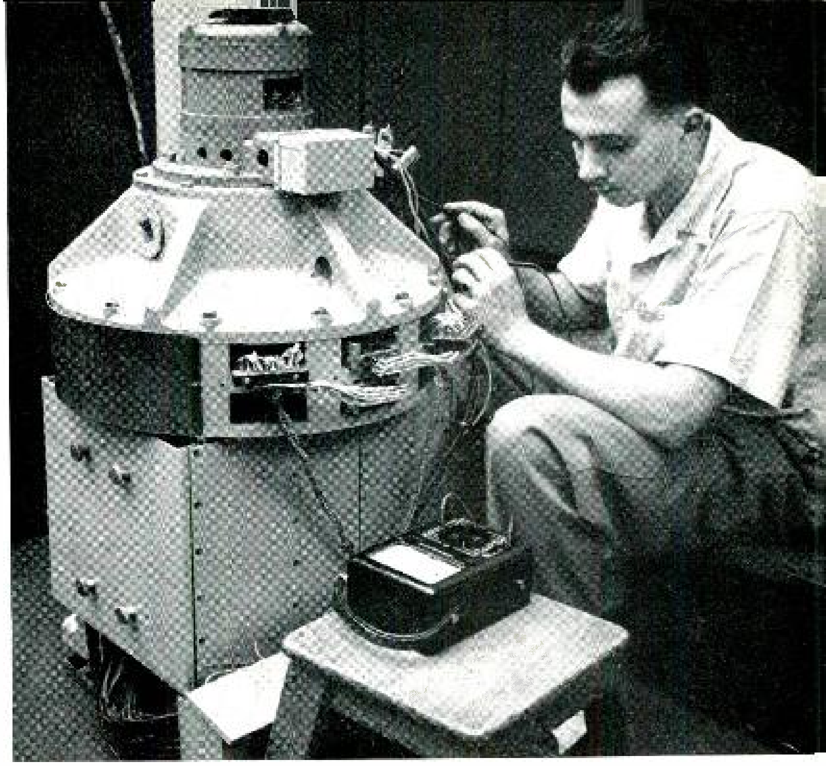
DIAD–
An Experimental Telephone Office



W. A. MALTHANER
and H. E. VAUGHAN *Switching Research*

In the search for faster and more efficient telephone service, Bell Telephone Laboratories evaluates offices that incorporate new discoveries and new principles of design. "DIAD" is the most recent of these: a system that uses a magnetic drum to "remember" facts about customers and the numbers they are calling. Though DIAD is not a commercial office, its drum and electronic circuits make it the fastest operating telephone system to date.

The simple analogy that exists between a computer and an automatic telephone switching system has been pointed out in an earlier Record * article. This analogy led the Switching Research Department a few years ago to consider the possibility of using computer-type tools – the magnetic drum in particular – as devices for processing information to control telephone calls. As a result the Laboratories has built an experimental telephone switching system that combines the drums, as memory elements, with electronic switching devices to make up the data processing or control part of the system. This system has been called "DIAD," a coined name explained below.

Like the latest circuits in commercial use – the No. 5 crossbar system for instance – DIAD is a common-control system. This term common control arises from the way in which a number dialed by a customer is used in switching a telephone call. Older systems – such as step-by-step – use "progressive control" in which the individual digit generated on each pull of the dial directly controls a switch leading toward the called line. In such an arrangement, the control equipment is an intimate part of the switching equipment. In the newer systems, however, the control equipment is centralized for more efficient use. "Memory" mechanisms store up the information received from customers. On the basis of complete items of information obtained from this memory, switching control circuits select talking paths through the office. In this way many customers share control circuits and memory, which are common to the entire system. In DIAD, magnetized areas on the surface of a rotating drum supply the memory in which information is assembled, and electronic units provide fast control circuits to which the assembled information is dispatched. From this arrangement of common control, the system derives its name DIAD, for "Drum Information Assembler and Dispatcher."

If common-control equipment can be made to operate fast enough, a single circuit can perform a given group of functions for the whole office. Such

Above — G. G. Bailey testing dc voltage at scanner terminals of DIAD magnetic drum.

* Record, *September*, 1954, *page* 321.

a circuit serves the customers one after the other on what is called a "one-at-a-time" basis. This could mean both faster service and lower costs. With the combination of magnetic drums and electronic switches, the speed necessary to provide every control function on a one-at-a-time basis is attained. A simple example highlights the meaning of the one-at-a-time principle — before a connection may be made to a called customer's line, a test is made to see that the line is not already in use. In DIAD a single circuit makes all such "busy tests". In other words, busy tests are on a one-at-a-time basis. No. 5 crossbar uses several busy-test circuits because its

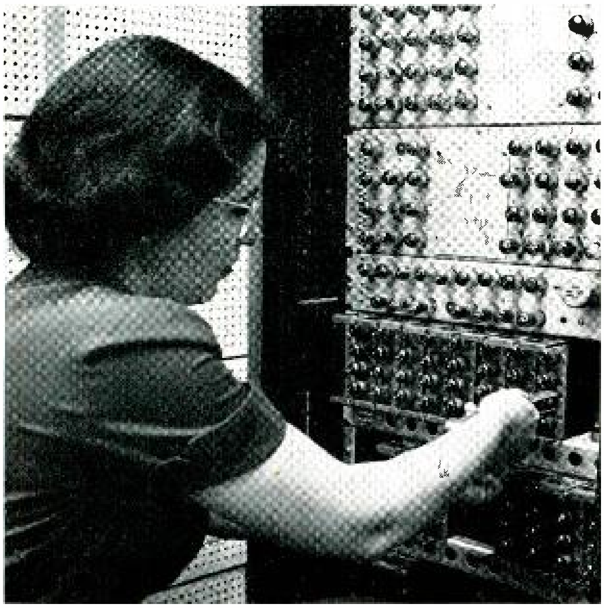


Fig. 1 — Miss A. V. Deininger testing amplifiers in line bay of the DIAD telephone system.

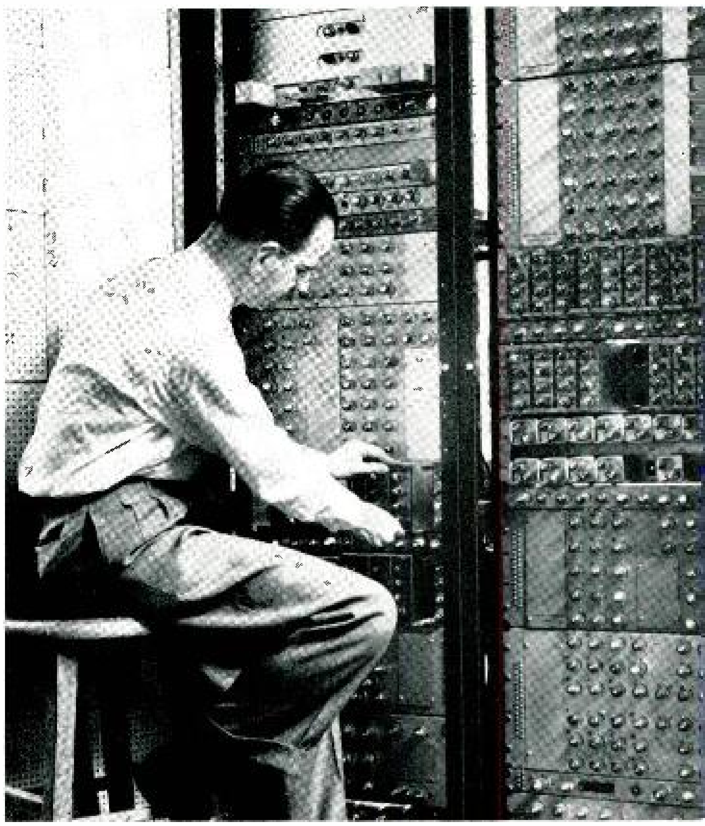
control circuits are slower. These circuits make busy tests simultaneously, a many-at-a-time operation.

On paper, DIAD was designed as a heavy traffic, 10,000-line telephone office. Time studies were made to be sure that each common-control unit would handle the information offered to it in the busy hour. The actual laboratory system, however, was skeletonized to conserve manpower and space. Nevertheless, the system is a small telephone office; the number of control functions is essentially the same as in a full-sized office, but switches are provided for only twenty-seven lines and twelve trunks.

The laboratory system, illustrated in the accompanying photographs, consists of a single magnetic drum and ten standard relay-rack cabinets set on a raised platform. These cabinets house approximately 1,100 electron tubes and 2,200 germanium diodes. Ducts under the platform carry cables between bays, and a forced-air system removes much of the heat generated by the electron tubes. Two of the bays, of the sort shown in Figure 1, house equipment associated with customers' lines; two others, Figure 2, represent the outgoing or trunk section; and one bay contains the signaling system. Two other bays house the switching network and its associated controls. Although the switching network has been skeletonized to twenty-seven lines and twelve trunks, about half the control required for a full-sized office has been provided. The final three of the ten bays house power supplies and miscellaneous equipment. The regulated dc voltage supplies range from plus 300 to minus 150 volts. The total power consumed in the system is approximately ten kilowatts.

To demonstrate and maintain the DIAD system, a large functional block-diagram display board, as seen in Figure 4, was built above the laboratory bays. In each block, neon indicator lamps connected to the system show the data which the functional block is using at the moment. A manual control console, also seen in Figure 4, has a group of keys by which the demonstrator can allow a call to proceed slowly through the system to indicate the principles of operation. In a similar manner, a maintenance man can trace a call through the system stage

Fig. 2 — W. A. Malthaner examining trunk bay equipment.



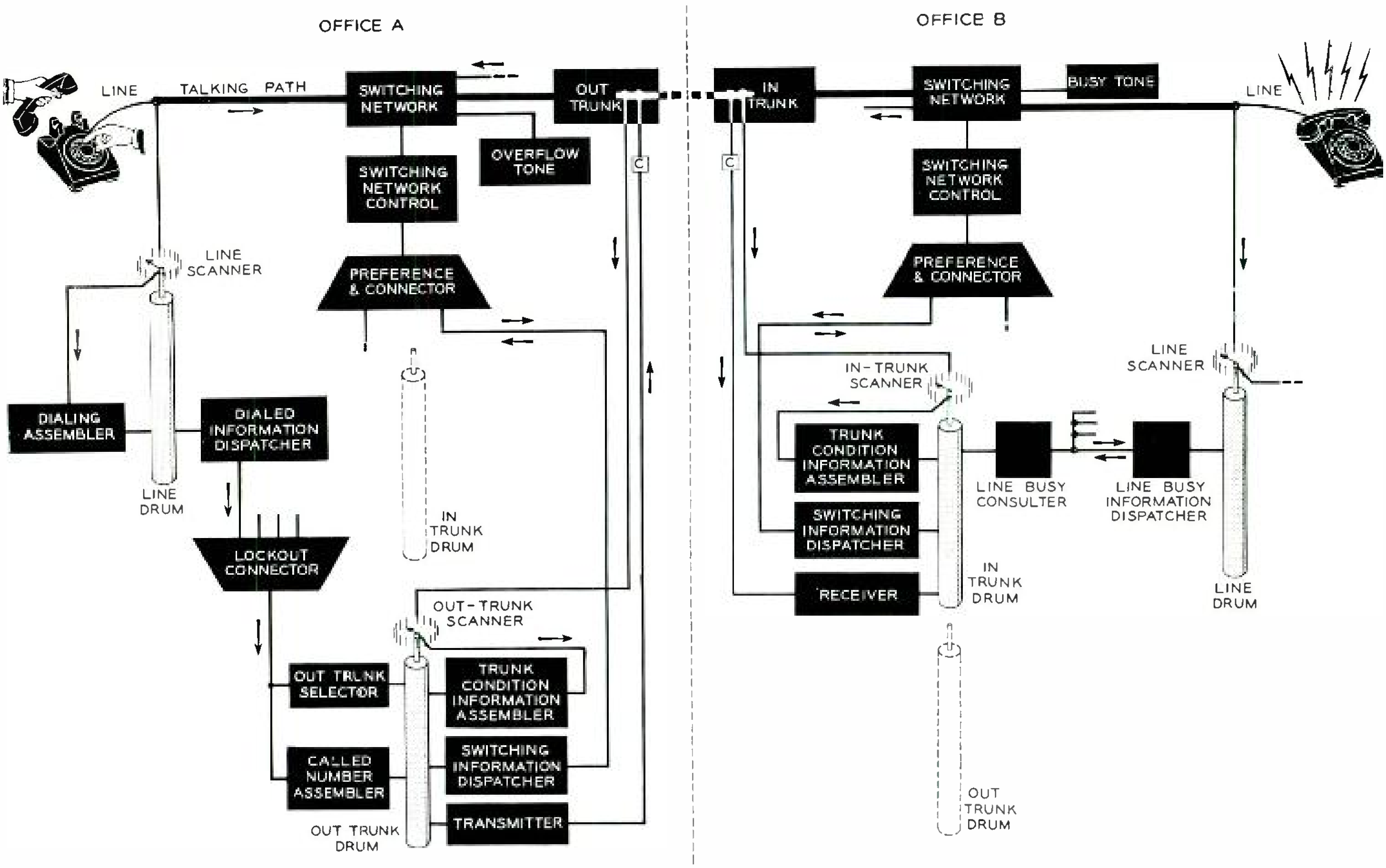


Fig. 3—Block diagram of two DIAD telephone offices, showing switching of call from Office A to Office B.

by stage to locate a trouble condition. When all keys are normal, test telephone calls proceed automatically through the system at the regular speed.

Some idea of DIAD's operation can be gained by tracing a call through the system, much as is done in an actual demonstration at the Murray Hill Laboratories. The "customer" picks up the handset of a telephone and immediately dials the number of the telephone he wishes to reach. He does not wait for dial tone, because none is necessary in the DIAD system. All of the digits dialed are assembled or collected on a specific area of the magnetic drum. This area, parallel to the axis of the drum, is called a "slot", and each slot is permanently assigned to its specific telephone line. Since it is always available to the customer, dial tone is unnecessary.

In the laboratory, a single drum is divided into two sections to serve the functions of the line and the trunk drums. The drum on which the dialed number is collected is called the "line drum", since it serves the customers' lines. After the number is collected on the line drum, it is transferred to the outgoing "trunk drum", which sends information and orders to the switching network for the establishment of an electrical path between the calling customer and a trunk to the line he is trying to reach. The switching control unit sets up this path rapidly, then disassociates itself from the call and goes on to serve others. The complete connection can be established by this method in about 0.023 second, which, compared to about 0.150 second for the more conventional systems, illustrates why, for a given volume of traffic, less DIAD equipment would be required in a telephone office.

To explain in some detail how such rapid service is possible, we must look more closely at the construction of the magnetic drum and the arrangements of the associated equipment. Figure 5 identifies the important features of the drum and scanner, and Figure 3 is a block diagram of two DIAD telephone offices, for which we may assume that a customer served by Office A dials a customer served by Office B.

The magnetic drum and a scanning head mounted on the same shaft rotate at 3,450 revolutions per minute. The customer's line is permanently con-

Fig. 4 — J. F. Muller placing call at control panel. Display board overhead shows progress of call.

nected to one of the 1080 fixed plates (Figure 5). The scanning head looks at the condition of each fixed plate on each revolution and leaves in the drum slot associated with each fixed plate a record of the condition found. By this process the scanner converts dial pulses appearing at a fixed plate to a record of the dialed information in the particular drum slot allotted to the customer.

These digits, as recorded in the customer's line drum slot, and other information derived from them, are termed the "temporary" information, since it will change with different calls. The magnetic drum "remembers" this temporary information for the duration of the call. The magnetic drum, however, also stores "permanent" information necessary for the system. This includes data that identify individual lines and trunks and that determine classes of service. Such information may be altered only by the operating staff. The DIAD system must use both types of information in handling a telephone call.

A built-in program directs the handling of calls. Certain temporary magnetic marks written on the drum provide, for each line and trunk, a summarizing record of the stage reached so far in the program. These are the "call-progress marks". Electronic circuits, such as the "information dispatchers" and "information assemblers" of Figure 3, under control of these call-progress marks, receive information from the drum, or in some cases from the scanner. These dispatcher and assembler circuits temporarily store the information received while they execute the orders indicated by the call-progress marks. In addition, they advance the call-handling program by altering the call-progress marks on the drum.

The combining circuits which respond to a call-progress mark condition, and the circuits which alter these marks to advance the call, perform "logical" functions. These are called "logical" because the statement specifying the output defines the relations between the input conditions by the use of logical connectives such as "and" and "or". "If it is raining or if the temperature is less than 50°, and if I have to go out, I must wear a topcoat" is a statement of this logical form. Such a statement from DIAD is: "The dialed information dispatcher, if idle, shall start to select a trunk for the customer as soon as he has dialed three digits, but shall start on the first digit alone if the first digit is zero". A single call-progress mark on the line drum, indicating the fulfillment of either of these conditions, controls the

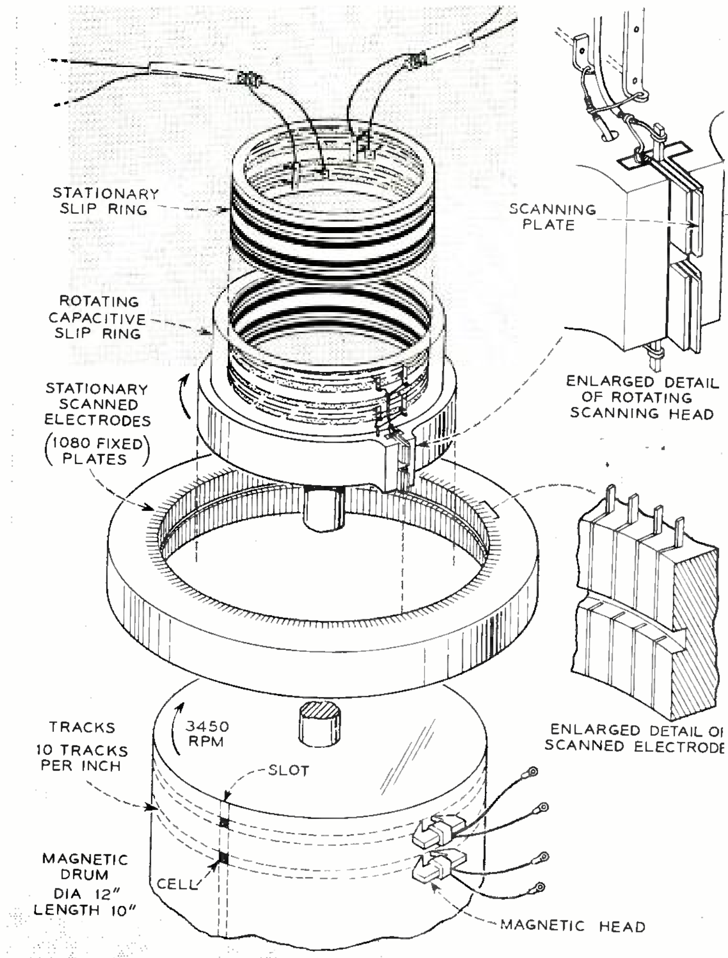


Fig. 5 — Drawing showing details of line scanner and magnetic drum used in the DIAD telephone system.

dialed information dispatcher. In recognition of the condition, the dispatcher records on the line drum a new call-progress mark indicating that a trunk has been selected.

After dialing is completed, the necessary information is dispatched from the drum memory to the switching network indicated in the upper part of Figure 3, and when necessary, to a signaling transmitter, to route the call to Office B. In Office B the operations are similar to those at the calling end. The talking path is established through the switching network of Office B to the line of the called customer. But before this path can be established, connections through the "line busy information dispatcher" between the in-trunk drum and the line drum must determine that the called line is not busy. If the line is busy, appropriate information will appear on the called customer's permanently-assigned slot on the line drum, and busy tone will be sent back to Office A and to the calling customer.

These are, of course, only a few of the major features of the DIAD system, and others can be touched on only briefly. The customer, for instance, may dial one digit ("Operator"), three digits ("Long Distance," 211), or a complete seven-digit number. DIAD checks such dialed information against the permanent information to determine when sufficient digits have been dialed for the call to proceed. In the various transfer operations, DIAD removes dialed information from the drum in parallel. Since all the necessary numbers are thus taken off in a group, the control processes are not delayed. In signaling from one DIAD office to another, the speed of operation is increased by the use of a type of pulse code modulation system of data transmission. By this method, digits are transmitted to the called office at the rate of 150 per second, compared to about 10 per second by systems presently in use. These features, combined with an electronic switching network, make the DIAD the fastest operating telephone system yet devised.

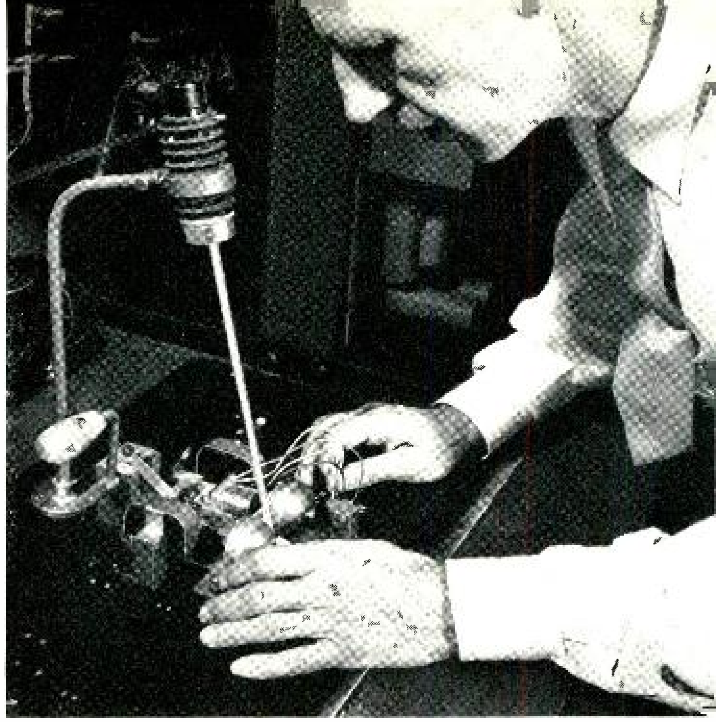
It must be emphasized that DIAD is not a commercial telephone office. During the period that DIAD has been in operation at the Murray Hill Laboratories, however, the people associated with its operation and maintenance have gained valuable experience that will aid in the development of faster and better telephone service.

THE AUTHORS

W. A. Malthaner received a B.E.E. degree from Rensselaer Polytechnic Institute in 1937 and shortly thereafter joined the Laboratories. For two years he was concerned with development and testing of circuits for commercial automatic telephone central offices. In 1939 he turned to research and development of new switching circuits and subscriber signaling arrangements as well as the associated central office switching systems. During World War II, Mr. Malthaner worked on the development of fire-control radar and other fire-control systems for the military. Since 1945 he has been concerned with new automatic telephone central office systems, subscriber dialing and supervisory arrangements, and inter-office signaling systems. He is an associate member of the A.I.E.E., a senior member of the I.R.E. and a member of Sigma Xi and Tau Beta Pi.

H. Earle Vaughan received a B.S. in C.E. degree from Cooper Union in 1933. He had joined the Laboratories in 1928 and had been engaged in work on voice operated devices for toll transmission systems and transatlantic radio and cable. In 1937 he turned to studies of the effect of speech and noise on voice frequency signaling systems. During World War II he worked on anti-aircraft computers, fire-control radar and other military projects. Since the war he has been engaged in research on high speed digital signaling systems and automatic switching systems using electronic devices. More recently he has been concerned with work on ferromagnetic cores and investigation of new switching systems. Mr. Vaughan is a senior member of the I.R.E.

A Universal Telephone Ringer



W. KALIN *Station Apparatus Development*

As part of the constant Bell System objective of standardization and simplification, a new and more efficient ringer, or bell, has been developed for the 500-type telephone set. Because this single, standard ringer can be used for all classes of telephone service, two important savings will be realized. Manufacturing costs will be reduced by eliminating the necessity for different types of ringers, and service costs will also be reduced, since there will be no need for substituting a new ringer when a customer wishes to change his grade of telephone service.

The bell that summons you to the telephone has been classified, by the communication engineer, as a ringer. This bell must ring when you are being called regardless of the miles between your telephone and the central office from which the calling signal is generated. But the central office generates other signals as well. It is of equal importance that this bell refuse to ring for all extraneously induced voltages and all signaling voltages not intended for your particular telephone set. It is this combination of a carefully controlled "ring" requirement and an additional carefully controlled "no ring" requirement that marks the ringer as a highly specialized bell and as an important component of telephone apparatus.

Telephone ringers have been regarded so specially in the past, that in 1952 the Western Electric Company found it necessary to manufacture twenty different ringers to satisfy the Bell System demand for ringers in new and repaired telephone sets. Most of these were adopted prior to the tremendous expansion of telephone plant that has occurred in the last twenty-five years. As the size of the plant increased, the need for strict standardization of apparatus became a necessity.

The new and much improved 500-type telephone set* was introduced to the public in the latter part of 1949, and about four million have since been produced. While this set was being developed, serious consideration was given to the possibility of designing a single ringer that would meet the ringing requirements for all major classes of Bell System service.

Since no practical means was then at hand to realize this objective, two new ringers were developed and introduced.† One of these, the C2A, was to be used in all individual, two-party, four-party semiselective, and some multi-party coded ringing

Above — The author placing a telephone ringer in automatic adjusting machine used to balance magnetic and mechanical forces.

* RECORD, *September*, 1951, *page* 414.
† RECORD, *October* 1951, *page* 473.

installations. The other, the C3A, was to be used in all four-party full-selective and eight-party semi-selective installations.* To obtain this selective ringing, the latter ringer was always used in conjunction with a cold cathode tube.

Thus, only two ringer codes were needed to supply all of the ringing requirements of the new telephone set. This was a noteworthy improvement over previously introduced telephone sets with their multiplicity of ringer codes.

Since many advantages would be gained by the use of a single ringer, however, further work was undertaken with the objective of developing a design suitable for use with all classes of service. If this could be done, only one coded ringer would need to be manufactured for all of the various types of new telephone sets. This would in turn simplify field operations, since any change in grade of service could be taken care of without changing the ringer in the regraded set.

In attempting to use the individual line ringer in four-party service, there were limitations that made this application impracticable. Its sensitivity, adjusted by the shop to meet the requirements of a single-party line service, was insufficient to guarantee operation in all multi-party services. In addition, the ringer impedance was considerably higher than that desired for the efficient use of the power available in four-party selective telephone service.

Perhaps the most serious limitation of the single-party ringer, however, was one of fundamental design. An automobile engine designed to run on gasoline will not run as well on any other fuel. Similarly, this ringer, designed to operate on a symmetrical full-wave current, behaved badly and occasionally became non-operative when used with the unidirectional pulsating current of four-party telephone service.

The four-party selective ringing circuit used by the Bell System is shown in Figure 1. The activating voltage used in selective ringing consists of a twenty-cycle alternating voltage on which a direct-current biasing voltage has been superimposed. In four-party selective ringing, two parties are connected between each side of the line and ground, and signaling is accomplished by impressing this combined ringing voltage across one side of the line and ground. The direction of the dc bias on the impressed voltage determines which of the C3A ringers connected to that side of the line will ring. Selection is obtained by connecting the cold cathode tube and the ringer coil in each of the telephone sets so that one is activated with a negatively biased signaling voltage and the other with a positively biased signaling voltage.

To illustrate, assume in Figure 1 that the plus party on the tip side of the line is being called. At the central office a connection is established between the ringing generator and the tip side of the telephone line (switch 1). The other side of the generator in turn is connected to the positive terminal of a grounded central office battery (switch 2). The ring side of the line is also grounded to insure against false operation of party telephones on that side of the line. This positively biased twenty-cycle ringing

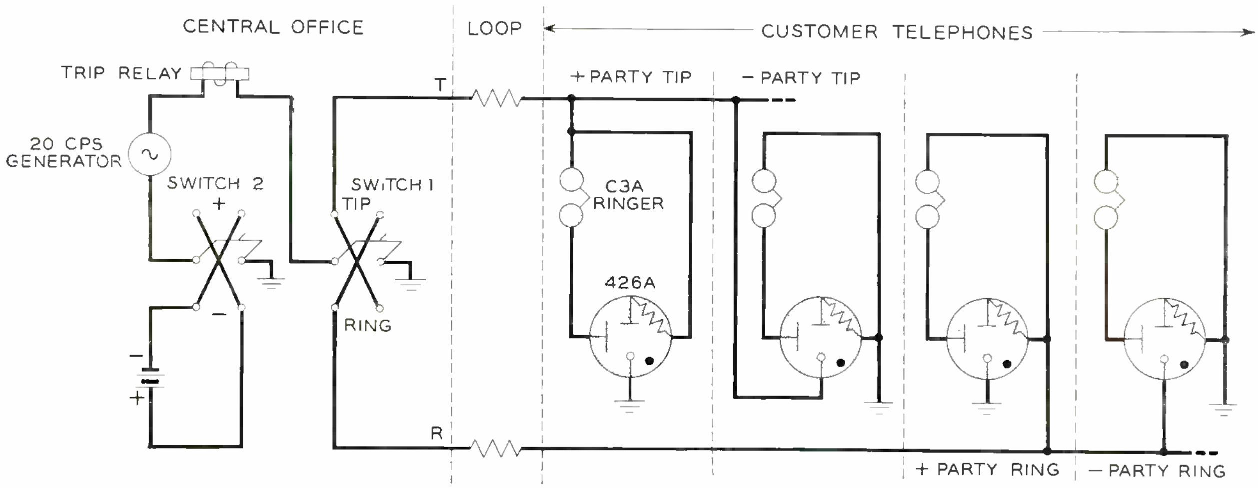


Fig. 1 — Circuitry involved in selecting one ringer from the four telephones on a four-party line.

* With full-selective ringing, the customer hears only one ring — his own; with semiselective and coded ringing, he hears in addition one or more other ringing combinations.

voltage, which is being impressed between the tip side of the line and ground, alternates between a rather large positive value and a relatively small negative value because of the dc bias. The cold cathode tube in the plus party tip telephone, being connected to pass those positive voltages that exceed the breakdown voltage of the tube, will allow a considerable portion cf each cyclic positive pulse to pass through the ringer to ground. These pulses activate the ringer and summon the customer.

Now let us see what happens when this voltage is impressed across the ringer circuit of the noncalled party on the tip side of the line. The cold cathode tube is so connected that it will not pass the positive voltages. The magnitude of the voltage during the negative portion of the cycle is low, and even if it exceeds the breakdown voltage of the tube, it is insufficient tc activate the ringer. Since little or no current will flow under these circumstances, the ringer will not ring and needlessly disturb the noncalled customer.

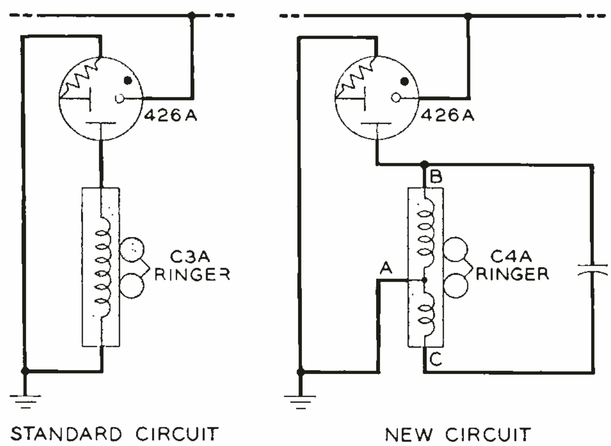


Fig. 2 — Left: standard ringing circuit for multiparty lines; right: the newly developed circuit that has made possible the use of C-4 telephone ringers in multi-party lines.

Thus four families can be provided telephone service through the cooperative use of a single pair of wires, and any one of them can be summoned to the telephone without disturbing the other three.

It has been shown that the current flowing through the ringer in four-party selective service is unidirectional and pulsating. Therefore each ringer must be properly poled on installation so that it will be activated by the ringer current intended for it. When thus poled, the initial ringing pulse will cause the armature to operate, allowing the clapper ball to strike the furthest gong. During the time interval between pulses, the armature must restore to the nonoperate position, allow the clapper ball to strike the other gong, and be available for reactivation by the next pulse of current. This ringer must therefore be adjusted with a sufficiently high mechanical restoring force to assure that the armature returns to its original position between ringing pulses.

Should the armature stick magnetically in the operate position, the ringer would be incapable of responding to succeeding signaling impulses. The customer's telephone would then be out of service to all incoming calls and could only be restored to service through a visit by a telephone repairman.

The best ringing tone is realized when the mechanical restoring force is held to a minimum. The single-party ringer is therefore purposely adjusted to have a minimum restoring force, and there is a real danger that a ringer so adjusted will stick and thus become inoperative if used in four-party selective service.

A new ringer circuit has now been developed which overcomes the major difficulties of operating, in four-party selective service, a ringer designed for individual party service. Figure 2 shows the newly developed circuit as well as the standard circuit previously used for multi-party operation.

The single coil of the individual party ringer is composed of two separate windings: an inner low impedance winding and an outer winding of considerably higher impedance. In single-party service the two windings are connected series-aiding and act as a single winding. In two-party message rate service the low impedance winding is connected, for all tip-party dial message-rate installations, as a one thousand ohm bridge between the tip side of the line and ground for purposes of tip-party identification. Since this bridge to ground is not present in the ring-party installations, identification can be established between parties on the basis of line impedance to ground. In the new circuit the double winding is used to advantage by connecting the ringer as an auto transformer. The low impedance winding in series with a 0.4-mf condenser is bridged across the second ringer winding. This resonant circuit is also connected in series with the main gap of the three-element cold cathode tube.

In the interest of over-all economy, only one network was coded for all 500-type sets. Since the ringing capacitor is contained within the network, it is available for four-party selective and eight-party semi-selective service, even though the previous multi-party connections had not called for its use in the telephone circuit. By taking advantage of the

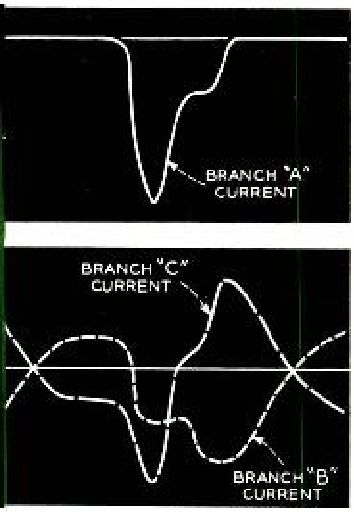


Fig. 3 — Above: *current in Branch A of Figure 2;* below: *currents in Branches B and C of Figure 2.*

double ringer winding and by making use of an available component of the telephone set, a major step was thus taken toward the use of a single ringer code for all 500-type telephone sets.

With these connections, the ringer impedance is considerably reduced. This increases the signaling efficiency since it enables more power to be delivered to the ringer.

In addition, the unidirectional pulsating activating current normal to four-party service is converted to approximately a symmetrical full-wave current within the ringer windings through the use of this resonant circuit connection. Thus the single-party ringer, designed to operate on full-wave current, can now also be used for full-selective four-party service. Sticking of the armature is no longer to be feared since the reverse half cycle of activating current is now present to drive the armature back to its normal position. In addition, there is a marked improvement in the character of the ringing tone due to this full-wave operation.

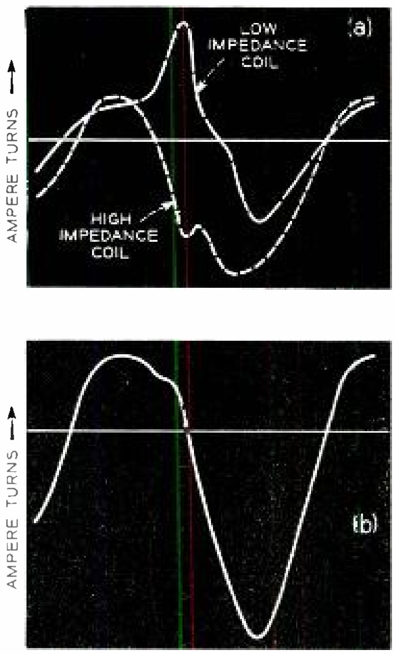


Fig. 4 — *Curves illustrating the full-wave characteristics of the new C4A ringer when connected for four-party selective service.*

The upper half of Figure 3 shows the pulsating current wave in the main (A) branch of the ringer circuit marked on the schematic of Figure 2. This is the characteristic current curve that in the past has made it necessary to design special ringers to insure proper operation in four-party selective service. In contrast, the lower curves show the full-wave characteristic of the currents flowing in the branches (B and C) of the new resonant circuit.

To further clarify how ringer performance is improved, an additional set of curves is shown as Figure 4. The curve, Figure 4(a), marked ampere turns in high impedance coil, represents the current curve of branch B of Figure 3 multiplied by the number of turns in the ringer winding through which that current is passing. The curve marked ampere turns in low impedance coil represents the current curve of branch C of Figure 3 multiplied by the number of turns in that ringer winding. In addition, however, this curve is inverted with respect to Figure 3 to indicate that the winding connections have been reversed. This has been done to phase the currents in the two ringer windings.

Having connected the ringer windings for optimum operating efficiency, the two curves of ampere turns can be added to give the curve shown in Figure 4(b). This curve represents the total effective ampere turns through the entire ringer coil.

The force acting on the armature of the ringer is proportional to the ampere turns present in the ringer. The curve therefore clearly indicates the approximately symmetrical full-wave character of the forces generated during a ringing interval. Because of the greatly improved character of the generated driving forces, ringer efficiency was improved, ringing tone was made steady and clear, and the restrictions previously imposed by the pulsating voltage source no longer applied.

Although these circuit changes made it possible to use the individual line ringer in four-party selective and eight-party semiselective service, further work was required to determine the capabilities of the then standard individual line ringer to meet the sensitivity requirements of four-party and eight-party services under adverse circuit conditions. A detailed study was therefore made of ringer capabilities, and this in turn led to a statistical evaluation of the single-party ringer when this was utilized as proposed in multi-party service. On the basis of this study it was concluded that the ringer then standard would be satisfactory except for a very small percentage of installations. An attempt was then made to evolve a satisfactory installation procedure for the Operating Telephone Companies. It became apparent that any procedure that involved tailoring telephone installations in the field would be unduly complicated and difficult to administer properly. A better solution was to increase the efficiency and thereby the sensitivity of the individual line ringer so that it would meet all of the ringing requirements of multi-party service.

Evaluation studies on the C-type ringer had progressed sufficiently in the years since it was first introduced to indicate ways in which its efficiency could be improved without altering the fundamental design. Since the ringer is a large production item with the usual associated high tool costs and specialized assembly procedures, it was important that any changes be of such character that they could be incorporated into the design with a minimum of inconvenience to the manufacturing department. It was equally important that both old and new design ringers could be treated substantially alike when returned from the field for repair.

An increase in efficiency was realized by a redesign of the armature and clapper assembly. Since this assembly was the only major component altered in the ringer design, it could be incorporated into the assembly procedure with a minimum disruption of shop effort. By restricting the change to this one component, repair procedures could be maintained as before, and old ringers returned for repair could be converted to the new, more efficient ringer design by the replacement of the armature assembly and a simple alteration in the bias spring bracket. With this increase in efficiency it became

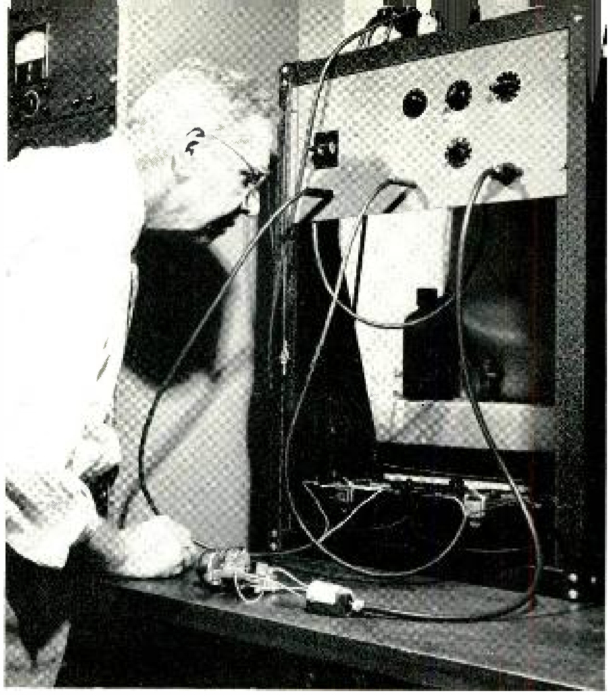


Fig. 5 — R. T. Jenkins checking the performance of a telephone ringer.

possible to increase the sensitivity of the ringer in shop adjustment by an amount sufficient to guarantee effective ringer operation in all four-party selective and eight-party semiselective service.

This new ringer has been coded the C4A ringer and replaces both the C2A and C3A ringers which have been classified "manufacture discontinued."

A design objective long sought has been realized. A single code of ringer is now being used in all 500-type telephone sets regardless of the class of service these sets are intended for. This new ringer is more efficient than any of its predecessors, being capable of operating effectively in individual line service on telephone lines that are somewhat longer than those previously used. In addition, the new ringer can be used in all four-party selective and eight-party semiselective services now offered by the Bell System.

THE AUTHOR

Walter Kalin started his Laboratories career in 1924, working on the development of loud speakers for motion picture sound systems. He was next concerned with the problems related to a new telephone handset. In 1938 he turned to the development of hearing aids, temporarily interrupting this work during World War II to help develop a military headset for use under the battle helmet. Since 1948 he has been concerned with problems associated with ringers used in new telephone sets. He is currently in charge of the ringer development group. Mr. Kalin received the B.S. degree from Cooper Union in 1929.

Centralized AMA Switchboard

F. H. MARTIN *Switching Systems Development*

Centralized Automatic Message Accounting equipment in a tandem office permits customers in outlying offices to dial their own long distance calls. An operator at the CAMA switchboard intercepts a dialed charge call for a brief interval of time, obtains the calling number, and keys it into the automatic equipment for billing purposes. This switchboard is presently used at crossbar tandem offices, but in the near future will be used with other types of offices when these are equipped with CAMA.

Operators at recently installed switchboard, Uptown Toll Center, Washington, D. C.

There has been an increasing trend in the telephone industry toward the development and use of automatic switching and recording equipment so that customers can dial their own toll and multi-unit calls without assistance from an operator. In many dial areas, the number of such calls is not sufficient to justify the installation of recording equipment in the local office. To realize the advantages of customer dialing in cases where the toll calling rates are low, plans have been made to centralize the recording equipment, instead of installing it in each separate office. With this arrangement, calls requiring automatic switching and recording will be routed to a crossbar tandem office. at which the equipment will handle the billing information necessary for as many as 200 central offices.

This new centralized automatic message accounting system,* commonly referred to as CAMA, was recently introduced into Bell System tandem offices. It provides an economical means of obtaining the benefits of direct dialing by customers of multi-unit and toll calls without requiring extensive modification of the central offices in which they originate.

Prior to rendering the system completely automatic, however, an operator will be required to record the calling customer's telephone number. To the customer this will mean merely that after dialing the number he wants, an operator will be connected momentarily to obtain the calling number and key it into the recording equipment. Thereafter, the call

* Record, *July* 1954, *page* 241.

and the information for billing it will be handled on a completely automatic basis.

To the Telephone Company personnel in the tandem office, CAMA will mean the installation of new equipment, including switchboards designed to facilitate the identification of the calling customer's number. The CAMA switchboard recently installed in Washington is shown on page 371, and a drawing of an individual switchboard section and cable-turning section, showing the location of parts, is seen as Figure 1. The switchboard section consists of two operator positions. The cable-turning section, shown at the left, is used, as its name implies, for bringing the necessary cables into the lineup from above or below. The required number of switchboard sections may be lined up for growth either to the left or to the right of the cable-turning section.

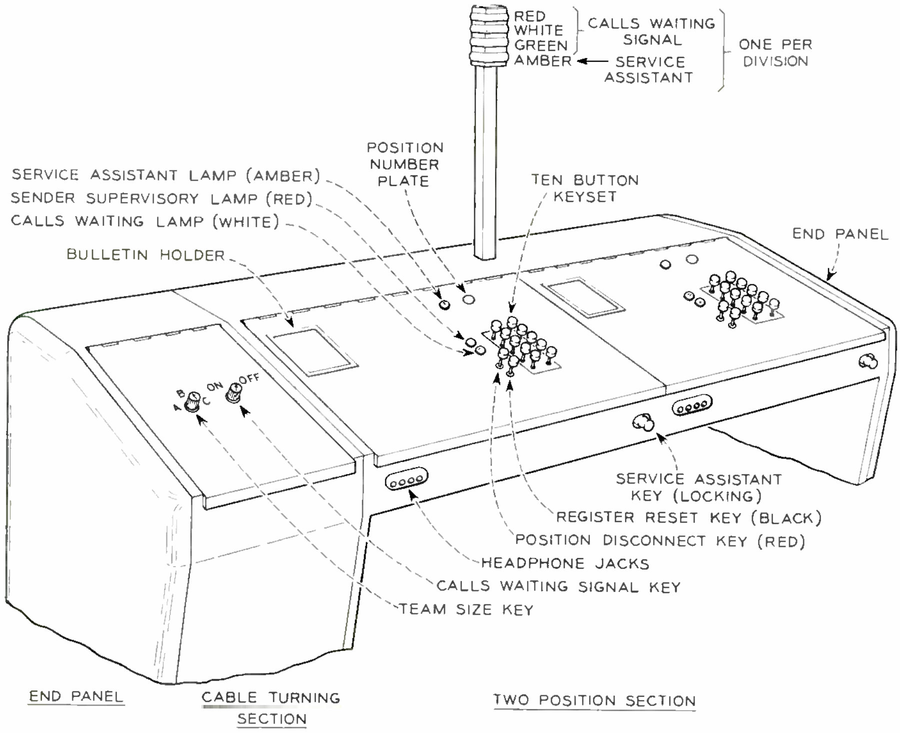


Fig. 1 — A two-position CAMA switchboard section and a cable-turning section, showing locations of keys and lamps.

The number of switchboard positions required in a tandem office depends upon the traffic during busy hours, and may consist of a few to as many as 100 positions. These may be subdivided for administrative reasons into smaller units in the same location as the tandem office or in a different building or buildings. For a typical office of twenty operator positions, ten switchboard sections would be required. For each group of five sections or ten positions, a lamp standard is provided and is placed in the center of the group.

A typical business day could begin with only light traffic through the office. Under this condition, perhaps only four operators would be assigned to the first group of ten positions of the switchboard. To receive the proper indication of the number of calls waiting per operator, the TEAM SIZE KEY in the cable-turning section (Figure 1) is set to correspond to the number of occupied positions. This key is turned to "A" when there are fewer than five operators at the board, to "B" when there are from five to ten operators, and to "C" when there are over ten. In this assumed case the TEAM SIZE KEY would therefore be set at "A", and with light traffic the green light on the lamp standard would be lighted. As the traffic increases, however, the light will change first to white and then to red, unless additional operators are added to the team. These different lamp colors are indications to the service assistant supervising the positions that progressively larger numbers of calls are waiting to be identified, and they warn her that more operators are needed to handle the load. With a team of four operators, the white light will be lighted when the number of calls waiting for each operator exceeds one, and the red light will be lighted when the number of calls waiting exceeds two per operator. When the light in the standard changes from green to white or red, the operator also receives an additional signal, in the form of a white CALLS WAITING LAMP on her keyshelf, to indicate that the load has increased.

When a call is connected to an operator, she receives a double order tone over her headset and sees

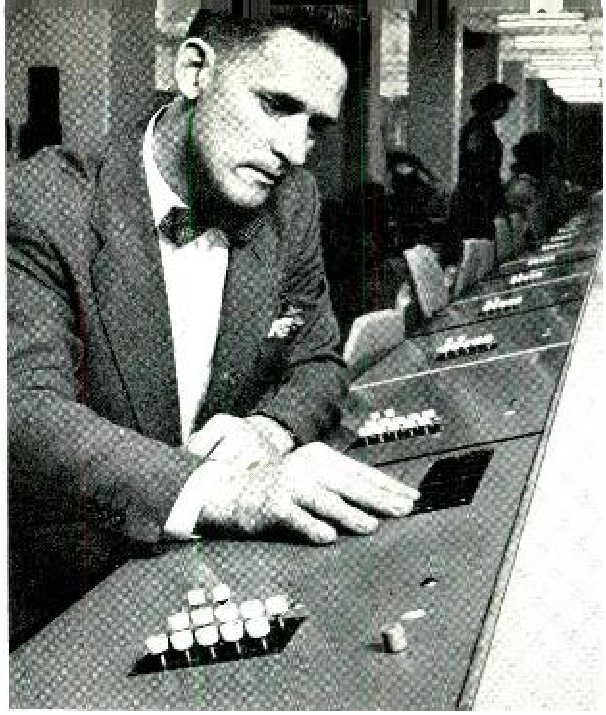


Fig. 2 — The author inspecting key-monitoring lamp panel of the New York City CAMA office.

a lighted SENDER SUPERVISORY LAMP on her keyshelf as indications that a call has been directed to her. She then asks the customer for his number, and keys it into the CAMA equipment (Figure 4). Upon the completion of her keying operation, the operator is released from that call and is now ready for the next.

Provision is made for several difficulties that may arise. If the operator keys incorrectly, the sender supervisory lamp on the keyshelf may begin to flash. This is an indication that the equipment has performed a check and has found an error. The operator will then press the REGISTER RESET KEY, which causes the sender to release the registered digits. She now either reascertains the customer's number or, in the event she realizes that she has keyed incorrectly, immediately keys the number again. If she is unable to complete the call satisfactorily, she will ask the customer to dial a local operator, after which she will depress the POSITION DISCONNECT KEY, which will cause the sender to release the call from the position.

The operator also has a SERVICE ASSISTANT KEY on the right-hand side of her position. When she operates this key, both the amber light on the lamp standard and a corresponding colored lamp on her keyshelf will light to summon the service assistant for any additional help that may be required.

During periods of light load, the positions may be vacated and the functions of the CAMA positions transferred to toll or to "Dial System A" (DSA)*

* RECORD, *April*, 1942, *page* 195; *November*, 1942, *page* 77.

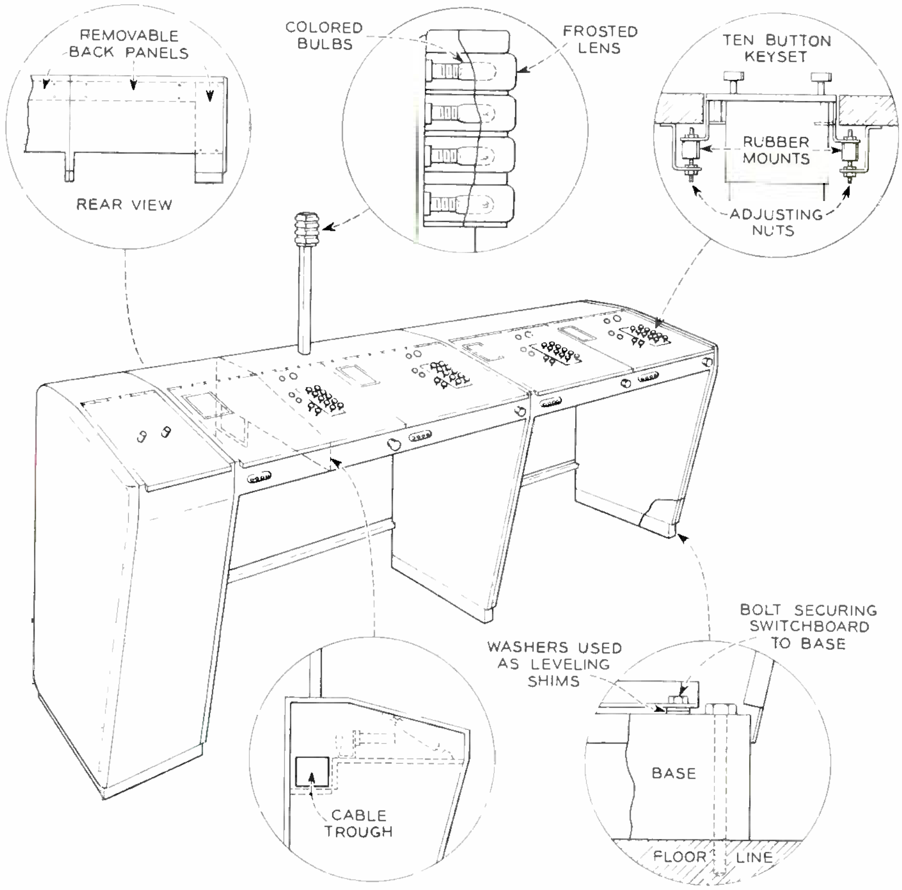


Fig. 3 — Drawing of switchboard sections and cable-turning section showing details of construction.

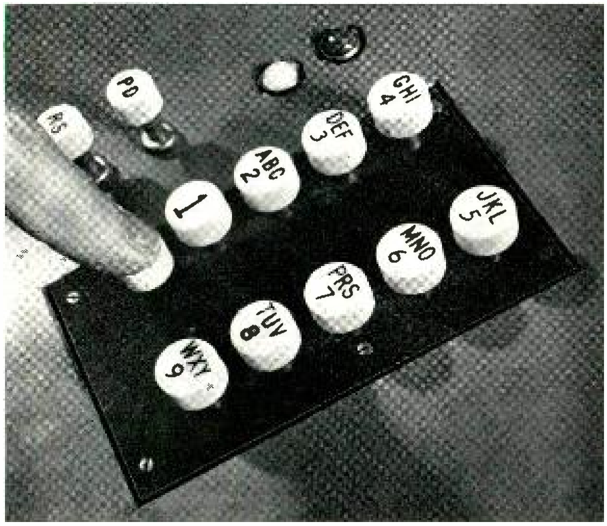


Fig. 4 — The CAMA keying operation; register reset and position disconnect keys in upper left.

switchboards in the same building that have been arranged to identify the calling number. Provision is also made for key monitoring any of the switchboard positions. One of these, usually the first in a line-up, is adapted to include a set of indicator lamps (Figure 2) by means of which the accuracy of operation at any other position can be observed. The number of the position is keyed into the regular keyset, and the calling number as given by the customer is checked against the number keyed by the operator, as displayed on the indicator lamps. The position arranged for key monitoring can be easily switched back to normal CAMA operation.

The CAMA switchboard differs in many ways from other switchboards previously used in the Bell System. It employs a number of novel design features, new materials, and a color scheme of light, harmonizing shades. It represents another step in the improvement in operating room appearance, and will lend more cheerfulness to the surroundings.

The more important details of construction are shown in Figure 3. The framework is finished in a light gray wrinkle enamel that conceals minor defects in the metal surfaces yet does not have objectionable dust-catching qualities. The sloping side panels present a modern appearance and provide more room than vertical panels for entering and leaving the position. The bases telescope inside these panels, and washers are used as shims to level the section. The cable trough is formed in one piece with the bottom panel or keypan, and accommodates the cables for as many as one hundred positions, which is the capacity of the unit. When the switchboard positions are placed back to back, a transparent partition is provided. This extends seventeen inches above the top of the position and reduces the level of sound noticeable by the operators.

The keyshelf uses a blue-green synthetic resin material, cemented to plywood. The blue-green color was chosen because of the preference shown for this color by a group of seventy-four people, many of whom were switchboard operators. In the keyshelf, the ten-button keyset is placed on four rubber mountings to deaden the noise of the keying operation and to reduce operator fatigue. The entire keyshelf is hinged in the conventional manner to provide access to the terminal side of the apparatus mounted inside.

The lamp standard extends seventeen inches above the switchboard to permit easy visibility by the service assistant. Colored bulbs are used, over which are mounted frosted "Plexiglas" lenses. There is a slightly greater spacing between the amber and green lamps, since the top three have a separate function.

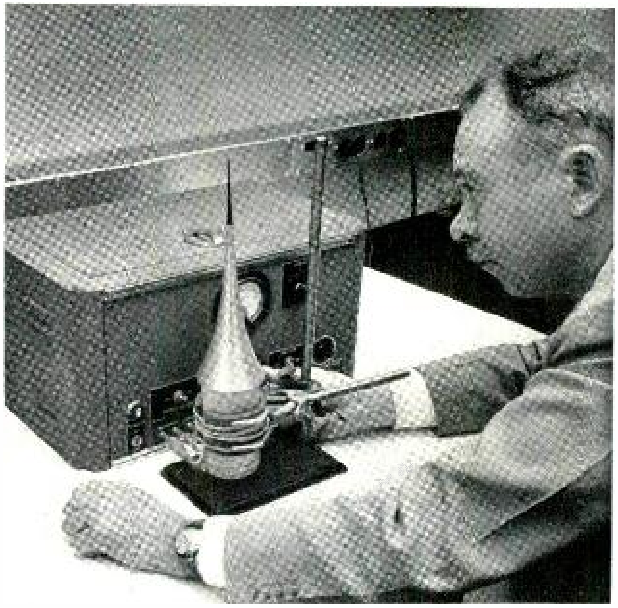
This CAMA switchboard is now in production, and the first installation was placed in service at the Uptown Toll Center, Washington, D. C., in November, 1953. A second CAMA installation was placed in service in Detroit, Michigan, in December, 1953, and a third in New York City in July, 1954.

THE AUTHOR

Frank H. Martin joined the Drafting Department of the A. T. & T. Co. in 1929. He transferred to the Laboratories in 1934 and until 1942 was engaged in design drafting of various sorts of Bell System equipment. During World War II he was concerned with projects such as the portable pack radar, microwave radio relay antenna and the battle announcing system. For almost a year he aided the development of the eagle antenna at the Radiation Laboratories of M.I.T. and later headed the Laboratories drafting organization at the Excello Corporation in Detroit where the antenna was manufactured. In 1944 Mr. Martin transferred to the Switching Development Department where he has been concerned with the development of frame work and equipment for the Automatic Message Accounting Center, CAMA for crossbar tandem, a military switchboard and other equipment. A member of the common systems development group, he is now engaged in the design of switching systems equipment.

New Techniques for Measuring Forces and Wear

W. P. MASON *Mechanics Research*



In developing new apparatus and equipment for modern communication systems, special attention must be paid to the durability of the components. These components must be designed to give long, trouble-free service without being prohibitively expensive to manufacture. Various testing and measuring techniques have been devised at Bell Telephone Laboratories to measure the effects and to study the fundamental nature of wear. One such technique is based on the use of a barium titanate piezoelectric ceramic.

To study and evaluate the performance of fast-acting devices such as telephone relays and other switching equipment, it is often necessary to measure not only the static forces that occur when the elements are at rest, but also the dynamic forces that result from the operation of the device. The common method for measuring these dynamic forces, which are often much larger than the static forces when various parts of a device impinge on each other, is by means of a piezoelectric crystal such as quartz.

The ability of piezoelectric crystals to generate a voltage that is proportional to the applied force makes them particularly useful in these applications. Quartz, for example, has been used to measure forces developed in explosions, and another piezoelectric crystal, Rochelle salt, has been used in phonograph pick-up units where it generates voltages proportional to the displacements in phonograph records. However, neither quartz nor Rochelle salt is well suited for measuring dynamic forces in telephone switching apparatus. Rochelle salt is very sensitive to changes in temperature, and moreover it is so fragile that it cannot withstand the large momentary stresses that may occur. Quartz, on the other hand, is not very sensitive and it has such a low dielectric constant that the input impedance of an associated amplifier must be prohibitively high if forces are to be measured that vary in magnitude over intervals longer than one-hundredth of a second.

These difficulties can be overcome, however, by using a new piezoelectric ceramic material – barium titanate.* This material is about 50 times as sensitive as quartz, and its dielectric constant is over 250 times as large. In addition, since the mechanical strength of barium titanate is comparable with that of quartz, it can withstand large momentary stresses. Pieces of this ceramic, 0.04 inch square by 0.02 inch thick weighing less than 0.003 grain, are small enough to put behind the wires and on the contacts of a wire spring relay, and are sensitive

* RECORD, *August*, 1949, *page* 285.

Above — ***R. F. Wick using apparatus to measure breaking strength of a plastic sample.***

enough to measure the dynamic forces that occur.

The time intervals in which dynamic forces can be measured accurately with this material are limited by the resonant frequencies of the natural vibrations set up in the ceramic plate. Since the lowest resonant frequency is about 1.6 megacycles in the small plates used, dynamic forces persisting for as little as one microsecond can be measured. All the forces that occur when a typical relay is operated last about 0.015 second, and therefore barium titanate is well suited for this application.

These small ceramic plates have an electric capacitance that may be as low as 20 micromicrofarads. Therefore, it is necessary to connect them to amplifiers having an input impedance as high as

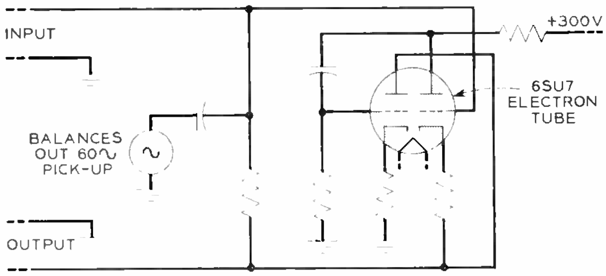


Fig. 1 — Circuit for amplifier used with barium titanate piezoelectric plates.

750 megohms to insure that the voltage generated by a steady force will not leak off in less than 0.015 second. An electron tube amplifier of this type, illustrated in Figure 1, is capable of providing a significant deflection on the screen of a cathode ray oscillograph corresponding to the voltage developed by forces as small as 25 grams.

Two types of force measuring units are used, one to measure compressive forces and the other to measure forces such as those that occur when one element slides over another. In the unit used to measure compressive forces, illustrated at the left of Figure 2, the ceramic plate is vertically "poled." That is, the material is subjected to a high voltage d-c field with the result that groups of atoms – domains – are oriented at right angles to the face of the plate. The second type unit, shown at the right of Figure 2, is poled parallel to the major face, and it responds only to forces directed parallel to that surface.

Although the compression unit (left of Figure 2) is electrically poled in the same direction as the force that is to be measured, it also responds to a compressive force at right angles to this direction. Hence, the total response depends in the distribution of the force over the top surface. If all the force

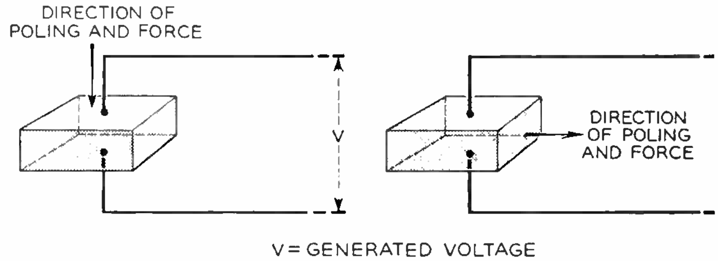


Fig. 2 — Barium titanate plates; unit at the left is used to measure vertical forces, and that at the right to measure sliding forces.

is applied at a point, it has been found that the response is only four-tenths as large as that resulting from a compressive force that is applied uniformly over the entire surface. For this reason, the compression units must be calibrated for the distribution of the force that is to be measured. In the second type unit (right of Figure 2), however, the distribution of the stress over the surface does not affect the value of the generated voltage. These two types of barium titanate units have been used extensively in measuring forces that occur in relay operation, and in measuring frictional forces associated with wear studies.

An oscillograph picture of a relay armature "make" and "break" is shown in Figure 3. In this illustration, the make curve shows the effects of wire vibration in the first two-millisecond period,

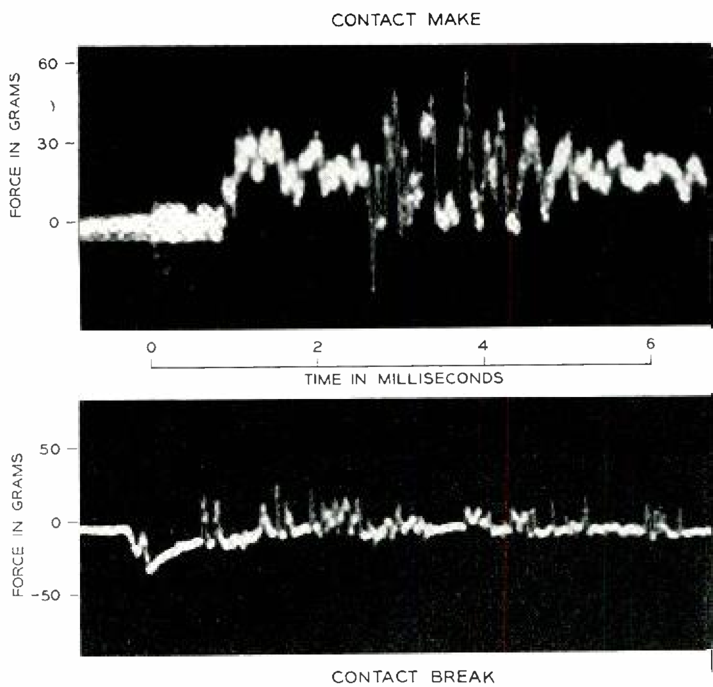
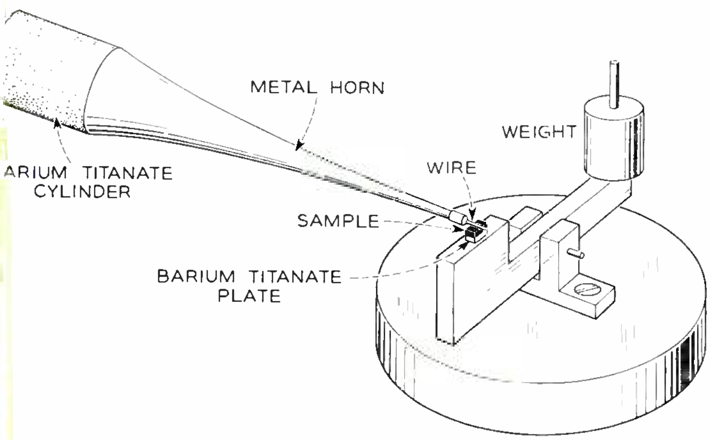


Fig. 3 — Oscillogram illustrating forces that occur during a relay armature "make" and "break."

and the large effect caused by the armature striking the backstop. The break curve shows the effect of wire vibrations as the armature leaves the backstop. These vibrations produce appreciable relay wear, and hence damping materials are used to reduce them quickly in relays that may be required to operate as many as one billion times during their life span. By using piezoelectric force-measuring techniques in this way, considerable information can be obtained about the operating performance of a relay or other fast-acting mechanical devices.

The unit shown at the right in Figure 2 has been used to measure forces that occur when a wire is drawn over a surface. An experimental arrangement for studying the resulting wear on such a surface is illustrated in Figure 4. As shown, barium



ig. 4 — Experimental arrangement used to measure wear at occurs when a wire is drawn over a surface.

titanate ceramic in the form of a hollow cylinder, four inches long, is set into vibration by applying an alternating voltage to its inside and outside electrodes. These vibrations are increased ten-fold in strength by means of a specially shaped metal horn attached to the end of the cylinder. The motion is then imparted to a wire attached to the end of the horn.

A material, such as a plastic whose wear against the wire is to be measured, is mounted on a force-responding barium titanate plate which is in turn mounted on one end of a pivoted arm. The plastic is held against the vibrating wire with a definite force determined by weights placed on the opposite end of the pivoted arm. These forces measured for various values of the wire motion are illustrated in Figure 5.

As shown at the top of the figure, the generated force is sinusoidal for a total wire travel of 0.00005

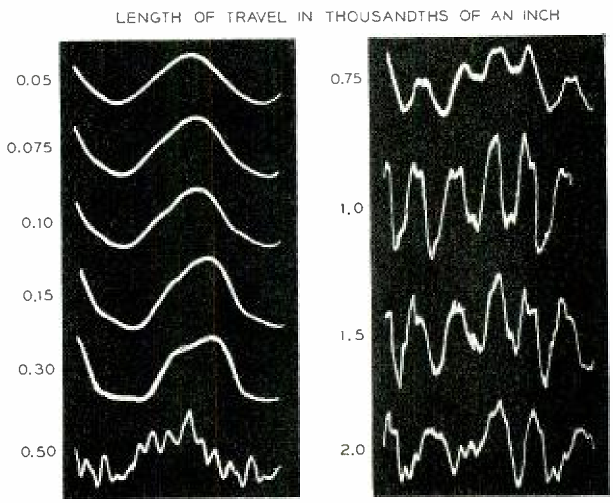


Fig. 5 — Oscillogram indicating forces generated in a sample for various values of wire travel.

inch. This shows that the response of the sample to the motion is elastic in that particles of the plastic that touch similar points in the wire simply bend and do not break contact. As the amplitude of the motion is increased to 0.0003 inch, however, the sinusoidal nature of the resulting force is lost; there is evidence that some points of contact have been broken and others established. This process is more pronounced when the amplitude of the motion is increased still further as shown in the lower frames of the figure. In this test set up, the wire vibrates 18,000 times per second and since a two-second exposure is required to produce each picture in Figure 5, the wire goes back and forth over the same high points a great many times during that period.

Results of these studies suggest a mechanism of wear: the material associated with the high points goes through a large number of bending cycles until these points finally fatigue and fracture. This is borne out by the fact that observed wear in these materials agrees with the data obtained from the described force measurements. Resulting wear measured in cubic thousandths of an inch and plotted against amplitude of motion is illustrated in Figure 6. As shown, for amplitudes of motion less than 0.0001 inch no measurable wear occurs. This corresponds to the elastic region indicated by the curves at the top of Figure 5. As the amplitude of motion increases above this value, however, measurable wear occurs that is approximately proportional to the length of slide, and also to the value of the static force with which the sample is pushed against the wire. These tests have shown

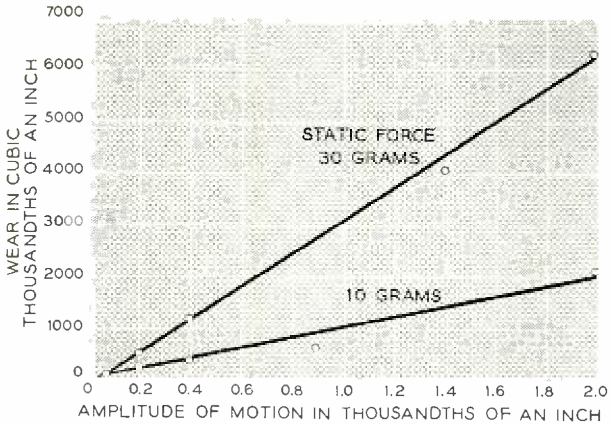


Fig. 6 — Wear versus amplitude of wire motion.

that the materials that wear best are those capable of bending the most without fracturing. Plastic materials such as phenolics and rubbers out-wear metals and glasses.

This use of barium titanate vibrations to produce large motions and stresses in samples has been extended to study fatigue and fracture in metals and plastics. One experimental arrangement used for these investigations is illustrated in the headpiece of this article. As shown, a large titanate cylinder forms the base for an aluminum horn that has the sample to be studied mounted on its tip. The amplitudes of vertical vibrations generated in the titanate are increased by the horn and imparted to the sample. To minimize heating effects, the titanate is vibrated only for short time intervals, and the breaking strength of the sample is determined from the value of the voltage applied to the unit. Fatigue effect is measured by letting the unit vibrate through a large number of such cycles.

Practical application of these force measurement tests has been made in designing the wire spring relay. Since all the moving spring wires have a bend at a definite distance from the clamping point, a given displacement of the wire actually consists of two motions as shown in Figure 7. One is a rotation about the effective clamping point, A in the diagram. The other is a motion about the bend, B. The first has a circle of motion, labeled "a," that tends to move the contacts to the right of the perpendicular line N-N, and the other has a circle of motion, "b," that tends to move the contacts to the left of N-N. By adjusting the location and height of the bend, B, these two displacements can be made to balance each other so that the motion takes place along the line N-N. As a result, very little rubbing motion occurs on the card or con-

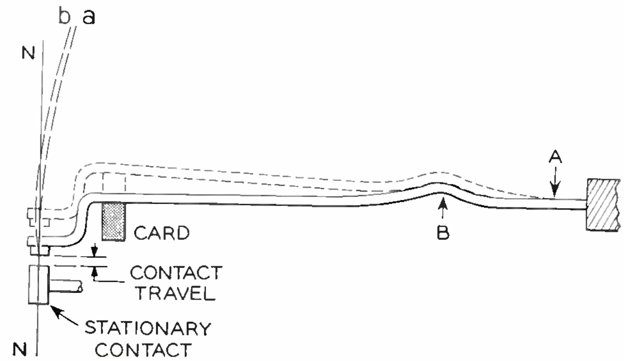


Fig. 7 — Wire spring relay armature showing clamping points and bend.

tacts of the relay, and wear is greatly reduced. Tests carried out over long periods have shown that such relays, including wire vibration dampers, can approach the design objective of one billion operations without requiring any readjustments.

THE AUTHOR

WARREN P. MASON joined the Western Electric Company's Engineering Department in 1921, soon after receiving a B.S. degree from the University of Kansas. He later took graduate work at Columbia University, earning an M.A. degree in 1925 and a Ph.D. in 1928. During his first four years with the Laboratories, he was concerned with investigations of carrier-transmission systems. Since then he has been occupied in studies of electrical and mechanical wave transmission networks, piezo-electric crystal research and in studying the mechanical properties of liquids and solids. Dr. Mason is now in charge of the Mechanics Research Department.

Dr. Kelly Warns of Urgent Need for Complete Continental Air Defense System

The Soviet Union's growing potential for intercontinental atomic air attack demands that the United States rapidly complete a comprehensive continental air defense system, Dr. M. J. Kelly, President of the Laboratories, declared before the annual convention of the Air Force Association at Omaha, Nebraska, in August.

"This in no sense represents a Maginot Line philosophy," Dr. Kelly said. American atomic striking power is still the major element of deterrence to the Soviet Union, but continental defense must now be brought into better balance with the strategic and tactical elements of our military might. Citing the closely knit cooperative effort of the Department of Defense and the Atomic Energy Commission in developing a wide variety of nuclear weapons for strategic and tactical applications, Dr. Kelly urged a similar unified technological effort in developing a continental air defense that would be as nearly impenetrable as possible.

Outlining the three essential parts of any effective air defense system, Dr. Kelly described, first, the Early Warning Radar Net, which must give a minimum of two hours warning of attacks, second, the methods of intercepting planes and guided missiles in the area of battle, off shore and beyond our borders, and third, the point defense of military installations, industrial complexes and cities.

In the course of his discussion, Dr. Kelly made a general analysis of the present world situation, a specific analysis of the United States continental defense problem, and finally, a progress report on how we are facing up to that problem.

In describing the post-war situation, where the United States and Russia have become the two power centers of the world, Dr. Kelly said the motives behind the Soviet Union's aggressive policy were "a mixture of the old Russian imperialism of the Czars and those of the dogmatism of communism." With these aims, the Russians are using two parallel methods to achieve world domination: ever-increasing military strength, and constant application of cold war techniques.

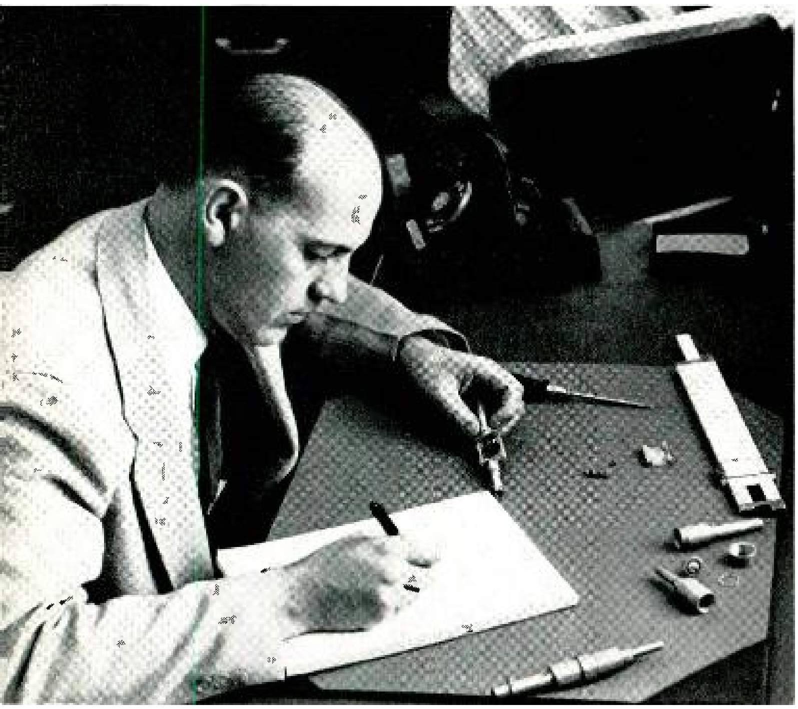
The Defense Department has had the responsibility of countering this mushrooming military strength, but under the enormous handicap of an almost complete national demobilization after World War II. The Russians, on the other hand, have maintained a large fraction of their military strength in combat readiness. During that demobilization period our only salvation lay in the existence of our then infant atomic warfare technology, Dr. Kelly said.

Tracing the development of nuclear technology since the first two bombs were dropped on Japan, Dr. Kelly reminded his listeners of the immense power increase achieved by our nuclear scientists, an increase from the 20 kilotons of TNT equivalent of the first bomb, to the 500 kilotons equivalent of the latest fission or A-bombs. Bombs of almost any intermediate power and size can now be constructed, —to fit almost any aircraft, to be placed in guided missile warheads, or to be used in artillery shells. All of these form a part of our offensive arsenal. At the same time we have made production economies in atomic weapons that are almost as important as the technological improvements.

"The Politburo has not stood idly by 'shivering in its boots' at our accomplishments" said Dr. Kelly. Rather it has organized a tremendous effort aimed at duplicating our atomic weapons and delivery capabilities. The gap between the striking ability of the two powers has been steadily narrowing, he said. With this increasing Russian capability of delivering nuclear bombs in our country, we must give immediate attention to developing an effective continental defense system that can, with our offensive capabilities, prove a positive deterrent to possible Russian aggression, he declared.

Using the Bell Telephone System as an example, Dr. Kelly outlined how an effective and economic defense system could be organized. Such a system could integrate future technological improvements without requiring a complete remaking of the system and, with careful planning and continual technological research, it could become a real protection to the nation and a real deterrent to Russia, Dr. Kelly said.

"Now the stern facts are," he continued, "that there can be no safety in the atomic age short of the elimination of atomic war. How and when this elimination may be brought about none can foresee. It must be brought about under conditions that insure man's freedom. Unless we maintain a position of superiority in the new atomic warfare this condition is unlikely to be met."



70-Megacycle IF Pads

A. S. MAY *Transmission Systems Development I*

A 19A pad is installed in a TD-2 bay in place of the older type pad.

A rapid expansion of TD-2 microwave facilities has resulted from the increased demand for network television and for more telephone channels throughout the country. Since many switching operations are performed at the IF frequency of 70 mc, instead of at microwave frequencies, a large number of 70-mc pads are required to permit all circuits to be adjusted to the same transmission level. An automatic channel switching system for TD-2, now in progress, will increase the number of such pads required. The new series of pads developed especially for 70-mc TD-2 applications not only takes care of former requirements, but provides additional features that have been found desirable in TD-2 maintenance, and at less cost.

With the increasing demand for network television and for more telephone message circuits, the need for TD-2 microwave radio equipment has increased rapidly. Since the television network is continuously changing to accommodate program requirements, there is much switching and patching at the 60- to 80-mc IF frequency. To connect a given circuit to any other circuit, the transmission level of all circuits must be the same. This is accomplished by inserting a pad in each IF circuit to adjust the transmission levels. The pad is a network of resistors designed to match the input and output circuits connected to it, and to reduce the level of the signals as they pass through.

Figure 1 shows schematically the 9A attenuator* originally used for this purpose. The three resistors

* RECORD, *June*, 1949, *page* 221.

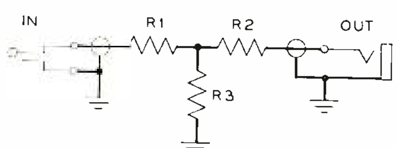


Fig. 1 — The schematic diagram of a 9A pad is a "T," with two series elements and a single shunt element.

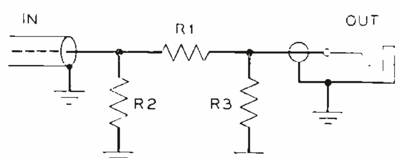


Fig. 2 — The new 19-type pad is essentially a π network, with two shunt elements and a single series element and is equivalent to the 9A pad.

form a "T" and match the 75-ohm IF circuits at both input and output of the pad. Values of the resistors are selected to provide the desired loss when inserted into the circuit. The 9A attenuator is a high precision device with excellent transmission qualities up to 1000 mc. It is constructed of rod and disc resistors mounted in a coaxial structure, with machined parts used to support the resistors and to form the housing. These parts are relatively expensive to manufacture, but are necessary and consistent with the high quality of the 9A attenuator.

When the design of an automatic channel-switching system* for TD-2 was begun, it was recognized that a much larger number of such IF pads would be required and that considerable money could be saved if a less expensive pad could be developed. Since the IF frequency band of TD-2 extends only from 60 to 80 mc it was immediately apparent that the frequency capabilities of a new pad could be less than those of the 9A attenuator. These considerations led to the development of the 19-type pad, featuring standard parts and die-cast construction. J. S. Elliott was active in this development with the author, and was responsible for transforming the experimental models into designs that were suitable for production.

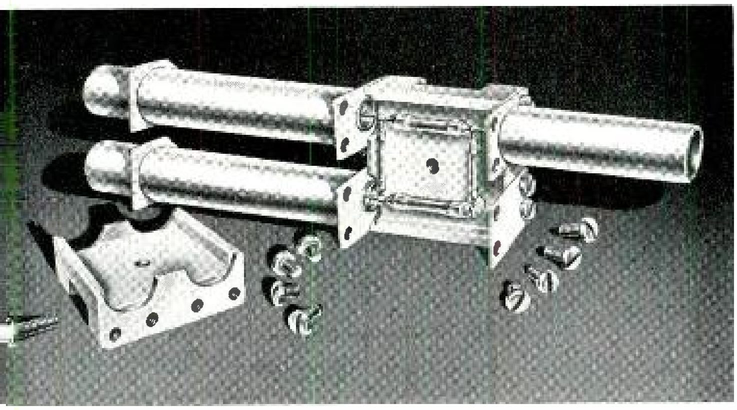


Fig. 3 — In the 20A pad, two resistors provide a dividing network for the monitoring tap at lower left, while at the same time acting as the output shunt arm of the pad.

In the design of circuits for 70-mc applications, the reactances resulting from lead inductance and capacitance between elements must be taken into account. IF amplifiers and other complex assemblies have tuning elements to compensate for these inherent conditions. Adjustable tuning elements in a small pad are impractical because of space requirements, and they add to the expense of manufacturing and testing the pads. The development of the new pads, then, was based on accurate control of the position of components, and of their relation to each other and to the housing. To simplify the connections to the resistors, an "π" type circuit was used that is electrically equivalent to the "T" circuit of the 9A attenuator. The schematic representation of the 19-type pad is shown in Figure 2.

Two identical die-castings form the body of the 19-type pad, and the external dimensions of the body were selected so that the pads can be mounted side by side in a standard jack field. Standard coaxial fittings are attached to the ends of the body and support the series resistor R1 mounted between them. The shunt resistors R2 and R3 are mounted on both sides of the series resistor and the three resistors lie in the same plane. Terminals are attached to the housing and support the grounded ends of the shunt resistors. The shape and depth of the cavity surrounding the resistors and their leads were designed and are carefully dimensioned to maintain the proper balance of inductive and capacitive reactances.

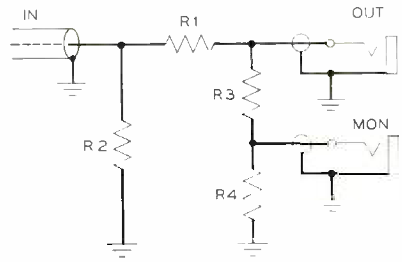


Fig. 4 — A schematic of the 20A pad.

Three options are available for connecting to the pad. A 19A pad, with a coaxial jack on one end and a coaxial plug on the other, is intended primarily as a testing tool in laboratory and field test setups. A 19B pad has a coaxial jack, with a mounting tab, on one end and a solderless coaxial cable fitting on the other. A 19C pad provides a coaxial plug and a cable fitting on the two ends and will replace the 9A attenuator in future production of the TD-2 repeater equipment. All three of the 19-type pads are available with fixed loss values ranging from one to fifty db.

New monitoring and terminal patching facilities for TD-2 use two additional new types of IF pads. These pads, coded 20A and 21A, also use die-cast housings and construction features similar to the 19-type pad. The 20A pad, Figure 3, is a combined IF pad and monitoring tap. One of the shunt resistor arms is divided into two resistors; their junction is connected to a monitoring jack, Figure 4. A cable fitting is used for the input connection to the

* This system will be discussed in a future RECORD article.

pad, while coaxial jacks provide output connections for the through and monitoring circuits. Pad values are available that will insert a fixed loss in the through circuit ranging from four to ten db. In all cases, the shunt resistors are so proportioned as to produce a signal in a 75-ohm monitoring circuit that is twenty-six db lower than the output level of the through circuit. Again, the cavity size balances the reactive components of the circuit elements for good transmission quality.

It is frequently necessary to monitor an IF circuit without disturbing through transmission and without inserting a loss in the through circuit. Figure 6 illustrates the 21A pad designed to do this. The die-cast housing for this pad is the same as that used for the 20A pad just described. The input cable connector and the output jack are connected by a straight-through wire. The diameter of this wire was

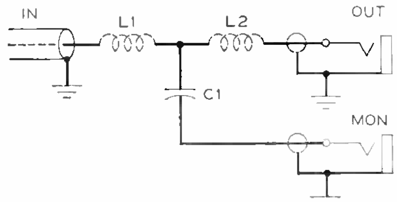


Fig. 5 — A schematic of the 21A pad.

chosen to give the proper inductance to the through circuit to balance the capacitive reactance of the other elements. Connection to the monitoring jack is through a small capacitor, Figure 5. At 70 mc the loss to a 75-ohm monitoring circuit is twenty-six db as in the 20-type monitoring pad. The frequency

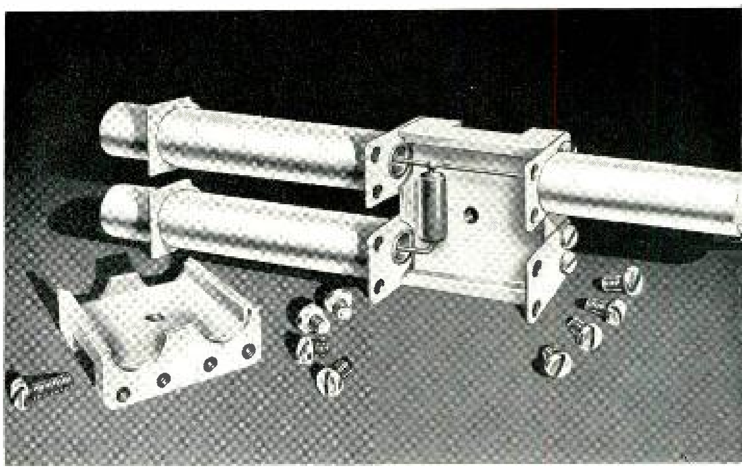


Fig. 6 — The 21A pad has only a straight-through wire instead of a network. Monitoring is made possible by a small capacitor connected to the wire.

characteristic of the capacitor causes the loss at 60 mc to be two and one-half db greater than the loss at 80 mc but this difference is negligible in the application for which the pad was designed.

Precision boro-carbon and carbon-deposited resistors are used in the 19-type and 20A pads, and a high quality ceramic capacitor is used in the 21A pad. Since these components have good aging characteristics, they are very stable and can be produced to close tolerances. All three types of pads have excellent transmission quality up to 100 mc. When connected to the proper 75-ohm circuits, the return loss is greater than forty db. This means that less than 1/10,000 of the signal energy is reflected back into the input line.

THE AUTHOR

Allan S. May joined the Laboratories in 1939 shortly after receiving the B.S.E.E. degree from West Virginia University. For two years he worked on trial installations of automatic teletype switching systems and then he turned to the analyzation of sections of a transcontinental carrier system. During World War II he designed radar equipment for the armed forces and since the war he has been engaged in design of microwave radio relay equipment for telephone and television transmission. He is currently engaged in work on the TH radio relay system.

Open-Wire Swing Test

Low-frequency high-amplitude oscillations produced by certain combinations of wire sag, wind, and sleet, may develop in open-wire lines. This condition, called "dancing" may result in failure of line wires where they are tied to insulators, failure of the ties themselves, chafing of wires in contact with the insulators, and loosening of the insulators from their supporting pins. To study means of minimizing the destructive effects of this dancing and to evaluate various tying methods, line wires, pins, and insulators, the Outside Plant Development Department has devised and installed an open wire "swing" test at its Chester Laboratory.

The equipment for this test consists essentially of two pairs of open wires mounted on crossarms on poles that are spaced 130 feet apart. A machine located in the middle of the center span, as shown in Figure 2, is arranged to make these wires dance by swinging them at their natural period through a path that is approximately elliptical. An associated counter registers the number of cycles completed. The machine runs continuously until a failure occurs. Arrangements are provided to stop the test automatically in the case of any type failure.

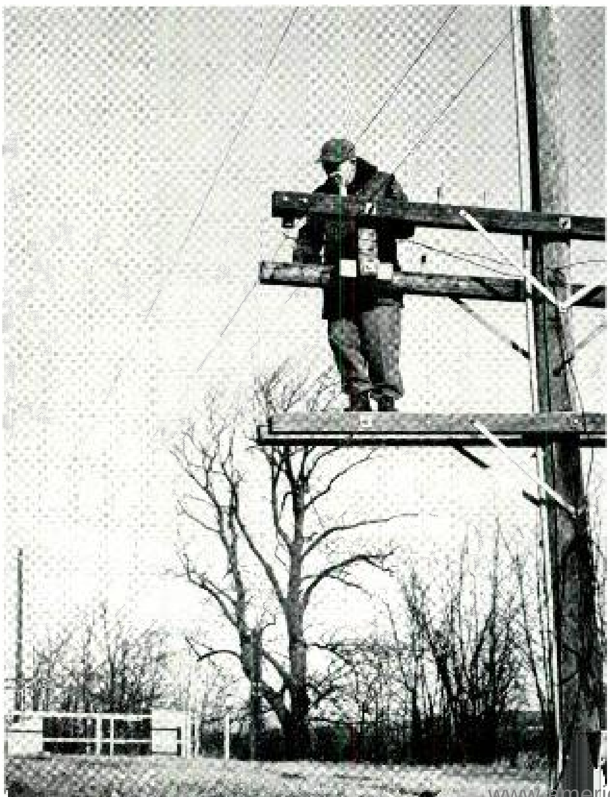
An interesting feature of this equipment is that the links between the driving arm and the wires themselves are "execiser" elastics such as are used in wall-type gymnasium arm and shoulder exercisers. This linkage was finally adopted as being ideal for the purpose after various other types of springs and elastic links were tested.

The crossarms on the swing line are located about 10 feet above the ground to be easily accessible, and are arranged to accommodate a pair of wires at each end with standard or special spacing. The entire line is shielded from the effects of cross winds by trees and brush on one side and a hill on the other.

In addition to its use in evaluating and comparing standard Bell System line wires and ties at insulators, this test has also been used to evaluate a number of suggested tying methods, devices, and transpositions. Tests on a suspension-type insulator, for example, are illustrated in Figure 1. Experimental aluminum-alloy line wires and steel reinforced aluminum (ACSR) conductors have also been tested recently in a similar manner.

W. J. Farmer,
Outside Plant Development

Fig. 1 — W. J. Farmer examining a suspension-type insulator being tested on the open-wire swing line.



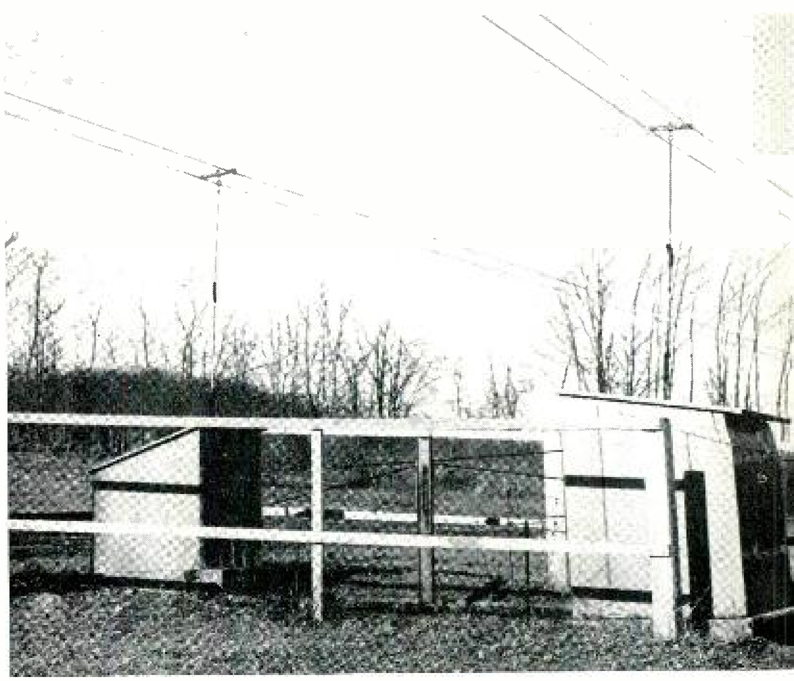
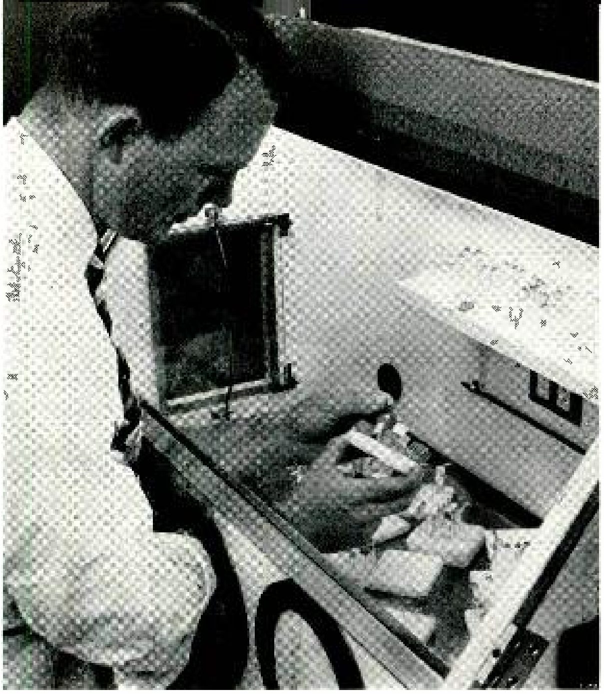


Fig. 2 — Open-wire swing test at the Chester Laboratory.



New Ultra-High Frequency Transistor Developed at the Laboratories

A new transistor triode that even in experimental form has operated at higher frequencies than any previous design — well into the range used by FM radios and television — has recently been developed at Bell Telephone Laboratories. The new device, called an "intrinsic barrier" transistor, has already operated at 440 million cycles, and frequencies as high as 3,000 million cycles are theoretically possible.

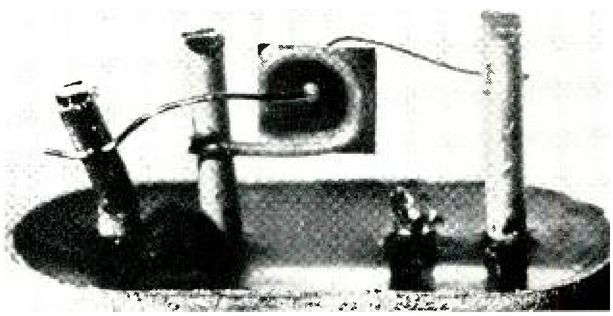
Transistors of the new type are expected to find widespread future use in home television sets, portable radios, the transcontinental radio relay system and submarine telephone and television cable repeaters. The new transistor also can be of considerable importance in military equipment. Inventor of the new transistor is Dr. J. M. Early of the Laboratories, who was assisted in its development by W. C. Hittinger and Dr. J. W. Peterson.

Like other junction transistors, the new device can operate at extremely low power, as little as a 50th of that used by an ordinary flashlight bulb and less than 100th of that needed by a vacuum tube. But, unlike earlier high-frequency transistors, it can also operate at relatively high power, perhaps as much as half a watt, and it can withstand as much as 100 volts. In addition to its ability to amplify an electric signal a thousandfold, it can also be used as a generator of electrical oscillations.

The new transistor builds on the basic theory underlying the first transistor, developed at Bell Telephone Laboratories, and the recently announced Bell Solar Battery. Constructed entirely of solid materials, transistors, unlike vacuum tubes, have no vacuum to maintain. They are "cold"; there is no need for a heater to boil off electrons, therefore they respond immediately to an electrical impulse. They are rugged, and have a long life expectancy since the parts do not wear out in use.

A junction transistor is basically a germanium crystal composed of a very thin region of one electrical type separating two adjoining regions of a different electrical type. The "intrinsic barrier" transistor has an added layer of intrinsically pure germanium added to this basic positive-negative-positive wafer, which acts as a shock absorber for high-voltage electrical charges. This chemically pure part of the germanium crystal remains neutral, while the three adjoining sections are positively or negatively charged. The "intrinsic" region in the middle of the transistor permits the faster movement of positive charges, isolates the input and output section and reduces the stored energy to make functioning at higher frequencies possible. The increased separation of input and output sections also permits operation at higher voltages than was possible in earlier transistors.

When current is applied to an "intrinsic barrier" transistor, "holes" introduced at the positive input section of the transistor at low voltage, spread across the negative region at increased speed. The "holes" then drift at maximum high velocity throughout the neutral region to the output section of the crystal. There, at greatly increased voltage, they are collected to provide useful power output and gain.



The heart of an "intrinsic barrier" transistor as seen through a microscope. In the photograph at the top of the page, W. C. Hittinger uses a "dry box" to assemble the transistor.

Regulation of the L3 Coaxial System

F. J. BRAGA
Transmission Apparatus Development

C. J. CUSTER
Transmission Systems Development II

Since the strength of communication signals decreases with distance, they must be amplified at intervals along any extended route. The amount of signal loss, and hence, the amplification required at specified points, can be precisely calculated for a particular set of conditions. A number of factors, however, including temperature variations and electron tube aging, influence the amount of signal loss. Some means must therefore be provided to regulate the amplifier gain, and so maintain the signals at the desired strength, despite changing conditions. In the L3 coaxial system, this is done with two basic types of regulating circuits.

A major problem in the design of any cable transmission system is that of compensating for variations in cable loss due to changes in temperature. In the L3 coaxial system, this problem is particularly acute because of the wide variations in temperature encountered in different parts of the country. Even though most of the cable is buried in the ground, it is subjected to temperature variations of the order of plus or minus 25° F. Resulting changes in loss at the end of a 4,000-mile system would amount to about 1,200 db at the highest transmitted frequency (8.5 mc), and would make the system completely unworkable. The gains of the compensating amplifiers, inserted in the line at four-mile intervals, therefore, must be automatically controlled in accordance with these temperature variations.

This process is called "regulation" and the devices that accomplish it are "regulators." There are two general types, pilot controlled and temperature controlled. Pilot regulators employ feedback, and control the transmission of the system in response to variations in the power of a transmitted pilot signal. They are highly accurate but have the disadvantage of being complex and relatively expensive. Temperature controlled (thermometer) regulators, on the other hand, are simple devices that operate in response to changes in the temperature of the cable. They are considerably less accurate than pilot regulators. As many as three thermometer regulators can be used in tandem, however, and any error that accumulates in them is compensated for by the following pilot-controlled unit. In this way the cost of the L3 regulation system has been materially reduced from what it would be if pilot-controlled regulators were used at each repeater.

A pilot-controlled regulator with an associated line amplifier is illustrated in Figure 1. It is in a typical line repeater following four miles of cable. This cable has a loss (measured in db) versus frequency characteristic proportional to the square root of frequency. If such a frequency characteris-

Above — C. J. Custer examining a thermometer-controlled regulator at a repeater hut.

tic is determined for each of two different cable temperatures, the difference in loss when plotted against frequency is also found to vary in the same manner.

To compensate for cable loss, each line repeater is designed to produce flat transmission through four miles of cable and the associated repeater when the cable temperature is 55° F. The networks that insure the necessary gain-frequency characteristic in the amplifier include: input and output coupling networks, the feedback circuit, and a regulating interstage. This interstage contains a thermistor that is effectively in shunt with the main transmission path. The thermistor driving current is supplied by either a pilot-controlled or thermometer regulator, and when its resistance increases, the line amplifier gain increases and vice versa. Since this resistance change is opposite to the corresponding change in driving current, however, to decrease the gain of the amplifier the thermistor current must increase, and to increase amplifier gain the thermistor current must decrease.

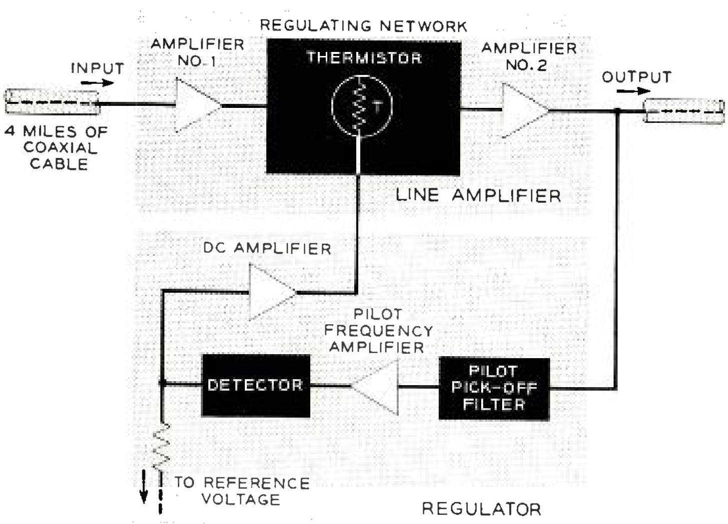


Fig. 1 — Block schematic of line amplifier and pilot-controlled regulator.

In the operation of a thermometer regulator, an auxiliary thermistor is buried in the ground beside the cable to measure the temperature of the surrounding soil. This thermistor is connected in parallel with the thermistor in the regulating network of its associated line amplifier, and both are fed from a single high impedance source of dc power. Current from this source therefore divides between the regulating thermistor and the auxiliary thermistor in inverse ratio to their respective resistances. As the soil temperature increases, the temperature of the cable and therefore its loss also increases. The resistance of the auxiliary thermistor decreases, however, robbing current from the regulating thermistor and hence causing the resistance of the latter to rise. The gain of the amplifier then rises to compensate for the increased cable loss. A decrease in soil temperature causes an inverse action to take place thereby reducing the amplifier gain. This compensation process is made fairly accurate by choosing an auxiliary thermistor with the proper resistance versus temperature characteristic. Once this has been done, however, no further increase in accuracy is possible with a thermometer regulator.

As its name implies, the pilot-controlled regulator, to which the remainder of this article is devoted, operates in response to variations in the power of a pilot signal transmitted at 7266 kc. This signal is picked off the line at the repeater output, and fed through a narrow-band crystal filter to the pilot frequency amplifier as shown in Figure 1. The output of this amplifier is rectified to produce a direct voltage that is subtracted from a constant reference voltage obtained from the repeater power supply. The resulting difference voltage constitutes the input to the dc amplifier which, in turn, supplies current to the thermistor. Any deviation of the pilot from its normal value of −16 dbm at the repeater output results in a change in this current. The amplifier thereupon changes its gain in just the right amount and direction to restore the pilot to its original value.

A circuit operating in this manner is a feedback system. Normally the feedback is negative and any disturbance in the pilot amplitude at the repeater input is suppressed at its output. However, it is possible that pilot disturbances may have a periodicity such that the feedback becomes positive, resulting in amplification rather than suppression of these disturbances. This phenomenon, called "gain enhancement," accumulates from repeater to repeater, and in a long system involving many pilot controlled repeaters in tandem it constitutes a major design problem. Although it is impossible to eliminate gain enhancement completely, by careful design it can be held to an acceptable minimum. This is done by proper choice of the thermistor in the regulating network and by careful design of the crystal filter and dc amplifier in the regulator itself.

Another problem that has plagued the regulator designer heretofore is how to separate thermistor resistance changes caused by pilot level variations from those due to changes in ambient temperature. In the L3 regulators this problem has been solved

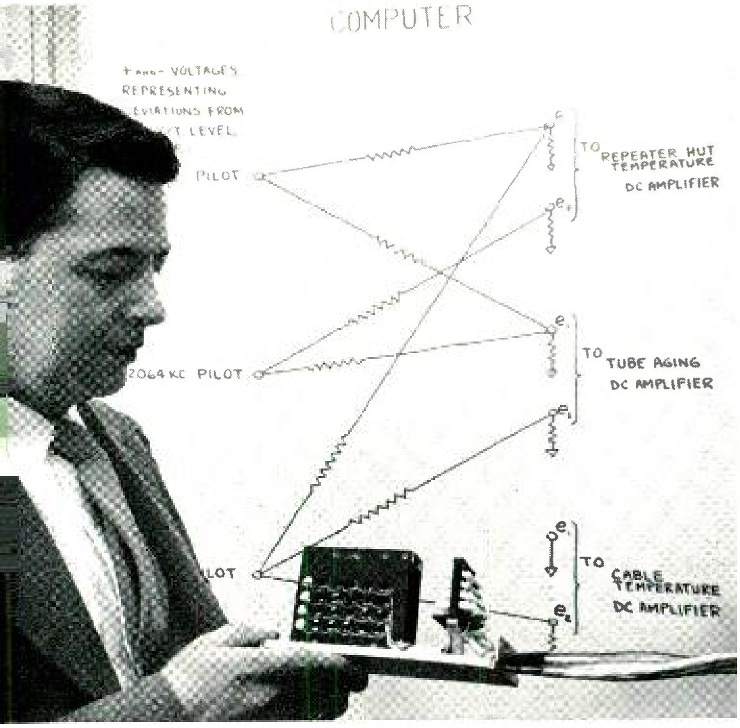


Fig. 2 — G. W. Eftang holding a regulation system computer. The board in the background shows a typical schematic of the connections.

by using a temperature compensating oscillator shown in Figure 3. Two identical thermistors are mounted in a single envelope so as to be subjected as nearly as possible to the same ambient temperature variations. One of these thermistors is the variable element in the regulating network. The other is one of the arms of a 4-kc bridge feedback oscillator, the other arms of which are fixed resistances.

Stable oscillations take place when this bridge is unbalanced by a definite amount corresponding to a specific value of thermistor resistance. Any deviation of this resistance caused by a change in ambient temperature momentarily changes the degree of unbalance. This, in turn, causes the oscillator level to shift so as to restore the thermistor resistance to its original value. The power output of the oscillator then stabilizes at a new value corresponding to the changed ambient temperature. Part of this power is supplied to the heater of the regulating thermistor. By adjusting the magnitude of this power, the resistances of the two thermistors can be made to match to a high degree of accuracy. Therefore, since the auxiliary thermistor's resistance has been made independent of ambient temperature by the oscillator, the resistance of the regulating thermistor is also independent.

In addition to the transmission variations due to changes in cable temperature, there are other less significant effects caused by variable temperatures in repeater huts, and by aging of electron tubes. These "cause-associated" effects are small enough to be corrected by equalizers installed at main repeaters, spaced at approximately 125-mile intervals. These equalizers contain thermistor controlled networks driven by regulators similar to the line regulators. They are controlled by pilots located at 308-kc and 2,064-kc as well as the 7,266-kc pilot which also controls the line regulators. The gains of the regulators driven by the 308-kc and 2,064-kc pilots are higher than that driven by the 7,266-kc pilot, however, since these pilots are transmitted with 20 db less power than the line pilot.

Cause-associated characteristics, which are broad effects covering the entire band, lead to a severe interaction problem because no single pilot is a measure of the transmission changes due to a specific cause. However, in theory it is possible to determine the amounts of the individual characteristics that are necessary to return deviated pilots to their normal values. This process is similar to the solution of a set of simultaneous equations, and can be performed by an analog computer. The computer, illustrated in Figure 2, consists of a network of resistances with three inputs driven by the outputs of the detectors in the three regulators. The outputs of the computer drive three dc amplifiers, which in turn supply current to the thermistors in

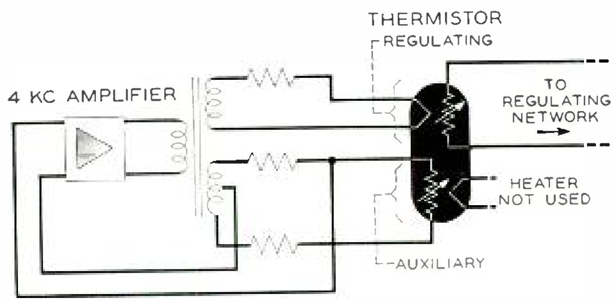


Fig. 3 — Ambient temperature compensating oscillator for L3 regulators.

the regulating network as shown in Figure 4. This resistance network connects the computer inputs to the outputs in such a way that no individual thermistor is driven by a single pilot, but by a properly proportioned mixture of all three.

The effect of using the computer can be illustrated as follows. Suppose one pilot changes. All the regulating networks compensate for the change, but in such proportions and polarities that there is no net change in gain at any pilot frequency except the

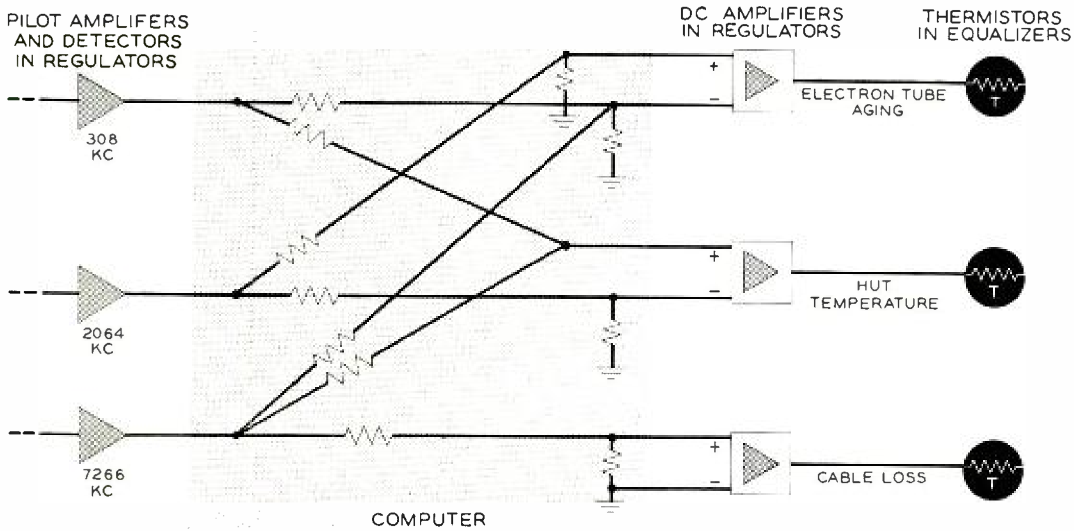


Fig. 4—Schematic of regulation system computer.

one originally deviated. In addition, if a single cause such as hut temperature changes the transmission characteristic, all the pilots will change and all the regulators will deliver error signals to the computer. The computer then combines these signals in such a way that only the proper equalizer network is operated.

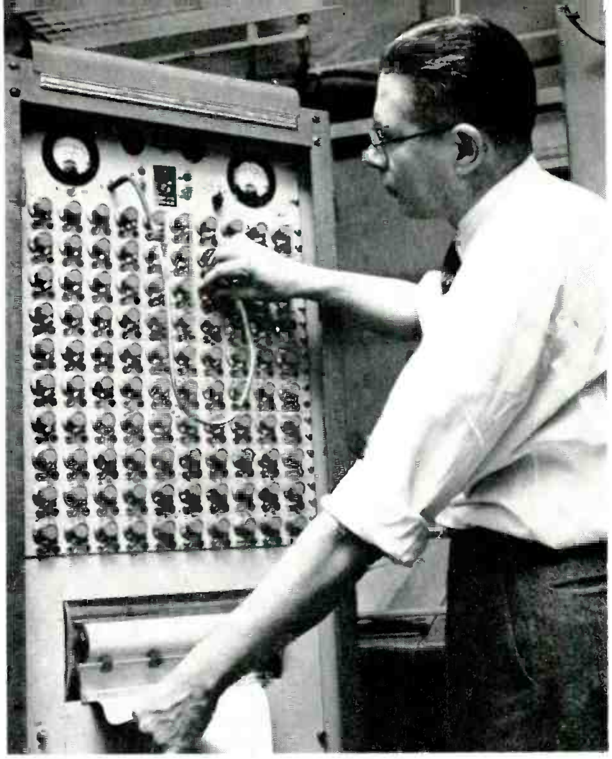
This use of a computer has considerable economic advantage in that it removes restrictions on the choice of equalizer characteristics imposed by interaction effects. Also, if it is found desirable in the future to alter any network as a result of better data acquired after the system has been in operation, this can be done without having to alter any of the other existing networks. All that is necessary is to change a few resistors in the computer. Provision has also been made for the addition of three more pilot controlled equalizer networks. When they are added to the system, the computer can readily be modified accordingly. These networks will operate on pilots which are now being transmitted at 556 kc, 3,096 kc and 8,320 kc.

THE AUTHORS

F. J. Braga graduated from the University of Minnesota in 1930 with a B.E.E. degree. He took graduate work at both the University of Minnesota and Brooklyn Polytechnic Institute before coming to the Laboratories in 1936. He had previously served for three years in the outside plant engineering department of the Illinois Bell Telephone Company. Mr. Braga has engaged in development and design of equalizers, and regulating, interstage and other high-frequency networks, except during World War II when he worked on gun computers, wideband video amplifiers, pulse and sweep circuits used for checking video amplifiers, and delay and sweep networks. At present he is engaged in designing networks for undersea repeaters, equalizers and for cable terminals for the transatlantic submarine cable.

Charles J. Custer joined the Laboratories in 1929, shortly after receiving a B.S. degree from Massachusetts Institute of Technology. For nearly 10 years he was engaged in work on aircraft radio receiving equipment. Since 1938 he has been in transmission systems development where he was first concerned with measuring equipment for television and the L1 carrier system. During World War II he worked on the radio proximity fuse and radar projects. He was later concerned with the L3 coaxial system with particular emphasis on pilot regulators. He is currently engaged in submarine cable development. Mr. Custer is a member of the I.R.E. and Kappa Eta Kappa.

The 100-Pen Recorder



C. H. ERVING, JR., *Switching Engineering*

Recording devices are widely used in testing and evaluating telephone circuits and systems. These devices are of many types, using different recording methods for specific applications. The Laboratories makes frequent traffic studies, and data from many separate recordings must be subsequently compiled and correlated. This requires a good deal of time and effort; the 100-pen recorder, which can record simultaneously the events occurring in 100 separate circuits, was developed to expedite these studies.

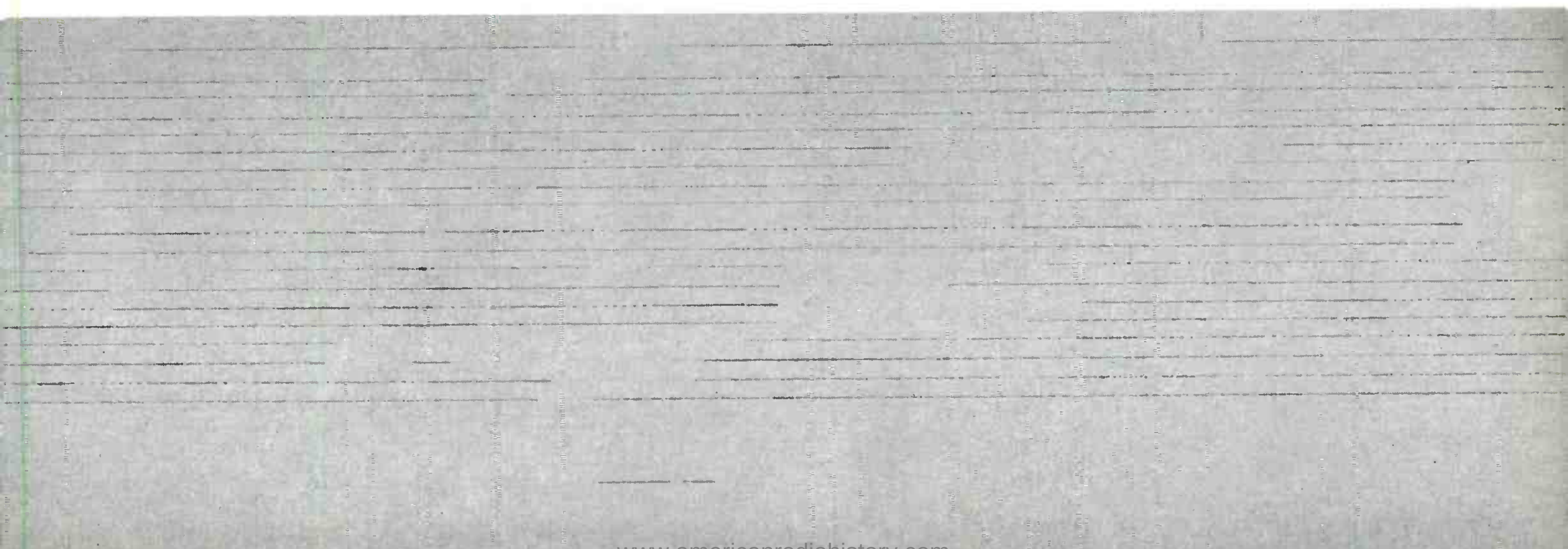
Experience has shown that there are many uses in communication and other fields for a device that will simultaneously record on one chart the events occurring in many separate circuits. The 100-pen recorder,* built for studies by the Laboratories, provides the desired combination of 100 separate traces, fast response, self-contained amplifiers, a dry-type chart paper, and electrical marking.

This recorder will chart longitudinally, at any one of six paper speeds, the off-on voltage conditions occurring in 100 circuits. The traces are laterally spaced in groups of ten on continuously-moving, electrically-marked chart paper. A sample of a typical chart is shown in Figure 1. All amplifiers are built into the cabinet, and good timing accuracy is

* This laboratory model recorder is not standardized for use by the Operating Companies.

Above—The author adjusts the marking current of one of the amplifiers. Once the currents have been adjusted, the used portion of the paper is torn off and the recorder is ready for operation.

Fig. 1—A sample portion of a recording. Dial pulses may be seen in some of the lines.



achieved because the amplifiers themselves are the marking current sources. The only delay between an input signal and a mark is the transient time from cutoff to conduction of the amplifier circuit. The marking frequency is better than 325 cycles per second at the fastest paper speed.

The chart paper used is "Teledeltos," a patented, commercially available product. This semi-conducting paper consists of a cuprous thiocyanate coating applied by a lacquer binder to the paper stock. The marking surface of the paper is light gray in appearance while the reverse side has a metallic coating. The cuprous thiocyanate coating is partially decomposed by marking currents passing through the paper, producing a black recorded marking. Electric current flows from a positive potential connected

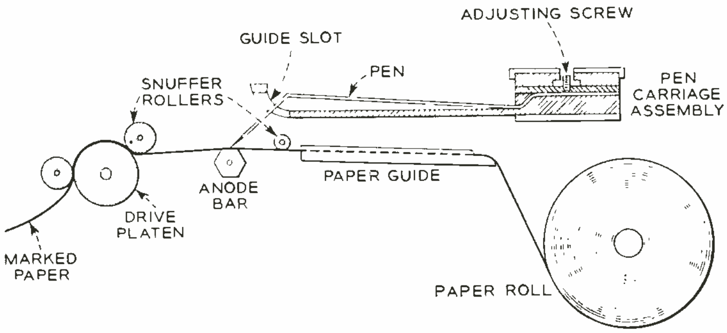


Fig. 2 — Details of the pen-carriage assemby and the paper drive arrangements.

to the metallic coating, through the paper to a pen or stylus at a negative potential.

A platen, two inches in diameter, pulls the paper past the pens and over one face of a hexagonal, stainless steel bar, Figure 2. This bar is at ground potential and is the anode supply terminal for all the amplifiers. The hexagonal shape increases the useful life of the bar because it can be rotated one-sixth of a turn in the event that one face should become pitted from the marking currents. Two "snuffer" rollers at either side of the anode bar keep the paper taut on the bar, and quench any embers or sparks that might develop if the recording current is too high.

The marking stylus, or "pen," is a thoriated tungsten wire tip, having a diameter of 0.008 inch, soldered to a preformed steel music wire three times as thick. Preforming the music wire gives each pen a force against the paper of five grams. The combination of the small-diameter marking tip and good electrical contact with the paper produces a clearly defined trace. The pens are mounted in slots in the pen assembly unit that prevent axial rotation and

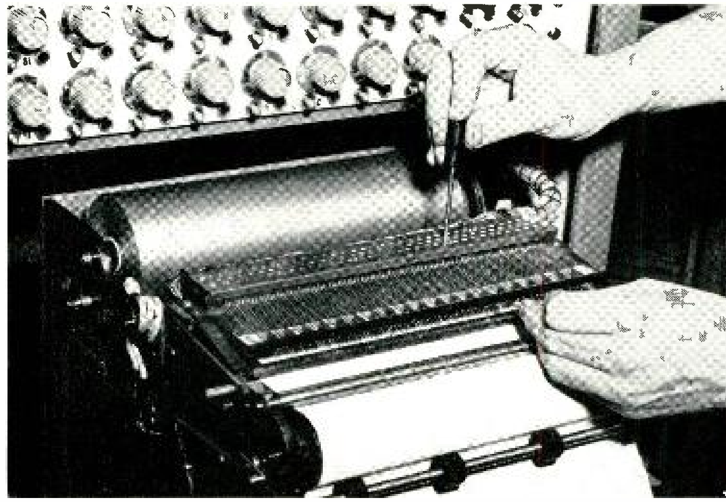


Fig. 3 — Set-screws in the pen-carriage assembly permit adjusting the pens individually.

electrical crosses, yet allow free vertical movement of the pens. Each pen is individually removable for replacement or alignment. Small set-screws over each slot on the top of the pen carriage hold the pens in place. The pens are arranged laterally in groups of ten for convenience in identifying traces on the chart paper. The pen-carriage assembly is mounted over the paper drive unit and is so positioned that the pens rest on the paper, over the anode bar.

The platen is chain-driven by two gear-train units coupled to a constant-speed motor. The chart drive and pen assembly units are mounted on a retractable tray. Chart paper is installed and other maintenance is performed while the tray is in the extended position, Figure 3.

The amplifier circuit was designed to keep the

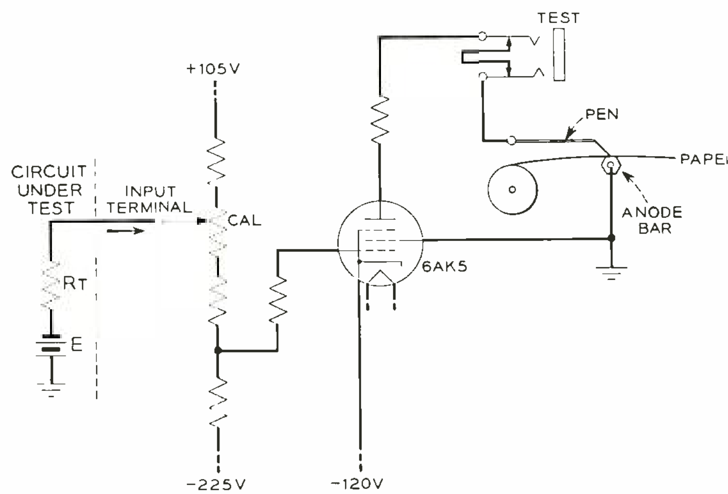


Fig. 4 — The basic circuit shown here is used in each of the one-hundred amplifiers.

metallic backing of the paper at ground potential. Figure 4 shows the basic circuit. With voltage E absent and R_T grounded, the calibration potentiometer CAL is so adjusted that the tube conducts sufficiently to make a good mark. When voltage E is present, the tube is biased to cut-off; a five volt swing in E will cause a change from no mark to mark. The normal, or "no mark," voltage on the circuit under test may be any value from minus 50 to 0 instead of ground as indicated, but the resistance R_T of the circuit under study must be small compared to the one megohm input resistance of the amplifier. The plus 105 volts prevents the input terminal from going to minus 225 volts when there is no external circuit connected, which might otherwise possibly give the user a mild shock should he touch the terminal.

All components of the recorder are contained in a single cabinet, as shown in the headpiece. At the top is the control-calibrate-test panel. A voltmeter for measuring power supply voltages and calibrating the amplifiers, a milliameter for measuring the marking current, and various control switches are mounted in this section. Immediately below are the amplifiers, built in strips of ten amplifiers each. Below the amplifiers is the paper drive and pen assembly unit, Figure 3. The six paper speeds of 1.1, 4.4, 18, 72, 270, and 1,150 centimeters per minute are available through the gear-train units. The gear-train units and drive motor may be seen in Figure 5. A blower draws cooling air through an intake filter and it exhausts through an activated-charcoal canister to remove any fumes resulting from the marking process.

Fig. 5—W. Shaw changes the gear ratio to obtain a different speed of operation.

For calibration or testing purposes, a cord may be inserted into the milliameter jack and any one of the 100 marking current circuits, with or without chart paper in the recorder. The headpiece shows a typical calibration set-up. Tube failure or open pen circuits may also be detected in this way. When desired, a ground supplied from any one of the circuits under study can be used to give automatic start-stop operation.

The 100-pen recorder has been in nearly continuous use by the Laboratories since it was built. Studies using it have been made on switching circuit behavior, both in the laboratory and in the field. It was successfully used in a study, among others, of customer dialing habits.

THE AUTHOR

C. H. ERVING, JR., served as a radar specialist with the United States Army for four years before coming to the Laboratories in 1946. His first year in the Laboratories was spent in the wiring shop after which he worked on systems for identifying calling subscribers' telephone numbers. Later he was concerned with traffic test equipment and switching equipment models. Mr. Erving is now engaged in preliminary engineering of private line signaling and switching circuits. He was a member of the first class of the Bell Laboratories School for War Training.

Color Television Now Available to 65 Cities

Color television can now be transmitted to 65 cities across the nation. Already 145 TV stations in these cities are receiving network television service and 95 of them are receiving it in color, as well as in black and white. Most principal television routes will be equipped for color by November and will be able to transmit color programs to about 95 cities by the end of the year, the Long Lines Department of A. T. & T. Co. announced recently.

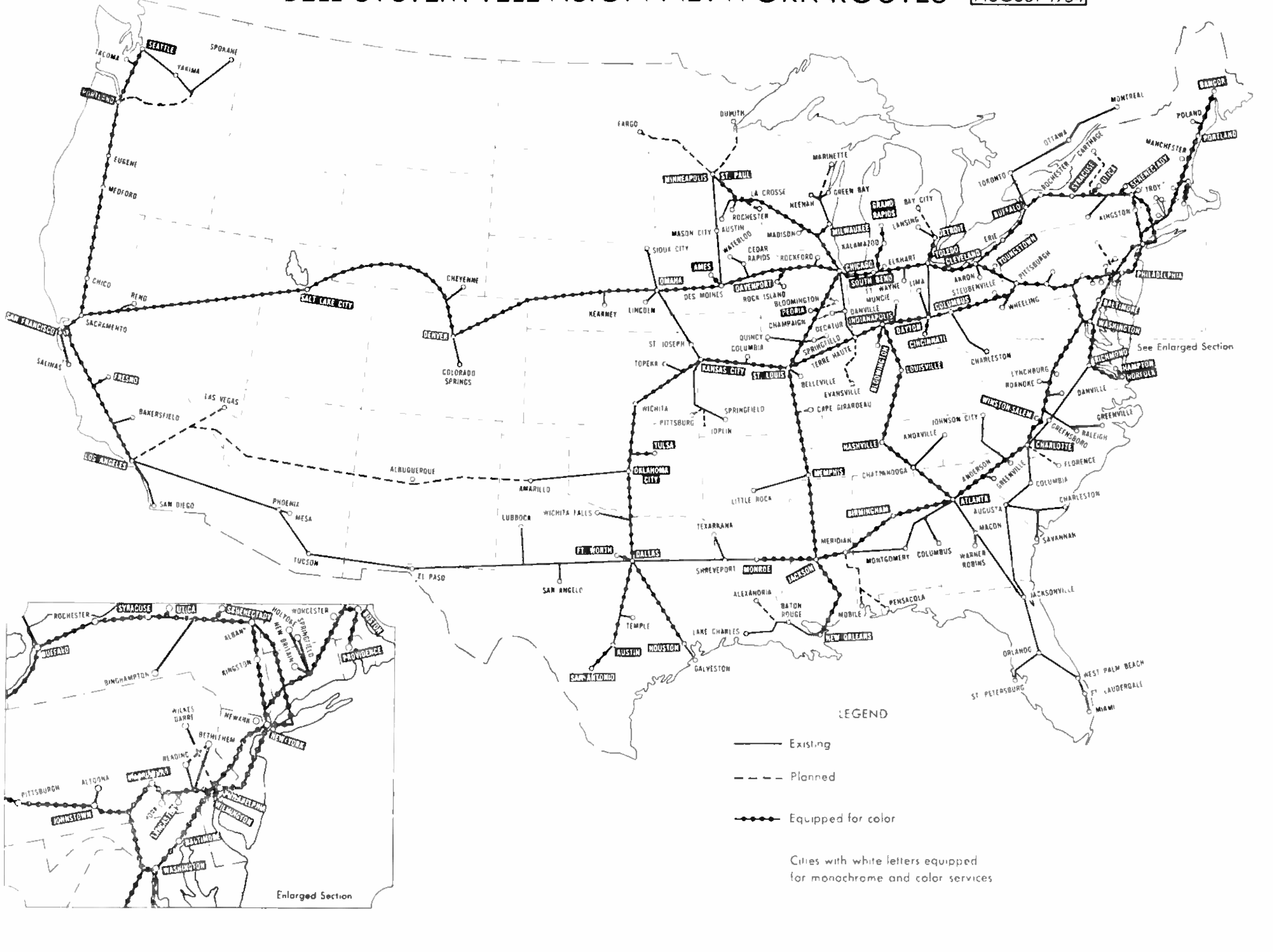
Of the 187 stations presently located in these cities and receiving network service, a total of about 125 are expected to be ready to broadcast in color by late December. The Company announcement pointed out that about 31,000 of the 59,000 channel miles of TV facilities now in service had been re-engineered and re-equipped to carry color.

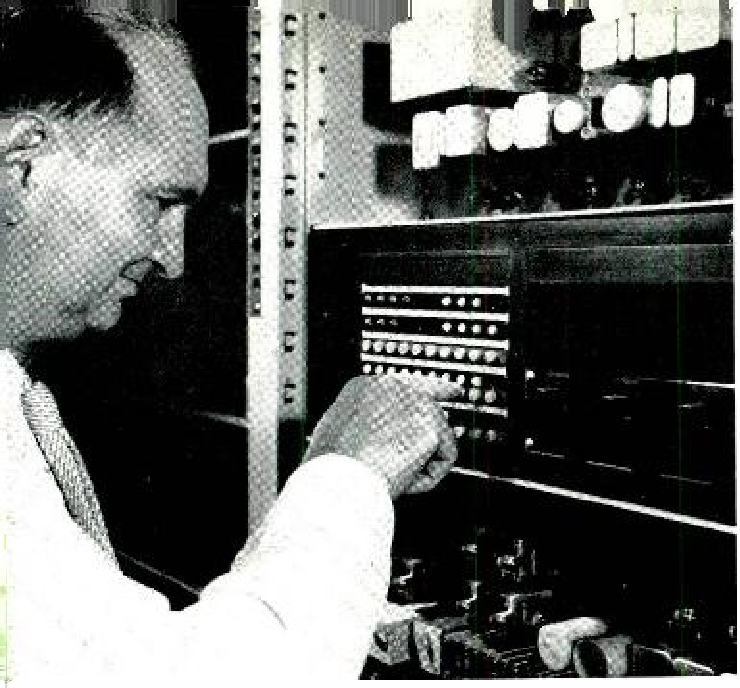
Bell System facilities had been used for experimental color transmission for several years, but it was not until the approval of the compatible system by the Federal Communications Commission on December 17, 1953, that color television got under way on a regular basis. Use of the compatible system makes it possible for owners of conventional black and white television sets to receive color broadcasts in black and white. Owners of color sets can receive both black and white, and color programs as broadcast.

The transformation of the thousands of miles of existing TV channels for satisfactory color transmission was a project of considerable magnitude. New equipment for transmission, testing and monitoring had to be provided, and additional specially trained employees were needed to set up the original channels and to maintain them.

On January 1, 1954, the first public colorcast was carried from coast-to-coast when the Tournament of Roses Parade in Pasadena, California, was fed to stations in 18 cities in the United States. By May 1, the first coaxial cable route, between Dallas and Houston, Texas, had been readied to carry color. Long Lines also noted that 1954 marks the 25th anniversary of the first public demonstration of color TV. On June 27, 1929, a group of newspaper reporters gathered at Bell Telephone Laboratories in New York to see a colorcast of an American flag rippling in the breeze.

BELL SYSTEM TELEVISION NETWORK ROUTES AUGUST 1954





Line Insulation Test Circuit

F. E. BLOUNT *Switching Systems Development*

Impaired insulation on wires connecting a customer's telephone to a central office introduces electrical leaks which, especially in wet weather, may interrupt or reduce the quality of service he receives. To facilitate measuring line insulation resistance, an automatic test circuit has been designed for use in No. 1 and No. 5 crossbar offices. Thus, rapid and more frequent tests capable of detecting incipient troubles may be made, with the result that a larger proportion can be detected and repaired before service is affected.

Insulation resistance of customer lines has an important bearing on telephone service. If this resistance decreases much below the design limit, 10,000 ohms for the No. 1 and No. 5 crossbar systems, dial pulses may be distorted, and the dialed number registered incorrectly. In addition, ringing may be stopped prematurely because a "tripping" relay in the central office may be operated by the additional current that will flow through the insulation. Low insulation resistance may also create noise and thereby affect speech. If it is low enough, relays within the central office are held operated resulting in a condition known as a "permanent signal."

To provide a customer with the best service at minimum cost, it is necessary to obtain a record of line troubles before they approach the point where service is impaired as a result of low insulation resistance. Repairs can then be made on a routine rather than an emergency basis, and line conditions that are most likely to cause trouble can be taken care of first.

Experience has shown that the major sources of low insulation resistance on customer lines are damaged insulation on the wires leading from the pole into the house (drop wires), holes in cable sheaths, and dirt on the terminal plates where drop wires are connected to the cable conductors. These conditions are illustrated in Figure 1. Tests made during dry weather may indicate that insulation resistance of lines having impaired insulation is high. In rainy weather, however, the resistance is reduced by a factor of ten or more as moisture wets dirty terminal plates, enters damaged cable sheaths or wets damaged insulation on drop wires.

Since moisture has such an important bearing on the insulation resistance of a line, it is desirable to test all lines of an office in as short a time as possible, while the resistances are at their lowest values, even during a brief summer shower. In the past, such tests were performed manually * but this is not practical in crossbar offices. As a result, it became necessary to develop automatic equipment to provide for rapid and inexpensive testing in these offices.

Automatic testing has additional advantages over manual testing. One is that a series of tests may be

* RECORD, *December*, 1952, *page* 449.

Above — The author starting a line insulation test cycle at the Fairlawn, New Jersey, No. 5 crossbar central office.

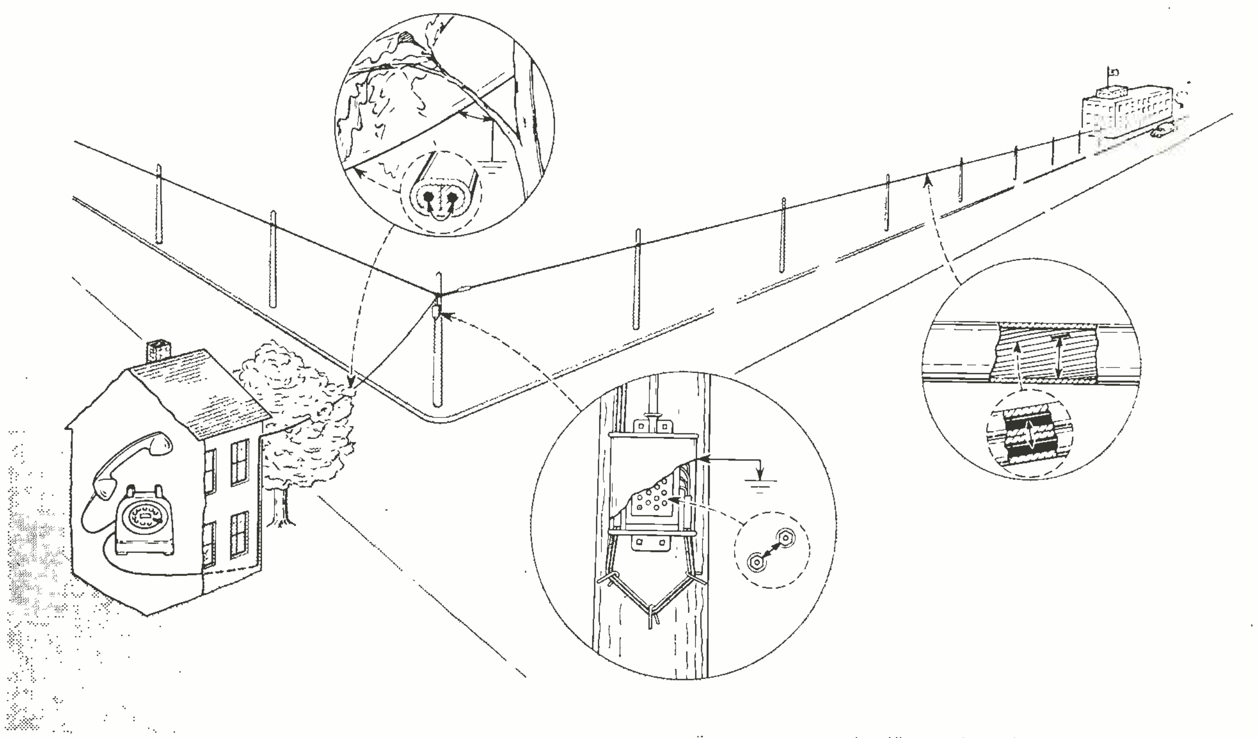


Fig. 1 — Most important sources of low insulation resistance: at the upper left, leaks occurring in drop wires resulting from chafing by tree branches and so forth; in the center, leaks resulting from dirt on a pole cross-connection terminal plate; and at the right, leaks due to a damaged cable sheath.

made when an office is unattended. This is done under remote control from a central test bureau whenever a change in the weather indicates that such tests are desirable. Another advantage is that more frequent tests can be made economically, and hence a better check on the condition of the lines can be obtained.

The circuit described in this article tests the insulation resistance of each line to which it is connected. An associated circuit, called the "Test Control Circuit," which automatically makes the test connections, will be described in a subsequent issue of the RECORD. The method used to determine the insulation resistance is essentially that of measuring the current that flows when a voltage is applied across that resistance. Both the test and control circuits perform their functions automatically once a test cycle is started. Although the operations performed by the control circuit are the same for the No. 1 and No. 5 crossbar systems, differences in method are required. Separate control circuits have therefore been designed for use in the two systems.

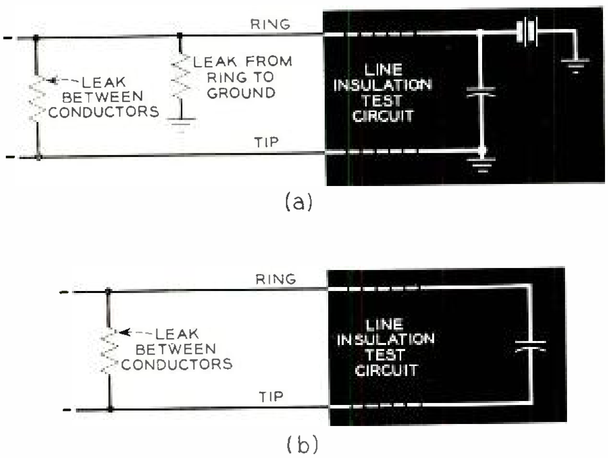
This automatic equipment has four essential functions: (a) to connect the test circuit to a line, after that line has been found to be idle; (b) to determine the insulation resistance of the line; (c) to connect to recording equipment when the resistance is less than a given value, and record the line identity, the type of test made, and the sensitivity of the test used; and (d) to advance to the next idle line whether a record has been made or not. This sequence of events is followed until all idle lines are tested. Busy lines and certain special lines are not tested.

The line insulation test circuit may be connected to a line in various ways, and each different connection normally identifies a different type of trouble. Low insulation resistance in a drop wire, for instance, appears as a low resistance between the two conductors. A test for this type of leak, illustrated at the left of Figure 1, is made as shown in Figure 2(a). The value of the insulation resistance is indicated by the current that flows. Since the same indication could be obtained by a leak from the ring conductor to ground, a second test is made with battery and ground disconnected as shown in Figure 2(b). The only path over which current from the charged capacitor can then flow is the one directly between conductors. Low insulation resistance at a terminal plate, shown at the center of Figure 1, on the other hand, normally shows up as a leak to ground. The value of this resistance would, on the average, be higher than that obtained between conductors in a drop wire, and hence a more sensitive test condition may be used. A check for this type of leakage is made as shown on Figure 3(a). Here again, to further identify the source of the leak, a second test is made. In this, the test circuit is connected to only one conductor as shown by Figure 3(b).

Leakage occurring within a cable can be to other conductors, or to the cable sheath. To isolate this type of leak (shown at the right of Figure 1), the test circuit is connected to ground as is shown in Figure 4. Current flows from battery over the associated lines through the leak to the line under test, and through the test circuit to ground. The drain of current from the test set resulting from a leak from the line under test to the grounded cable sheath as illustrated in the figure, is inconsequential since the resistance of the test circuit is low compared with that of a normal leak within the cable.

Each of these three general types of leak tests can be made at any one of three sensitivities or ranges as indicated in Table 1. Once the desired range has been selected, the line insulation test circuit records an indication if the magnitude of the insulation resistance lies in the band between a set value and half that value, between one half and one fourth the value, or between one fourth the value and zero. As shown in the table, for example, these resistance bands corresponding to range A are such that an indication will be given if the insulation resistance falls between 160,000 and 80,000 ohms, between 80,000 and 40,000 ohms, or below 40,000 ohms. By changing certain cross connections, the sensitivity for each range may be shifted to half the value shown in the table or twice this value. That is, the sensitivity could be adjusted so that for range A the highest resistance on which an indication would be obtained could be either 80,000 ohms or 320,000 ohms. The sensitivity for the other ranges would normally be shifted by a corresponding ratio. As shown in Table I, each combination of test and range is designated by a number. These ranges can be selected for a particular type of test by operating a particular key or by positioning a selector switch under remote control.

Fig. 2 — Method of connecting line insulation test circuit for checking leaks in a drop wire, (a) leaks from ring conductor to ground or leaks between conductors. (b) leaks between conductors.



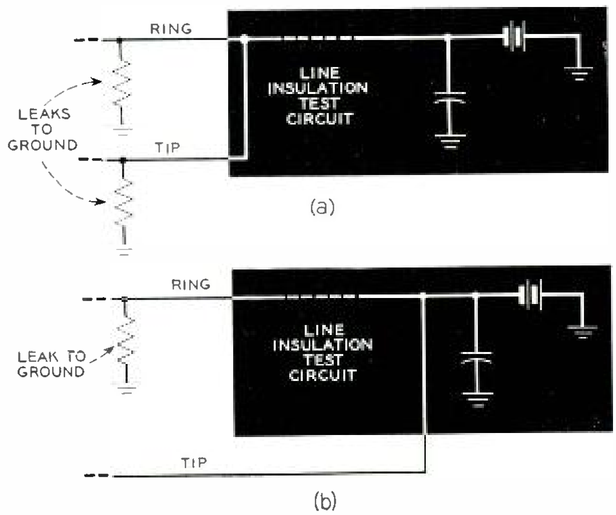


Fig. 3 — Method of connecting line insulation test circuit for checking leaks to ground, (a) general test, (b) test to determine identity of conductor.

Energy for the various tests is obtained from the central office battery, the normal voltage of which is approximately 50 volts. With this voltage and the insulation resistance as given in Table I, the current for which an indication is required will vary from 5 to 2,500 microamperes or more. The lower current values impose severe requirements on the test circuit when both reliability and high speed of operation are required.

If frequent adjustments were required, the value of automatic operation would be lowered materially. To attain the necessary high order of stability, a low input resistance is essential. This is obtained by the use of a magnetic modulator or magnettor with an associated stabilized ac amplifier and signal level indicators. The magnettor converts the direct current that flows due to a leak to a proportional ac voltage.

The resistance of the test circuit is kept low in comparison with the insulation resistance to be checked so that any difference between the test potential, and the voltage on the line and on the ringing circuit capacitors can be equalized quickly when a connection is established. This is essential to rapid testing, since the current which flows due to this difference in voltage cannot be differentiated from that due to low insulation resistance.

At times, current that results from capacitive or inductive coupling with other conductors carrying alternating currents may flow in the lines being tested. Since this may be many times as large as the direct current to be measured, a filter is used to block the ac at the input of the test circuit.

A block diagram of the test circuit is shown in Figure 5. In the magnettor as shown, a 1,000-cycle carrier current drives the magnetic flux in the two cores to very near saturation on each half cycle. Direct current due to low insulation resistance flowing in separate windings produces a magnetic flux which adds to that due to the alternating current on one half-cycle, and subtracts from it on the other.

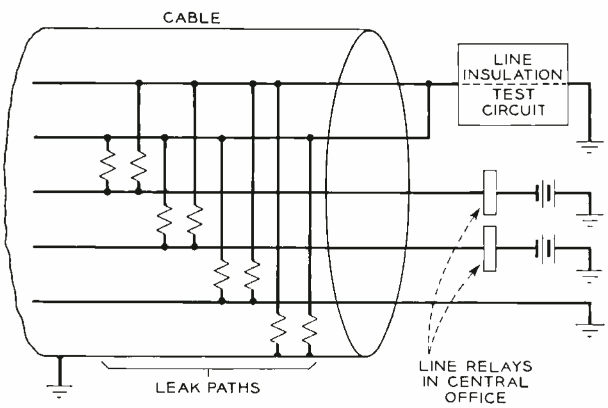


Fig. 4 — Method of connecting line insulation test circuit to check for leaks within a cable.

This produces harmonics of the carrier frequency. The fundamental and odd harmonics are balanced out by the use of two coils that are identical except that their output windings are oppositely poled, and the second harmonic is selected by the use of a filter. The amplitude of this harmonic is approximately proportional to the direct current over the 5 to 40 microampere range within which the magnettor is required to operate. The resulting 2,000-cycle signal is then amplified and used to operate three thyratron detector tubes, each biased by a different amount. Test conditions are provided so that amplifier gain and detector bias can be adjusted to obtain tube operation on a minimum of 10, 20, and 40 microamperes respectively. Operation on 5, 10, and 20 microamperes for the highest sensitivity condition (10 megohms) is obtained by doubling the gain of the amplifier. This operation of the detectors on currents having the ratio of 1, 2 and 4 corresponds to the resistance bands shown in Table I. Resistances in shunt and in series with the magnettor determine the line current and thus the range on which a leak indication will be recorded.

The outputs from the three thyratron detectors control three associated relays designated H, M, and L corresponding to the high, medium, and low resistance bands indicated in Table I. These relays, in turn, direct the circuit to either record an indication or advance to the next line as shown in Figure 5.

An interrupter driven by a 60-cycle supply is inserted in the dc supply lead for the high detector tube when a test is started. If the dc leakage current is below the value required to operate the high detector tube, current will cease to flow in the H relay winding and it will release. This indicates that the test has been completed, and the control circuit then drops the associated line and sets up a connection to the next line. If the direct current continues to flow at a high enough value to reoperate the high

TABLE I — TYPES OF TESTS AND TEST NUMBERS

Short and Ring Ground	*Tip and Ring Ground*	*Foreign E.M.F.*	*Range*	*Resistance Bands Kilo-ohms* — *Low*	*Medium*	*High*
1	4	not used	A	0-40	40-80	80-160
2	5	7	B	0-160	160-320	320-640
3	6	8	C	0-640	640-1250	1250-2500
Not used	Not used	9	D	0-1250	1250-2500	2500-5000

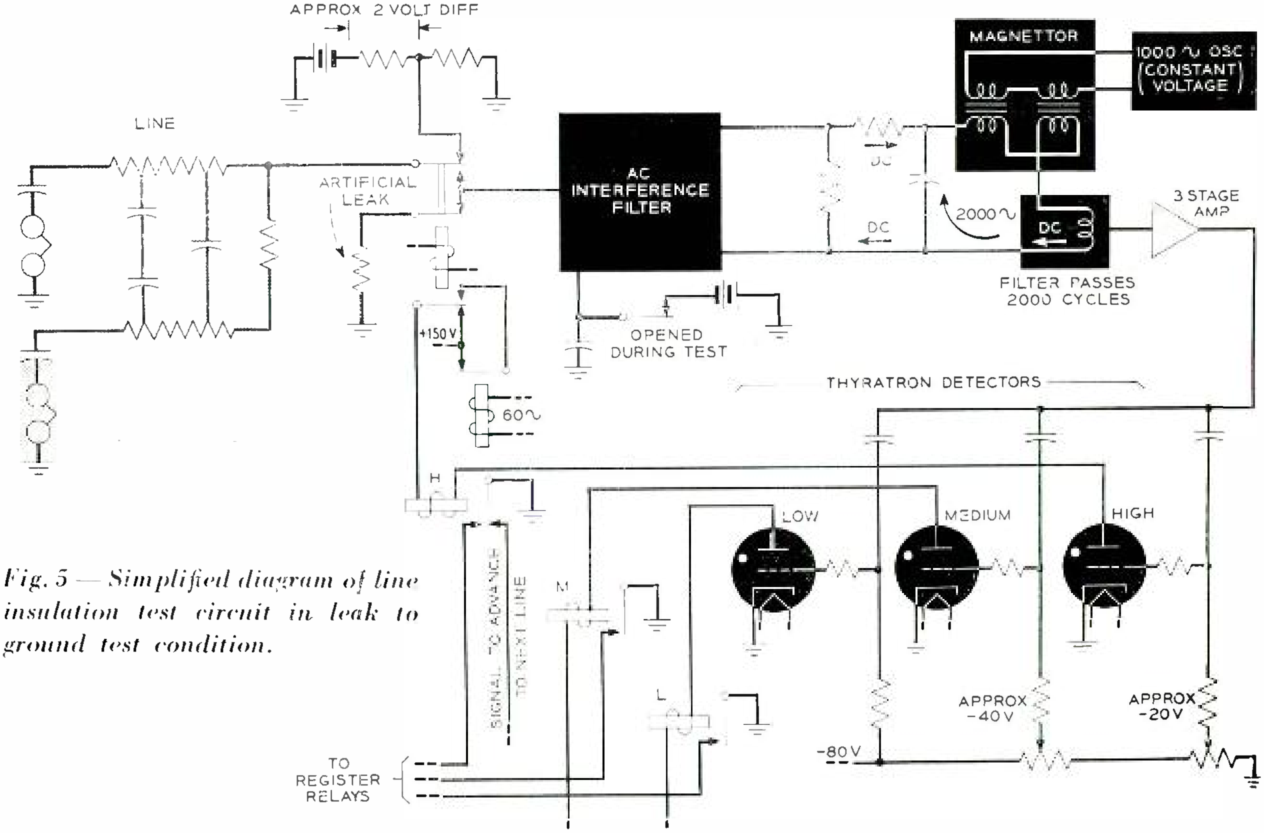


Fig. 5 — Simplified diagram of line insulation test circuit in leak to ground test condition.

detector tube on each closure of the 150 volts supply to the anode, the H relay is held operated. Since the leakage current may be due to a transient disturbance created by ac on the line or by additional current for charging the capacitors on a long multiparty line, the circuit waits for approximately 0.6 second before accepting the indication.

Circuits for operating the "medium" and "low" detector tubes and their associated relays are closed at the end of the 0.6 second interval. The control circuit accepts signals from the H, M and L relays if they are operated. By operating in this way on a "release" rather than an "operate" basis, the testing time for each line is determined essentially by the existing conditions, and hence optimum testing speed is obtained.

In the normal sequence of operation, the line capacitance is charged to approximately the voltage that would exist under test conditions with a high resistance band leak present. The charging circuit is maintained for a timed interval. During this interval, and the preceding period while one line is being

THE AUTHOR

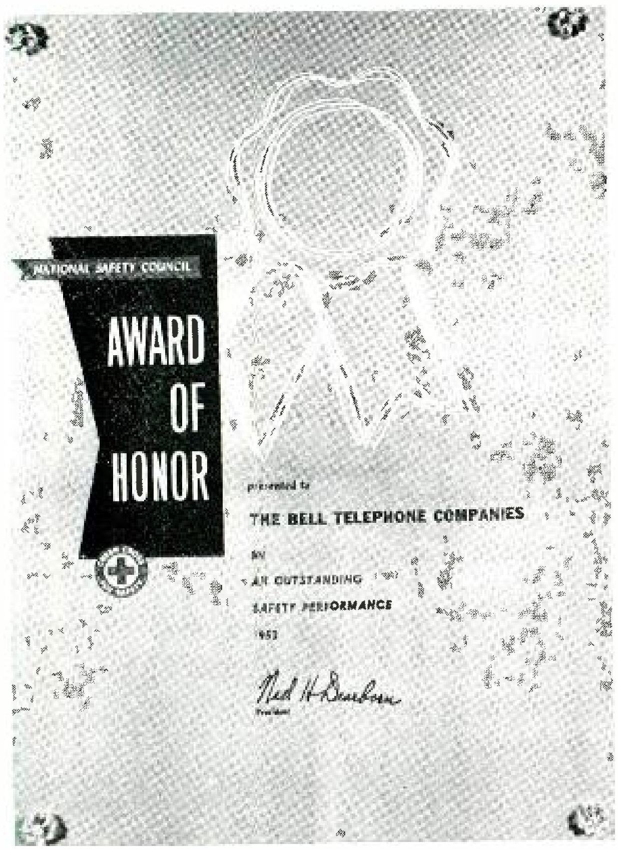
FRANK E. BLOUNT joined the Laboratories in 1928, and after testing panel switching systems for the first year, transferred to a group engaged in fundamental studies of switching circuits in signaling. He continued in this field until 1940, when he worked on automatic ticketing for the step-by-step system. During World War II, he helped develop test equipment for radars and then turned his attention to the design of circuits for the No. 5 crossbar system. Recently he has been concerned with the development of the magnetic drum auxiliary sender for use in panel and No. 1 crossbar systems. Mr. Blount received the B.S. degree in E.E. from Oregon State College in 1928. He is a member of Tau Beta Pi, Eta Kappa Nu and Phi Kappa Phi.

dropped and a second is being connected to the test circuit, an artificial leak resistance is connected to the input to the test circuit. The value of the leak is determined by the range setting and the resulting current is slightly higher than that required for operating the high band detector. This method of operation serves three purposes. First, the operation of the relay associated with the high band detector informs the control circuit that the test circuit is ready for testing. Second, it indicates that the test circuit is in adjustment, and is capable of detecting a leak comparable in magnitude to the artificial leak used. Third, the capacitors in the filter are conditioned so that little or no disturbance will be created at the time when the test circuit and line are joined at the end of the timed interval for conditioning the line.

A record is made showing the line under test, a number indicating the type and sensitivity of test, and the resistance band for the leak indication obtained during the test, and also on retest, when made. This record can be made by a trouble recorder in a No. 5 crossbar office or by a teletypewriter located at a test center under control of the line insulation test control circuit for both No. 5 and No. 1 crossbar systems.

Bell System Receives Third Consecutive Safety Record Award

For the third consecutive year, the Bell System has been named to receive the National Safety Council's Award of Honor. The citation, which is the Council's highest award, is based on the number and seriousness of accidents during 1953. "Accident Facts," a booklet published each year by the National Safety Council, shows that the Communications Industry continues to lead all industries in its safety record.



Bell System companies had only one-eighth as many accidents as did the average company in all industries reporting to the National Safety Council last year. The severity rate for the Bell companies was only 0.09 days lost per 1,000 man hours, or one ninth the average days lost for all industries.

An improvement of 31 per cent in frequency and a five per cent improvement in severity was recorded by the Bell System in 1953 as compared with the average of Bell companies for the previous years.

Eugene S. Gregg Elected President of Westrex

At a recent meeting of the Board of Directors of the Westrex Corporation, Eugene S. Gregg was elected President, succeeding Frederick W. Bierwirth who retired August 31 under the age retirement rule. Mr. Gregg since 1941 has been Vice President and General Manager of the corporation, a Western Electric subsidiary.

Westrex handles the sales, distribution and service of motion picture sound recording and reproducing equipment for studios throughout the world and theaters outside the United States and Canada. The firm also distributes communication and related electrical equipment.

Mr. Gregg, born in Bryan, Texas, was graduated from Austin College in Austin, in 1913. During World War I he was a captain in the shipping section of the Army's general staff. In 1921 he became chief of the transportation division of the Dept. of Commerce. He joined Western Electric in 1926 as a statistician.

Papers Published by Members of the Laboratories

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

Anderson, O. L., see Mason, W. P.

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

Bullington, K., Reflection Coefficients of Irregular Terrain, Proc. I.R.E., **42**, pp. 1258-1262, Aug., 1954.

Dewald, J. F., and Lepoutre, Gerard, The Thermoelectric Properties of Metal – Ammonia Sodium and Potassium at – 33°, J. Am. Chem. Soc., **76**, pp. 3369-3373, July, 1954.

Fletcher, R. C., Yager, W. A., Pearson, G. L., and Merritt, F. R., Hyperfine Splitting in Spin Resonance of Group V Donors in Silicon, Letter to the Editor, Phys. Rev., **95**, pp. 844-5, Aug. 1, 1954.

Galt, J. K., Motion of Individual Domain Walls in a Nickel-Iron Ferrite, B.S.T.J., **33**, pp. 1023-1054, Sept., 1954.

Garrett, C. G. B., and Brattain, W. H., Self Powered Semiconductor Amplifier, Letter to the Editor, Phys. Rev., **95**, pp. 1091-1092., Aug. 15, 1954.

Herring, Conyers, Pole of Low Energy Phonons in Thermal Conduction, Phys. Rev., **95**, pp 954-965, Aug. 15, 1954.

Kelly, H. P., Differential Phase and Gain Measurements in Color Television Systems, Elec. Eng., **73**, pp. 799-802, Sept., 1954.

Kelly, H. P., Color Video Tester Checks Distortion, Electronics, **27**, pp. 128-131, Sept., 1954.

King, R. A., and Morgan, S. P., Transmission Formulas and Charts for Laminated Coaxial Cables, Proc. I.R.E., **42**, pp. 1250-1258, Aug., 1954.

Lepoutre, Gerard, see Dewald, J. F.

Mason, W. P., and Anderson, O. L., Stress Systems in the Solderless Wrapped Connection and Their Permanence, B.S.T.J., **33**, pp. 1093-1110, Sept., 1954.

McHugh, K., Speculation on the Failure of Telephony, Telephony, **147**, No. 7, pp. 17-19, 42-43, Aug. 14, 1954.

Merrill, J. L., Rose, A. F., and Smethurst, J. O., Negative Impedance Telephone Repeaters, B.S.T.J., 33, pp. 1055-1092, Sept., 1954.

Merritt, F. R., see Fletcher, R. C.

Merz, W. J., Domain Formation and Domain Wall Motions in Ferroelectric $BaTiO_3$ Single Crystals, Phys. Rev., **95**, pp. 690-8, Aug. 1, 1954.

Morgan, S. P., see King, R. A.

Pearson, G. L., see Fletcher, R. C.

Rafuse, I. S., A New Multicontact Relay for Telephone Switching Systems, B.S.T.J., **33**, pp. 1111-1132, Sept., 1954.

Rose, A. F., see Merrill, J. L., Jr.

Smethurst, J. O., see Merrill, J. L., Jr.

Suhl, H., and Walker, L. R., Topics in Guided Wave Propagation Through Gyromagnetic Media Part III – Perturbation Theory and Miscellaneous Results, B.S.T.J., **33**, pp. 1133-1200, Sept., 1954.

Walker, A. C., Hydrothermal Growth of Quartz Crystals, Ind. and Eng. Chem., 48, pp. 1670-1676, Aug., 1954

Walker, L. R., see Suhl, S.

Yager, W. A., see Fletcher, R. C.

Patents Issued During July to Members of Bell Telephone Laboratories

Alsberg, D. A. – *Method of and System for Measuring Phase Shift* – 2,685,063.

Anderson, F. B. – *Automatic Control of Amplification in Long Distance Transmission Systems* – 2,683,777.

Barney, H. L. – *Impedance Inversion Networks* – 2,685,066.

Briggs, H. B., Haynes, J. R., and Shockley, W. – *Infra-Red Energy Source* – 2,683,794.

Bruce, E., and Straube, H. M. – *Telephone Selecting Systems Employing Combined Selecting and Talking Path Gas-Discharge Tube and Selective Disconnection* – 2,684,405.

Haynes, J. R., see Briggs, H. B.

Hysko, J. L., Ostendorf, B., Jr., Rea, W. T., and Watson, E. F. – *Frequency-Shift Carrier Telegraph System* – 2,683,189.

Jensen, R. M., and Samek, C. T. – *Tuning Dial Assembly for Electrical Apparatus* – 2,682,859.

Kock, W. E. – *Compressional Wave Guide System* – 2,684,725.

Kock, W. E. – *Sound Wave Refractor* – 2,684,724.

Koos, P. V., and Oberle, L. A. – *Switch Attenuator for Wave Guides*–2,683,255.

Little, J. B., and Teal, G. K. – *Production of Germanium Rods Having Longitudinal Crystal Boundaries* – 2,683,676.

Martin, M. L. – *Heat Treatment of Microphonic Carbon* – 2,683,652.

Millman, S. – *Microwave Amplifier* – 2,683,238.

Mohr, M. E. – *Variable-Frequency Relaxation Oscillator* – 2,683,219.

Oberle, L. A., see Koos, P. V.

Ostendorf, B., Jr., see Hysko, J. L.

Rea, W. T., see Hysko, J. L.

Samek, C. T., see Jensen, R. M.

Shockley, W., see Briggs, H. B.

Straube, H. M., see Bruce, E.

Teal, G. K., see Little, J. B.

Thomas, F. M. – *Stepping Mechanisms* – 2,682,775.

Watson, E. F., see Hysko, J. L.

Talks by Members of the Laboratories

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

Anderson, A. E., Junction Devices for Switching, I.R.E. Western Electronics Show and Convention, Los Angeles.

Bode, H. W., Stability Conditions for General Linear Circuits, International Scientific Radio Union Meeting (URSI), The Hague, Holland.

Early, J. M., p-n-i-p Junction Triodes, I.R.E. Western Electronics Show and Convention, Los Angeles, Calif.

Hannay, N. B., Mass Spectroscopic Analysis of Solids, Gordon Research Conference (A.A.A.S.), New Hampton, N. H.

Honaman, R. K., Frontiers of Communication, Telephone Supervisors, Montreal, Canada; Rotary Club, Quebec, Canada; and Aluminum Company of America, Arvida, Canada.

McMillan, B., Information Rates and the Information Lattice, American Mathematical Society, Laramie, Wyoming.

Molnar, J. P., Electron Ejection from Metals by Positive Ions, International Scientific Radio Union Meeting (URSI), The Hague, Holland.

Molnar, J. P., see Quate, C. F.

Myers, P. B., Operations Research, Third Naval District Headquarters, New York, N. Y.

Pierce, J. R., Some Recent Advances in Microwave Tubes, I.R.E. San Diego Section, San Diego, Calif.

Pietenpol, W. J., Recent Reliability Tests on Semiconductor Devices, I.R.E. Western Electronics Show and Convention, Los Angeles, Calif.

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

Quate, C. F., and Molnar, J. P., Focusing of Long Electron Beams, International Scientific Radio Union Meeting (URSI), The Hague, Holland.

Terry, M. E., Using a Shewhart Chart in Conjunction with the Analysis of Variance, Summer Statistical Seminar, University of Conn., Storrs, Conn.

Members of Laboratories on A.I.E.E. Committees, 1954

A number of Laboratories people have been appointed to General and Technical Committees of the American Institute of Electrical Engineers for the fiscal year 1954-55.

General Committees: *Board of Examiners*, R. A. Heising, E. C. Molina (retired), F. J. Scudder (retired), and H. M. Trueblood (retired). *Code of Principles of Professional Conduct*, G. D. Edwards. *Edison Medal*, O. B. Blackwell (retired). *Membership*, C. Clos. *Planning and Coordination*, E. I. Green and J. D. Tebo. *Prize Awards*, R. M. Bozorth, E. I. Green, and E. F. Watson. *Publication*, J. D. Tebo. *Public Relations*, R. K. Honaman. *Safety*, L. S. Inskip. *Liaison Representatives to Standards Committee*, R. B. Shanck, S. B. Ingram (alt.), and L. S. Inskip (alt.). *Electrical Standards Board of A.S.A. and U.S. National Committee of International Electrotechnical Commission*, R. D. deKay. *Student Branches*, R. A. Deller. *Technical Operations*, J. D. Tebo, chairman, H. A. Affel, and E. I. Green. *Transfers*, C. Clos.

Technical Committees: *Communication Division Committee*, H. A. Affel, chairman, J. Meszar, secretary, L. G. Abraham, and E. F. Watson. *Communication Switching Systems*, W. Keister, vice-chairman, R. C. Davis, and J. Meszar. *Radio Communication Systems*, A. C. Dickieson. *Telegraph Systems*, E. F. Watson, chairman, R. B. Shanck, secretary. *Wire Communications Systems*, L. R. Montfort, vice-chairman, D. T. Osgood, secretary, and P. G. Edwards. *Electronic Power Converters*, D. H. Smith. *Mechanical Rectifier Subcommittee*, D. H. Smith. *Feedback Control Systems*, J. G. Ferguson. *Protective Devices*, P. A. Jeanne. *Lightning Protective Devices Subcommittee*, L. S. Inskip. *Fault Limiting Devices Subcommittee*, P. A. Jeanne. *Dielectric Tests Subcommittee Working Group on Specialty Transformer Insulation Requirements*, L. W. Kirkwood. *Transmission and Distribution*, P. A. Jeanne. *General Systems Subcommittee*, P. A. Jeanne. *Science and Electronics Division Committee*, R. M. Bozorth. *Basic Sciences*, R. M. Bozorth, V. E. Legg, and J. D. Tebo. *Applied Mathematics Subcommittee*, J. W. Tukey. *Electric Circuit Theory Subcommittee*, R. L. Dietzold. *Magnetics Subcommittee*, R. M. Bozorth, chairman, and R. A. Chegwidden. *Dielectrics Subcommittee*, G. T. Kohman and D. A. McLean. *Working Group on Evaluation of Thermal Stability of Insulating Materials*, G. T. Kohman. *Semiconductors and Transistors Subcommittee*, J. N. Shive. *Basic Concepts Subcommittee*, V. E. Legg. *Computing Devices*, B. D. Holbrook, and W. H. MacWilliams, Jr. *Digital Computer Comparison Subcommittee*, W. H. MacWilliams, Jr., chairman. *Electronics*, D. E. Trucksess. *Subcommittee on Electron Tubes*, D. S. Peck, secretary. *Hot Cathode Converter Subcommittee*, D. H. Smith and D. E. Trucksess. *Subcommittee on High Frequency Conductors, Cables, and Connectors*, W. J. King. *Papers Review Sub-Committee*, S. B. Ingram. *Instruments and Measurements*, J. G. Ferguson. He is also a member of the *Group Subcommittee on Recording and Controlling Instruments*, a representative of this subcommittee on the *Feedback Control Systems Committee*, member of the *Group Subcommittee on Electronic and High-Frequency Instruments*, and the *Group Subcommittee on Special Instruments and Auxiliary Apparatus*. *Magnetic Amplifiers*, A. B. Haines, secretary, and P. L. Schmidt. *Magnetic Amplifier Theory Subcommittee*, *Applications Subcommittee*, and *Definitions Subcommittee* (chairman) A. B. Haines. *Metallic Rectifiers*, D. E. Trucksess, vice-chairman, and J. Gramels. *Power Rectifiers Subcommittee*, J. Gramels. *Publicity Subcommittee*, D. E. Trucksess, chairman, *Joint A.I.E.E.–I.R.E. Subcommittee High Frequency Measurements*, E. W. Houghton. *A.I.E.E. Representatives on Engineering Foundation Board*, E. I. Green.