept., 1954.

Law, J. T., A Mechanism for Water Induced Excess Reverse Dark Current on Grown Germanium N-P Junctions, Proc. I.R.E., **42**, pp. 1367-1370, Sept., 1954.

Law, J. T., and Francois, E. E., The Adsorption of Gases and Vapors in Germanium, Annals of the New York Academy of Sciences, **58**, pp. 925-936, Sept. 15, 1954.

Lee, C. Y., Switching Functions on an *n*-Dimensional Cube, A.I.E.E. Commun. and Electronics, pp. 289-291, Sept., 1954.

Lewis, H. W., see Schawlow, A. L.

Logan, R. A., and Schwartz, M., Thermal Effects on Lifetime in Germanium, Phys. Rev., **96**, p. 46, Oct. 1 1954.

Maita J. P., see Morin, F. J.

Matthias, B. T., see Schawlow, A. L.

Morin, F. J., see Geballe, T. H.

Morin, F. J., and Maita, J. P., Electrical Properties of Silicon Containing Arsenic and Boron, Phys. Rev., **96**, pp. 28-35, Oct. 1, 1954.

Nesbitt, E. A., Williams, H. J., and Bozorth, R. M., Factors Determining the Permanent Magnet Properties of Single Crystals of Fe_2NiAl, J. Appl. Phys., **25**, pp. 1014-20, Aug., 1954.

Pierce, J. R., Social Uses of Science, Am. Scientist, **42**, pp. 646-650, Oct., 1954.

Pierce, J. R., Theorem Concerning Noise in Electron Streams, J. Appl. Phys., **25**, pp. 931-938, Aug., 1954.

Pierce, J. R., and Danielson, W. E., Minimum Noise Figure of Traveling-Wave Tubes with Uniform Helices, J. Appl. Phys., **25**, pp. 1163-5, Sept., 1954.

Pierce, J. R., and Tien, P. K., Coupling of Modes in Helices, Proc. I.R.E., **42**, pp. 1389-1396, Sept., 1954.

Read, W. T., Jr., Theory of Dislocations in Germanium, Phil. Mag., **45**, pp. 775-796, Aug., 1954.

Rigterink, M. D., Ceramic Cores for Deposited Carbon Resistors, Ceramic Age, 63, pp. 10-13, Jan., 1954.

Ross, I. M., see Ryder, E. J.

Ryder, E. J., Ross, I. M. and Kleinman, D. A., Electron Multiplication in Germanium at Low Temperature, Letter to the Editor, Phys. Rev., **95**, pp. 1342-3, Sept. 1, 1954.

Saunders, H. O., see Bullard, W. R.

Savant, C. J., and Howard, R. C., Multiplier for Analog Computers, Electronics, **27**, pp. 144-147, Sept., 1954.

Schawlow, A. L., Matthias, B. T., Lewis, H. W., and Devlin, G. E., Structure of the Intermediate State in Superconductors, Letter to the Editor, Phys. Rev., **95**, pp. 1344-1345, Sept. 1, 1954.

Schwartz, M., see Logan, R. A.

Severiens, J. C., see Fuller, C. S.

Smethurst, J. O., E-Type Telephone Repeaters (Digest), Electrical Engineering, **73**, p. 937, Oct., 1954.

Tien, P. K., see Pierce, J. R.

Tien, P. K., Focusing of a Long Cylindrical Electron Stream by Means of Periodic Electrostatic Fields, J. Appl. Phys., **25**, pp. 1281-1288, Oct., 1954.

Vogt, E., and Wannier, G. H., Scattering of Ions by Polarization Forces, Phys. Rev., **95**, 1190-1198, Sept. 1, 1954.

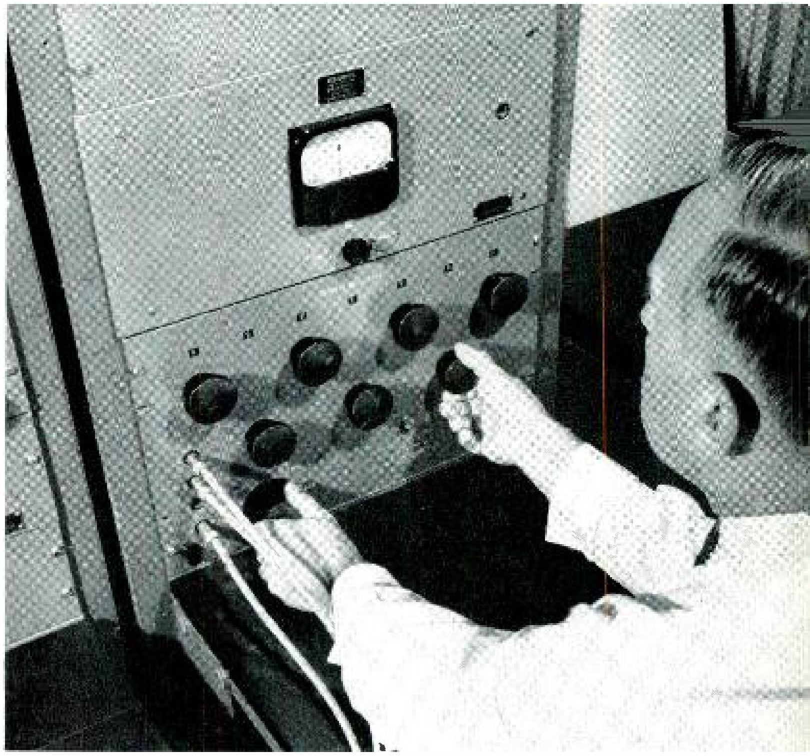
Wannier, G. H., see Vogt, E.

Williams, H. J., see Nesbitt, E. A.

Wolff, P. A., Theory of Electron Multiplication in Silicon and Germanium, Phys. Rev., **95**, p. 1415, Sept. 15, 1954.

Wood, E. A., see Geller, S.

A Comparator for Precise Transfer Conductance Measurements



C. H. YOUNG *Transmission Development*

Modern electronic techniques for both military and civilian applications are called upon to perform increasingly complex tasks quickly and accurately. Individual circuits must therefore be designed more and more precisely. To insure that the required precision has been attained, instruments that are capable of measuring the electrical characteristics of various circuits with an even higher order of precision are essential. A transfer conductance comparator developed at Bell Telephone Laboratories makes it possible to measure one set of these characteristics far more precisely than with any other available apparatus.

Many military electronic systems, such as those in modern gun and guided missile directors, include groups of "T" networks (Figure 1) connected in parallel. Since these systems must be designed to operate with a specified high degree of accuracy, it is necessary that the electrical properties of the component networks be known precisely.

One of the conditions required in the circuits is that the direct-current transfer conductance of each component T network in a group be precisely related to that of all the others. The transfer conductance, G, of a network can be defined as the short circuit output current divided by the potential difference across the input terminals as shown in Figure 1. The apparatus described in this article has been designed to compare this transfer conductance in two T networks with a precision of one part in 10 million. Although accumulated errors make a complete system fall short of this precision, the basic elements must be constructed as accurately as is economically feasible to provide adequate over-all performance.

Prior to the development of this apparatus, transfer conductance ratios could be measured with a precision of one part in a million. The process, however, employed only passive elements, and required considerable skill and patience on the part of the operator. Moreover, external conditions including ambient temperatures had to be completely and carefully regulated. The new comparator, using active as well as passive components, does not require control of ambient conditions beyond that furnished by ordinary room air conditioning. With this apparatus, conductance ratios can be measured about ten times more precisely than was previously possible, and the measurements can be made quickly and accurately by relatively untrained personnel.

If two T networks of the type shown in Figure 1 are connected as indicated in Figure 3, the transfer conductances can be compared. In this diagram, the two voltages E_1 and E_2 have opposite polarity, and it is assumed that they can be adjusted to any desired ratio. The two conductances are then given by the relations:

$$I_1 = E_1 G_1 \qquad (1)$$
$$I_2 = E_2 G_2$$

If the values of E_1 and E_2 are adjusted to a point where the potential at (1) in the figure is equal to the potential at (2), no current will flow through the detector, D. Under these conditions, I_1 is equal to I_2, and equations (1) can be expressed as

$$\frac{G_1}{G_2} = \frac{E_2}{E_1} \qquad (2)$$

In this way, a knowledge of the ratio of the impressed potentials will yield the desired conductance

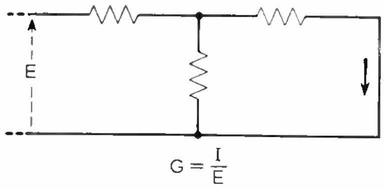


Fig. 1 — Basic T network with the short-circuit output current and the input potential indicated.

ratio. The precision with which this measurement can be made, however, depends on the accuracy with which the potentials can be measured, and the sensitivity of the detector. Since sufficiently sensitive detecting instruments are available, the design of a satisfactory conductance comparator depends on devising a method of supplying the potentials E_1 and E_2 in such a way that the ratio of their values remains independent of small changes in supply.

In recent years, direct current feedback amplifiers with high gain characteristics have been developed to the point where they can be used as precision instruments. A special amplifier of this type was designed to supply the required potentials in this transfer conductance comparator. By using this amplifier in conjunction with a voltage divider consisting of the resistors R_1 and R_2 as shown in Fig-

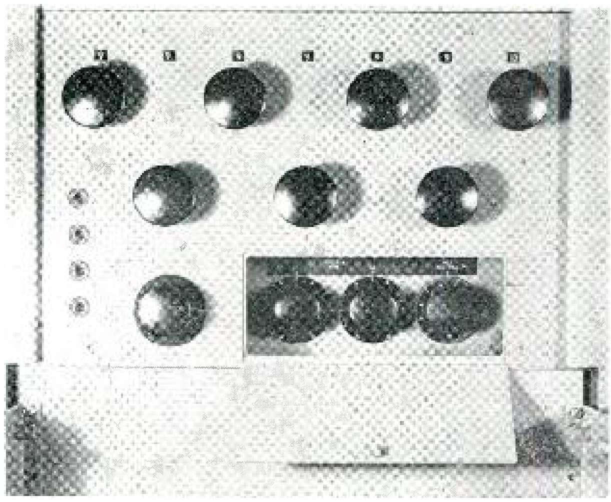


Fig. 2 — Precise resistance ratio unit showing the self-contained features for checking and correcting the unit for direct reading.

ure 4, the potential ratio E_1/E_2 can be varied as required.

In this circuit, the ratio of the impressed voltage E_1 to the output voltage E_2 is given by the relation

$$\frac{E_1}{E_2} = \frac{R_1}{R_2}\left[1 + \frac{1}{\mu}\left(1 + \frac{R_2}{R_1}\right)\right] \qquad (3)$$

If R_1 is approximately equal to R_2 the bracketed factor in equation (3) reduces to approximately $(1 + 2/\mu)$. For an amplifier with a gain of 20 million, $\mu = 2 \times 10^7$, this factor has the value of 1.0000001. Under these conditions, E_1/E_2 is equal to R_1/R_2 to within one part in 10 million. This precision is not appreciably affected by variations in the amplifier gain. The value, $\mu = 2 \times 10^7$, is, in fact, merely a lower limit. With gains of this order, any reasonable variation in μ will have a negligible

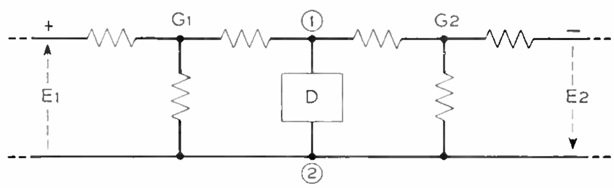


Fig. 3 — Two T networks and a detector are here arranged in such a way that the transfer conductances can be compared.

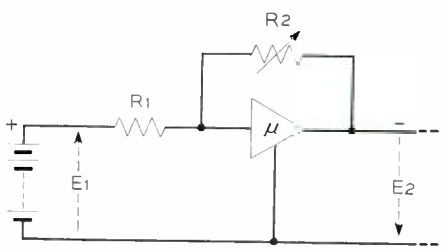
effect on the value of the bracketed factor in equation (3). The actual gain in the amplifier used in this circuit was in excess of 3×10^7. Furthermore, as R_2 is decreased, the value of $(1 + R_2/R_1)$ decreases and E_1/E_2 becomes even more nearly equal to R_1/R_2.

The circuit arrangement of Figure 4 provides two potentials of opposite polarity and a means for precisely adjusting the ratio of their values. These are the conditions that were required to measure the ratio of the transfer conductances of two T networks connected as in Figure 3. The final transfer conductance comparator design is based on the amplifier circuit of Figure 4 and the network arrangement of Figure 3. A simplified diagram of the resulting circuit is illustrated in Figure 5.

The ratio of the conductances, G_2/G_1, can be obtained with this circuit by holding R_1 constant and varying the value of R_2 until the ratio of R_1 to R_2 is such that the values of E_1 and E_2 result in equal potentials at points (1) and (2) as shown by a zero deflection on the detector. Under these conditions, the ratio R_1 to R_2 is equal to the ratio of G_2 to G_1 to within one part in 10 million.

A complete comparator, built under Air Force contract, required the design of a new dc feedback amplifier. A survey of the available dc amplifiers indicated that units having gains of the required order with satisfactory transient response were available, but their noise level—about 0.3 of a millivolt—was 100 times greater than could be tolerated in this application. A new amplifier was therefore designed in which care was directed toward materially reducing the noise level. As a result of this effort, an amplifier system was obtained having a noise level of less than three microvolts.

Equation (3), which forms the basis for the comparator operation, is valid only when the internal output impedance of the amplifier is small compared with the impedance of the network G_2 (Figure 5). The output impedance of the amplifier has been measured, and found to be less than 0.0005 ohm. On this basis, a lower limit of 10,000 ohms has been placed on the input impedance of G_2 so that the error due to this source shall not exceed one part in 20 million.

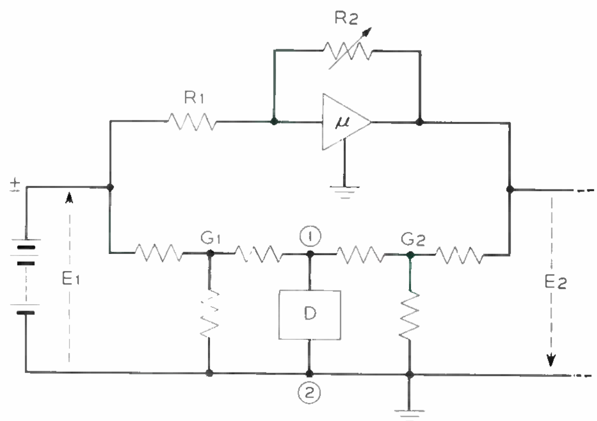


$$\frac{E_1}{E_2} = \frac{R_1}{R_2}\left[1 + \frac{1}{\mu}\left(1 + \frac{R_2}{R_1}\right)\right]$$

Fig. 4—High gain dc amplifier and voltage divider arranged in such a way that the ratio E_1/E_2 can be varied as required.

With an adequate amplifier, the precision attainable with the circuit in Figure 5 is limited by the precision with which the ratio of R_1 to R_2 can be established, and the sensitivity of the null detecting element. The resistance ratio unit that is illustrated in Figure 2 was especially designed and constructed by Leeds and Northrup Company for Bell Laboratories in the form of a resistance bridge, which can be operated as a conventional bridge, and thus be checked independently of the amplifier portion of the comparator.

In this bridge, R_1 has a fixed value of 100,000 ohms provided by ten 10,000-ohm resistors connected in series. The adjustable branch, R_2, consists of seven decades having ten steps each. This unit can be adjusted in steps of 0.01 ohm to a maximum of 111,111.10 ohms. The elements in the first of these decades are 10,000-ohm resistors identical to those used in the fixed branch. These resistors were carefully selected to have matching temperature coefficients. The decade of next lower value, having 1,000-ohm steps, employs resistors constructed with the same size wire taken from the same manufacturing lot as that used in the 10,000-ohm resistors of the first decade and fixed branch. The remaining five decades use regular precision type resistors.



$$\frac{G_2}{G_1} \approx \frac{R_1}{R_2}$$

Fig. 5—Simplified diagram of the transfer conductance comparator circuit.

Because the temperature coefficients in the two branches of the ratio unit are carefully matched, the precision of the ratio is essentially free from the effects of ambient temperature variations existing in an air conditioned area. Also, since both ratio branches always carry the same current, the effects of self heating have a negligible effect on the ratio.

The adjustment knobs for the seven decades forming the adjustable branch of the ratio unit are shown in the headpiece of this article. Since space limitations did not permit them to be arranged in one horizontal row, they were staggered and mechanically coupled to indicators arranged along the top of the panel. To make the instrument direct reading, the value assigned to the decades is indicated in terms of the desired ratio expressed in millionths of unity.

The ratio unit has self-contained facilities for checking its accuracy at a setting of unity, and means are provided for adjusting the fixed resistance R_1, so that the indicated ratio of unity is exact to within one-tenth of a millionth. To make use of the precision afforded by this ratio unit, the detector unit must be sufficiently sensitive to indicate the condition of no current flow with the same order of precision. Moreover, this instrument must be so arranged that measurements of transfer conductance ratios can be made quickly and simply. The instrument developed to meet these requirements has an input resistance of one megohm and an approximately logarithmic response covering a range of one to one million microvolts. Near the null point, it has a sensitivity of one microvolt per scale division. With an input signal of 80 volts, the maximum permissible value of E_1, this indicator sensitivity is close to one part in 40-million, well beyond the required precision.

The detector response time is about one-tenth of a second, and it can recover 80 per cent of full sensitivity in approximately three seconds after an overload of ten volts. Errors due to residual thermoelectric potentials in the circuit are eliminated by a manually adjusted compensation system included in the apparatus. The results are then checked by reversing the polarity of E_1 (Figure 5) and using the mean value of the two resulting indications as the true value.

In addition to determining the ratio of the direct current transfer conductances in two networks, the absolute value of this quantity can be determined in a single network. This is done by replacing one of the networks in Figure 4, by a network with a known transfer conductance. The ratio of the conductance in the known and the unknown circuits can then be measured and from this the absolute value of the transfer conductance in the unknown can be determined. If desired, either or both T networks can be replaced by a simple series resistor. A precision of one part in 10-million is also possible in this application, if the transfer conductance that is used in the reference network is known sufficiently accurately.

THE AUTHOR

Clarence H. Young joined the Laboratories in 1927 and until 1942 he was engaged in the development of electrical impedance measuring apparatus. He also taught an out-of-hours course on impedance measurements in 1937-38. During the war Mr. Young worked on military projects such as the magnetic airborne detector and on underwater projects. Since 1946 he has been concerned with the development of electronic measuring apparatus, including oscillators and detectors. Mr. Young received his B.S. in E.E. degree from the University of Michigan in 1927. He is a senior member of the Institute of Radio Engineers and a member of Tau Beta Pi, Sigma Xi and Phi Kappa Phi.

Decoders and Markers in 4A Toll Crossbar

C. G. MORRISON *Switching Systems Development II*

The inclusion of nationwide dialing features in the 4A toll crossbar system requires much greater versatility of the common-control equipment than previously. Translation functions have therefore been separated from the marker, and are embodied in the decoder and card translator. The translator acts as a "card-file" wherein coded information is stored, the decoder reads and interprets the translator output, and the marker acts on the information to complete a call through the 4A office.

Markers in the No. 4 and A4A crossbar toll switching systems have two basic functions: translating a three-digit code, received from a sender, into information that can be understood by the common-control equipment; and utilizing this information to establish a talking connection through the toll office. In these earlier systems, translation is accomplished by route relays, cross-connected to provide the desired output information. In the 4A system, however, the need for six-digit translation and a flexible means of adding and changing route information, led to the development of the card translator.

Circuits were needed to control the operation of the card translator and to read and interpret the information contained on the translator cards. These circuits could have been incorporated in the marker; however, since the translation function is so much greater in scope in the 4A system and is performed prior to other marker operations, more efficient use of common-control equipment is achieved by separating the translation function from the marker. Thus, in the 4A system, the decoder and card translator together perform translation, and the marker retains the function of establishing a connection.

A marker and decoder, with a card translator, are equipped to perform additional nationwide dialing functions such as automatic alternate routing, determining the number of code digits to be "spilled" forward to the next office, and determining new code digits to be outpulsed in place of, or in addition to, the code digits received (code conversion).

Briefly, a decoder and marker operate as follows: A decoder uses the received code to select a card in a translator, containing information required to set up a call. The decoder reads the translator output, determines the routing procedure to be used, and seizes a marker. It then passes to this marker information from the card, such as the location of the outgoing trunk group, instructions on how to handle the call if all trunks are found busy, and instructions to be later passed to the sender. When assured that the marker has sufficient information, the decoder releases. The marker selects an outgoing trunk, determines on what link frames the incoming and outgoing trunks are located, and connects to these link frames. It then selects and closes a path between incoming and outgoing trunks, passes the necessary instructions to the sender, checks the established connection, and releases.

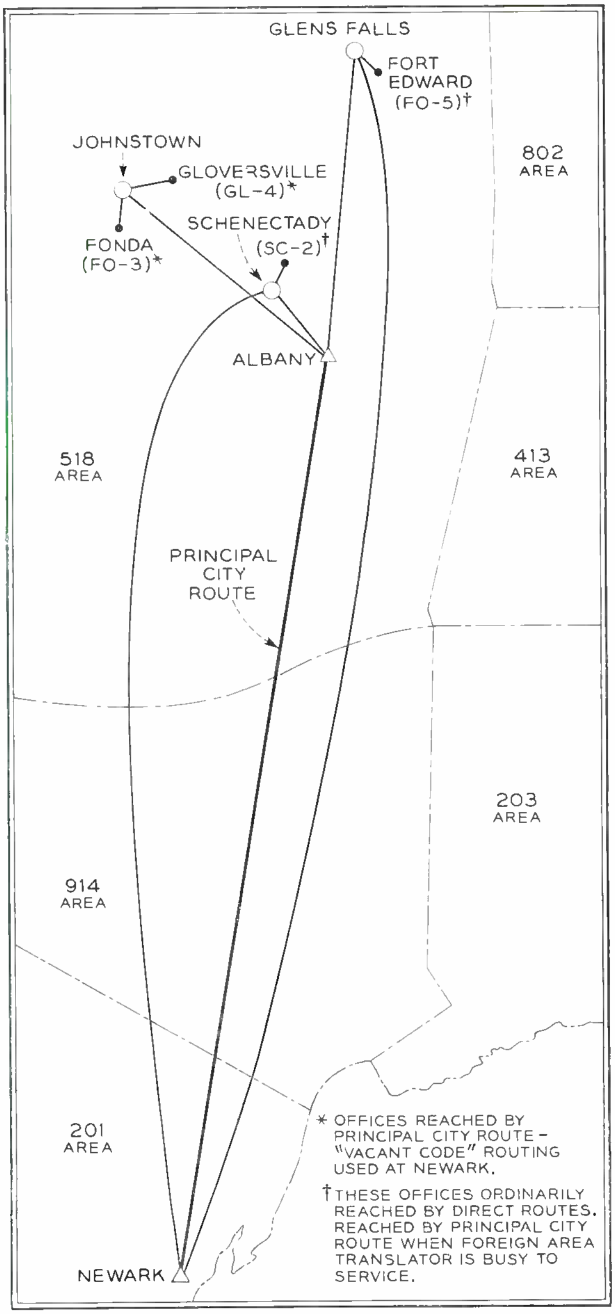


Fig. 1 — The route from Newark to Albany is an example of the "principal-city route" for calls to the "518" numbering area.

Since a sender does not know how many digits are required for translation, it seizes a decoder as soon as three digits have been received. The first action of a decoder is to select* a three-digit card in its decoder translator and determine from it the total number of code digits required for translation. Should the card say "NCA" (no come again), three digits are enough; the decoder and marker read the remaining information from the card and set up the call toward its destination. If, however, the card says "CA4", "CA5", or "CA6", then four, five, or six digits are required to route the call. Unless the sender has received the required number of code digits, it releases the decoder and attempts another seizure when the complete code has been received. This prevents the decoder from being held unnecessarily.

The sender, having received the complete code, again seizes a decoder and presents six digits for translation. If the code consists of only four or five digits the sender automatically adds zeros to bring the total to six. Since the six-digit card may be in the decoder translator or in any one of a number of foreign area translators, the decoder must next determine where the desired card is located. It again drops the three-digit card and reads from it the number of the translator containing the desired six-digit card. The indicated translator is then seized and the six-digit card is selected and read.

In some cases, where calls are routed to foreign areas, six-digit cards may be saved by the use of "principal-city routing." In Figure 1, the route to Albany is an example of a "principal-city route" from Newark. Every office in the "518" numbering area may be reached from Newark by way of Albany and the principal-city route is the normal route to offices not having a more direct route from Newark, such as FO3 and GL4. Other offices, such as SC2 and FO5, are normally reached by more direct routes. Offices of the latter type require six-digit cards to provide the most direct routing. However, offices normally reached by the principal-city route all require the same routing information. Six-digit cards for these offices are therefore omitted and the decoder obtains its routing information by "vacant code" routing. If the three-digit card indi-

* A card is selected by dropping it below its normal position so that light may pass through the proper holes, actuate phototransistors, and send appropriate signals to the decoder and marker.

cates that principal-city routing is possible, and no six-digit card is found, the decoder reads from the three-digit card the information required to route the call to the principal city.

Principal-city routing permits a further reduction in cards. Most six-digit cards are located in a pool of foreign area translators to which all decoders have access. When principal-city routing is not possible, duplicate six-digit cards are provided in a pair of translators; if a decoder cannot gain access to one foreign-area translator it selects an identical card in the other of the pair on second trial. However, when principal-city routing is possible, six-digit cards are not duplicated. When a decoder cannot gain access to the desired six-digit card, it returns to the original three-digit card in its decoder translator and routes the call by way of the principal city.

When a card cannot be dropped, and the decoder cannot complete the call by principal-city routing, a "card failure" signal is given to the decoder connector. The connector releases the first decoder and a second trial is made using another decoder, decoder translator, and foreign-area translator (when required). The connector tells the second decoder that a card failure has occurred. Should a card again fail to drop, the decoder assumes that it has received a fictitious code and routes the call to reorder. If, however, a card drops on second trial, the decoder knows that the card failure on first trial was the result of a trouble condition or card omission, and causes a trouble record to be made before routing the call to its destination.

The routing procedure followed by a decoder depends on the trunking facilities available. When there is only one group of forty or less trunks toward the destination and no alternate routes, the decoder drops the only card that may be used for routing the call, passes information from this card to the marker, and then releases. When more than one trunk group or more than forty trunks are available for routing the call, three different routing procedures are possible: relay-to-relay, card-to-relay, and card-to-card.

One of the features of the 4A system is its ability to automatically select an alternate route when all trunks in the direct route to a destination are busy. There may be as many as six routes toward a given destination. A means for testing this large number of trunks rapidly is to provide each decoder with a route relay for each trunk group that may serve as an alternate route. The route relay representing the first alternate route is operated from the card representing the direct route. If all trunks represented by this route relay are busy, succeeding route relays will operate in a sequence conforming to the basic switching plan. In this way, the decoder can quickly select the first trunk-group having at least one idle trunk.

When the direct route to a called destination is represented by a route relay, the direct-route card

Fig. 2 — M. J. Norton replaces a gas-tube in a laboratory model of a 4A decoder.

will have the routing instruction "relay-to-relay." On reading this instruction, the decoder pre-tests the direct trunk-group with its route relay. If the first-choice trunks test idle, the decoder signals the marker to read the dropped card. Should the direct trunk-group test busy, the decoder restores the card and tests the alternate routes by the route-relay method. On finding an idle trunk-group, the decoder drops and reads the corresponding alternate-route card.

"Card-to-relay" routing is used when route relays are provided for alternate routes but not for the direct route. When a card with this instruction is dropped, the marker tests the direct trunks specified on the card while the alternate routes are being tested by the route relays. Should the marker find a direct trunk idle, the decoder will release. If not, the decoder drops an alternate-route card for the trunk-group found idle by the route relays, and the decoder and marker set up the call to a trunk in this group.

On calls where the decoder pre-tests trunks, there is an interval between the decoder and marker trunk tests during which the last idle trunk in the selected group may become busy. In this event, it is desirable to allow the equipment another chance to set up the call rather than to route it to a no-circuit or reorder trunk. For this reason, alternate route cards are usually coded "follow with second trial."

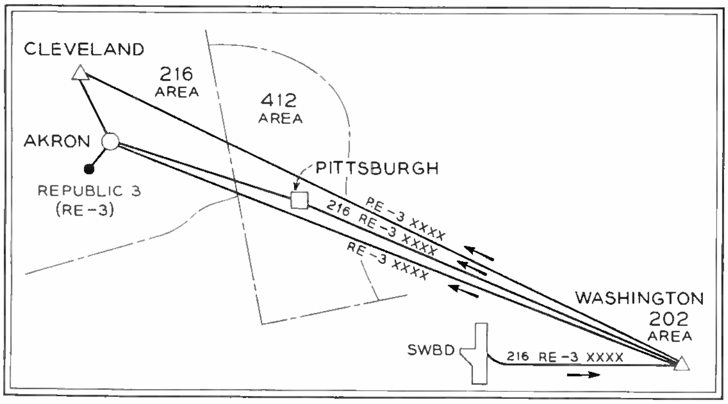


Fig. 3 — A call from Washington to Akron requires pulsing forward the area code 216 when alternate routed through Pittsburgh.

There may be several groups of trunks to a given destination not having facilities for decoder pre-test. On calls to such a destination, "card-to-card" routing is used. When a translator card has such an instruction, the decoder submits to a marker the information from the card and, when assured that the marker has received it, restores the card but does not release. If the marker finds all trunks busy, the decoder causes the translator to drop the card for the next trunk-group. This card may also have a "card-to-card" routing instruction, in which case the procedure is repeated. The card for the last such group of trunks will usually have the instruction "follow with reorder." In this case, the decoder releases as soon as the routing information has been passed to the marker and the marker sets up the call to reorder if it cannot find an idle trunk. Four groups, or a maximum of 160 trunks, may be tested by "card-to-card" routing.

The decoder usually remains connected to the marker only long enough to pass on information necessary to set up the call. On all calls except those where the decoder indicates that it has more information for the marker, decoder release will start before the marker has completed its trunk testing. Therefore, in the event that all trunks are found busy, the marker must be able to dispose of the call without assistance from the decoder. It does this according to instructions from the decoder indicating that, if all trunks are busy, the marker should either make a second trial or direct the call to an overflow, reorder, or no-circuit trunk.

To meet the requirements of nationwide dialing, the 4A equipment must be able to "spill" forward to the next office all digits received by the sender, to delete code digits, or to prefix new code digits. In some cases, new digits must be substituted for all or part of the received code (code conversion). One, two, or three digits may be manufactured for code conversion or prefixing purposes. To determine how many digits are to be spilled forward, the code-conversion digits, if any, plus one of three "variable spill" items, are read from the card. These items are NSK, indicating that all received digits are to be pulsed forward; SK3, that the first three received digits are to be deleted; and SK6, that the first six received digits are to be deleted. This information is then passed from the marker to the sender.

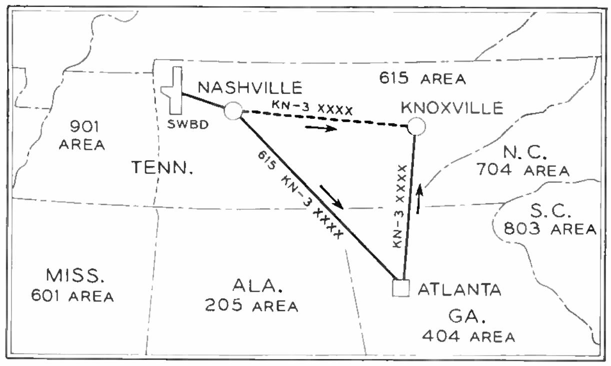


Fig. 4 — A call from Nashville to Knoxville requires pulsing forward the home area code 615 when alternate routed through Atlanta.

When an alternate-route card is dropped, the decoder must determine whether or not the called-area code is to be pulsed forward. Assume, for example, that an operator dials into a 4A office at Washington the number 216 RE3 XXXX for a customer in Akron, Ohio, (see Figure 3). When the direct trunks to Akron are busy the call may be alternate routed through either Cleveland or Pittsburgh. Routing through Cleveland does not require outpulsing of the area code since Cleveland is in the 216 area. However, when the call is routed through Pittsburgh, the area code is required to direct the call from Pittsburgh into the 216 area. On a call of this type, the decoder must first determine whether the first three digits comprise an area or office code. This information, obtained on all calls from the initial three-digit card, is stored in the decoder for use in case an alternate-route card is dropped. In this example, having determined that the digits 216 comprise an area code, the decoder determines whether this code is to be pulsed forward by comparing it with digits punched on the code-conversion holes of the alternate-route card. On alternate route cards these holes are punched with the three-digit code for the area in which the route terminates. When the alternate-route card for Cleveland is dropped, since the punched digits 216 match the first three digits from the sender, the area code is deleted. If the Pittsburgh alternate-route card is dropped, the punched digits 412 will not match the 216 area code from the sender. Consequently, the decoder signals the sender to outpulse the area code.

When a call for an office in the home numbering area is alternate routed through a foreign-area, it is necessary to prefix the home area code, Figure 4. Suppose that the number KN3 XXXX for a customer in Knoxville, Tennessee, is dialed into the Nashville office and the decoder finds all direct trunks to Knoxville busy. This call may be alternate routed through Atlanta, but the 615 code must first be pulsed forward to Atlanta to direct the call back to its home area. The decoder, having ascertained from the original card that KN3 is an office code, determines from the Atlanta alternate-route card whether or not Atlanta is in the home area. Since the card indicates that Atlanta is outside the home area, the decoder furnishes information to the sender to prefix the home area code 615.

Failure of a decoder or marker to perform a particular function within an allotted time indicates a trouble condition or an excessive traffic delay. Each decoder and marker has a work timer to check its own internal operation and additional timers to prevent holding of these circuits for excessive periods when various types of traffic delay are encountered. When one of these timers runs out, the decoder or marker, or both, connect to the trouble recorder where a trouble-card is perforated, indicating the nature of the trouble.

THE AUTHOR

Charles G. Morrison has been concerned with testing equipment since joining the Western Electric Company in 1942. He first prepared test methods for shop testing of switchboards and later designed test equipment and prepared shop testing methods for toll crossbar equipment. Mr. Morrison transferred to the Laboratories in 1948 and since then has been concerned with laboratory testing and design of toll crossbar circuits. He served in the Signal Corps for three years, working with voice secrecy communication equipment. A graduate of Cornell University (B.E.E., 1943), Mr. Morrison received the M.S. degree from Stevens Institute of Technology. He is an associate member of the A.I.E.E. and a member of Eta Kappa Nu.

Western Electric Announces New Vice Presidents

Paul A. Gorman

Timothy E. Shea

Gus F. Raymond

The Western Electric Company recently announced the election of three vice presidents.

Paul A. Gorman, formerly assistant vice president of personnel relations in the A. T. & T. Co. became vice president-defense projects, a new post, effective October 1. On the same date, Gus F. Raymond, formerly personnel director of Western Electric, became vice president-purchasing and traffic. Timothy E. Shea left his Albuquerque, New Mexico, post as vice president and general manager of the Sandia Corporation, a Western Electric subsidiary, on October 15 to return to the parent Company as vice president-manufacturing, Eastern area.

Mr. Gorman's post as vice president-defense projects has been newly established as a result of Western Electric's expanding responsibility to the U. S. Government in the management and supervision of major continental defense projects.

Mr. Raymond succeeds George A. Landry, who retired September 30, under the Company's age retirement rule. Mr. Landry has been on loan to the U. S. Government since last spring as a director in the office of Defense Mobilization. Mr. Shea replaces Arthur B. Goetze who was appointed vice president-finance.

Since joining Western Electric in 1929, Mr. Gorman has served as assistant engineer of manufacture, central zone distributing manager, and personnel director. He became assistant vice president of personnel relations in the A. T. & T. Co. in 1953.

Mr. Raymond has 30 years' service with Western Electric, during which time he has served as manager of the Indianapolis Works, manufacturing division comptroller and personnel director.

Mr. Shea was assistant engineer of manufacture and personnel director of Western Electric, president of Teletype Corporation, vice president of the Laboratories and assistant vice president of personnel relations in the A. T. & T. Co. before he became vice president of the Sandia Corporation. He started his Bell System career in 1920.

Increased Efficiency Obtained with Bell Solar Battery

The Laboratories recently announced a one-third increase in the efficiency of the Bell Solar Battery, with a technical paper by G. L. Pearson, who, with C. S. Fuller and D. M. Chapin invented the device, before the National Industrial Conference Board in New York.

A six per cent efficiency in converting sunlight directly into electricity had been achieved when the battery was first demonstrated five months ago. Laboratories development groups have now built experimental cells which yield a record 8 per cent efficiency. The value of 8 per cent is ten to fifteen times greater than the efficiency of the best photovoltaic devices available. It is expected that in time a 10 to 15 per cent efficiency can be achieved. The maximum theoretical efficiency is estimated to be 22 per cent. The improved cells can be electrically linked to deliver power from the sun at the rate of 80 watts per square yard of surface.

It is believed that certain factors that tend to decrease the device's efficiency can be partially eliminated. At present, a considerable amount of the radiant energy is lost by reflection from the silicon surface and a part of the electrical energy is lost within the cell itself. Increased efficiency has been obtained in experimental cells by reducing these losses. The speaker demonstrated to the audience that the Bell Solar Battery could power telephone equipment or a portable FM transmitter.

A similar report of increased efficiency was given by D. M. Chapin before a combined meeting of the A.I.E.E. and the I.R.E. in New York.

Key to the Laboratories' technique for producing these experimental silicon devices is the controlled introduction of a foreign element into a microscopic layer near the surface of a thin slice of arsenic-doped silicon. Treatment under gas at high temperatures permits the introduction of minute traces of impurities into the atomic structure at the surface of the silicon. Introduced at a precise rate and under carefully controlled conditions, the impurities reach a depth of less than one ten-thousandth of an inch. This is what is known as a "p-n junction," which is the heart of the device and which, when built into a germanium single crystal, is the basis for the junction transistor, also an invention of Bell Telephone Laboratories.

J. R. Bransford Named Director of the Laboratories

Joseph R. Bransford, vice president and director of the Western Electric Company, was recently named to the Laboratories' Board of Directors succeeding Frederick W. Bierwirth. Mr. Bierwirth retired August 31 under the age retirement rule after a telephone career of nearly forty-two years. He had been a vice president of Western Electric and a director of the Laboratories since 1942.

Mr. Bransford, vice president in charge of the telephone and installation division of Western Electric, joined that company in 1928. He was elected vice president-finance and director in 1950.

Mr. Bransford is president and a director of the 395 Hudson Street Corp., and is vice president and a director of the Western Electric Company Ltd. of Canada. He is also a director of the Nassau Smelting and Refining Company, Teletype Corporation, and the Westrex Corporation.

H. T. Friis Named to Receive I.R.E. Medal of Honor

H. T. Friis, Director of Research-High Frequency and Electronics, has been named recipient of the Institute of Radio Engineers' Medal of Honor, regarded as the highest technical award in the radio engineering profession.

The award, accompanied with a citation for Dr. Friis's "outstanding technical contributions in the expansion of the useful spectrum of radio frequencies, and for the inspiration and leadership he has given to young engineers," will be presented during the National Convention of the Institute of Radio Engineers that will be held in New York City next March.

Dr. Friis began his career in 1916 as Assistant to Professor P. O. Pedersen in Copenhagen, Denmark. For the next two years he worked as Technical Advisor at the Royal Gun Factory in Copenhagen. He received a Fellowship from the American-Scandinavian Foundation in 1919. In the same year Dr. Friis joined the Western Electric Company's Research Department, later to become Bell Telephone Laboratories.

His first work was on ship-to-shore radio reception. From 1921 to 1929 he took part in pioneering theoretical studies of radio reception and then assumed direction of a group working on short-wave studies. Dr. Friis served as Director of Radio Research from 1945 to 1952 when he was appointed to his present position.

During his years of association with the Laboratories, Dr. Friis has made notable contributions in radio transmission, including methods of measuring signals and noise; in the creation of a receiving system for reducing selective fading and noise interference; in microwave receivers and measuring equipment; and during the war in radar work. He has published numerous papers and is the co-author, with Dr. S. A. Schelkunoff, of a book on the theory and practice of antennas, published by John Wiley and Sons, New York.

He is a Fellow of the Institute of Radio Engineers and of the American Institute of Electrical Engineers. His professional activities also include membership in the American Association for the Advancement of Science; Danish Engineering Society; American Section, International Scientific Radio Union; Danish Academy of Technical Sciences; Panel for Basic Research, Research and Development Board, Washington, D.C.; and the Scientific Advisory Board, Army Air Force.

E. L. Nelson Named Signal Corps Research and Development Chief

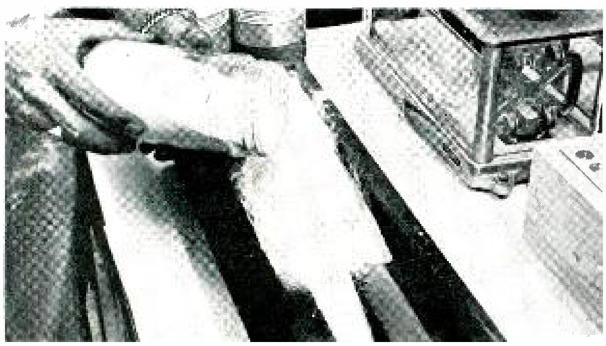
Edward L. Nelson, Technical Director of the Signal Corps Engineering Laboratories, Fort Monmouth, N. J., has been appointed Scientific Chief of Research and Development for the Army Signal Corps. In his new assignment, Mr. Nelson will be responsible for the technical direction of the research and development mission of the Army Signal Corps, which includes highly specialized and complex scientific and engineering programs in electronics, applied physics, meteorology, photography and many other allied fields.

Prior to his appointment as Technical Director of the Signal Corps Engineering Laboratories on February 15, 1951, Mr. Nelson was with Bell Telephone Laboratories where he had been engaged in the development and design of military weapons systems and communications equipment under Army and Navy contracts.

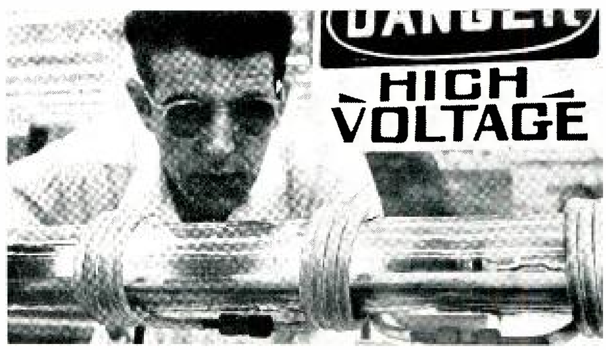
He joined the Laboratories in 1921, where he served as supervisory engineer and later as Radio Development Engineer responsible for the design and development of commercial radio transmitting and receiving equipment. During World War II he was in charge of numerous military radio and radar projects of the Bell Telephone Laboratories for both the Army and Navy. In 1946, Mr. Nelson was responsible for the design and development of equipment for the Bell System mobile radio telephone service and high-frequency radio transmitting and receiving equipment for installation in commercial ships to afford communication with Bell System coastal harbor and high-seas radio stations. During this period, Mr. Nelson was responsible, also, for the development of the Signal Corps AN/GRC-3 through 8 series of vehicular radio sets.

Manufacturing a Transistor

Now that transistors have left the laboratory stage and are in wide-spread manufacture, new techniques and methods have been developed for their production. The accompanying photographs, taken in Western Electric's Allentown Plant, show the main steps in this production.

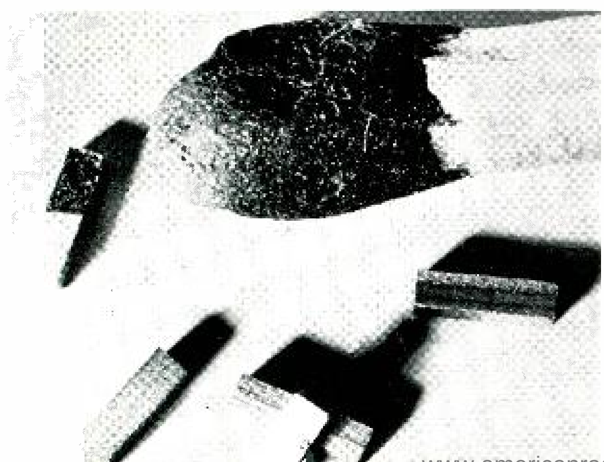


In first step of transistor manufacture, the raw material (germanium oxide) is poured into a carbon "boat" in which it will be "cooked."



In this furnace, heated by induction coils, raw material undergoes zone refining in which impurities in molten state are forced to one end of ingot.

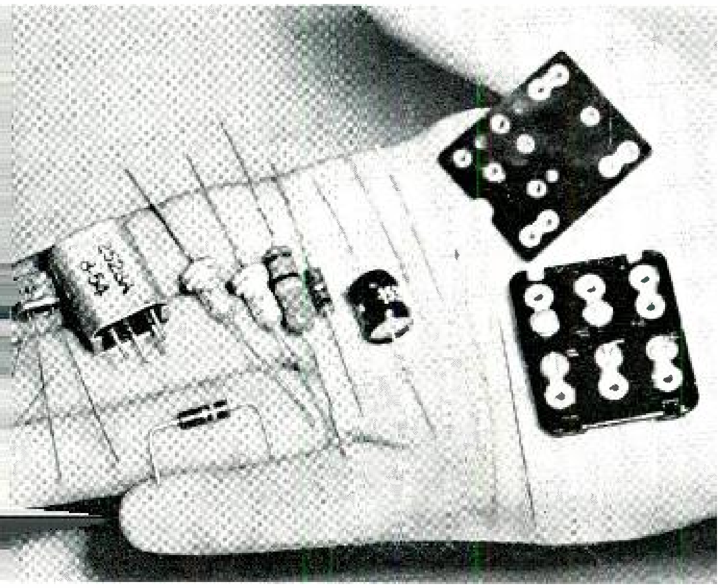
Photographed alongside a matchhead to indicate their relative size are bars of germanium after slicing to size used in the junction transistor.



Point of pin provides graphic proof of tiny size of n-p-n transistor bar mounted on glass with metal header and three wire leads.

New Telephone Set for the Hard of Hearing

Among the latest telephones being produced in the Western Electric Company's plants is a set with two characteristics that distinguish it from the other new 500-type telephones. This is the volume control set which is especially designed for people with impaired hearing. Its primary feature, from the customer's standpoint, is a small plastic knob with which the sound power can be turned up 100 to 200 times normal. An additional feature of the new set is the fact that operating current for the amplifier comes over the customer's line from the central office battery, eliminating the need of a separate battery at the amplifier. The amplifying unit that permits the sound power increase contains the first transistor to be used in a telephone set. Except for this amplifying unit, a small box about the size of an ice cube, the volume control set is the same as other 500-types.



Left — All components of amplifying unit in new 500-type volume control set can be held in palm of hand. Note transistor (far left) resting on tip of index finger.

Over-The-Horizon Radio System

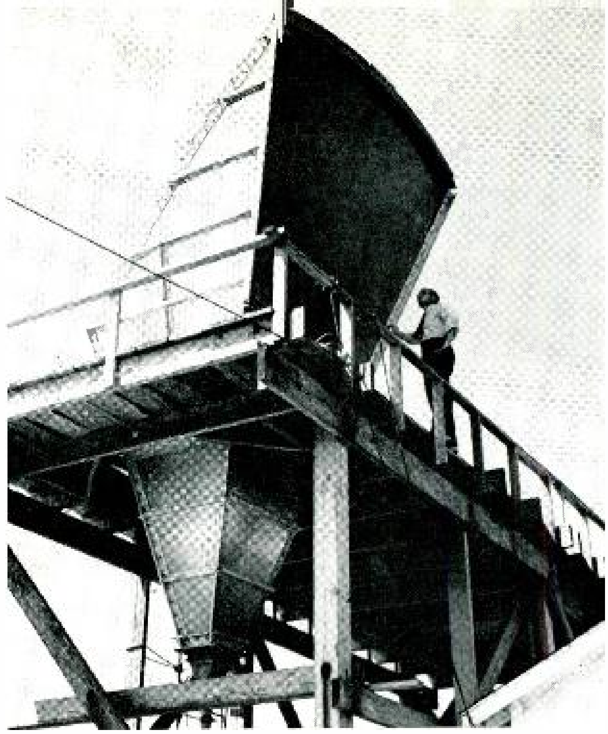
Plans for the construction of an over-the-horizon radio transmission system between Florida and Cuba, which may pave the way for international television service, were contained in a petition filed recently with the Federal Communications Commission by Long Lines Department of A. T. & T. Co.

This would mark the first commercial use of over-the-horizon radio transmission in the broad bandwidths required for multi-telephone circuits and television. While over-the-horizon radio transmission is still in the developmental stage, research by Bell Laboratories indicates that transmission for distances up to at least 150 miles without intermediate amplification is presently feasible in the frequency range of about 500 mc to 1,000 mc, and in the band widths required for broadband telephone and TV transmission. The proposed system would make use of a high-power transmitter and a large antenna to force signals beyond the curving earth surface — in this case, from a point on the southern part of Florida to a point on the northern coast of Cuba.

The proposed radio system would furnish many additional telephone circuits and provide diversification of facilities. It would have the further advantage of permitting experimentation with television transmission, looking forward to the establishment of international TV program service over this route.

To meet the requirements of the system, the petition asked for a change in FCC rules to permit fixed radio stations in Florida to use frequencies in the 470-890-mc band "subject to no harmful interference being caused to the broadcast service of the United States or other countries." Studies of the UHF allocations for Florida indicate that by proper selection of frequencies for the Florida-Cuba circuit there would be no interference with television broadcasting.

New Radio Relay Antenna



A new type of antenna resembling a giant sugar scoop has been designed by Bell Telephone Laboratories engineers to receive and transmit telephone and television signals. The horn-reflector antennas, to be used on Bell System radio relay routes, may eventually handle up to about 20,000 telephone circuits or 30 television programs at one time. They would handle simultaneously radio systems in the 4,000, 6,000 and 11,000-mc bands. Microwaves are deflected from the curved back of the receiving or transmitting antennas which will be mounted on radio relay towers. After being amplified at each station, strengthened signals are relayed to their next stop on a different frequency. Here the process is repeated. Since microwaves travel in straight lines, towers as high as 300 feet are often required.

Talks by Members of the Laboratories

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

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

Barstow, J. M., Intercity B-W/Color Television Transmission, I.R.E. Meeting, Fourth Annual Broadcast Symposium, Cleveland, Ohio.

Beck, A. C., Early History of Radio Astronomy, N.B.S. Dedication, Session on Radio Astronomy, Boulder, Colorado.

Bescherer, E. A., Packaging Circuit Elements for Reliability in Military Electronic Systems, National Security Industrial Association Meeting, Winston-Salem, N. C.

Bode, H. W., Stability Conditions for General Linear Circuits, U. R. S. I., The Hague, Holland.

Chapin, D. M., The Bell Solar Battery, Baulstrol Golf Club, Springfield, New Jersey.

Cornell, W. A., Transistors, Third Naval District Headquarters, New York City.

Elliott, S. J., Solderless Wrapped Connections, The National Security Industrial Association, Ordnance Advisory Committee, Subcommittee on Improved Electrical Connections, Winston-Salem, N. C.

Felch, E. P., and Israel, J. O., A Simple Circuit for Frequency Standards Employing Overtone Crystals, National Bureau of Standards, Boulder Laboratory, Boulder, Colorado.

Ferrell, E. B., Advanced Concepts of Quality Control, Sixth Annual All-Day Conference on Quality Control, Rutgers University, New Brunswick, New Jersey.

Flaschen, S. S., see Garn, P. D.

Garn, P. D., and Flaschen, S. S., Differential Thermal Analysis as an Analytical Tool, American Chemical Society Meeting, New York City.

Geller, S., The Crystal Structure of Co_2Si, American Chemical Society, New York City.

Gohn, G. R., Fatigue and Its Relation to the Mechanical and Metallurgical Properties of Metals, Society of Automotive Engineers, Hot Springs, Virginia.

Honaman, R. K., Frontiers of Communication, Illinois Bell Employees, Chicago, and the 75th Anniversary Luncheon of the Illinois Bell, Springfield, Ill.

Israel, J. O., see Felch, E. P.

Monro, S., Some Elementary Aspects of Applied Statistics, Meeting of the American Statistical Association, Montreal, Canada.

Pearson, G. L., Silicon in Modern Communications, Northern New Jersey Section of I.R.E.

Pierce, J. R., The Wave Picture of Microwave Tubes, Stanford University; Some Recent Advances in Microwave Tubes, I.R.E., Palo Alto, San Francisco.

Pollak, H. O., Complex Biorthogonality for Certain Sets of Polynomials, American Mathematical Society, Laramie, Wyoming.

Shackleton, S. P., Counselling of High School Students, General Motors Technical Center, Detroit, Michigan.

Tanenbaum, M., see Valdes, L. B.

Tukey, J. W., Weather Forecasting and Air Sampling, American Statistical Association, Montreal, Canada.

Valdes, L. B., and Tanenbaum, M., Grown-Junction Silicon Transistors, Arnold Auditorium, Murray Hill, New Jersey.

Warner, A. W., Parameters Affecting the Quality of High-Frequency Quartz Crystal Units, National Bureau of Standards, Boulder, Colorado.

Winslow, F. H., Baker, W. O., and Yager, W. A., Odd Electrons and Electrical Conductivity in Polymer Molecules, American Chemical Society, New York City.

Wood, Elizabeth A., Phase Transitions in Ferroelectric and Ferromagnetic Crystals, American Chemical Society, New York City.

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