Centralized Automatic Message Accounting

M. E. MALONEY
Switching Engineering

Automatic message accounting has helped solve the difficult problem of how to keep track of calls that are dialed directly by telephone customers. The required equipment could not be justified economically, however, except in central offices that handle a relatively large number of calls to charge points. To bring other offices into the extended area customer dialing plan, such equipment has been centralized and adapted so that one installation can serve as many as 200 central offices. In this way, another step has been taken toward full nationwide customer dialing.

Today, the field of greatest activity in switching development is that concerned with direct customer dialing of long-distance calls. In this connection, automatic ticketing* and AMA† have been developed within the past ten years, and dial service with message register recording of up to three, four, and five message units has increased rapidly during this period in metropolitan areas. The AMA system enables a subscriber to dial directly to points outside his local area by automatically recording all the necessary billing information. The equipment that makes this possible is located at each central office in regions where dial traffic to charge points is sufficiently heavy to warrant the investment required for its initial installation.

There are, however, many offices in areas where such traffic is relatively light, and the installation of AMA equipment at each of these offices would not be economical. But customers in these regions, too, should be offered the benefits of direct dialing to long distance or multi-charge points. The solution to this problem is to centralize the machinery for recording the charging information; that is, to make one AMA unit serve a number of low-traffic areas, and thus gather into the dialing network many stations that were previously thought to be outside the economical range of any extended customer-dialing plan. In addition, CAMA – Centralized Automatic Message Accounting – can be installed in areas served by local AMA to extend the dialing range of four-party customers who are not as yet served by the local AMA equipment. When the amount of traffic that could be handled by one such CAMA unit is considered, its installation cost can be justified more easily. This service is available for crossbar tandem offices; billing information on any extra-charge calls that normally pass through these points, originating in and terminating at offices within the area served by the CAMA, will be recorded automatically.

Above, CAMA operator position as it may be used in future installations. This preview photograph was taken in the switchboard room at West Street.

* RECORD, *July*, 1944, *page* 445.

† A bibliography of articles on AMA appeared on page 427 of the November, 1952, issue of the RECORD.

At present, charge data can be recorded automatically by message registers, local AMA or automatic ticketing, on calls routed directly or through a tandem office. These services may be retained and CAMA added for additional automatic recording service on calls routed through a tandem point; CAMA cannot be used on direct routed calls.

Broad plans have been prepared for CAMA using No. 5, No. 4A, and step-by-step as the centralized switching systems, and specific developments for its use with crossbar tandem offices have already been completed. The first system of this type was put into service in Washington, D. C., in November, 1953, to serve the District of Columbia and nearby points in Maryland and Virginia. Applications of CAMA to switching systems other than crossbar tandem, and descriptions of the equipment developed for the first application, will be included in future articles in the RECORD.

tion about a call from the trunk to a transverter. In addition, the transverter receives the billing information from a billing indexer which compares the calling and called codes and determines the charge. It then forwards all its information to a recorder. The trunk also informs the recorder through a call identity indexer when a call is answered and when it is disconnected. The recorder then directs a perforator to include all this information on a punched tape for use by the accounting center in compiling customers' bills.

Many of the pieces of equipment indicated in Figure 1, including the transverter, call identity indexer, the recorder, the perforator, and the master timer, are similar to those previously used in local AMA. In addition to the work of local AMA, however, CAMA has certain other problems to solve. In the local equipment, one marker group operates into the AMA unit which must then be able to

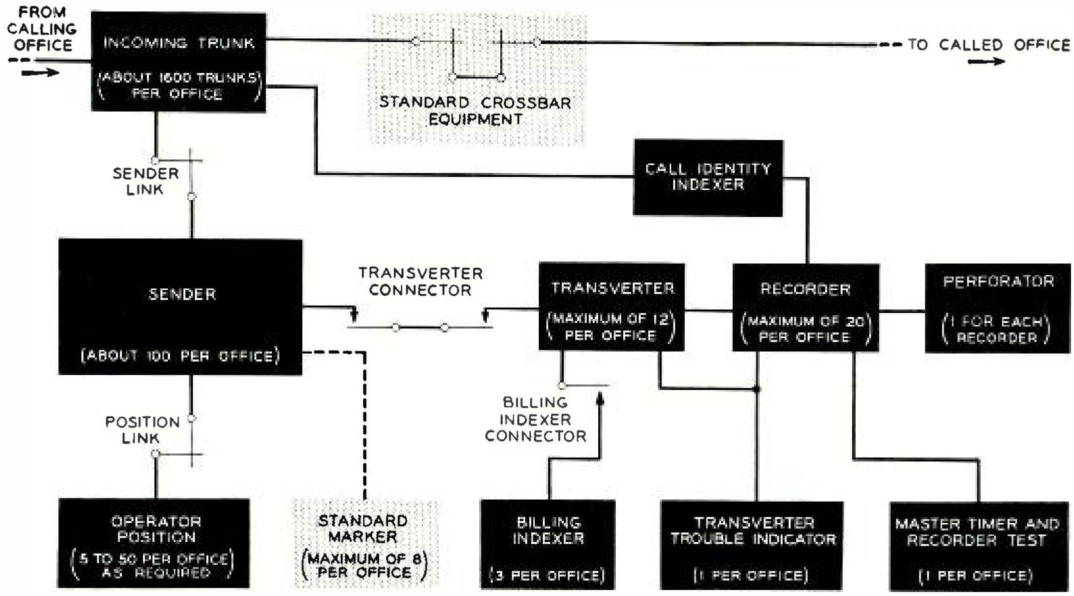


Fig. 1 — Block diagr illustrating the op tion of CAMA equ ment in a crossbar dem office.

CAMA at crossbar tandem offices has been equipped to handle only calls originating in panel, No. 1 crossbar, and No. 5 crossbar central offices. All these offices can use both PCI—panel call indicator—and revertive outpulsing, but, since the number of called office codes that can be transmitted by revertive pulsing is restricted, the CAMA equipment has been designed to receive PCI. It will outpulse, however, with revertive, PCI, dial, or multi-frequency pulsing as needed. At present, CAMA is designed to handle calls originating from a maximum of 200 central offices.

The operation of CAMA as illustrated in Figure 1 is basically quite similar to that of local AMA. In both cases, a sender transmits the required informa-

identify as many as ten calling office designations. CAMA has the additional problems of identifying one of a possible 20 recorder groups with a maximum of 200 offices. These offices may have widely differing rate treatments even though the actual charge on a particular call as indicated by the billing indexer is one of only nine. Two central offices, for example, may have identical rates on calls to 25 other offices but different rates on calls to the 26th and the CAMA equipment must provide for the various combinations.

Identification of the calling customer is, of course, necessary for proper billing in any automatic system. The types of identification circuits used in local AMA and automatic ticketing, however, are

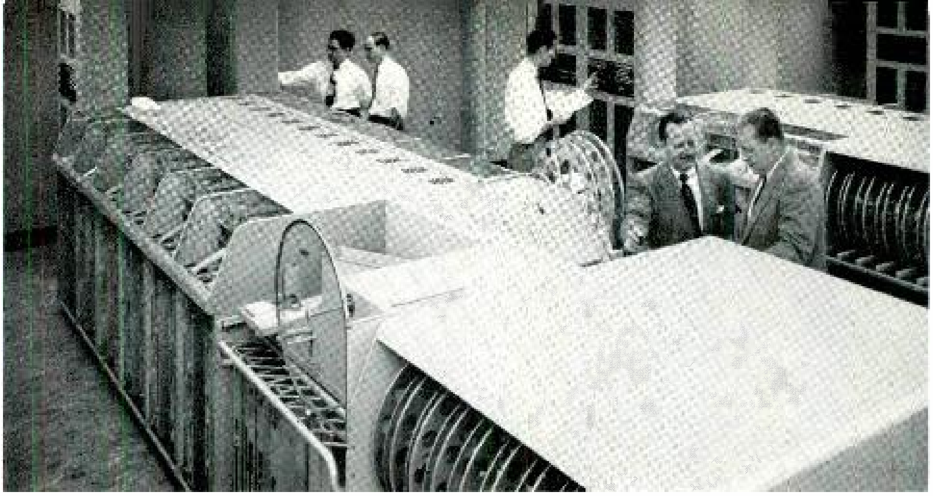


Fig. 2 — In the center, W. A. Turczyn of the New York Telephone Company and J. J. Cozine of the Laboratories inspect CAMA equipment at the Vesey tandem office. In the background, New York Telephone and Western Electric engineers are running tests.

impracticable for use in this application. In the early CAMA installations, therefore, identification of the calling customer by an operator will be used. Shortly after the train of pulses representing a called number begins to enter it, a sender in the equipment will signal for an operator position. This signal is timed so that, on the average, an operator will be available just at the end of the pulsing. If the office load is high and an operator is not immediately available, however, the customer will hear a ringing signal to assure him that the call will be handled. When an operator is cut into the connection, a tone tells her to request the calling number. After the response, she will key the number into a register in the CAMA sender circuit, and with this information, the final output of the system will be a punched tape record identical to that produced in a local AMA office.

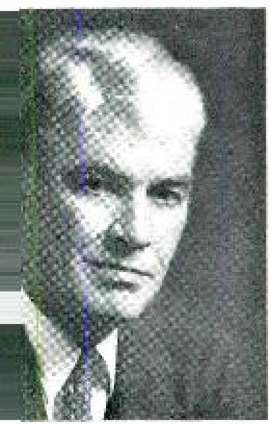
Active development work directed toward automatic identification of the calling subscriber on one- and two-party lines is now in progress. When perfected, this equipment will reduce the load on the CAMA switchboard, which will then be used primarily for the identification of subscribers on multi-party lines. The new equipment has been designed with provisions to include automatic identification and it is expected that automatic and operator identification will operate smoothly side by side. The operator will then handle calls from very small offices and from four-party or multi-party lines. Automatic party-line identification of four or more parties, when developed, will further reduce the load on the operator.

The position link used to connect the sender to the operator position is a primary-secondary crossbar link similar in principle to many other sender and register links. It has some unique arrangements in its controller, however, to ensure an even distribution of calls over all the occupied operator positions. An operator's position has an improved key shelf arrangement mounted in a modern gray and green desk of light, rigid, metal construction.

AMA and CAMA facilitate the widespread use of FACD — Foreign Area Customer Dialing. Basically, a call from Albany, New York, to Delmar, one of its suburbs, does not differ from a call from Bangor, Maine, to San Diego, California. The equipment required, the switching plan, and the numbering plan for this service have all been worked out and its pioneer installation at Englewood, New Jersey*, has been widely publicized. This, however, represents only a tiny preview of what will be made available in the future. FACD will make North America (and conceivably larger areas) in effect, one multi-office city. This will not only offer rapid and convenient service to the customer, but also savings in operating costs to the operating telephone companies.

Some of the other new developments for CAMA such as transverter, the billing indexer, the trouble indicator, and sender test circuit, and additional maintenance items, will also be described in future issues of the Record.

THE AUTHOR



Martin E. Maloney is currently engaged in engineering on centralized automatic message accounting systems and expansion of applications of crossbar tandem switching systems. He joined the Laboratories in 1927 and since has contributed to the development of PBX, crossbar, automatic ticketing, and nationwide dialing systems. During World War II he worked on the development of communications for aircraft warning and fighter plane control. B.S., Georgetown University, 1923, and E.E., Cornell University, 1927.

* Record, *December, 1951, page 571.*

Dr. Kelly Gives Schwab Lecture Before American Iron and Steel Institute

Automation – the use of advanced electronic art to control manufacturing processes and to solve business problems – is probably the century's greatest contribution to the reduction of man's burden, M. J. Kelly, President of the Laboratories, told the 62nd general meeting of the American Iron and Steel Institute in New York recently. In his talk, the annual Schwab Memorial Lecture, Dr. Kelly said that "automation through electronic digital systems will relieve man from the more routine and repetitive mental operations of the civilian economy."

Clerical operations, Dr. Kelly said, such as accounting, payroll, stock-keeping, production control, sales analyses, and market forecasts, are areas where electronic automation will supply business with a new tool of large economic significance. The manufacture of radio and television sets can be programmed and made completely automatic by electronic digital computer techniques, while complex chemical processes like those required to produce synthetic materials can be placed under complete automatic control by similar electronic systems.

The advantages automation brings to the civilian economy are rooted in scientific research and technology applied originally to military devices, Dr. Kelly pointed out. Modern anti-aircraft guns and guided missiles are controlled by electronic computers that gather information, assess it, and program a course of action for the weapons in fractions of a second. These automatic techniques were developed in the laboratories of industry, government, and the universities under government sponsorship, at an accelerated tempo due to the demands of modern warfare. Business and industry can now apply them for the benefit of mankind in many routine and monotonous office and factory operations.

"There is probably no area of production where automation through digital methods will not provide economies," Dr. Kelly said. "The completely automatic factory can, indeed, be foreseen."

These advances in business, banking, merchandising and manufacturing areas, he said, will not come as a revolution of present methods but rather as a hard-earned, step-by-step evolution. The new electronic systems bring business and industry to the threshold of an interesting, exciting and worthwhile area of development. The rapid introduction of synthetic rubbers, polyethylene plastics and the light structural metal, titanium, into civilian use is another example of peacetime benefits from research and development undertaken for military purposes.

"Advancing the date of introduction into the civilian economy of new materials and new facilities is one of the most significant contributions that the military development programs make to the civilian area," Dr. Kelly said. The almost unlimited financial support government can give to projects of great promise to the military, at the same time gives materials and facilities to industry years earlier than would be possible under peacetime conditions.

Atomic weaponry is another technical area where research for the military promises major contributions to civilian life. These contributions, Dr. Kelly predicted, will be of greater significance than those of any other military research program.

"As our knowledge of the atomic power reactor problems, technical and economic, has grown," Dr. Kelly said, "hope for an ultimate economic role of atomic power in the civilian economy changed to confidence. I do not believe it an overstatement to say that confidence is now changing to certainty. Also the estimates of the time interval before economic application would be possible have become steadily less. Only a few years ago the more conservative of the knowledgeable experts were predicting intervals as long as thirty years; today the same experts speak of ten years. The more optimistic speak of five to ten years. These changing evaluations imply favorable progress in the development programs. They have indeed been favorable.

"We are well on our way in the application of atomic power through nuclear fission to the peaceful pursuits of man. A new source of energy essential to the life of a highly industrialized society will soon be available. It insures adequate power for mankind for many hundreds of years.

"We are in this fortunate situation through knowledge arising from our military preparedness research programs. Here is perhaps the most striking example of the acceleration of the time of application to the civilian economy of new scientific knowledge through the military research programs."

Although statistical methods and quality control have been used in the Bell System for many years, the development of the L3 coaxial system probably marks the first time that these techniques have been used extensively to set up design requirements for system components. Quality control used in this way to establish and maintain system performance has, in fact, played an essential role in making it possible to equalize the L3 system.

Quality Control and the L3 System

B. J. KINSBURG *Transmission Systems Development II*

Recently, when a package received from a supplier was opened, a small slip of paper fell to the floor. When retrieved, it proved to be an official document labeled "Quality Control Statement." The legend underneath read:

"Number of units" – *6*

"Counted by" –*Joe*

Incidentally, Joe was right; there were six units in the package. This example might seem far-fetched but it actually happened. A similar package containing some component elements for an L3 repeater, for instance 1500A inductors, would be marked with a much more mysterious inscription, such as "made per KS-4765, Section II." This is also a Quality Control Statement* but a much more scientific one, and one that is vital to the L3 system. It was a joint development of the Systems and Quality Control Departments at the Laboratories, and the Western Electric Company. Behind this statement is the story of the design of the L3 system, the general features of which have been described in a previous issue of the RECORD.†

The application of statistical quality control to the manufacture of individual items or components is widely spread through various industries. Usually the purpose is to avoid the manufacture of parts that are not within prescribed limits by making use of control chart trends showing where the manufacturing process is tending. Except for the purpose of avoiding rejects, the manufacturer has little interest in the average value of the dimension or other parameter that he is controlling.

In the manufacture of the L3 system, a somewhat different use was made of these familiar statistical quality control concepts. Instead of setting tight maximum-minimum limits alone on components and using quality control to get maximum yield, control of the process average itself was the main objective. This control of the process average, in turn, made it possible to find an economic solution of the problem of equalizing the system. The concepts of quality control were thus, probably for the first time, applied to the complex problem involved in long distance broadband carrier system design.

At an early stage in the design of any transmission system, one of the questions to be answered is how much allowance must be made for element deviations in manufacture. A large allowance is

* B.S.T.J., *July*, 1953, *page* 943.
† RECORD, *January*, 1954, *page* 1.

expensive in first costs since more equalization equipment is required and fewer channels can be carried. An allowance that is too small requires manufacturing processes that are excessively expensive. The correct choice of this allowance is extremely important in the L3 system because of the large number of repeaters used – a 4,000-mile L3 system will have about 1,000 repeater sections in tandem. Each such section consists of approximately four miles of coaxial cable and a repeater designed to compensate for signal loss in the cable. Thus, the over-all gain (or loss) of a repeater section is ideally equal to unity or zero db. Actually, there

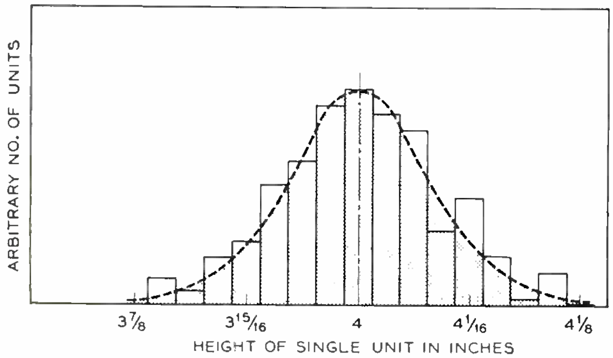


Fig. 1 — Normal distribution of single units distributed about a four inch center.

will be deviations from this ideal which are undesirable since they tend to degrade the signal-to-noise ratio of the system. Major sources of these deviations are variations from the design values due to manufacture, temperature changes, and aging. The broad system objective is to provide sufficient control of these deviations to meet, at all times, the terminal-to-terminal requirements for the communication being transmitted.

First it is necessary to estimate how big deviations will be when a large number of repeater sections are placed in tandem. To illustrate this problem, let us assume that we are dealing with wooden building blocks instead of repeater sections. Suppose we had a process for making 4-inch building blocks. Let us try to answer the question: how high will a pile-up of four such blocks be? Ideally it will be 16 inches. Actually, the height of each block may be slightly different, and to answer our question, we have to know more about the blocks. Let us take the output of the building block factory, and plot a histogram which can be fitted by a distribution such as that shown by the broken line on Figure 1. In this diagram, the abscissa is the height of each block, and the ordinate is the number of blocks of a given height. The resulting bell shaped curve is known as a normal distribution. If we take four blocks at random from a big pile, put them back, mix up the pile, take four more, and repeat this process many times, each time measuring the height of the four blocks, we will get another normal distribution as shown in Figure 2. In this new distribution the abscissa is the average height of a four block sample, and the ordinate is the number of samples. This new distribution will be exactly one-half as wide as the original distribution plotted on Figure 1. If, instead of samples of four, we took samples of "n" units, the width of the distribution made up of the averages of these samples would be $1/\sqrt{n}$ of the original distribution.

Now we are ready to answer our original question, how high will a pile-up of four blocks taken at random be. From Figure 2 we know that the average height in a sample of four blocks will be within 1/16 inch of the desired four inch height. Thus the pile-up of four blocks may be as high as

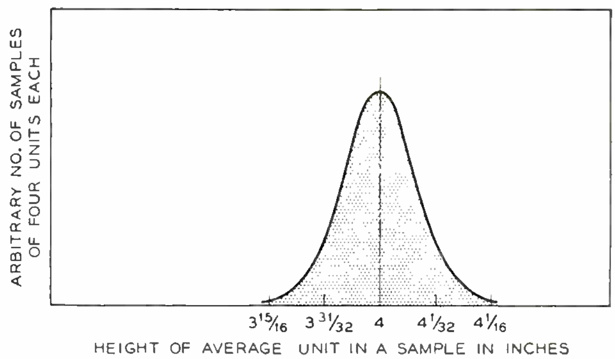


Fig. 2 — Normal distribution of sample averages derived from Figure 1.

16¼ inches or as low as 15¾ inches. Most of the time, however, the pile would be closer to 16 inches than these extreme limits indicate. Statisticians tell us that in two-thirds of all possible cases it will be within ± 1/12 inch of our ideal.

Suppose, however, that the process shifts, so that the average is slightly more than four inches, but that the distribution is otherwise the same as that shown in Figure 1. This would yield a product like that shown in Figure 4, where the average is 4-1/32 inches high.

To estimate the height of four blocks picked at random from this process, we must take this bias in the average into account as well as the distributions of the individual blocks around the average. The pile of four blocks will now be as high as 16⅜ inches or as low as 15⅞ inches, and the average of many such pile-ups will be very close to 16⅛ inches. Hence, the effect of bias is to introduce a systematic deviation in the ideal (or desired) height. This deviation is directly proportional to the number of blocks in the pile-up; the 1/32 inch systematic deviation causes our 4 block pile-ups to be, in general, further from 16 inches than the original ± 1/16 random deviation did. As we increase the number of blocks in a sample, the relative importance of systematic deviations becomes greater.

We are now equipped with the basic principles that enable us to estimate how deviations accumulate when a large number of repeaters are placed in tandem. To do this we must know the magnitude of both the random and the systematic components of gain deviations in individual repeaters. Usually a fairly good estimate of the random deviations can be obtained, but an estimate of the probable systematic deviation is more difficult. Fortunately the statistician can help us here too. By use of statistical theory it is possible to set up control requirements on the process such that the shifts in the long term process average will, in general, be held to not more than 1/10 of the random variation of individual units.

The requirement that the systematic deviations be held to narrow limits arises, in fact, from particular requirements associated with the L3 system equalization plan. The choice of 1/10 of the random deviation distribution as the limit on systematic shifts appears to be generally practicable,

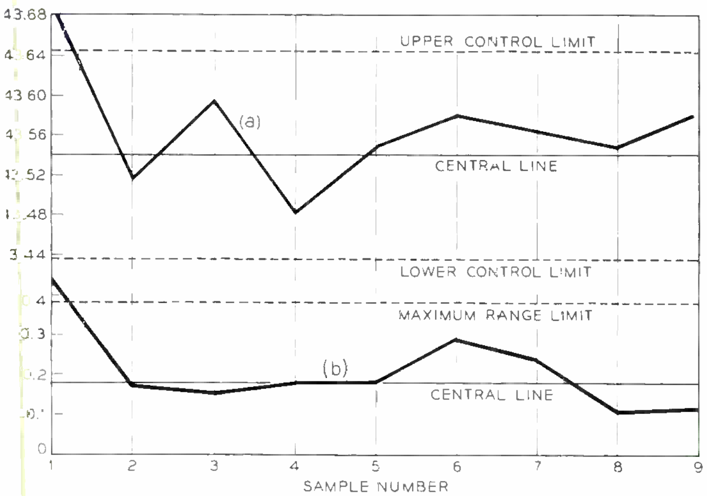


Fig. 3 — Control chart; (a) average of samples of five units each, (b) range of units in each sample. The ordinate scale on this diagram may be considered as being in arbitrary units.

provided that two conditions are met. These conditions are first, that sufficient measuring accuracies for manufacturing testing be available, and second that basic variables in the process be investigated and known so that when a shift occurs, application of remedial action is possible.

With the proper statistical controls operating in the manufacture of all critical elements, we can estimate in advance from our knowledge of the circuit and previous experience with such elements, that individual amplifiers, for example, will show random deviations of ± 0.3 db in gain at a frequency of 4 megacycles per second. The systematic deviations will be not more than 1/10 of the random value, or ± 0.03 db. If we put 25 such amplifiers in tandem along a 100-mile transmission circuit we can further estimate the magnitude of the resulting equalization problem. The accumulated gain deviations due to the random component, except in a negligible number of cases will not be more than ± 1.5 db (the square root of 25, times 0.3 db). In most 100-mile sections they

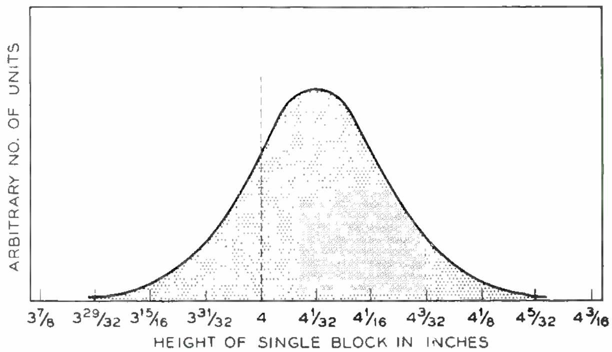


Fig. 4 — Normal distribution with center shifted 1/32 inch from that in Figure 1.

will be less than ± 0.5 db and the accumulated systematic deviation will not exceed ± 0.75 db (25 times 0.03 db). Thus the maximum range to be provided in the equalizers at the end of a 100-mile section is 2.25 db.

In the design of the L3 coaxial carrier system, advantage was taken of the general principles outlined to specify the component limits and the equalizer ranges needed, and to minimize the signal-to-noise margin built into the system. Statistical quality control in the manufacture of the system elements is essential if the performance predicated on this design technique is to be realized. Therefore, we require sensitive statistical gauges with which we can monitor our processes to insure the required control of the average.

Instead of plotting our measurements of the product in the form of Figure 1, perhaps much too late to take corrective action, it is possible to determine whether the output of the factory meets the distribution requirements if we periodically take a sample of the output and plot the results on a control chart of the type shown in Figure 3(a). This is a quality control chart for the averages of samples of five units each. It has a central line that indicates the desired process average, and lines for maximum and minimum limits called upper and lower control limits. In plotting such a control chart, it is essential that the samples be taken in the sequence of production. It is, in fact, a time record that is very sensitive to variations in the production process. The beginning of the chart in Figure 3 shows one point outside the upper control limit. Probably a correction was then made, for the succeeding points indicate that the process was "in control." This is evidenced by the fact that the points, each representing the average of five units, do not exceed the limit lines, and are not consistently above or below the desired process average.

A control chart on averages of this type tells only a part of the story, however, and it must be supplemented by a chart that shows the spread of the measured values in a sample. The chart in Figure 3(b) is a control chart for ranges, or the difference between the maximum or minimum measured value in a sample of five units. For samples of this size, only a maximum limit is needed on the chart.

Even though we do not know the exact process of manufacture, we can still determine from such charts whether the product is in what is known as the state of statistical control. If it is, the manufacturer is probably using some method of production quality control. That is, he not only measures the output of the process, but also takes remedial action every time there is evidence that the process is either out of control, or is definitely headed in that direction.

In addition to the use of statistical tools in designing the system from the standpoint of amplifier and equalizer spacing, and the development of formal methods for process observation to assure that the manufactured product is in conformance with the basic design assumptions, quality control techniques were also applied to problems of L3 element design. Some examples are the 1500A inductor, Type-505 quartz disk capacitors, type-500 silvered mica capacitors, type-200 borocarbon resistors, type-1507 combined elements (combination of inductor and resistor), 2504A transformers, and 435A, 436A and 437A electron tubes.

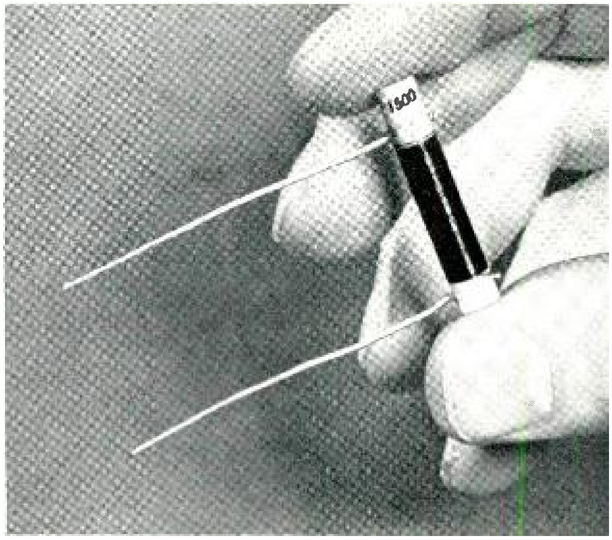


Fig. 5 — Type-1500A inductor.

The 1500A inductor shown in Figure 5, for example, is used in the coupling network that connects the amplifier to the coaxial cable, and its inductance is ideally 43.54 microhenries. It is used to separate or split the high side capacitance of the transformer from the capacitance of the adjacent amplified elements. This inductor was hence nicknamed the "splitting coil." At the time plans for the L3 amplifier were being made, the available inductor design consisted of a single-layer solenoid wound on a phenolic plastic spool. The manufacturing tolerances to which this inductor could be made were ± 4 per cent, about one-half of which could be systematic. With extreme care, perhaps the tolerances could be reduced to 2 per cent, but with no assurance of a satisfactory distribution. The temperature coefficient of the existing design was of the order of one hundred parts per million per degree fahrenheit, and the aging during the life span of 15 years was estimated to be 1 per cent.

Deviation studies of a preliminary circuit design indicated that it would probably be more economical to reduce manufacturing tolerances to about 1 per cent, of which 0.1 per cent could be systematic. Additional requirements included improvements in the temperature coefficient and aging by about an order of magnitude. Also, small distributed capacity, coupled with a low variability was needed. After considering various possibilities, the design that looked most promising was a tension-wound solenoid on a ceramic core.

The requirements on the ceramic form were ± 0.5 mil, and two suppliers were found who were willing to work to these limits. There ensued the usual period of reconciling the measuring techniques used by the part supplier, the Western Electric Company, and the Laboratories – one of the first tasks to be undertaken after any process is mapped out.

Statistical techniques, involving basic principles that are essentially the same as those used in deciding how high a pile-up of several wooden blocks would be, were used in determining these measuring accuracies. The resulting studies indicated that a satisfactory inductor could be made if cores were manufactured to ± 0.2 mil "go-no-go" limits, and one supplier was willing to try. Unexpectedly, the control chart of the inductances wound on these ± 0.2 mil cores showed them to be out of control. The assignable cause was found to be a defect of the tension winding mechanism, and when this was corrected the final product was well within the ± 1 per cent limits. Although it was not identified, this control chart was used for the diagram in Figure 3.

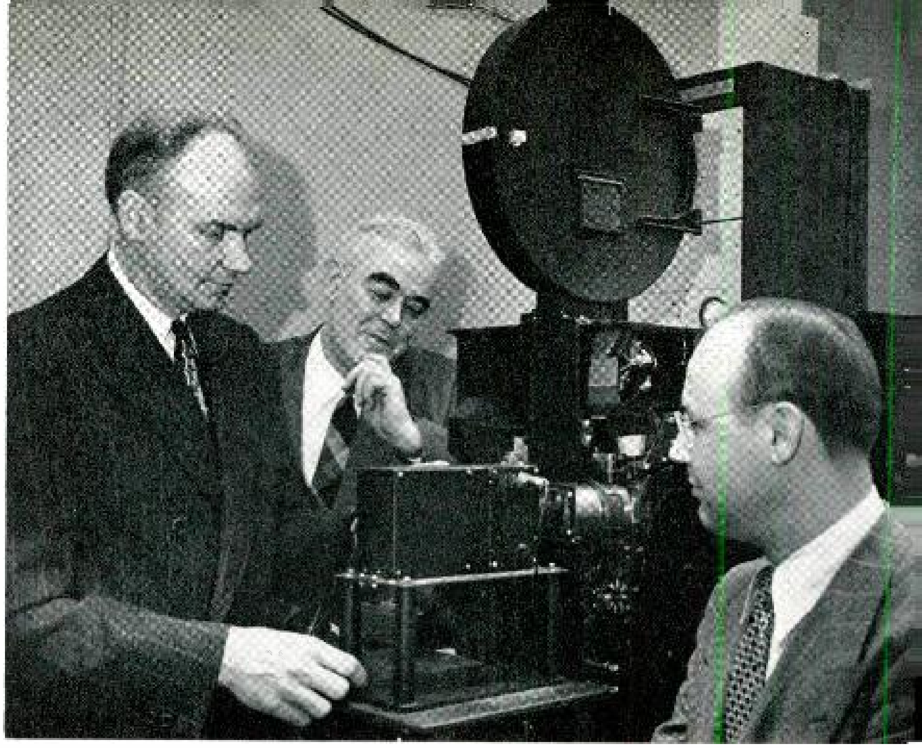
In general, the tighter the control limits, the more individual units will cost. If the limits are too wide, however, it may be necessary to spend more money on some other part of the system to compensate for the degradation in performance that results from these wider limits. Frequently the additional system cost can be expressed in terms of the added equalizers that would be needed. Here the splitting coil is typical; in all cases that were investigated, economics favored a reduction in tolerances on individual elements rather than an increase in number of equalization points. As it turned out, the cost of this new inductor compared favorably with that of less accurate coils of the old design. This was contrary to expectations, and is an interesting and significant example of a frequent by-product of quality control.

The basic assumption in the over-all L3 system design that the major part of each of the component deviations would add on a random basis was fundamental in providing an 8-megacycle bandwidth. If it had been necessary to assume direct addition of component deviations, the design would have had to include substantially fewer channels and, at the same time, provide more complex and costly equalization equipment. Thus, extensive application of statistical techniques in design, and use of quality control techniques in the production of component elements have made the wideband L3 system possible.

THE AUTHOR

Boris J. Kinsburg was with the Southern California Edison Company from 1928 to 1930. Since joining the Laboratories in 1930 he has worked on research and development of broadband carrier systems using coaxial cable as the transmission medium. This includes amplifier development, study of crosstalk in coaxial conductors, requirement studies for coaxial equipment, equalization studies and television echo requirements. He is currently concerned with quality control studies of the L3 system components and reliability studies of the long-range submarine cable development. Mr. Kinsburg received his B.S. degree at the University of Southern California in 1926, and his M.A. degree from the same institution in 1928. He is a member of the Institute of Radio Engineers, American Association for the Advancement of Science, Society for Social Responsibility in Science, American Society for Quality Control, and a member of the Engineering Panel of the Committee on Statistics in Physical Sciences of the American Statistical Association.

Continuous Scanner for Televising Film



R. E. GRAHAM
Television Research

To maintain the requisite high quality of television picture transmission over the nationwide circuits of the Bell System, transmission studies involving picture signals are continually being made. Moving-picture film is a good laboratory source of picture signals for such studies. Since, however, the usual techniques for scanning film do not provide a sufficiently high quality of signal, the Laboratories has developed a new type of film scanner. Instead of the intermittent "frame-by-frame" operation normally used, this scanner provides a continuous "lap-dissolve" from one frame to the next.

Particularly during the past year or so, the pictorial quality of film television has occasionally been excellent. Nevertheless, the prevailing superiority of "live" studio programs has clearly indicated that the production of video signals from motion-picture film presents serious technical difficulties. Then, perhaps, it might seem surprising that the Laboratories would choose film scanning to meet its continuing need for a local source of high-quality picture signals. The reasons are: the obvious suitability and convenience of film as a repeatable source of moving scenes, and the development of an unusual type of motion-picture scanner that eliminates a serious stumbling block to quality heretofore encountered in televising film.

Before describing this special scanner and its peculiar advantages, let us review the difficulties found in the conventional methods of film television. The principal problem in televising motion picture film in the United States is posed by the incompatibility of two numbers, 24 and 30, or perhaps 24 and 60*; 24 movie frames per second and 30 television frames – 60 fields – per second. These periodic rates just don't blend properly to make an easy scanning job of it. The film is always moving to the next frame, or picture, when the television scanner is not ready, or vice-versa.

Commercial film scanners have avoided this difficulty by employing a "storage" type of camera tube such as the iconoscope, which is capable of "soaking-up" an image on a light-sensitive mosaic during a brief exposure and holding it there while the television scan is completed. An "intermittent" film projector is used with this storage camera tube,

The author, right, and A. G. Jensen, center, are interested onlookers as C. F. Mattke adjusts the photomultiplier pick-up portion of the film scanner.

* The television scanning pattern is "interlaced"; that is, the scanning beam traces alternate lines of the pattern during one "field" scan, and then returns (called "flyback") to scan the interlaced lines during the next field. Two successive fields make up a complete television "frame."

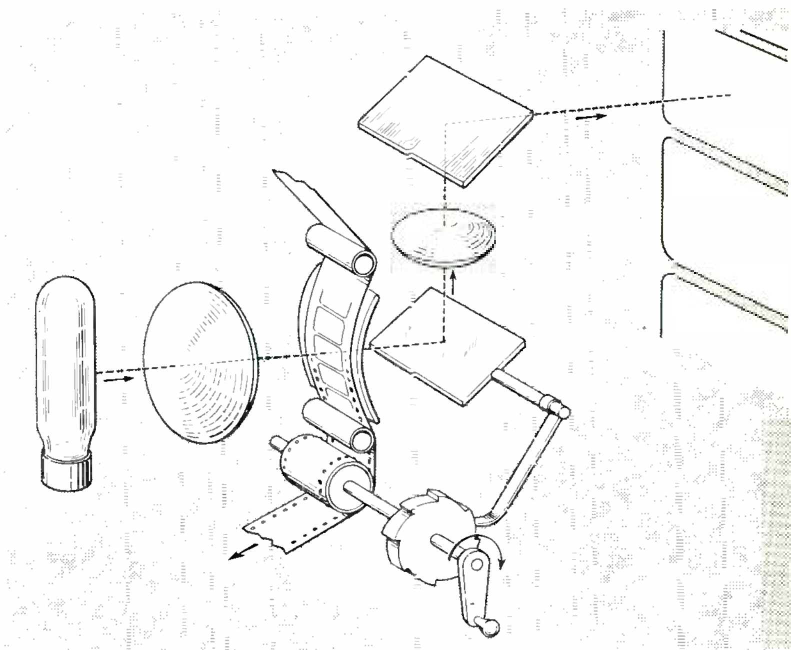
the film being moved through the machine in start-stop fashion, at an average rate of 24 frames per second. Very short intense bursts of light are flashed through the stationary film onto the storage mosaic and this mosaic is then scanned during the dark interval between light flashes at the television rate of 60 fields – 30 frames – per second. The long dark interval is used to pull the film down to the next frame, and so on. To fit the 60-field rate to the 24-frame movie rate, one frame is scanned twice, the next three times, and so on alternately.

This technique is subject to the limitation that some storage-type camera tubes tend to introduce spurious "clouds" or "blotches" into a reproduced picture, and are limited in contrast range and tone rendition. As a result, pictures obtained by televising film often do not have the quality available from 35-millimeter film originals. It is well known that satisfactory reproduction quality can be obtained by scanning the film transparency with a flying spot of light from a cathode-ray tube (CRT) having a fast-decay phosphor, and picking up light transmitted through the film with a suitable photocell. This combination is called a "flying-spot scanner." This, however, is not a storage method, so that we no longer can use short exposure flashes spaced by long dark intervals. Without storage, the picture must be constantly available to the scanner, except during the retrace or flyback periods of the television scan. The field retrace period is approximately 0.001 second; this means that if we were to be confined to intermittent, or start-stop, film motion it would be necessary to jerk the film down from one frame to the next, and *stop bouncing*, all in less than one millisecond. Some very interesting work has been done on this fast "pull-down," with some success.

However, a possibly more fundamental attack on the problem of televising film combines a flying-spot scanner and a new type of projector to produce television signals from standard 35-millimeter motion picture film. One of the novel properties of this projector is that the film is not moved intermittently but, instead, flows past the film opening, or "gate," in a smooth continuous fashion. For this reason the projector is called "continuous" or "non-intermittent." Actually, the function of the "projector" in televising film is not that of projection in the usual sense. However, the basic principles of the machine will be described first in terms of its use for simple optical projection, with the details peculiar to the scanner application reserved until later.

The basic idea of this machine is shown in Figure 1. Here we have a light source, condenser lens, circular arc forming a film gate, a deflecting mirror that may be rotated about the center of curvature of the film gate, a projection lens, a fixed deflecting mirror, and a viewing screen. Let us ignore the hand crank shown, and just say that if the film moves around the arc of the gate at a constant speed, and if the mirror rotates in the same direction but at half the angular speed of the film, then the film image reflected from the rotating mirror will be perfectly stationary. Thus, the projection lens will see a stationary film, and the image on the viewing screen will be frozen. However, if we turn the mirror through too great an angle, we will no longer be able to fill the projection lens, and will begin to lose light. In other words, we simply run out of mirror area. Theoretically, we could avoid this trouble by allowing the mirror to track the film while it moves through one frame height, then snap it back instantaneously to catch the next frame, and so on.

Fig. 1 — The optical principle of the film scanner is illustrated here in a simplified projector.



A more practical way of making a flow process out of this simple arrangement is shown in Figure 2. Here we have most of the elements of the previous figure – the light source, circular gate, projection lens, fixed mirror, and viewing screen. However, we have replaced the simple rotating mirror with a system of 18 mirrors mounted on a revolving drum (not shown). This mirror drum rotates at a constant speed geared to the film motion. The mirrors are mounted on the drum with their axes perpendicular to the plane of the diagram, and equally spaced around the drum circle. Also, each mirror has its own cam-follower arm and roller, riding on a common stationary cam shown by the dotted oval.

Each mirror has two components of motion – its center is carried around the periphery of the revolving drum, and it is rotated about its own center by cam action. The net effect of these two motions is such that all of the mirrors in the useful or "active" zone near the lens axis rotate about a common point in space – the center of curvature of the film gate – at one-half the angular speed of the film. Notice that if we extend the surface of these mirrors, they will pass through this center point, so each mirror is rotating in the same way as the single mirror of Figure 1. Each mirror therefore arrests the motion of the film, as described previously. What, then, have we gained over the simpler arrangement? Just this, in addition to the *rotation* described, each mirror is being *constantly translated* parallel to itself. It is this translation that makes the flow process. As each mirror rotates through its useful angle it also *slides* along to make room for a new mirror.

If we look at the active, or useful, region of the mirror drum, we see that there is a constant angular difference between adjacent mirrors (the actual difference in this active region is 10 degrees). This angular spacing is such that one mirror tracks one particular film frame along, the next mirror the next frame, and so on; there is a one-to-one correspondence between mirrors and frames. This means that the action of the mirrors in sliding into and out of the useful optical region produces a continual lap-dissolve from one frame to the next.

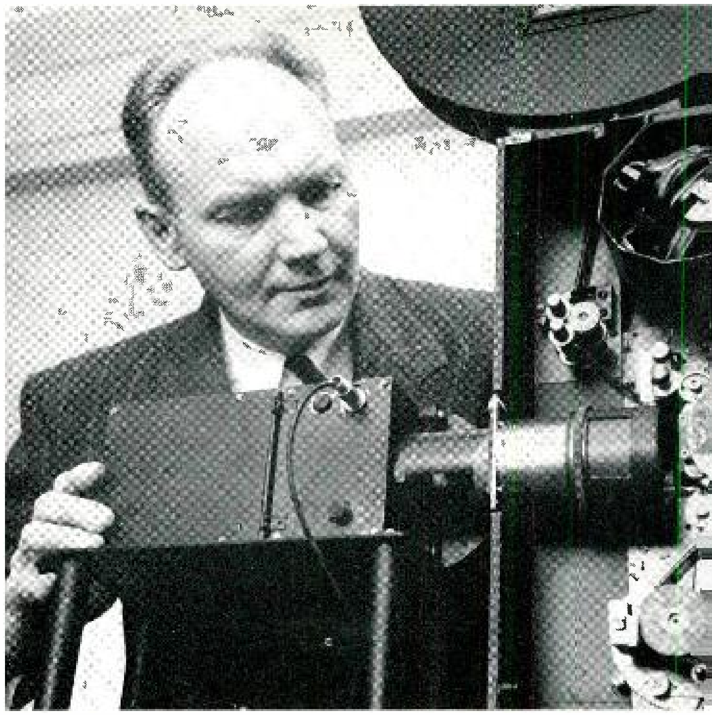


Fig. 3 — The film scanner of the projector is checked by C. F. Mattke preparatory to making a test run.

To facilitate discussion, let us assume that our film consists of successive frames of a still picture – a vase of flowers for instance. Then, the projection lens always sees a single stationary film image having constant brightness, and is unaware of the film motion. The image it projects onto the

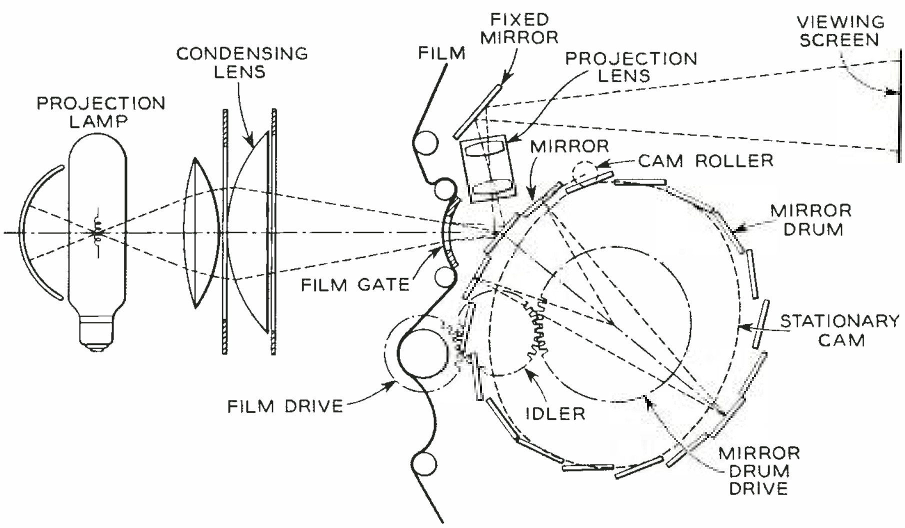


Fig. 2 — The simple mirror-and-crank arrangement of Figure 1 has been replaced by several mirrors placed on a moving drum.

screen will be just as constant and permanent as though it were painted there. All periodicity of the frame rate will have been completely erased. This means that we can televise this picture off the screen at *any scanning rate whatever* — 30 frames/sec, 2 frames/sec, or 1,000 — it doesn't matter; and, of course, no synchronizing is needed.

There are many details of design and construction in such a projector; consider, for example, the characteristics of the cam surface. Only about 50 degrees of this surface, corresponding to about a 2½-frame traverse of the film, is needed in the operation of the machine. The rest of the surface has only to bring the mirrors smoothly back around to the starting point. The cam is made symmetrical about the center, insuring that the mirror array will also be symmetrical about the center and the drum will be in dynamic balance. Actually, centrifugal forces do not present a problem, since for 24 frames/sec and 18 mirrors, the drum revolves at only 1.33 revolutions per second (rps) or 80 revolutions per minute (rpm). Also, the cam contour is very smooth and gentle. Because of the low speed and gradual cam surface, it is easy to obtain accurate follower action and no problem of cam wear is presented.

Some of the details of the projector are shown in Figure 3, including the film gate, mirror drum, projection lens, and fixed deflecting mirror. Figure 5 is a close-up of the film gate, driving sprocket, and some of the 18 mirrors on the revolving drum.

So far, we have described this machine as a straight optical projector. Figure 4 shows its use for televising film. The viewing screen has been replaced by a flying-spot CRT. As before, we have the deflecting mirror, the projection lens, the drum mirrors (only 3 are shown), and the film gate. Finally, we replace the light source by a photocell pick-up and the conversion is complete. The CRT scans out a normal rectangular area, or raster. This raster is then imaged upon the moving film through the mirror drum. The same principles that held the film image stationary on the viewing screen now make the raster image move along with the film, stationary with respect to the moving frames.

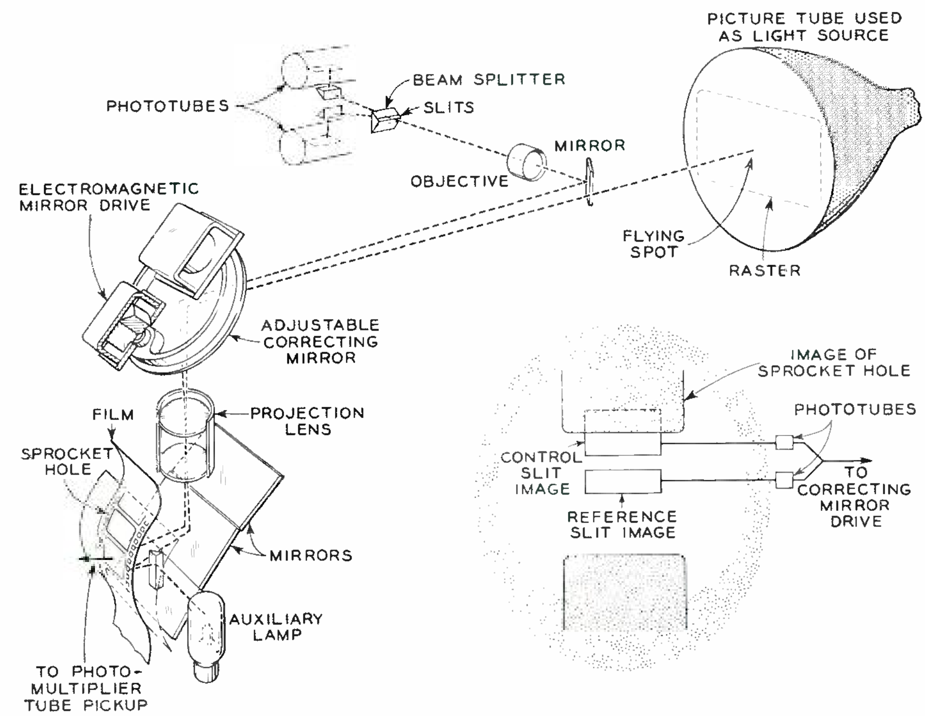


Fig. 4—Combination of projector and flying-spot scanner for televising film. A "jitter" servo adjusts the correcting mirror according to the position of an image of a film sprocket hole.

This arrangement may be used for televising color film, by placing a suitable beam-splitting pickup behind the film gate.

Now, according to the basic principles of this scanner, the rotation of the mirror drum will exactly cancel the film motion. In practice, imperfect gear teeth, slight perturbations in film speed, and other troubles keep the motion cancellation from being complete. Even with rather precise machining, there tends to be an objectionable amount of vertical jitter in the projected image. The solution

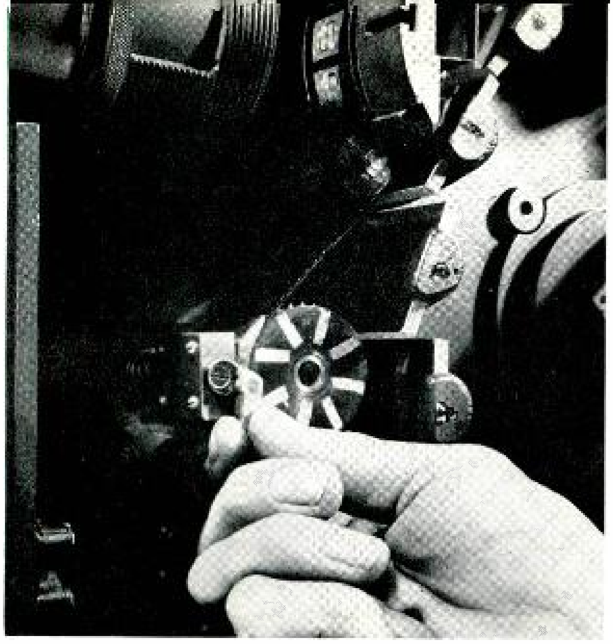


Fig. 5 — A close-up of the film gate and driving sprocket. The relative angles of the mirrors on the drum may be clearly seen.

to this problem was found in a rather obvious idea, also shown in Figure 4. We illuminate the sprocket-hole region of the film with an auxiliary lamp, through a deflecting prism. Light is reflected off the film, from the mirror drum, through the projection lens, from the deflecting mirror, and produces an image of the sprocket holes in the plane marked "slits."

The inset of Figure 4 shows a view of the image obtained in this plane. Here we have a pair of slits, each of which admits light to its own photocell, and the image of a chosen sprocket hole (a neighboring hole is also shown). The "hole" part of the image will be dark, since it reflects no light. If the machine works properly, the image of the

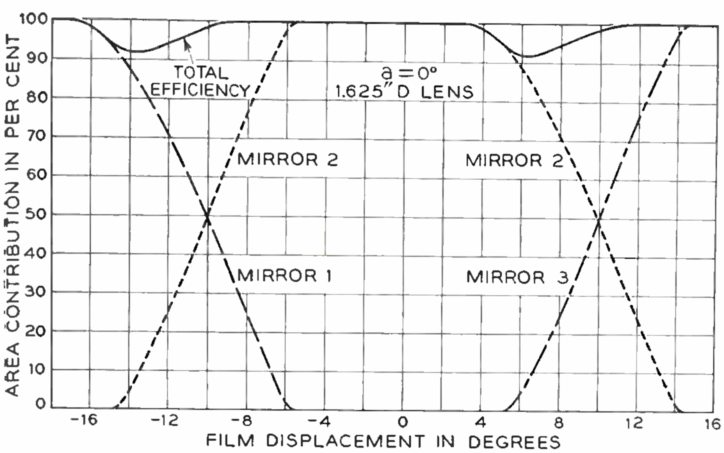


Fig. 6 — The lap-dissolve is not perfect as one mirror slides into the position of another. The slight changes in light efficiency are eliminated by a "flicker" servo.

sprocket hole will be perfectly stationary in the reference position shown. In this reference position, the larger of the two slits is bisected by an edge of the sprocket hole. The gains of the two photocells are so adjusted that they produce equal outputs under this condition. Any small vertical fluctuation of the image will cause the total light in the larger slit to change, leaving the illumination of the other slit unchanged. This unbalances the photocell outputs, the unbalance signal being am-

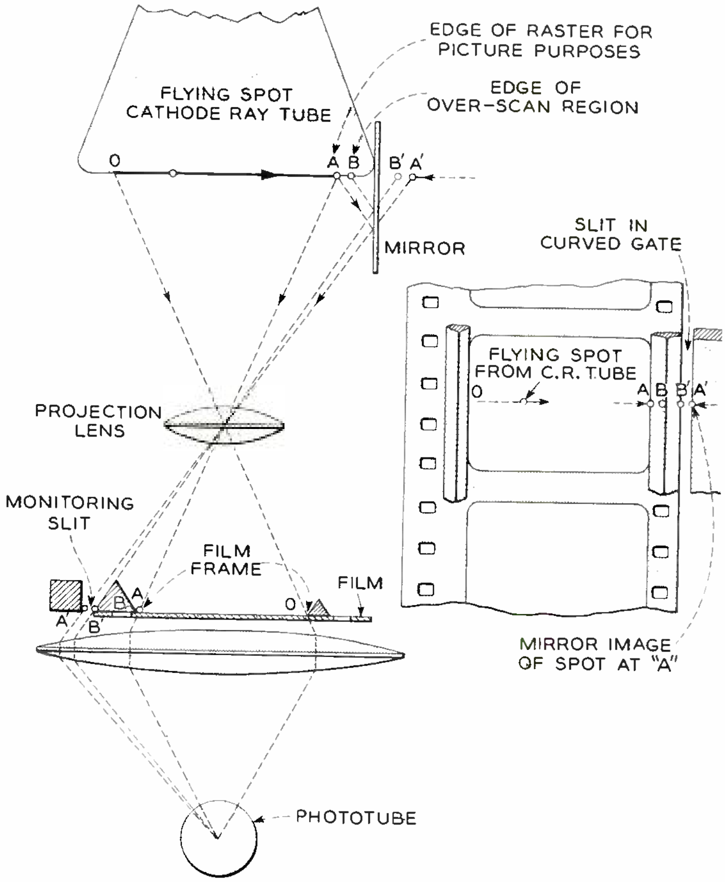


Fig. 7 — The "flicker" servo uses the light intensity at the monitoring slit of the film gate to control the brightness of the CRT spot.

plified and applied to a pair of "moving coil" loudspeaker motors to tilt the deflecting mirror. The resulting tilt of the deflecting mirror – which now may be called a *correcting* mirror – restores the sprocket hole image, and thus the main picture image, to its correct position.

This system constitutes a negative feedback loop or servomechanism, and has a response time of about 1/1000 of a second. In spite of the large correcting-mirror mass, this fast response is obtained with a peak driving power of about one watt because the maximum deflection required of the mirror is no more than five minutes of arc — a few thousandths-of-an-inch motion at the tips of the mirror.

This "jitter" servo effectively eliminates the vertical fluctuation, leaving a residual jitter of only about 1/2000 of the picture height. The effect of switching the correcting loop in and out is quite marked. The servo is an economical way of obtaining "super-precision" in the gearing; it also eases the tolerances on various adjustments and lessens the accuracy needed in the cam contour. Still another operating advantage is contributed by the servo system — it supplants the mechanical filter usually needed to smooth out fluctuations in film speed. As a result, the projector will come substantially up to speed in a fraction of a second. This, together with the complete absence of synchronizing requirements, means that this type of projector may be used to insert filmed material into a "live" TV program without having to start the machine running ahead of time.

Another source of trouble in the projector is a small fluctuation in light efficiency throughout the cam cycle. That is, the lap-dissolve action isn't quite perfect. This is illustrated in Figure 6. Here we see that as a typical mirror (1) slides out of the optical path and "fades" out, the succeeding mirror (2) moves in to take over. However, the contribution of the first mirror falls off slightly faster than the contribution of the new mirror builds up, resulting in a momentary drop in over-all light efficiency of about 8 per cent. This lasts for a small fraction of the projector cycle. When the machine is used simply as an optical projector, this cyclical variation in efficiency causes an unnoticeable amount of 24 cps flicker. However, when the projector is used for television scanning, objectionable low-frequency beats are formed between the television scanning frequency and various harmonics of the 24 cps fluctuation.

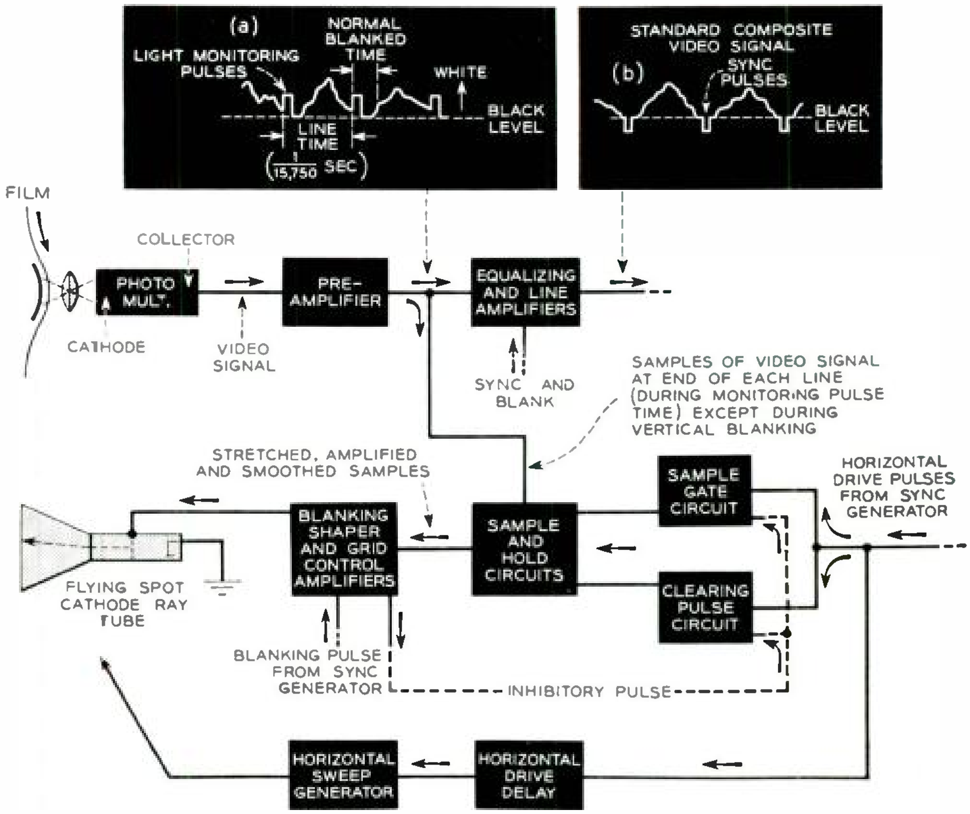


Fig. 8 — The CRT beam intensity is controlled by light-monitoring pulses that have been properly sampled, smoothed, and amplified.

This fluctuation in light efficiency, shown in Figure 6 and inherent in the basic design of the projector, results from interference between adjacent mirror edges. Additional fluctuations in efficiency can be caused by uneven coverage of the film-gate area by the photocell, by non-uniform raster brightness on the flying-spot CRT, or by variation in lens transmission with the angle of the optical path. The last two factors do not cause flicker, but non-uniform brightness over the picture area. To suppress all such cyclic variations in light efficiency, a flicker-suppressing servo system has been incorporated.

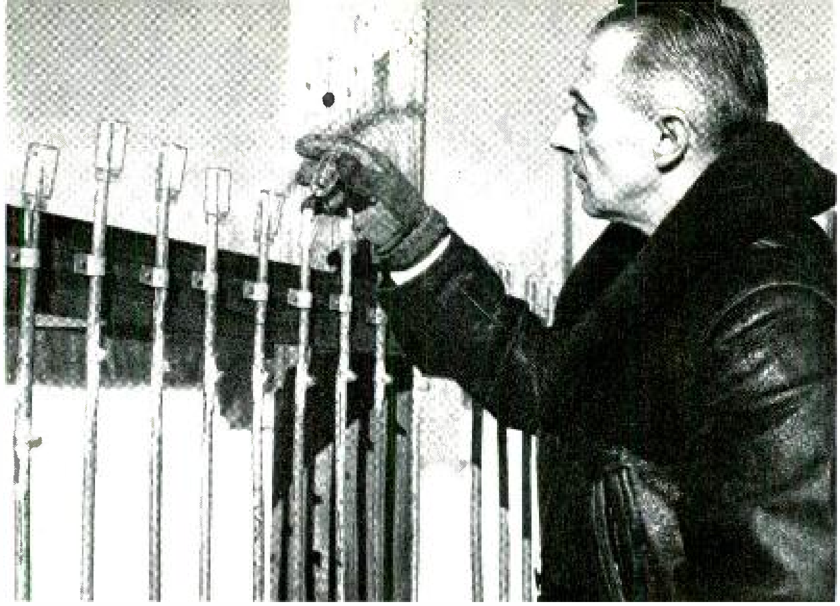
The essential elements of this "flicker" servo are shown in Figure 7. For simplicity the mirror drum and the position-correcting mirror have been omitted. The normal CRT horizontal scan extends from O to A, this region of the tube face, of course, being imaged upon the film frame by the projection lens. Now, the flying spot sweep is adjusted to provide about a three per cent "over-scan" from A to B, the image of this region being masked off by the side of the film gate. An auxiliary mirror is placed at one side of the CRT to produce a secondary image A′-B′ of the "over-scan" region, which is in turn imaged by the lens upon a clear slit opening to the left of the film gate. An elevation view of the film gate and monitoring slit is shown at the right in Figure 7. The light through both the film gate and the clear opening is collected by a condenser lens and imaged upon the photocell.

As a result, each television line scan is followed by a two-microsecond period during which the photocell output simply indicates the amount of light incident upon the film gate, unaffected by film density. The appearance of these "light monitoring pulses" in the video output is illustrated at (a) in Figure 8. This figure indicates some routine operations whereby the light monitoring pulses are sampled, smoothed, and amplified to control the beam intensity, and thus the brightness of the flying-spot tube. The polarity of transmission around this closed path is chosen to provide negative feedback, and thus to suppress any variation in light incident upon the film gate. The response time of this loop is about one-fifth of a millisecond – fast enough to suppress predominant "vertical" fluctuations in light, but slow enough to "live with" the intermittent information delivery. The resulting servo performance is sufficiently good to suppress the flicker to a satisfactory level – the degree of suppression being limited ultimately by the precision to which the monitoring pulses can be made to measure the fluctuating light efficiency of the projector.

The projector-scanner described here is now being used as a research tool, to produce television signals from standard black-and-white 35-millimeter film. Pictures obtained from these signals have the fidelity of halftone rendition expected from the flying-spot type of scanner – supplying good detail in the shadows while avoiding the chalky, washed-out highlights often found in film television. Also, image sharpness and contrast are high enough, and the inherent picture "noise" low enough, that we can start with signals from this scanner and introduce controlled amounts of noise and distortion to find out what imperfections may be tolerated in transmitting television signals over long distance facilities such as coaxial cable, waveguide, and microwave radio links.

THE AUTHOR

ROBERT E. GRAHAM received his B.S. in Electrical Engineering at Purdue University in 1937 and has done graduate work at Columbia University. Mr. Graham joined the Technical Staff of the Laboratories in 1937 and has since been engaged in television research. During the war, he worked on radar and automatic tracking problems, and on servomechanism research. More recently, Mr. Graham has also been engaged in research on transistor applications and is now in charge of a group concerned with the application of information theory to television transmission.



The author inspects some of the C resin plugs being tested under field conditions at Chester, N. J.

Cold-Resin Gas Dams for Telephone Cables

J. A. RATTA *Outside Plant Development*

Gas pressurization has long been used in toll cables, and the resulting improved maintenance made it desirable to extend pressurization to the exchange-cable plant. Since older types of cable terminals are not gas-tight, gas dams, or "plugs," must be constructed in terminal stub cables to maintain gas pressure. The hot-asphalt plugs used on toll cables are too expensive and time-consuming to be used in the large numbers required by the exchange cable plant. Therefore, Bell Telephone Laboratories has developed a new cold-resin plug that is less expensive and is easier and faster to construct.

One of Benjamin Franklin's famous and truthful adages, "A small leak will sink a great ship," applies with particular significance to the vast mileage of telephone cable that is kept under gas pressure as a preventive maintenance measure. Gas leaks, large or small, are the enemy of this maintenance system. Even a small leak, if allowed to go unrepaired long enough, will "sink" the internal pressure of a complex cable network to the point where moisture may enter the cable and cause a service failure.

Gas pressure within the cables prevents the majority of cracks or breaks in the sheath from resulting in moisture-induced trouble. In addition, gas flowing from a leak causes a gradual drop in cable pressure and thus the leak will reveal its presence by means of signals from pressure-operated switches, or contactors, permanently installed at intervals along the cable. When a leak is detected, its location can be found by the use of a variety of techniques utilizing either pressure-sensitive instruments* or gas detectors. These two maintenance facilities, gas pressure and leak detection, aid materially in curtailing the number of circuit troubles and associated service failures, and permit sheath-break repairs to be made on a scheduled basis.

The beneficial aspects of maintaining long-distance, or toll, cables under continuous gas pressure have long been recognized. Because of their importance to industry, government services, and the public, toll cables were the first to be pressurized. Before such a pressure system could be successful, some means of "plugging" the cable ends had to be devised. It would have been of no use whatever to pressurize a cable and then let the gas escape at the ends. Gas dams, more commonly called "plugs," were developed for this purpose, and toll cables have been pressurized for many years. Actually, such cables are sectionalized for pressure maintenance purposes by the construction of gas plugs at usual intervals of about 10 miles. The pressure system used for toll cables has been designated as the "periodic charge" system because, generally, the cables in such a system are tight enough to

* Record, *April*, 1954, *page* 132.

maintain the desired pressure for a considerable period with one charging.

The successful application of gas pressure to toll cables directed attention to economies in maintenance costs and improvements in service that appeared possible if pressurization could be extended to include the exchange cable plant. This type of plant includes many small branch cables, and contains many distribution terminals which, in the older varieties, are not gastight. Also, it is frequently necessary for craftsmen to open these cables for circuit rearrangements. Pressurizing such cables, then, would mean frequent charging. Development of a continuous-feed gas system that would tolerate some nominal leakage was therefore undertaken. Because of the large number of cable terminals, successful pressurization of exchange cable systems would require many more gas plugs per mile of cable than would toll cable plant. In addition, to make such a system economically attractive, gas plugs for use in cable terminal stubs would have to be inexpensive and easy to construct.

Toll-cable plugs, developed primarily for large size cables, are made by removing a short length of cable sheath and installing a lead sleeve over the sheath opening; hot mineral wax is then repeatedly poured into the sleeve and drained off to impregnate the paper insulation on the wires. Finally, the sleeve is filled with hot asphalt. Making these plugs is a difficult and time-consuming operation, too much so for their use in the many small cables of the exchange plant. A new type of asphalt

Fig. 2 — The tools used to make a C resin plug. The sample plug shows that constrictions in the cable sheath are not required.

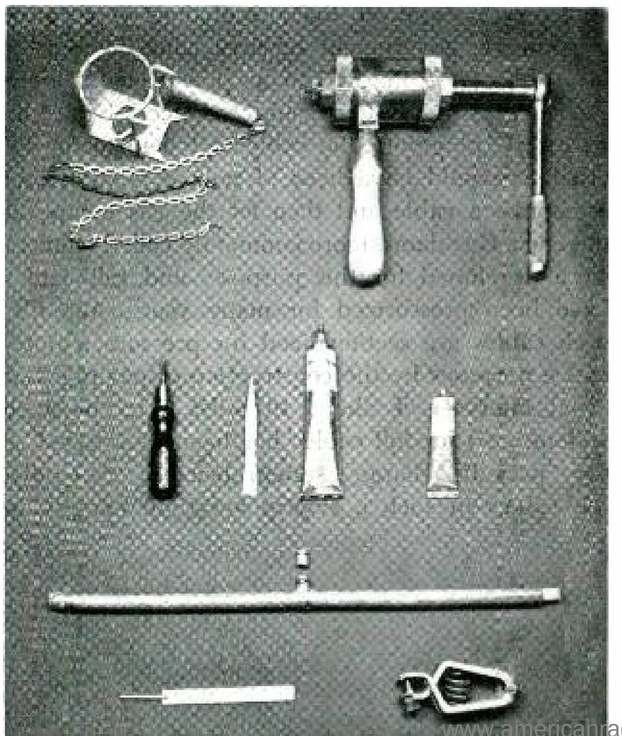


Fig. 1 — The tools required to make a hot-asphalt plug. Constrictions in the cable sheath may be seen in the sample plug at the bottom.

plug was therefore designed by the Laboratories.

Figure 1 shows the tools necessary to make one of these small-cable asphalt plugs. Two men are required. A workman on the pole removes the cable fastenings, arranges the cable in a convenient position, drills a hole in the sheath, and removes the core-wrapping paper at the hole. He then solders a threaded flange over the hole and makes annular constrictions in the sheath about four inches on each side of the flange. Meanwhile, a man on the ground tends a heating furnace, heats asphalt in a kettle, pre-heats a pressure gun over the furnace, fills it with hot asphalt, and passes it to the man on the pole by means of a handline. When the workman aloft receives the pressure gun filled with hot compound, he attaches it to the flange, injects the hot asphalt, closes the opening in the flange, and restores the cable to its original position.

Although this method was found to be an improvement over the more complicated method used on toll cables, it was still too time-consuming for general use. In addition, forming the annular constrictions in the sheath occasionally caused excessive crushing of the paper insulation on the wires, with resultant cable-pair troubles. Further development objectives were established to reduce the quantity and bulkiness of equipment required, eliminate the need for handling hot material and, if possible, omit the troublesome cable-sheath constrictions. This would generally simplify the procedure as well as improve safety conditions for the workmen. What was visualized was a compound that, without heating, could be injected into the cable core as a low viscosity liquid but would solidify sufficiently to form a gas-tight plug. It was judged to be necessary that this material saturate the paper core-wrapper and the paper insulation on each wire, as well as coat and adhere to each wire and the inner wall of the cable sheath.

Some of the newer organic chemicals seemed to offer many of the desired properties, and a number of compounds were developed and exhaustively tested and appraised in the laboratory. The material finally selected is a low-molecular-weight liquid polysulfide containing an amine which, when combined with a modified phenolformaldehyde liquid polymer, forms a rubber-like solid. When first mixed, this compound is an amber-colored liquid of syrupy consistency. The components are so proportioned as to provide, at a temperature around 70 degrees Fahrenheit, a "working" period of about one hour before the mixture sets – that is, ceases to be fluid. This liquid interval permits balanced distribution of the material in the cable section, and adequate penetration of the paper insulation and core-wrapper. At lower temperatures, the setting time is increased, and experience indicates that this material should not be used to make gas plugs at temperatures below 45°F without supplementary heating of the material and cable.

For use by telephone craftsmen in plugging distribution terminal stubs, each of the two ingredients is packaged in a collapsible metal tube. The packaged quantities are such that, when the contents of one tube of each ingredient are combined, a charge for one plug is provided. The two components of the plugging material have been named C plug resin and C resin activator. Figure 2 shows the tools used in making a cold resin plug, including the tubes of resin and activator. One man can do the job, and can do it all while on the pole. He drills a hole in the cable sheath, removes the core-wrapping paper at the hole, and solders a flange over the hole as in the older method, but no further preparation of the cable is required. While being filled, the gun is held firmly against the pole by the gun-holder, as shown in Figure 3. The workman squeezes the full charge from both tubes into the gun. After the mixture is thoroughly stirred he caps the gun and screws its nozzle into the flange on the cable. By operating the ratchet handle of the gun, Figure 4, he forces the plugging mixture into the cable core. He then unscrews the nozzle from the flange, and completes the operation by sealing the flange with a screw plug. The entire job usually requires less than a half hour. Although the plugging mixture normally reacts sufficiently to arrest flow of the material within the cable in about one hour, an interval of twenty-four hours is required to form a reliable gas dam.

This cold-resin method requires fewer tools than the hot-asphalt method. It also obviates such work operations as arranging and restoring the

Fig. 3 — The full charges of both C resin and C resin activator are squeezed into the gun to make the mixture for one plug. The snap-on gun holder keeps the gun in the proper position, leaving the man's hands free.

Fig. 4 — After the filled gun is screwed onto the cable fitting, the craftsman operates the ratchet handles of the gun to force the plugging mixture into the cable core. He then seals the flange with a screw plug.

cable, heating asphalt and handling hot material, and making constrictions in the sheath. Tools and materials for the resin method are light in weight, compact, and can be carried up the pole in pouches attached to the body belt of an individual workman.

Two primary operational requirements must be met by gas plugs in cable. First, the insulation resistance must be of such value as to preclude interference with operating or fault-locating measures; secondly, the plug must be gas-tight for the life of the cable, usually a matter of twenty years or more. The effect of the resin plug on insulation resistance was determined by bridge measurements made on short stub cables before and after plugging. The minimum value obtained was approximately 5,000 megohms between the wires of a cable pair, with the sheath isolated. Insulation resistance of this order of magnitude is high enough not to interfere with standard cable-testing techniques or with the transmission and signaling performance of the cable.

Tests of the operating life of resin plugs were made in the laboratory, at the Chester outdoor field laboratory, and in the operating plant. Pressurized resin plugs in the laboratory were subjected to cyclical changes in temperature between 150°F and —40°F. Their satisfactory performance under this rigorous test, consisting of exposure to as many as twenty-five such cycles, provides a basis for belief that a long and satisfactory life may be expected from C Resin plugs under field conditions. At the Laboratories' testing grounds at Chester, New Jersey, approximately 150 plugs were built under ambient temperatures ranging from freezing to 95 degrees F, and during periods of rain and snow; they are now aging under normal outdoor conditions. A test set-up is shown in the headpiece.

Field trials of the new type plugs were made in several locations; one of the earliest trials was on Nantucket Island, Massachusetts, in the territory of the New England Telephone and Telegraph Company. Nantucket Island is some twenty-five miles off the southern coast of Cape Cod, and its cable system presents the situation of forty miles of isolated cable. Repairmen must be dispatched from the mainland, using transportation facilities that operate infrequently – and during stormy weather, perhaps not at all. Pressurization of such a system assumes major importance since it greatly reduces the probability of service disruptions. Sheath injuries, requiring immediate attention in a non-pressurized system, may be accumulated and repaired under favorable conditions without producing interruptions in service. About 530 plugs were made in the Nantucket field trial without a "leaker", and without introducing a single case of cable-pair trouble. Nantucket, of course, has a northern climate. To gain experience in a warm southern climate, a trial of the resin plug has been made in Brownsville, Texas. To date, both trials have proved entirely satisfactory.

Resin plugs show an improvement in installed first-cost over the hot-asphalt plugs formerly used. Including labor costs, the resin plugs are about one-third as expensive as the asphalt type. This decreased cost per plug is one more factor in easier pressurization of exchange cable plant, with its resultant maintenance and service advantages.

THE AUTHOR

J. A. RATTA, JR., entered the Bell System in 1920 via the New England Telephone and Telegraph Company in Boston. While with the New England Company he was concerned with tools, materials and methods of outside plant construction. From 1923 to 1934 Mr. Ratta designed outside plant hand-tools at A. T. & T. Mr. Ratta became a member of the Laboratories technical staff in 1934 and has been concerned with the design of outside plant tools, and the design of airborne and shipborne radar. He is presently working with a cable methods group on joining and splicing problems. He received his B.S. degree in Civil Engineering in 1920 at Tufts College.

The author (left) and R. A. Hauser, equipment maintenance supervisor at the Long Lines No. 4 crossbar office in New York City, discussing a detached contact schematic.

Introduction of common-control systems, such as crossbar and automatic message accounting, has substantially increased the complexity of switching circuits. Understanding these circuits so that they may be engineered and maintained properly is an increasingly difficult task. To help with this problem, Bell Laboratories has developed detached contact schematics, a simplified method of showing complex circuits.

Detached Contact Schematics

J. W. GORGAS *Switching Engineering*

A new type of schematic drawing has been developed by the Laboratories and adopted by the Bell System. It is basically different from the older type in that it emphasizes circuit paths and functions, rather than the physical associations of apparatus. Contacts of relays and other electromagnetic devices are shown "detached" from the rest of the structure to give the simplest and clearest possible circuit path representations. As a result, circuits are more easily learned and maintained. In addition, tracing devious circuit paths, unavoidable with the older type of drawing, is no longer necessary. Since paths for an entire function can be seen at a glance, time is saved, costs are reduced, and job performance is improved.

Telephone switching systems schematic drawings provide the entire basic circuit information needed for: (a) maintenance of the circuit by Operating Telephone Companies, (b) training personnel to understand the operation of the circuits, (c) manufacture of equipment by the Western Electric Company, and (d) use by engineers in various ways. Traditionally, these drawings have been prepared in the "attached" contact form. A typical example of this type, showing a part of the 4A toll crossbar system marker circuit, is illustrated in Fig. 1. The outstanding characteristics of this form of drawing are that each piece of apparatus is shown with all its components attached, and the content of each figure is based upon physical associations. This results in devious circuit paths. One of these, the RL relay, is shown in Figure 1 by red lines to make it stand out among the other intersecting paths. In large circuits, paths are seldom completed in one figure but must be traced through several others. The RL path, for example extends to six other figures, each on a different sheet. Tracing these leads requires scanning brackets which include ninety-one leads to find the seven involved. All of this is time consuming and wearies the mind with details such as sheet numbers, location coordinates, and lead designations.

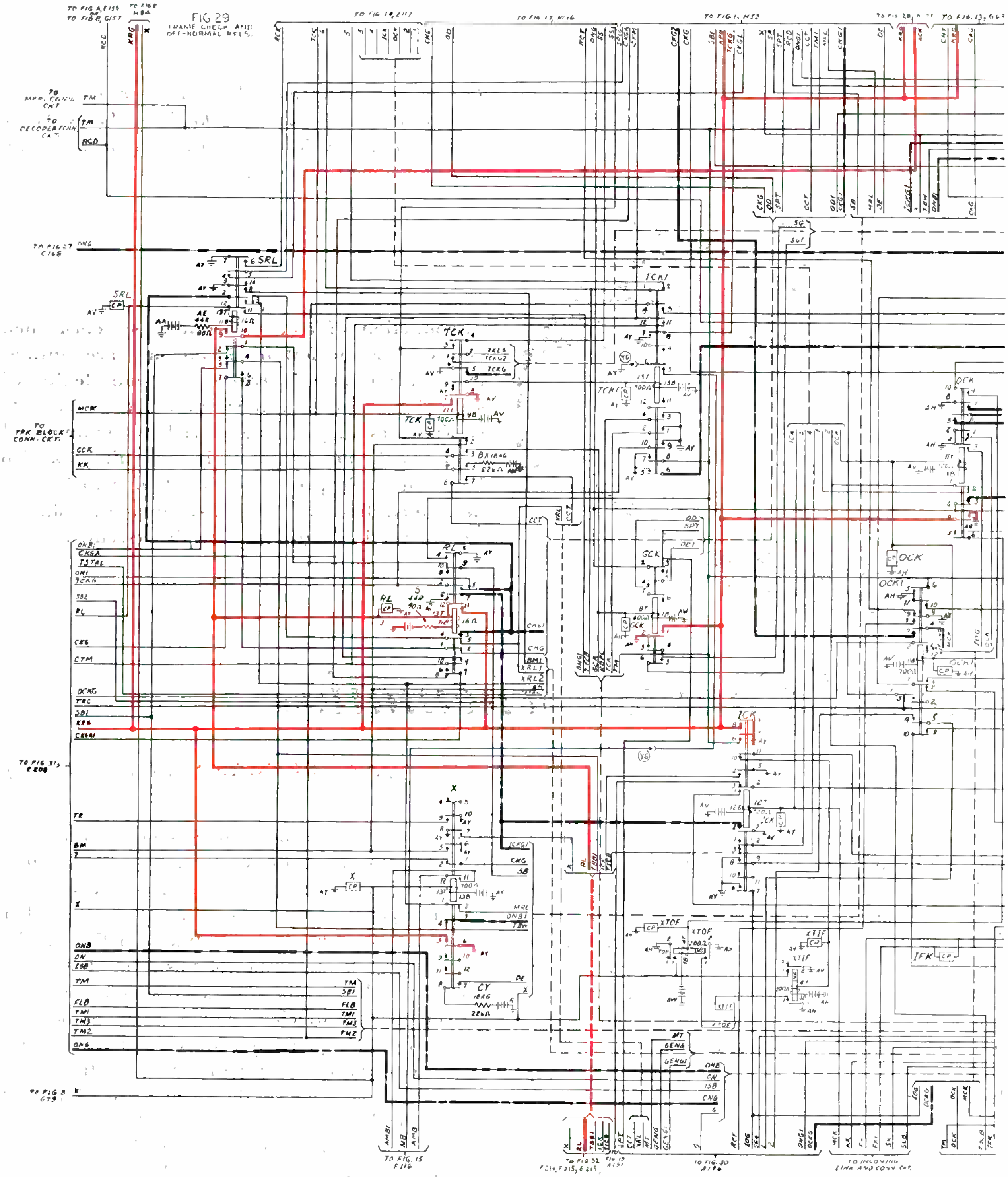


Fig. 1 — A portion of an "attached contact" schematic showing part of the 4A toll system marker circuit. The part of the RL relay circuit path included is shown in red.

As circuits and systems became increasingly complex, the difficulties involved in using this type of drawing led some of the operating companies to prepare simplified drawings for training purposes. Later, these were prepared for new systems by the Laboratories. At first, training drawings took the form of simplified schematics using attached contacts, but it was soon evident that greater ease of understanding was obtained when the contacts were detached, and the circuit presented in a series of figures, each depicting a circuit function or closely related group of functions. Improved symbols used to represent circuit elements, such as relay contacts, further simplified the drawings and increased their usefulness.

Although they were originally prepared for training, the new drawings were found to be equally valuable for maintenance. For this purpose, however, there was the problem of keeping the simplified drawings up to date with respect to the installed equipment. This problem does not exist with a drawing which is used for manufacture since the actual field installations are derived from it, but it is almost impossible to keep the simplified training and maintenance drawings in step with those used for manufacture. The present type of detached contact circuit drawing was developed by the Laboratories to avoid the necessity of preparing and maintaining two forms of drawings for the same circuit. It combines the advantages of the simplified form of training drawings with the completeness and accuracy included in the older attached contact schematics. Since the new type drawing is also used for manufacture, it is always accurate, complete, and up to date, and is therefore well suited for maintenance purposes.

Comparison of a circuit path as shown in the new type drawing with the same path in the older attached contact form, demonstrates the simplicity and advantages of the new method. For this purpose, the RL relay path, shown in part by red lines in Fig. 1, is illustrated in detached contact form in Figure 2. Here the path is complete and no tracing labor is required to examine and study it. To show such paths by straight lines, new symbols are used to represent relay contacts. These are illustrated in Figure 3. A make contact (open when not actuated) is represented by an "x", a break contact (closed when not actuated) is represented by a "–" and a transfer contact, by a combination of "x" and "¬". Other compound contacts are similarly shown by a combination of "x" and "–" symbols. As with schematic symbols in general, these may be rotated to any position without affecting their meaning.

Besides the new contact symbols, a number of other improvements in symbols and methods have been introduced with the new schematic. Typical of these are replacement of the battery symbol by its polarity and voltage, and the simplification of the relay core symbol by removing the single turn used to represent the windings.

In the new schematic, the functional relationship of each part of a path is easily understood. In Fig-

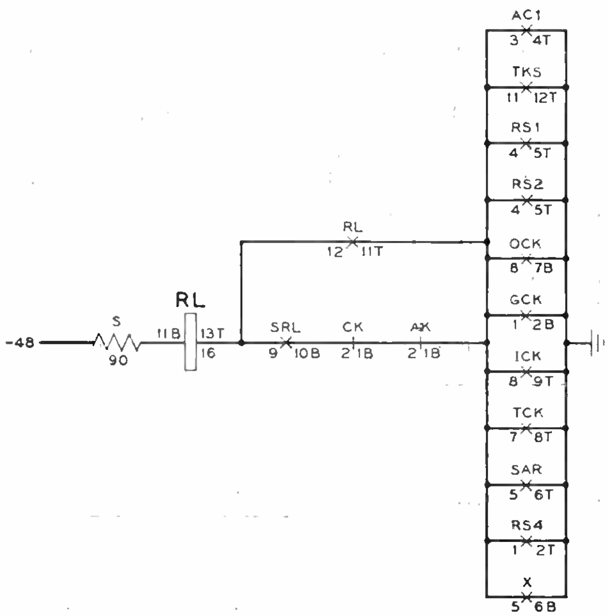


Fig. 2 — A detached contact schematic showing the complete RL relay path. The designations below each contact symbol refer to spring numbers of the top and bottom of each relay.

ure 2, for example, it is apparent that the AK and CK relays must be unoperated and the SRL and one of the eleven relays at the right of the figure must be operated, before the RL relay can operate. This cannot be seen in the portion of the old schematic illustrated in Figure 1, since the complete path is not included on one page. Further, in Figure 2 it is easy to see that, having operated, the RL relay holds through its own locking contact, independent of the SRL, CK, and AK relays, as long as any one of the eleven other relays remains operated. In fact, the entire electrical path can be analyzed quickly.

A basic feature of detached contact schematics is the use of two series of figures. Circuit paths of the type illustrated in Figure 2 are shown in one series called "functional schematics" or "FS's", and the apparatus content of the physical units is shown in another series called "apparatus figures". The latter also serves as an index of the scattered relay contacts.

Each FS comprises a group of paths that are functionally related. Figure 4, for example, shows one of these for the channel test and hold magnet operation of a 4A toll crossbar switching system marker. It was difficult to understand these functions with the attached contact schematic since the paths had to be traced in and out of many circuit figures. In the FS, however, the paths can be seen at a glance.

The complete paths for the hold magnet operation and channel test are shown not only within the marker but extended beyond it to the hold magnets of the incoming and outgoing link and connector circuits. Such information is often furnished by the new type schematic because it is recognized that functions which involve more than one circuit can be understood more readily when the complete intercircuit paths are in view. A distinctive double line boundary, as shown near the top of Figure 4 is used to enclose the foreign circuit information to show that this portion of the schematic is not intended for manufacturing purposes and may not be complete.

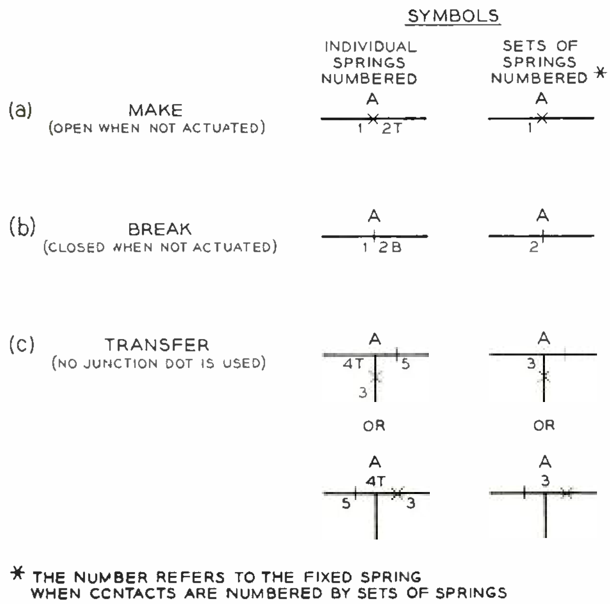


Fig. 3 — Basic contact symbols used on detached contact schematics.

One of the devices used in the new schematics to make circuits easier to understand is a geometrical arrangement of contacts which makes a function self-explanatory. Checking information-reception where uniform codes such as one-out-of-three, two-out-of-five, or three-out-of-eight are used, for example, is treated in this manner. A circuit of this type which checks one-out-of-three for a tens digit and two-out-of-five for a units digit is illustrated in Figure 5. The symmetry of this contact arrangement is such that it lends itself to a representation in the form of parallelograms. As shown, a circuit that checks for only one out of a series is "one story" high, and a circuit that checks for two out of a series is "two stories" high. The break contacts are represented on the horizontal lines, and the make contacts on the oblique lines. When the user is familiar with this method, the significance of such paths can be understood at a glance without any need for further circuit description or analysis.

The equipment aspects of a circuit are described in apparatus figures, each of which lists the apparatus included in an equipment unit. These units are groupings of apparatus convenient for manufacturing and optional ordering purposes. Figure 6 illustrates a typical figure of this type including relays, resistors, capacitors, a network, a jack, a key, a timer, and an electron tube. Besides furnishing equipment lists, the apparatus figures provide information as to the type and sequence characteristics of each relay contact, and its location in the FS's. Two methods are used to accomplish this. One of these, used for apparatus having individual contact spring numbering, symbolizes the contacts in attached form as in the older type of schematic. The U and Y type relays shown at the top of Figure 6 illustrate this method. As shown, location coordinates are given adjacent to each set of contact springs. These coordinates which show the location of each contact in an FS, include a sheet number prefixed to ordinary maplike coordinates consisting of a letter and a number. Spare contacts are indicated by the absence of such coordinates.

The other method of listing relays, tabular in form, is used for relays such as the new wire spring type which have contacts numbered in sets. Some of these designations are shown in Figure 6 just below those for the U type relays. For each relay, one column includes the location coordinates and another the contact arrangements. In the latter, abbreviations are used to describe the contacts, M for a make or front contact, B for a break or back contact, EBM for an early break-make transfer contact, and EMB for an early make-break transfer contact. The EBM transfer breaks its back contact before making its front contact, and the EMB trans-

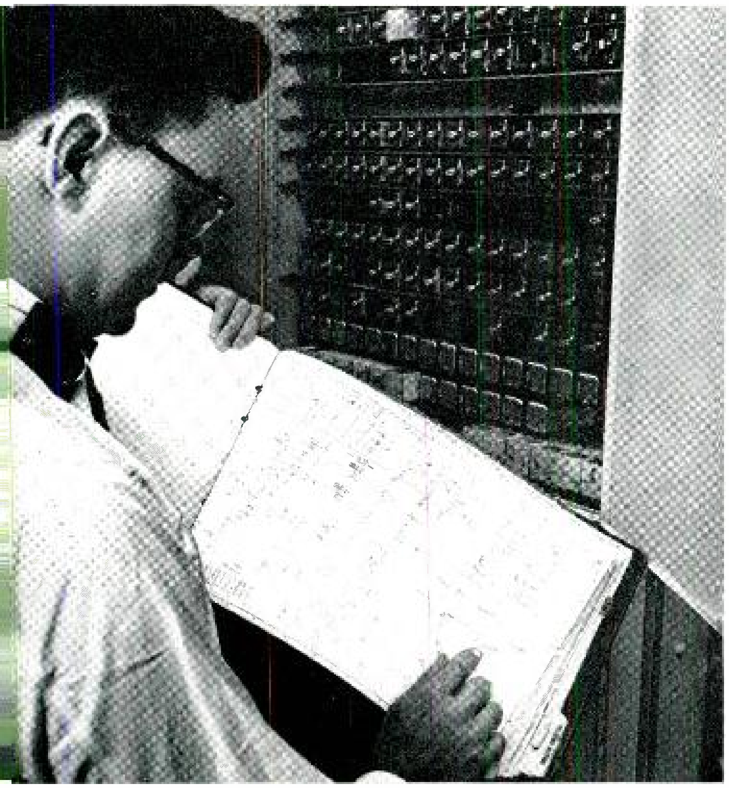


Fig. 4 — J. M. Sangster, equipment maintenance man, using a functional schematic at the Long Lines No. 4 crossbar office in New York City.

fer makes its front contact before breaking its back contact. The abbreviation BM is used to designate a third type transfer contact in which the sequence may be make-break or break-make. These abbreviations furnish information as to the nature and sequence characteristics of contacts, equivalent to the information furnished by the "pictorial" symbols illustrated at the top of Figure 6 for older type relays. An unequipped contact position is indicated by the absence of a type abbreviation, and an equipped but spare contact, by the presence of a type abbreviation without corresponding location coordinates.

The division of circuit information into functional groups, and the inherent compactness of the new method of showing circuit paths has permitted the use of a uniform small sheet size. This is a great advantage to all who use them. In the older schematic, not only the devious nature of circuit paths, but also the mechanical difficulty of unfolding large sheets of drawings and handling them so as to refer from sheet to sheet was a considerable handicap. The new drawings are drafted uniformly on 22 by 34 inch sheets and reduced to 11 by 17 inch pages. This smaller page is suited to use in binders, a method of handling proved to be convenient by previous Bell System experience with training material.

A graphical description of the circuit operations provided by diagrams called sequence charts* is included with each detached contact schematic. These compact sequence charts, describing the circuit operations under normal and trouble conditions, are sufficiently comprehensive in scope to include variations due to optional features. An improved and simplified written description, also furnished for each circuit, lays the broad foundation for understanding the circuit, explains its interrelations with other circuits of the system, and clarifies any features not easily grasped from the schematic drawing and sequence charts.

A comprehensive set of indexes, also provided as a part of the schematic, shows the content of each sheet, the location of each circuit element in the FS's and in the apparatus figures, the location of options, and the location of leads from other circuits. Some of these indexes may not be provided for smaller circuits, but for larger circuits, provision has also been made for indexing the physical location of the apparatus elements on the frames.

The new type of circuit schematic will be used for all new telephone switching systems, and for major new circuits added to existing common control telephone systems. In addition, it will be used for major circuit changes in existing telephone

* RECORD, *December*, 1953, *page* 492.

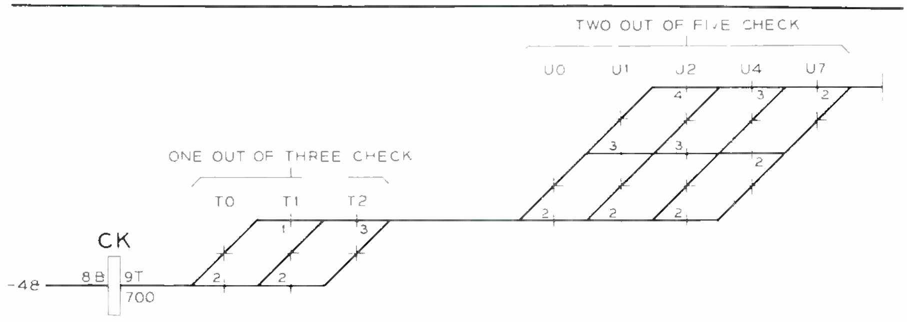
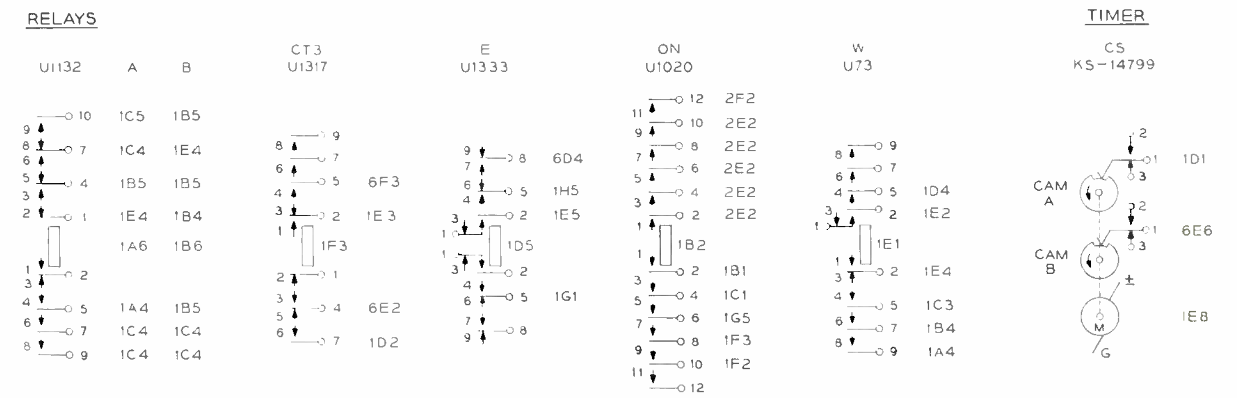


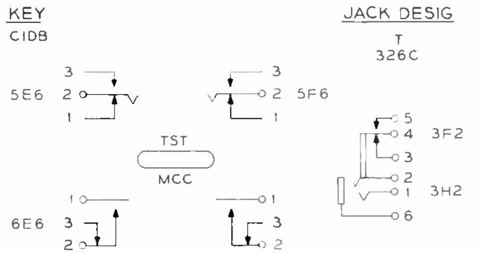
Fig. 5 — Representations used on detached contact shematics to depict a circuit checking one-out-of-three and two-out-of-five uniform codes.



RELAYS

DESIG CODE OPTION	OVL AF 62 CONT ARR	OVL LOC	RO AF 54 CONT ARR	RO LOC	TM AF 60 CONT ARR	TM LOC	TMA AF 70 CONT ARR	TMA LOC	TMB AF 85 CONT ARR	TMB LOC	CONT ARR	LOC	DESIG CODE OPTION
12			M		M	6F7							12
11													11
10	M		BM	6A7	M	6F7			EBM				10
9									PM				9
8	EBM	6G1	BM		M		EBM	6H2					8
7	B		B	7F6	B	5B1	B						7
6	EBM		BM	(a)	M		EMB	6B5	EBM	6A6			6
5			B										5
4	M		BM	(b)	M	6B7	M	6C5	PM	6E6			4
3									M	6D6			3
2			M	5B1	M	5G1							2
1													1
COIL		6D5		6C5		6G3		6A5		6B5			COIL

(a)	7E7 7H3
(b)	6E6 7E6



CAPACITORS

DESIG	LOC	CODE
TM	6G2	2-437 QA
TMA	6G0	KS-13368, L3, 0.001 μF

NETWORKS

DESIG	LOC	CODE
OVL	6D5	185A
TMA	6A5	185A
TMA-S	6B5	185A
TMB	6C5	185A

RESISTORS

DESIG	LOC	CODE
TM1	6G1	KS-13490, L3, 0.1 MEG
TM2	6G2	KS-13490, L3, 1000
TM3	6F1	145A, 3.83 MEG
TM4	6G1	145A, 0.866 MEG

ELECTRON TUBE

DESIG	LOC	CODE
TM	6G1	313CC

Fig. 6 — A typical apparatus figure.

switching systems. Although relatively few circuits have been issued in the new form, there has been sufficient experience with these, and with training material employing similar techniques, to warrant the prediction that the introduction of the new schematic with sequence charts will make a significant contribution toward the understanding of our complex switching systems.

THE AUTHOR

J. W. Gorgas' twenty-two years' experience with the Bell Telephone Company of Pennsylvania included dial system maintenance, maintenance engineering, and plant training. He transferred to the Laboratories in 1946 to help in planning the No. 5 crossbar training literature and school. He was subsequently associated with the design of the 4A toll system decoder, marker, test and trouble recorder circuits, and later was responsible for the development of new circuit description and schematic methods. Until recently he was engaged in the design of sender test circuits in the various No. 4 systems. He is currently a member of a switching engineering group concerned with nationwide dialing. Mr. Gorgas' electrical engineering training included two years at Drexel Institute of Technology.

Dr. Kelly Discusses Future of Electronic Computers

"What Is Ahead in the Field of Electronic Computers" was the subject of a recent talk by Dr. M. J. Kelly, President of the Laboratories, at the Sixth Annual Business Conference held at Rutgers University, New Brunswick, N. J. The conference was under the joint auspices of the Sales Executives Club of Northern New Jersey and the Rutgers School of Business Administration.

Dr. Kelly gave his talk during the session on "What's Ahead for Business as Affected by Science?" Two other speakers, E. W. Engstrom, Executive Vice President of R.C.A. Laboratories, and Henry DeWolf Smyth of the Atomic Energy Commission, also participated in this session.

Laboratories Men Awarded Honorary Degrees

Two Laboratories members, J. A. Morton and C. E. Shannon, were awarded honorary degrees at ceremonies of two leading universities last month. Mr. Morton, Director of Transistor Development, received an honorary Doctor of Science degree from Ohio State University. His previous degrees include a B.S.E.E. from Wayne University in 1935, and an M.S.E. from the University of Michigan in 1936. He completed the course work for Ph.D. in 1941 at Columbia University. Mr. Shannon, in Special Research, was awarded an honorary Master of Science degree from Yale University. He had previously received a B.S. from the University of Michigan in 1936 and S.M. and Ph.D. from M.I.T. in 1940.

Patents Issued to Members of Bell Telephone Laboratories During April

Bacon, W. M. – *Telegraph Switching System* – 2,676,199.

Baldwin, E. G. – *Transistor Gate* – 2,676,271.

Bell, D. T. – *Transfer Conductance Test Set* – 2,677,103.

Bennett, W. R., and Peterson, L. C. – *Computation and Display of Correlation* – 2,676,206.

Brune, W. L. – *Transmission Measuring Means and Method* –2,677,101.

Buhrendorf, F. G. – *Method of Making Electromagnetic Transducers* – 2,674,031.

Buhrendorf, F. G. – *Magnetic Head and Method of Making Same* – 2,674,659.

Buhrendorf, F. G. – *Method of Making A Filamentary Electromagnetic Transducer* – 2,676,392.

Buhrendorf, F. G. – *Magnetic Head and Method of Making Same* – 2,677,019.

Christensen, H. – *High Temperature Coefficient Resistors and Methods of Making Them* – 2,674,583.

Cutler, C. C. – *Frequency Changing Repeater Employing Feedback Amplifiers* – 2,674,692.

Davey, J. R. – *Teletypewriter Trunk Circuit* – 2,677,016.

Dehn, J. W. – *Pulse Counting Relay System* – 2,676,313.

Fondiller, W. – *Isothermal Electric Cables* – 2,676,305.

Haynes, J. R., and Morton, J. A. – *Testing of Semiconductors* – 2,677,106.

Joel, A. E., Jr. – *Sorting Device* – 2,674,312.

Joel, A. E., Jr. – *Coin Controlled Telephone System in Which Tariff Rates for Telephone Calls are Audibly Transmitted Automatically to a Calling Subscriber* – 2,676,209.

Laidig, J. F. – *Harmonic Crystal Oscillators* – 2,676,258.

Lakatos, E. – *Electrical Generator of Products and Functions* – 2,674,409.

Lund, N. – *Frequency Control Circuits* – 2,674,720.

Malthaner, W. A., and Ring, D. H. – *Checking Circuit* – 2,675,538.

McGuigan, J. H. – *Checking Circuit* – 2,675,539.

Morton, J. A., see Haynes, J. R.

Newby, N. D. – *Electrostatic Scanning Mechanism for Scanning Both Tip and Ring of a Calling Line and Combining the Results of These Scanning Operations* – 2,675,427.

Peterson, L. C., see Bennett, W. R.

Phelps, W. A. – *Frequency Spacing in a Two-Tone Carrier System* – 2,676,203.

Read, W. T., Jr., and Ronci, V. L. – *Glass to Metal Seal for Deep-Sea Electric Cable* – 2,676,197.

Ring, D. H., see Malthaner, W. A.

Ronci, V. L., see Read, W. T., Jr.

Ross, J. E. – *Potentiometer Card Mounting Means* – 2,675,450.

Sears, R. W. – *Cathode-Ray Devices* – 2,675,499.

Shive, J. N. – *Conditioning of Semiconductor Translator* – 2,676,228.

Tinus, W. C. – *Potentiometer* – 2,675,451.

Vroom, E. – *Electronic Induction Number Group Translator* –2,675,426.

Young, C. H., – *Transfer Conductance Test Set* – 2,677,102.

The No. 5 crossbar switching system was originally designed for central offices situated in the suburban areas surrounding large cities, and for medium to large-sized offices in other areas. With the growth of automatic switching, however, this system has been adapted to other applications. In one such application, in addition to handling its own telephone traffic, it is used as an intermediate or tandem switching point. The tandem revertive-pulse incoming register was developed for this situation, where calls that are originated in a No. 1 crossbar office must be routed to a step-by-step office.

No. 5 Crossbar Tandem Revertive-Pulse Incoming Register

J. W. BRUBAKER *Switching Systems Development*

One of the most important developments in modern telephone service has been extension of the area in which customers are permitted to dial calls directly. New central office equipment has had to be developed and existing equipment changed to provide this service. In the No. 5 crossbar system the changes were of two kinds: first, those necessary to permit customers served by a No. 5 crossbar office to dial extended areas directly and second, those required to permit a No. 5 crossbar office to serve as an intermediate switching point for extended area calls originating and terminating in other offices. The tandem revertive-pulse incoming register has been developed to provide for the latter requirement.

When a call is originated in one central office and completed in a second, the called customer's number is transmitted from the originating to the terminating office by a signaling method known as "pulsing." Four types of pulsing are in general use for this purpose. These are dial, revertive, panel call indicator (PCI) and multifrequency. Any two offices that are to be interconnected to complete a call, however, must be arranged to use the same pulsing language. Some central offices, such as step-by-step, can send and receive only one type of pulsing, others – panel for example – receive one and send either of two, but dial offices in any one city usually use the same type. Two cities in the same part of a state, however, may use different types of pulsing because they may have different kinds of switching equipment. In the past, calls between such cities were normally routed through operators for charging purposes, and these operators selected the required pulsing facilities. Since customers are now able to dial other cities and areas without an intervening operator, other arrangements are required for such calls.

Above, the author examining No. 5 crossbar tandem revertive-pulse incoming registers at Bell Telephone Laboratories in New York.

It is normal practice to route calls between offices in different areas or cities through an intervening office called a tandem office, thus reducing the number of interoffice trunks required. These tandem offices solve the pulsing problem because they can receive one type of pulsing and transmit a different type. A No. 5 crossbar office can handle this tandem traffic in addition to serving its own subscriber traffic. It is unusually well fitted for tandem service since the inpulsing and outpulsing circuits are separate and the particular combination needed for a call can be selected as required.

Initially the No. 5 crossbar system included multifrequency, dial pulse, and revertive-pulse incoming registers, and multifrequency, dial pulse, revertive-pulse, and panel call indicator outgoing senders. These circuits provided for connection to all other types of offices for calls originating or terminating in the No. 5 crossbar office. For tandem service, an incoming register must receive the called office code as well as the customer's numerical digits. All incoming registers were so arranged except the revertive register. This could receive the numerical digits of a customer's number but not the office code.

Field situations indicated that a tandem revertive incoming register capable of handling office codes in addition to numerical digits should be developed for conditions where a No. 5 crossbar office is installed on the fringe of a large city in which central offices of the No. 1 crossbar and panel types require access to neighboring areas having step-by-step central offices. These No. 1 crossbar and panel offices can outpulse only revertive and PCI type pulsing and step-by-step offices can receive only dial pulsing. A crossbar tandem office can handle this traffic but the location of such an office is usually in the center of a city and thus considerable doubling back or "back-haul" is required for calls from offices in the outlying suburbs nearest to neighboring step-by-step areas. With the development of the tandem revertive-pulse incoming register, this traffic can be handled at a suitably located No. 5 crossbar office. This register receives the office code and the numerical digits of the called number and passes them through the marker to the dial pulse sender for outpulsing to the step-by-step office.

The map of Figure 1 illustrates the use of the tandem revertive-pulse incoming register. Customers in Royal Oak, a Detroit suburb served by a No. 1 crossbar office, are permitted to dial Pontiac, a step-by-step area. A No. 5 crossbar office at Birmingham is ideally situated to handle this traffic and thus avoid the long back-haul to crossbar tandem offices in downtown Detroit. The solid line shows the path from Royal Oak through the No. 5 office in Birmingham to a typical office in Pontiac. The dashed line shows the path that the call would have to take if it were routed through crossbar tandem in downtown Detroit. As a matter of interest the other No. 5 crossbar offices in the area are shown to illustrate the extent that the No. 5 crossbar system has been used to provide telephone service for the rapidly expanding suburbs of Detroit.

The general method of operation of the tandem revertive incoming register in its association with other circuits is similar to that of other incoming registers* of the No. 5 crossbar system. However, in addition to receiving revertive selections (or trains of pulses) which convey the four numerical digits of the customer's number, the tandem revertive incoming register receives two additional selec-

* Record, *March*, 1950, *page* 104.

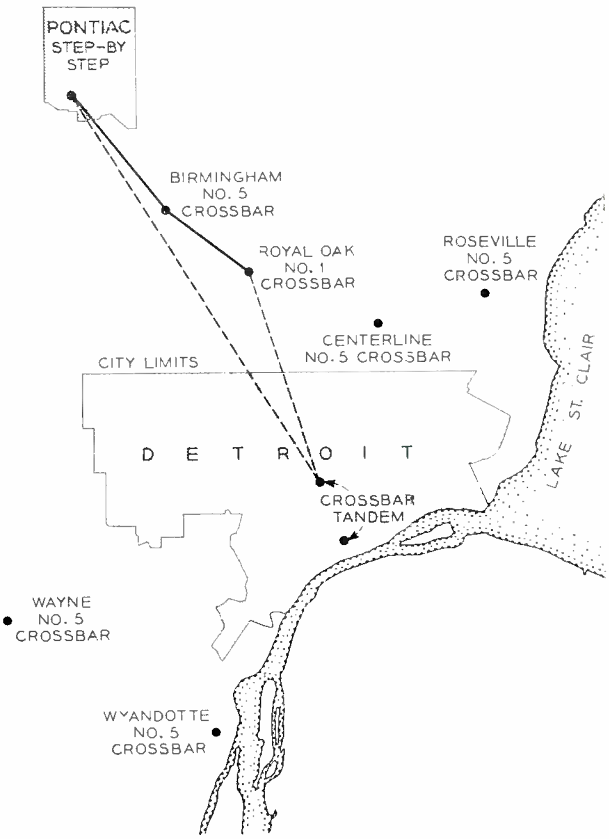


Fig. 1 — Map illustrating use of the No. 5 crossbar tandem revertive-pulse incoming register in the Detroit, Michigan Area. Solid line shows the path of a call from Royal Oak to Pontiac if a No. 5 crossbar office is used and the dashed lines indicate the route that would be required if that office were not available.

tions which convey the office code. Local terminating calls can also be completed through this register by use of the local office code. It is expected, however, that it will usually prove economically advantageous to handle terminating calls through the non-tandem revertive incoming register.

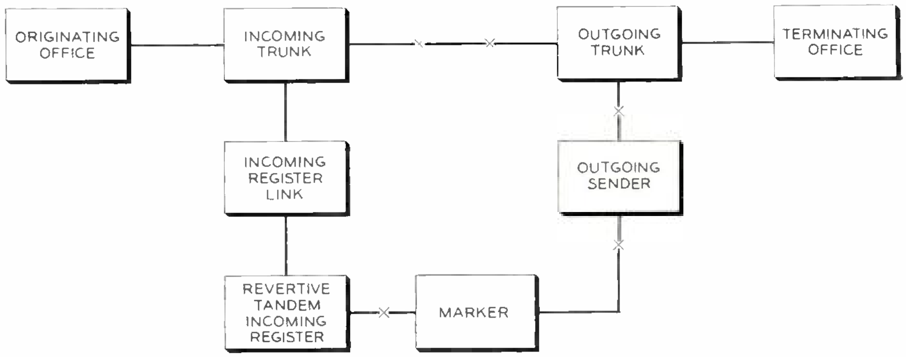


Fig. 2 — Block diagram illustrating the operation of the No. 5 crossbar tandem revertive-pulse incoming register.

The block diagram of Figure 2 illustrates a tandem connection through the No. 5 crossbar office. When an incoming trunk receives a call from the office where it originated, it signals a link circuit which connects it to an idle register. A maximum size link group is 200 trunks and 10 tandem revertive registers. When the trunk is connected to a register, pulsing starts and seven selections are received. These are called office brush, office group, incoming brush, incoming group, final brush, final tens, and final units because of their original use in the panel system. The first two convey the office code and the last five the numerical digits of the called number. When all the selections have been received, the register passes the information to a marker which establishes a connection between the incoming and an outgoing trunk, and associates a sender with the outgoing trunk. The called number is passed from the register through the marker to the sender; the marker and register then release. The outgoing sender pulses the number to the distant office, after which it releases.

Where revertive pulsing is used, from 1 to 5 pulses can be transmitted for the office brush selection, and from 1 to 10 pulses for the office group selection. This provides for transmitting 50 different office codes. A study of field requirements indicated that 40 office codes are all that a No. 5 crossbar tandem revertive register would be required to handle. Provision for this number has been made.

THE AUTHOR

J. W. Brubaker received a B.S. degree in Electrical Engineering from Union College in 1925, and then joined the Technical Staff of the Laboratories. With the Systems Development Department, he worked on circuit development until 1942, when he transferred to the School for War Training for the World War II period. Since the end of the war, he has been engaged in circuit design work for the No. 5 crossbar system.

Talks by Members of the Laboratories

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

I.R.E.-International Scientific Radio Union Joint Meeting, Washington, D. C.

Gyorgy, E. M., see Weiss, M. T.

Robertson, S. D., A Broad-Band Helix Traveling-Wave Amplifier for Millimeter Wavelengths.

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

Talpey, T. E., An Optical Method for the Determination of Complex Dielectric and Magnetic Constants at Millimeter Wavelengths.

Weiss, M. T., and Gyorgy, E. M., Low Loss Dielectric Waveguides.

Electronic Components Symposium, Washington, D. C.

Arnold, S. M., Metal Whiskers – A Factor in Design.

Elmendorf, C. H., Component Engineering as a Part of System Design.

Perry, A. D., Propagation of Electromagnetic Waves in Ferrites.

Remeika, J. P., The Growth of Barium Titanate Single Crystals for Use as Storage Elements.

Tidd, E. D., Recent Trends in Terminals for Hermetically Sealed Components.

Electrochemical Society Semiconductor Symposium, Chicago

Brattain, W. H., see Buck, T. M.

Buck, T. M., and Brattain, W. H., Investigations of Surface Recombination Velocity on Germanium by the Photo-Electromagnetic Method.

Hrostowski, H. J., and Tannenbaum, M., Electrical Properties of Some Group III-Group V Compounds.

Sullivan, M. V., Germanium Electrolytic Stream Etching.

Tannenbaum, M., see Hrostowski, H. J.

Other Talks

Anderson, O. L., Solderless Wrapped Connections, Department of Mechanical Engineers, University of Utah, Logan, Utah.

Beck, A. C., Some Interesting Aspects of Waveguide Transmission, I.R.E. Monmouth Subsection, Little Silver, N. J.

Becker, J. A., Can We See Atoms and Molecules with the Field Emission Microscope? Virginia Academy of Sciences, Charlottesville, Va.

Bozorth, R. M., Physics of Magnetic Materials, Physics and Applied Mathematics Symposium, New York University, New York City, and Carnegie Institute of Technology, Pittsburgh.

Chapin, D. M., A Demonstration of Bell Solar Batteries, Bernardsville High School, Bernardsville, N. J.

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Order Wire and Alarm Facilities for Type-N Carrier

R. L. CASE *Transmission Systems Development*

Two pairs in each type-N cable are set aside for use by operating telephone companies to help insure that the carrier system operating on the remaining conductors will experience a minimum number of troubles or breakdowns. One of these pairs is arranged to transmit alarm signals automatically to a terminal point when a trouble develops, and the other is equipped to enable maintenance men to communicate with each other along the route, or with other maintenance personnel at the terminal.

To maintain adequate service on a type-N carrier route, provision is made for maintenance men to talk with each other from stations along the line and from either terminal. In addition, since many of the stations in this carrier system are unmanned, some arrangement is included to indicate the location and nature of any trouble that might develop at those stations to a man on duty at an alarm point. Since it may be necessary to switch to a spare portable type-N repeater while troubles are being corrected, a source of dc power to operate the spare must also be available at intervals along the line.

To provide for these alarm and maintenance requirements, two additional wire pairs (or a quad) are included in the type-N carrier cable with the carrier circuits. One of these pairs is devoted to order wire use – provision for communication by maintenance personnel – and the other to the transmission of voice frequency alarm tones. Plus and minus 130 volts dc required to operate spare type-N repeaters are applied over both pairs. A typical layout of the voice repeaters and the other associated equipment required on these pairs is shown in Figures 1(a) and 1(b).

Above, H. R. Vreeland, switchman, at the type-N alarm and order wire terminal in New Brunswick, New Jersey.

The intermediate voice repeaters used in the order wire pair are illustrated in the block diagram in Figure 2. When the lineman's telephone, shown in the lower right-hand corner of the figure, is not connected to the repeater, an order wire hybrid bridge shown at the top center of the figure, is accurately balanced by resistance terminations. In this case, irregularities in the line impedance determine the balance of the repeat coil hybrid, and the useful gain that can be put into the repeater is limited by the degree of unbalance. When the telephone is connected and in use, a reasonably good balance can be obtained by the use of a special balancing network which more nearly matches the impedance of the telephone.

At non-power supply points such as pole cabinets, the lineman's telephone set which has a high impedance may be connected to a pair of terminals on a small bracket which bridges the set across the order wire pair. The addition of a high impedance telephone at these points, does not greatly affect the balance of the repeater. A high inductance coil is bridged across the order wire pair at power supply points that are not located at repeater stations as shown in Figure 1(b). The low impedance side of this coil is normally left open and hence the bridge has little effect on through transmission. To call from one of these points, the lineman plugs his telephone into the low impedance side of the coil, and adequate transmission is again provided without an undue effect on the repeater balance.

Provision is made along the line to allow maintenance personnel to signal to and receive signals from other intermediate points and the line terminals. This signaling system on the order wire pair in the type-N carrier differs from any previously used. A 1900-cycle oscillator with an appropriate receiver and bell is located at each intermediate repeater and at the line terminals. This signal system operates on a tone-on basis, and the output of each 1900-cycle receiver is passed through a circuit which introduces a delay of one second before the signal is passed to the bell. This delay is sufficient to prevent false operation by speech currents or transient disturbances but it is short enough to permit easy operation of the circuit by the signaling tone. The arrangement of these signal system components is illustrated in the lower left portion of Figure 2.

At pole cabinets or power supply points not equipped with a signaling circuit, the lineman can signal a terminal with a specially designed 1900-cycle whistle. By blowing this whistle near his transmitter, the lineman generates a 1900-cycle tone which is transmitted along the line and operates the

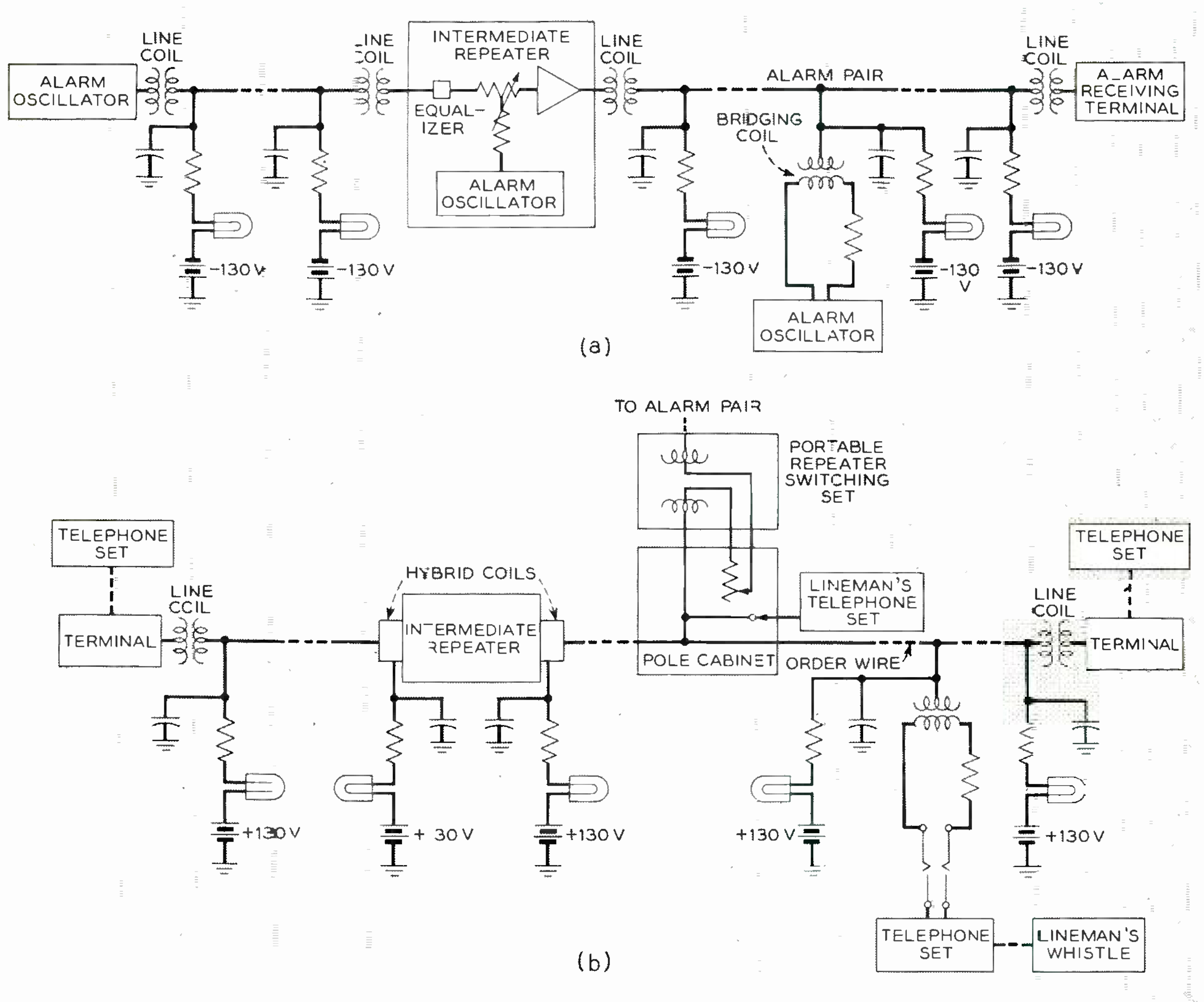

Fig. 1 — Block diagram, (a) alarm pair, (b) order wire pair.

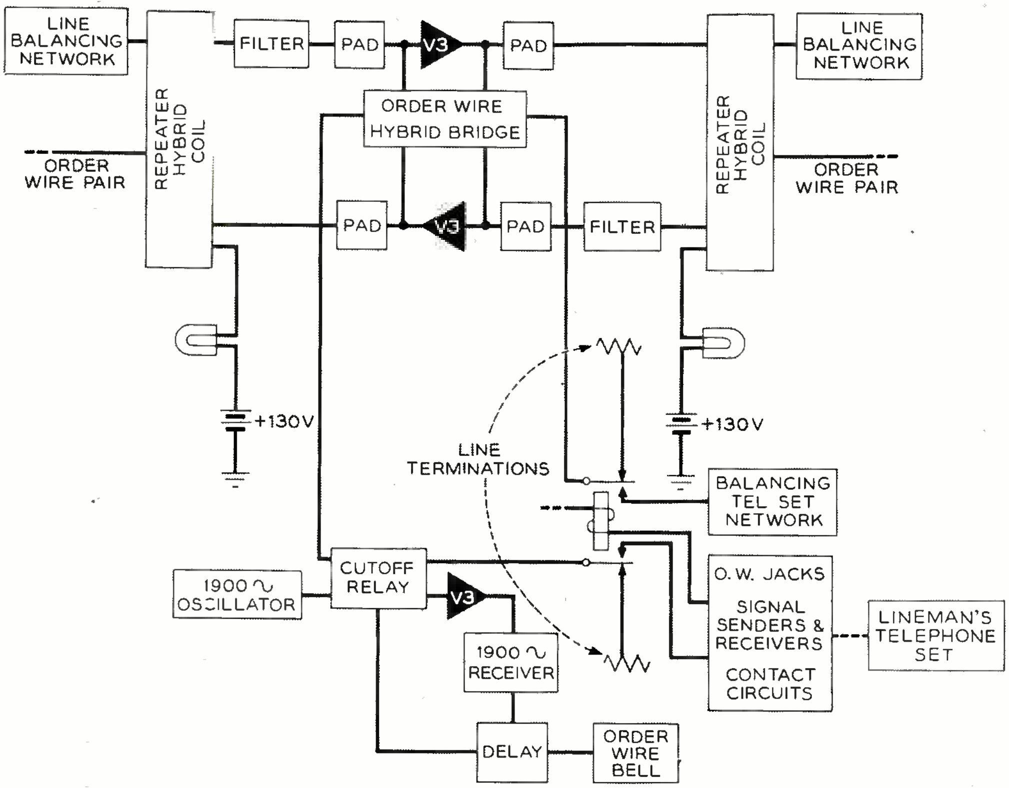

Fig. 2 — Block diagram of order wire intermediate repeater.

receiving circuit at the desired terminal. The whistle is a small fife-type device designed in such a way that air is blown across the resonant chamber of the transmitter as shown in Figure 3. This design was adopted to prevent condensations in the chamber that might change the frequency of the transmitted tone. The purity of this tone is independent of how hard the whistle is blown until a point is reached where the velocity of the air is high enough to produce an appreciable second harmonic.

The alarm system in the type-N carrier differs from the order wire and signaling systems in that it is designed for transmission in only one direction. One terminal of the alarm pair is a maintenance station designed to receive an individual indication from each power supply point along the route. These signals are generated by a number of alarm oscillators, each of which normally applies a characteristic audible tone to the line at its location to denote normal operation of the type-N system at that point. An abnormal condition such as a power failure or blown fuse results in a tone-off condition that activates an alarm at the remote receiving point. This alarm system is designed for a normal maximum of four alarm tones spaced at 400-cycle intervals. These oscillators are set at frequencies of 700, 1100, 1500 and 1900 cycles per second. When required, four additional tones with frequencies of 900, 1300, 1700 and 2100 cycles per second can be added to supply a total of eight alarm points.

The diagram in Figure 1(a) indicates the arrangement of the components in this type-N alarm system. As shown, an oscillator of the proper power forms one terminal of the alarm pair with the impedance of the oscillator itself terminating the line. At an intermediate repeater station, the tone from another alarm oscillator is applied through a variable resistance hybrid attenuator to the input of the line amplifier. This attenuator is arranged in such a way that as it is used to increase the loss between the alarm oscillator and the amplifier, the loss is simultaneously decreased between the amplifier and an adjacent equalizer. By properly adjusting this attenuator, the local alarm tone can be applied to the input of the amplifier at the same power as each of the tones coming in from the left. The equalizer in this section is used to adjust the power level of all the tones incident from the left to the same level at its output. A third alarm oscillator is shown in Figure 1(a) at an intermediate bridging point. Here, the coil ratio, building out resistance, and oscillator impedance are such that the bridging loss to through transmission is kept small. The output power of this oscillator is adjusted to make the power it applies to the line the same as that of the other tones reaching that point.

At the alarm receiving station, illustrated in Figure 4, all the incoming alarm tones pass through an equalizer circuit which equalizes the amplitudes of the various signals and applies them to the input of a V3* amplifier. From the amplifier these tones pass to individual alarm receiving circuits connected in parallel. Each of these circuits is provided with a gain control adjustment at the input of an associated individual amplifier used to adjust the input power level to yield a fixed relay operating current in the output of an amplifier detector circuit.

Each of the receiver circuits selects a tone with a particular frequency by means of a narrow band-pass filter. The circuit then amplifies this signal and rectifies it to hold a polar relay in the operated position. There is a corresponding narrow band-pass filter, amplifier, and detector for each alarm tone. The outputs of all these receivers pass through a common delay circuit where an interval of about five seconds is introduced between the opening of a polar relay and the operation of the alarm signal. Any sustained break in an alarm tone will release its corresponding relay and actuate an alarm. The five-second delay, however, prevents operation of the alarm by a momentary short circuit or open on the line.

The oscillators used in this alarm system are all identical except for two resistors whose values are changed to produce the particular frequencies required. The same oscillator circuit, set for 1900 cycles per second, is also used in the order wire signaling system previously described (Figure 2). These oscillators are two-stage RC type stabilized by negative feedback from the plate to the cathode of the tube through a thermistor and level control potentiometer. The thermistor is used to stabilize the oscillator input against variations in the power supply. The output of the oscillator is applied to the contacts of a cutoff relay through an attenuator with the same control circuit used in the miniature 4-wire terminating network†. With this relay in the normal operated position, the characteristic oscillator tone is applied to the line. When the oscillator is short circuited to release the relay and transmit an alarm, a 600-ohm impedance is placed on the line to match the oscillator impedance and thus maintain the proper release margin at the alarm receiving point.

As shown in Figure 1(a), minus 130-volts is applied to the center taps of the line coils at the alarm pair repeatered points and the line terminals. At intermediate points, this voltage is applied to the center tap of a bridging coil which applies the output of an alarm oscillator to the line. Figure 1 (b) illustrates the manner in which the positive voltage is applied to the order wire pair. Again, at the non-repeatered terminals, 130 volts is applied to the center taps of the line coils. The intermediate repeaters on the order wire pair are coupled to the line through hybrid coils since it is necessary to provide for voice transmission in both directions from these points. At these intermediate repeaters, the dc voltage is applied to these hybrid coils. At other power

Fig. 3 — L. L. Gibbs, Jr., transmission man of the New Jersey Company, using a 1900-cycle whistle at a pole-mounted repeater on the New Brunswick-Bound Brook type-N route in New Jersey.

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*Record, *February* 1949, *page* 45; *March* 1949, *page* 94; *August* 1949, *page* 293.

† Record, *April* 1951, *page* 158.

supply points, the voltage is applied to the center taps of high inductance bridging coils which have a negligible effect on the characteristic line impedance. As indicated on the diagram, a resistance lamp, resistor, and capacitor are placed in each voltage lead in order to provide an adequate degree of protection to the circuit.

When trouble develops or during preventive maintenance, at one of the N carrier repeaters located at a point where the dc voltage is not directly applied – as in a pole cabinet – the portable type-N repeater and its switching set derives the required 130 volts directly from the order wire and alarm pairs. This set, which takes over the functions of the permanent repeater while adjustments are being made or a new repeater is being substituted, contains a pair of high inductance coils which are bridged across the alarm and order wire pairs as indicated in Figure 1(b). A series resistance is provided at each of these non-power points which may be adjusted to give the proper voltage for the repeater switching set. With this arrangement, the switching set leaves the transmission characteristics of the alarm and order wire lines practically unaffected. The use of this portable apparatus also eliminates the necessity and expense of maintaining coil systems in every pole housing, and allows the lines to remain free of shunt bridges unless the switching set is actually in use.

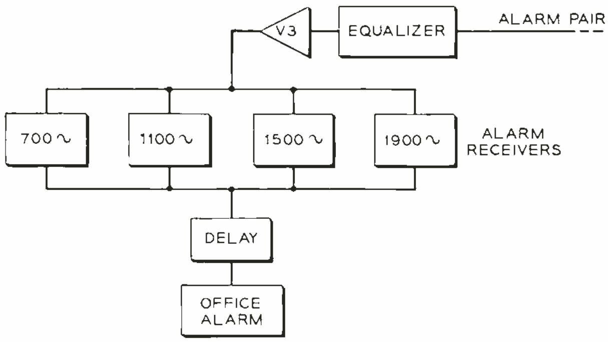


Fig. 4 — Block diagram illustrating a typical receiving station.

THE AUTHOR

Robert L. Case received the A.B. and B.S. degrees from Denison University in 1921, and joined the Laboratories in July of that year. In 1926 he received his M.A. degree from Columbia. His early work included the transmission design of two- and four-wire telephone repeaters, echo suppressors, and the terminal equipment for the first transatlantic radio circuits. In 1929 he was placed in charge of a group responsible for the design of repeaters, and later of amplifiers and associated equipment for voice-frequency program broadcasting facilities. In World War II he was responsible for voice and carrier wire-line facilities for the Armed Forces. Since then he has been concerned with the transmission design of radio control terminals and voice frequency repeaters of which the V3 amplifier is a recent development. He is also associated with the type-N carrier program and testing equipment for type-N and type-O carriers. Mr. Case is a member of the A.I.E.E. and Phi Beta Kappa.

Panel System Maintenance

J. H. SAILLIARD *Electromechanical Development*

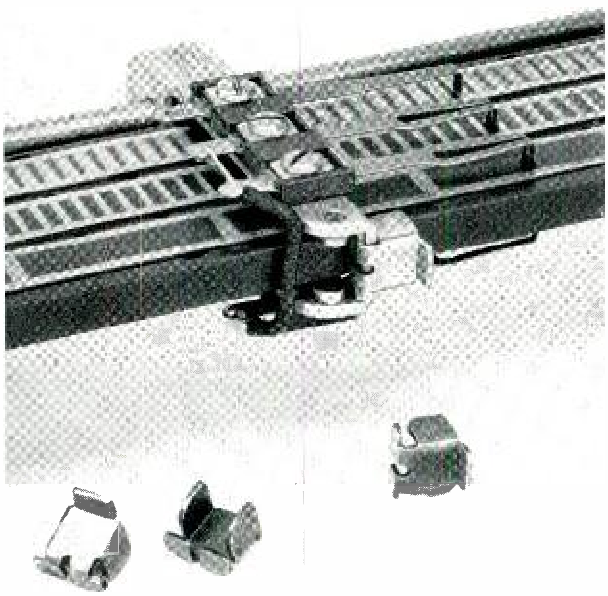
Formerly Switching Apparatus Development

Besides searching continuously for new and improved communications techniques, Bell Laboratories must be constantly watchful of equipment already in service. A number of new devices and new methods have recently been developed for better, more economical maintenance of panel equipment. These new facilities are reducing repair costs and loss of service time.

More than five hundred central offices, mostly in the larger cities of the United States and representing an investment of over a half-billion dollars, use the panel dial switching system. About seven million telephones are served in these panel system areas, and the traffic is such that the equipment is subjected to heavy usage. Some of it has been in service since 1921.

The importance of maintaining this equipment in good operating condition is emphasized by the high cost of replacement. In some cases it has been possible to compensate for the wear of years of service by providing for the renewal of certain parts of mechanisms not originally intended to be renewable, instead of incurring the considerably greater expense of replacing an entire unit. As a result, several procedures have been developed to facilitate maintenance and reduce its cost.

In the manual system, an operator completes an intra-office call by inserting a plug connected to



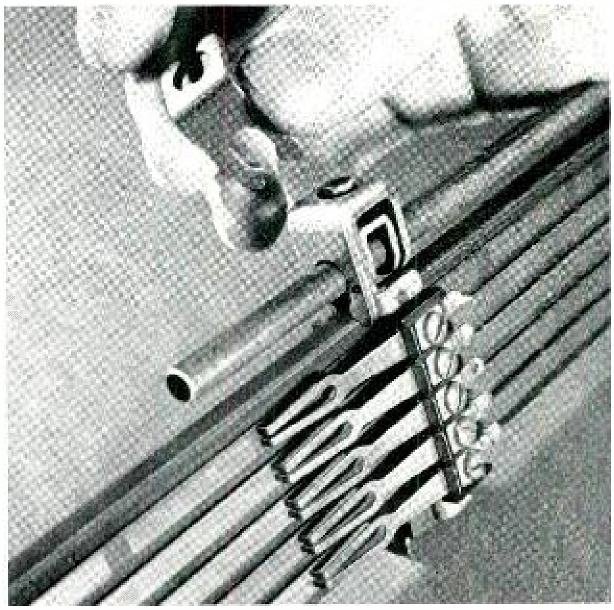


Fig. 1 — The two types of guides supplied for panel system maintenance. The photograph at the top of the page shows author installing a new commutator on a frame in Bell Laboratories panel test equipment.

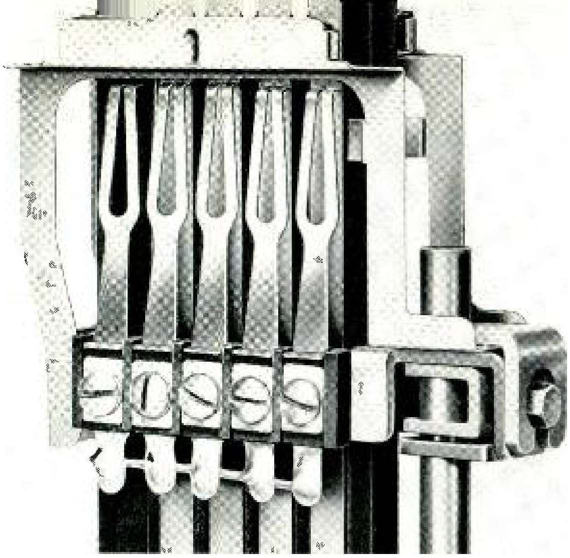


Fig. 2 — Cleaning device attached to commutator brushes. This device eliminates much manual work and lost service time.

the calling customer's line into a jack connected to the called customer's line. In the panel system, the jacks are replaced by a series of small, vertically stacked terminals, which are horizontally multipled to form a bank. The plug is replaced by a movable brush having contacting fingers that automatically travel up and down over the terminals of this panel bank.

This movable brush is mounted on a vertical rod, to which is also attached another brush that wipes over segments of a commutator mounted above the banks. When the guiding surfaces at the front and back edges of the commutator brush frame became so worn that a short circuit developed between the frame and commutator segments, it was the practice to install a new commutator brush. This was an expensive procedure requiring the replacement of several soldered connections on the brush and also on the commutator, since the wires to the commutator had to be disconnected to permit slipping the brush over its upper end. For simpler maintenance, two types of guides have now been provided. These guides, shown in Figure 1, compensate for worn guiding surfaces of commutator brush frames and are easily and quickly attached.

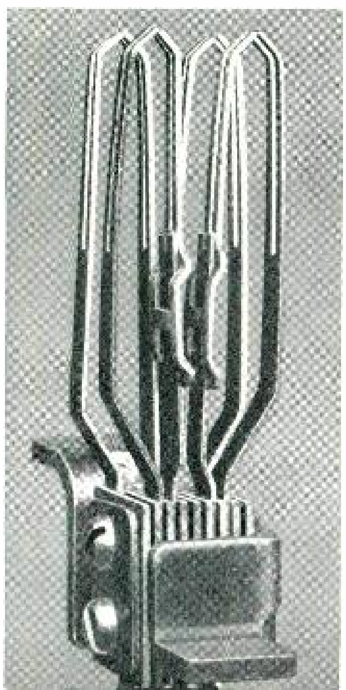


Fig. 3 — Nest of eight sequence switch springs. The middle two springs in the front have been replaced.

To insure good conductivity between the commutator brushes and their associated commutator segments, the contacting surfaces of the segments must be kept clean. To accomplish this, it has been necessary to clean the surfaces at least once per year with fine abrasive paper that has been impregnated with a lubricant. At more frequent intervals they have also been polished with oiled cloths. It has sometimes been difficult to determine how frequently the treatments should be applied because of the variable environmental conditions under which the apparatus operates. The circuit associated with the commutator must be disconnected from service for these treatments. A device has therefore been developed which cleans the contacting surfaces automatically every time the brush moves over the commutator. Tests of the device under severe environmental conditions show that the contacting surfaces are maintained in excellent condition.

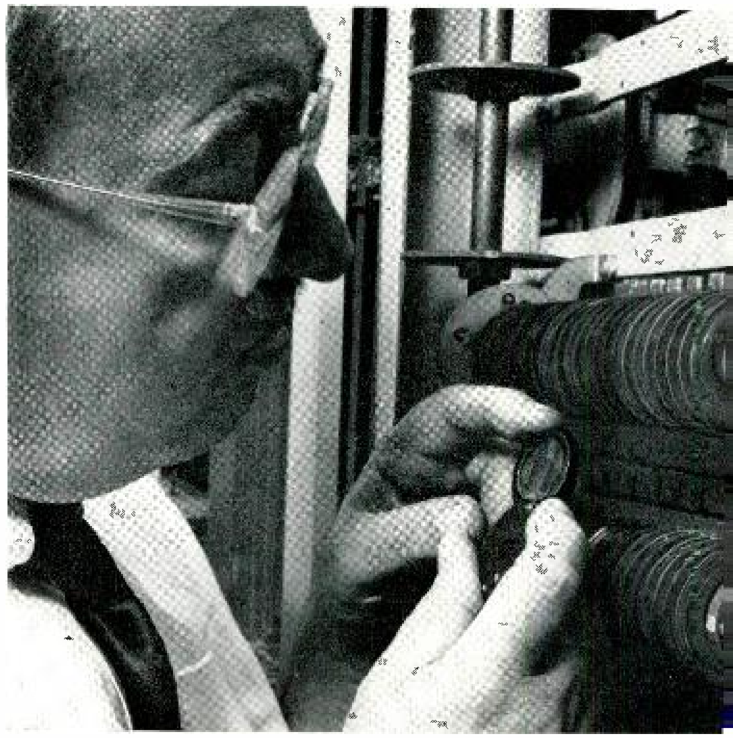


Fig. 4 — W. W. Seibert examining silver-faced cams now incorporated in all panel system sequence switches.

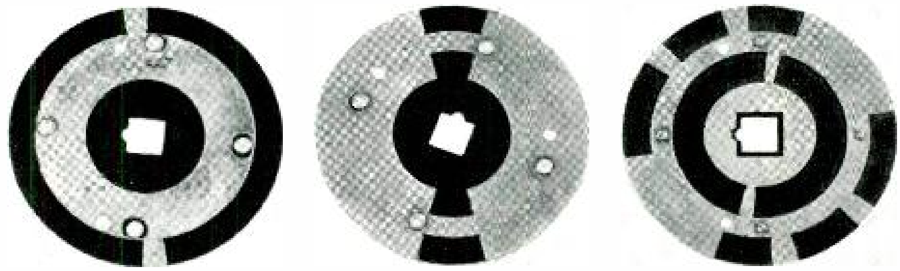


Fig. 5 — Types of silver-faced cams used in sequence switches.

As shown in Figure 2, this device, which is easily attached to the commutator brush, employs two wiper pads. The pads are made of nylon pile fabric resembling velvet, which presses lightly against the contacting surfaces. The fabric may be either oil-impregnated or coated with a mild abrasive, depending upon the commutator molding material. When necessary, it is possible to replace the pad quickly and inexpensively. It is estimated that 1,500,000 of these devices will be employed.

The circuits controlling the operation of panel apparatus necessitate the making and breaking of a large number of electrical connections. To reduce the number of relays required, and for other purposes, a "sequence switch" is employed. It consists of a number of discs or "cams," each composed of two plates of metal riveted one on each side of a disc of insulating material and all mounted on a square shaft which can be revolved. Four contact springs rest on each disc, and the tips of these springs are subject to mechanical wear and, in many cases, electrical erosion.

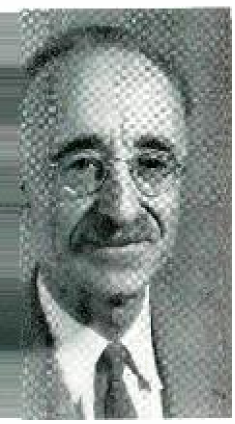
These springs are assembled in the sequence switch in nests of eight, located so close to each other that it is impractical to remove individual springs. Replacement was therefore accomplished by removing the entire nest. Four of the springs of each nest contact the face of the cam near its center of rotation and wear slowly. The other four contact the cam farther from the center of rotation and wear out comparatively quickly. Consequently, when the contacting tips of the outer springs wore out, the entire nest was replaced, even though the tips of the springs nearest the shaft still had considerable useful life. Furthermore, this required replacing eight soldered connections and adjusting eight contact springs.

Inexpensive replacement tips which can be soldered to the outer row of springs have now been developed, thereby making it unnecessary to replace the entire nest. Figure 3 illustrates a nest of eight springs wherein two springs have been renewed. This replacement work is done without removing the sequence switch. Special tools were developed for cutting off the old tip at the correct point and for attaching the new tip.

Two sizes of sequence switches are employed. The smaller size accommodates a maximum of 18 cams; the larger a maximum of 24 cams. Figure 4 shows several of these switches, and three types of cams are shown in Figure 5. Originally, most of the cams were made of sheet bronze. Later, the cams used for controlling voice paths and critical signaling circuits were made of bronze overlaid with silver to provide a lower contact resistance. The manufacture of plain bronze cams has now been discontinued, and all cams are now silver-faced. Although these cams have a higher first cost than plain bronze cams, they are easier to clean, and pitting, a frequent source of trouble in bronze cams, is reduced.

Other maintenance problems are being investigated at the Laboratories so that additional devices and procedures can be developed. By thus keeping a constant check on the panel system, Operating Companies are aided in their efforts to get maximum service from their equipment.

THE AUTHOR



J. H. Sailliard joined the Bell System in 1916 as a draftsman in Western Electric in the design of printing telegraph apparatus. He later became chief draftsman, then design engineer and a member of the Laboratories technical staff. In 1928 he was concerned with providing motion pictures with sound. During World War II he worked with the design and production of a two-way telephone (radio) used in U. S. Army tanks. Mr. Sailliard was later concerned with switching apparatus. Since 1952 he has been working on military projects at Whippany. He attended Cooper Union and Brooklyn Polytechnic. He is a member of the A.S.M.E.

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