Bell Laboratories RECORD

Volume XXXV

Number 2

February 1957

Bell Laboratories RECORD

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THE COVER: Deep-sea transatlantic telephone cable is spliced aboard HMTS *Monarch* during cable laying operations in 1956. The first of a series of articles describing the more interesting technical aspects of the transatlantic telephone cable system appears on the opposite page. Photograph by H. N. Upthegrove, Transmission Systems Development — II.

The BELL LABORATORIES RECORD is published monthly by Bell Telephone Laboratories, Incorporated, 463 West Street, New York 14, N. Y., M. J. KELLY, President; M. B. LONG, Secretary and Treasurer. Subscriptions: $2.00 per year; Foreign, $2.60 per year. Checks should be made payable to Bell Laboratories Record and addressed to the Circulation Manager. Printed in U. S. A.

First Transatlantic Telephone Cable System

E. T. MOTTRAM
Transmission Systems Development II

Culminating years of effort and research by the Laboratories, other Bell System Companies and the British Post Office, the first transatlantic telephone cable is now in regular service. This cable system, directly linking North America and Europe, was made possible only through the closest sort of international cooperation among engineers on both sides of the Atlantic. A series of articles by Members of the Laboratories and the British Post Office will be published in later issues of the RECORD to describe some of the more interesting technical aspects of this historic accomplishment.

At eleven o'clock on the morning of September 25, 1956, a group of people seated in the auditorium at 195 Broadway saw Cleo Craig, Chairman of the Board of the American Telephone and Telegraph Company pick up a telephone and heard him say, "This is Cleo Craig in New York calling Dr. Hill in London." Over the loud speaker system of the auditorium came back, "This is Dr. Hill in London, Mr. Craig." This was the start of the ceremonies which placed in commercial service the first transatlantic telephone cable system.

The system, shown on the map in Figure 2, is owned jointly by the American Telephone and Telegraph Company, the British Post Office and the Canadian Overseas Telecommunication Corporation. It provides 29 standard telephone message circuits between London and New York and 6 circuits between London and Montreal. An additional circuit from London is split between New York and Montreal and may be used for narrow band services or telegraph service to Montreal. The system thus serves as a connecting link between the telephone networks of two continents. Seven of the New York to London circuits have been extended to continental network centers — two to Frankfort and one each to Amsterdam, Berne, Brussels, Paris and Copenhagen. The Copenhagen circuit may also be extended to Oslo and Stockholm.

Starting at London, the British switching point, transmission to Oban, Scotland, is over the internal telephone network of the United Kingdom. Two alternate routes are provided on 24-channel carrier cables from London to Glasgow and then over coaxial cable from Glasgow to Oban. A third alternate route using coaxial cable — London to Aberdeen to Inverness to Oban — is being constructed.

From Oban to Clarenville, Newfoundland, transmission is over the deep-sea submarine cable system developed by Bell Telephone Laboratories. This link makes use of two cables each 1,950 miles long which are submerged in depths varying from a few hundred feet on the continental shelf to 2.6 statute miles at the deepest point. Each cable provides transmission in one direction for 36 standard telephone message channels. In addition, two narrow band message channels and two teletypewriter

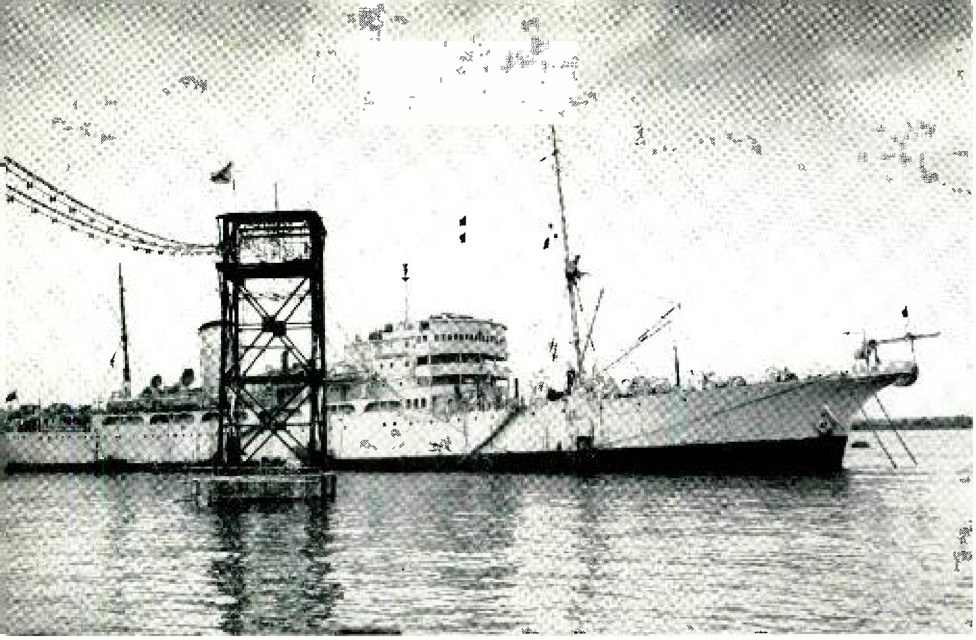

Fig. 1 — Deep-sea cable is loaded aboard HMTS Monarch *at Erith in England.*

channels are included for order wire and maintenance use. One-hundred and two repeaters are used to compensate for the cable attenuation of about 1.6 db per mile at 164 kc, the highest frequency. The repeaters of the deep-sea link are enclosed in a flexible housing designed to pass through the shipboard cable laying machinery without interruption and, at the same time, be capable of withstanding the pressure of 6,000 pounds per square inch on the ocean-bottom.

From Clarenville to Sydney Mines, Nova Scotia, a submarine cable system is used that was designed by the British Post Office. This link is 330 miles long and uses a single coaxial cable laid in waters up to 275 fathoms deep for transmission in both directions. In addition to order wire and maintenance channels, the cable provides 60 message channels in each direction; 36 of these channels are used for the transatlantic circuits. The remainder are available for local transmission between Newfoundland and the mainland. Sixteen repeaters enclosed in large rigid housings are used to compensate for cable losses of about 3 db per mile at 552 kc, the top frequency. Although on the map the route for the first 60 miles from Clarenville to Terrenceville appears to be over land, as shown in Fig. 4, it passes through muskeg, bog and pond so that submarine cable and repeaters are used which differ from the deep-water sections only in that it has been provided with additional shielding against external noise. The British rigid repeater is shown in Figure 3.

From Sydney Mines, transmission is over a TD-2 microwave system connecting with the Canadian telephone network at Spruce Lake near Saint John, New Brunswick, and the United States network at Portland, Maine. Canadian transmission facilities used from Spruce Lake are by radio to Saint John, then open-wire carrier to Quebec and on to Montreal by cable carrier. From Portland, transmission is by K carrier to West Haven, Connecticut, or Albany, New York, and thence by L1 coaxial cable to White Plains, New York.

The idea of a submerged telephone cable is far from new. As long ago as 1877 Alexander Graham Bell attempted to transmit voice signals over a transatlantic telegraph cable without success. Since that time much development has been carried out by both the British Post Office and the Bell System. Although initially this work had quite different objectives, each of these organizations has made important contributions to the present system.

Early British needs for communication with the Continent were met by providing circuits over short cables laid in relatively shallow water. Distances seldom exceed two hundred miles and most of the waters between Britain and the mainland are less than 50 fathoms in depth. The transmission band of these cables was split to provide two-way transmission. Attempts to increase the capacity of these cables resulted in the development of an amplifier housed in a large pot-like rigid casing which could be spliced into an existing cable.

In 1948 the British Post Office became interested in longer deep-sea systems and development was started on a smaller double-ended, rigid repeater housing which would offer less resistance to rotation in water. Because the cable is a spring-like structure, it tends to untwist under the high tension as it leaves the cable ship and to twist up again as it descends to the bottom and stress lessens. The deeper the water, the more severe this effect is. Any considerable resistance to this rotation tends to form loops and kinks in the cable with possible resulting damage. Laying tests with the new casing were conducted in deep water in the Bay of Biscay in 1951. The repeaters used between Clarenville and Sydney Mines are based on this design.

From very early days American development has been directed toward a long-haul system for use in deep water. When he was released from military service in 1919, Capt. O. E. Buckley, later president of the Laboratories, returned to the Engineering Department of Western Electric. There, he was assigned the task of looking into the possibilities of increasing the capacity of submarine telegraph cables. By 1921, however, sufficient progress had been made so that transmission of telephone messages over cable was possible and during that year three continuously loaded cables were laid between Key West and Havana. Two years later two cables were laid from the mainland to Catalina Island off the coast of California. But interest was centered on a long-haul transatlantic cable and, in 1928, discussions were started with the British Post Office looking forward to a single channel unrepeatered cable between the two continents. The business depression which followed, however, combined with significant developments in short wave radio transmission, resulted in the project being set aside; but a small group of people continued to work on submerged telephone cable problems.

About this time three advances served to renew interest in the possibilities of a transatlantic cable. These were the development of improved carrier techniques whereby a number of messages could be transmitted simultaneously over the same pair of conductors, development of the feedback-stablized amplifier and the development of long-life components. By 1938 a repeater had been designed which could justify the extensive testing necessary in anticipation of a deep-sea repeatered project. The advent of World War II reduced this testing effort to an absolute minimum. Fortunately with a design in hand, however, the most important element — time — could be accumulated on equipment under test with limited attention. The results of these life tests and deep-sea laying tests provided the confidence necessary to undertake a commercial installation. In 1950, two repeatered cables were successfully laid between Key West and Havana. These were 115 miles long, each with three repeaters to provide 24 standard message channels in each direction. This installation, required for commercial service, also served to verify under conditions of actual use, the testing done in the laboratory.

During World War II and immediately thereafter, the demand for transatlantic telephone service increased to a point where it exceeded the capacity of the radio channels available. It became necessary to schedule calls, and waits of several hours were not uncommon. The problem was further aggravated by a period of severe ionospheric disturbances, starting in 1950 and still in progress, which occasionally render unusable the channels across the North Atlantic for parts of some days. Although a few extra radio channels might be made available by rearranging existing facilities, no way is yet known of avoiding the effects of ionospheric conditions. Hence, it was apparent that an improvement in reliability or any large increase in message capacity would require a new facility.

As a result, early in 1952 Cleo Craig, then President of A.T.&T., appointed a committee to examine the practicability of a transatlantic cable. In view of the extensive testing and the favorable commercial experience on the Key West-Havana System, Dr. M. J. Kelly was able to confirm the technical feasibility of such a project.

During the preliminary discussions with the British Post Office which ensued, an exchange of technical information was arranged. In September of 1952, representatives of the Research Branch of the Post Office at Dollis Hill in London visited the Laboratories to review American cable developments. These visits were followed by visits of Laboratories people to Dollis Hill and the establishments

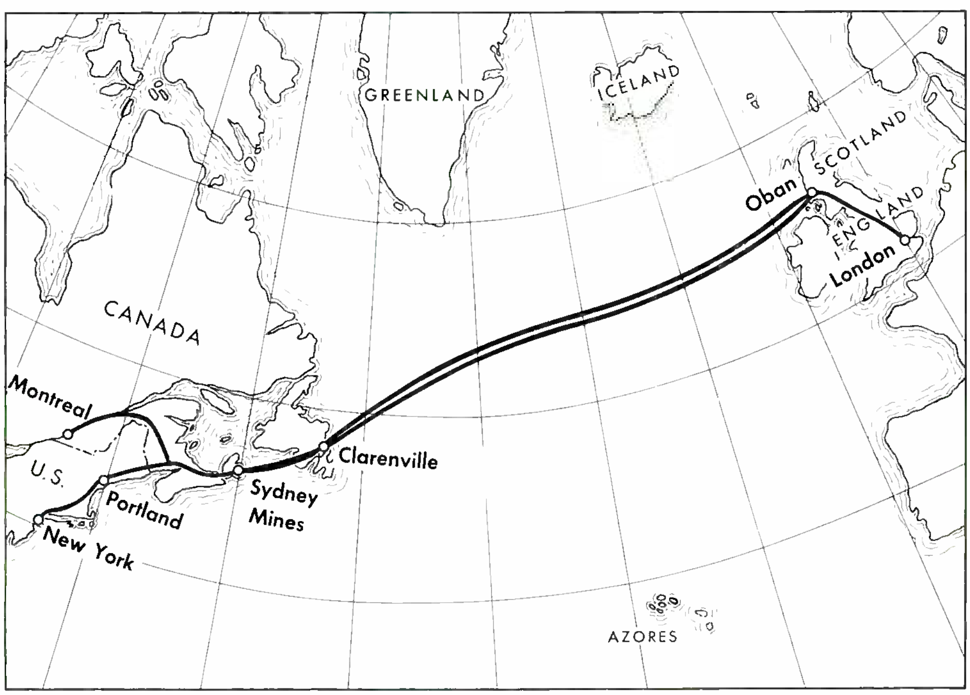

Fig. 2 — Map of North Atlantic area showing route of the submarine cable system.

Fig. 3 — A British rigid repeater is laid with the cable in the waters of Cabot Strait.

of Post Office contractors to make a similar review in Britain. Based on the findings of the two groups, Dr. Kelly and Sir Gordon Radley, then Engineer in Chief of the British Post Office, joined in November, 1952, in recommending to Mr. Craig's committee and the British Postmaster General that the Laboratories-developed system be used for the long, deep-water link between Newfoundland and Scotland. The Post Office system was recommended for use in the shallow waters between Newfoundland and Nova Scotia subject to technical review after laying tests were conducted in depths comparable to the Canadian waters and further experience was gained with circuits and components.

Canada was invited to join in the proposed project and on November 27, 1953, agreement was reached by the participants: the British Post Office, Canadian Overseas Telecommunications Corporation, A.T.&T. Co., and its Canadian subsidiary, the Eastern Telephone and Telegraph Co. The effort and cooperation of three nations were thus enlisted to carry out the objectives of the enterprise.

Detailed planning of the system was carried out in a series of technical meetings held alternately in London and New York. It was during one of the first series of meetings that a decision of far-reaching import was made. It was agreed that each problem would be solved on its engineering merits without regard for considerations of personal or national pride. This decision was perhaps the most important single factor in achieving a friendly cooperative atmosphere in which to conduct technical negotiations on the proposed system.

As the first step in planning, the services to be provided and the manner of operation were established. It was agreed that use of the system was primarily for message telephone service but consideration would be given to program, telephoto and telegraph service as permitted by technical, legal and contractual considerations. This provided a basis for setting the objectives which follow:

(1) Because the circuits were to be used to connect long networks, the broad objective was to hold the various forms of transmission impairment to a minimum. It was easy to visualize circuit lengths of 7,000 and 8,000 miles, (such as San Francisco to New York to London to Oslo) and it was necessary that detailed objectives take this into account.

(2) The nominal net loss objective between London and New York was set at 0.5 db. For calls terminating at London and New York this loss is normally increased by switching pads of 3.5 db at London and 2 db at New York, which result in a nominal net loss of 6 db. To allow for temperature effects, lack of perfect equalization and regulation, a standard deviation of 1.5 db was allowed. Allocations to the several links are given in Table I.

(3) For message circuits, the allowable tolerances recommended by C.C.I.F.* appeared to be satisfactory and were adopted with the expectation that they would be bettered by a factor of two because channel equipment would be used only at the circuit terminals.

(4) For program circuits, C.C.I.F. recommendations were also adopted for two and three message channel bandwidths. These were located at 68-76 kc and 64-76 kc in the 12 channel groups to avoid group pilots at 84 kc.

(5) Although no specific objectives were agreed upon for 12-channel group frequency characteristics, it was expected that the characteristic would be flat, plus or minus 2 db, except in the region of the filters in the split group.

(6) A frequency stability objective of plus or minus 2 cycles was established to meet the requirements of program and telegraph transmission.

(7) Noise objectives consistent with Bell System and C.C.I.F. standards for circuits of comparable length were established. The allocations by link objectives are listed in Table II.

(8) It was agreed to reserve the use of compan-

* C.C.I.F. is the abbreviation for the International Consultative Committee on Telephony.

dors to care for aging of the system or to improve the noise performance of any channel which might fail to meet the objectives in the future.

(9) Because the system was to be used primarily for message service, it was agreed that no channel used for other services should contribute more to the system RMS or peak load than if it were used for message service except by prior agreement among the engineering representatives of the partners.

(10) To conserve frequency space, it was decided to transmit all calling and supervisory signals within the telephone channels; limits on duration and power were also established.

(11) It was planned to open service using ring-down signaling, but the design was to permit use of dialing at a later date.

(12) The possibility of increasing the channel capacity by reducing spacing was considered, but it was agreed to initiate service with the 4-kc spacing common to long distance circuits on both sides of the Atlantic.

(13) It seemed clear that eventually it would be desirable to increase the number of circuits. A decision on method was held in abeyance, however, pending the outcome of exploratory work on plans which promised capacity increases with less degradation than would result from narrow band operation. It was therefore agreed that the transmission bands of the submerged systems would be designed so that the full bandwidth could be available should it be needed at some future time.

(14) A standard band for 12-channel groups in both America and Europe extends from 60 to 108 kc. A decision to use this band as a standard for connecting the several parts of the cable system simplified interconnection with land systems at the

Fig. 4 — Land cable being laid between Clarenville and Terrenceville in Newfoundland.

TABLE I — STANDARD DEVIATIONS OF NET-LOSS OBJECTIVES

Link	*Standard Deviations (db)*
New York-Portland	0.75
Portland-Sydney Mines	0.75
Sydney Mines-Clarenville	0.5
Clarenville-Oban	0.5
Oban-London	0.75
Over-all (assuming RMS addition)	
New York-London or Montreal-London	1.5

TABLE II — BUSY HOUR NOISE OBJECTIVES

Link	*Length (miles)*	*Noise (dba)*
New York-Sydney Mines / Montreal-Sydney Mines	1000	31
Sydney Mines-Clarenville	400	28
Clarenville-Oban	2000	36
Oban-London	500	28
Over-all-New York-London / Montreal-London		38

TABLE III — SYSTEM NOISE REFERRED TO 0-LEVEL POINT

Link	*Best Channel*	*Worst Channel*
London-New York	30 dba	36 dba
New York-London	29 dba	41 dba

terminals. At the same time, this arrangement established logical bounds for responsibility in the design and manufacture of the links. Thus, the submarine cable system included not only cable and repeaters but also the power equipment and terminal apparatus required to shift from the 60- to 108-kc bands to line frequencies and back.

The term objective rather than requirement was used in the planning period because it was early realized that, as the design progressed, departures might be found desirable without jeopardizing the utility of the system. The realism of the early planning has been well demonstrated, however, by early measurements made on the system. Indications are that all objectives have been met with the possible exception of noise. Noise in the busy hour referred to the zero level point is given in Table III.

At present two channels in the Clarenville to Oban cable exceed the noise objective by a small amount. Although this is not considered serious, refinements in equalization and level adjustment are planned after additional data on the effect of temperature are obtained. These steps are expected to bring the two channels within limits – still without resorting to the use of compandors.

With basic objectives established and the bounds of responsibility defined, it became necessary to press design and manufacture to meet the agreed service date, December, 1956. Schedules were set up and followed closely as a delay of a few weeks could result in a postponement of service for a whole year because the short season in which cable could be laid might be missed.

The problems differed for each of the partners. Each accepted responsibility for providing adequate circuits over his own internal network.

In the United Kingdom, it is normal practice for the Post Office research station to carry exploratory development to a point where feasibility has been established and broad requirements can be outlined. A contractor is then selected to complete development and manufacture the initial products. But, because of the very limited quantities involved and the exacting requirements, the Post Office carried development of their submarine cable system to the point of final development. Standard Telephones and Cables, Ltd., was selected to supply electronic equipment. Submarine Cables, Ltd., manufactured and sealed the water-tight containers. Representatives of the British Post Office were stationed at both manufacturing plants to assist the contractor and monitor the quality of his product.

The Long Lines Department of A.T.&T. and the Eastern Telephone and Telegraph Company, Canadian subsidiary of A.T.&T., assumed responsibility for making available the microwave link between Portland, Maine, and Sydney Mines, Nova Scotia. The route and tower sites were selected. Contracts were let to local contractors for the buildings and orders were placed on Western Electric and Northern Electric for equipment. Installation on the Canadian side of the border was carried out by the Northern Electric Company under contract to the Eastern Telephone and Telegraph Company.

Responsibility for the deep-sea link sponsored by the Laboratories imposed diverse and unusual tasks. Achievement of a minimum reliable life of 20 years was possible only by careful selection of materials with close attention to composition, stability and environment. Checks of each lot of every material were specified and assistance was provided to Supplies Inspection of Western Electric in the field and in-

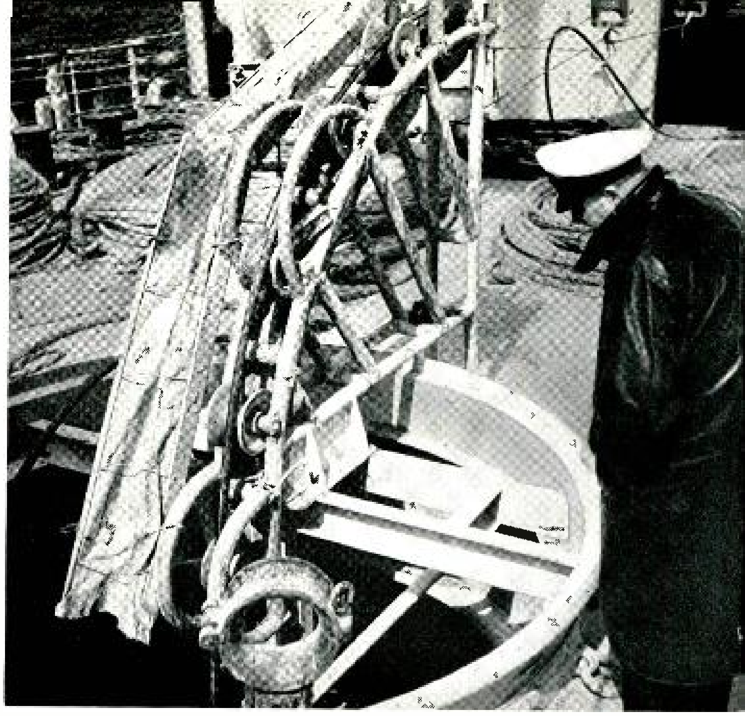

Fig. 5 — A Laboratories designed flexible repeater comes up from the No. 1 hold of the Monarch.

coming inspection at the factory to insure the intent of the specifications had been carried out. Details of many operations during manufacture affect the life of parts and components. Wherever this was thought to be the case, complete and detailed process specifications were prepared. In several cases processes and process controls were devised to make possible the precision required when 51 repeaters were to be placed in tandem without possibility of later adjustment or equalization.

For manufacture of cable, two suppliers were required. Simplex Wire and Cable Company produced cable in this country at Portsmouth, New Hampshire. Submarine Cables, Ltd., a well known manufacturer of submarine telegraph cable produced the British made cable at Erith near London. Automatic controls for the extruders of both factories were designed and fabricated at the Laboratories. Their use aided in achieving the uniformity of transmission characteristics necessary if cable and repeaters were to be complementary. During the manufacturing period, a Laboratories group assisted by Western Electric and British Post Office Supplies Inspection people was stationed at each factory to interpret specifications and monitor quality.

In the fabrication of repeaters, the close relationships of Laboratories and Western Electric proved invaluable. Western Electric established a new plant for the purpose at Hillside, New Jersey. In so far as it was practical, all parts were made at this location. Exceptions include such items as the vacuum and gas electron tubes which were made at the Murray Hill laboratory, and the glass-to-metal vapor seals for the repeaters which were made at Allentown. Throughout, the greatest care was taken to insure cleanliness and avoid contamination of the product. Workers were selected for their skill and sense of responsibility. Emphasis was placed on perfection rather than production and each operation was carefully inspected before it was concealed by a succeeding operation. Laboratories people were stationed at Hillside to assist in training operators and inspectors and to monitor quality. Data on each repeater was reviewed and the repeaters were accepted by the Laboratories, as a representative of the partners.

As repeaters and cable were accumulated, plans were made to lay the submerged links using the British Post Office cable ship HMTS *Monarch*. *Monarch* is the largest cable ship in existence today and the only ship capable of carrying enough cable of this type to span the deepest portion of the Atlantic. Modifications of her cable handling gear were required, however, to make her better suited for laying the flexible repeaters. Requirements for these modifications were prepared by the Laboratories, and the changes were carried out under the direction of Long Lines engineers who also assumed responsibility for deep-sea laying.

To permit adjustments during laying, repeaters and cable were assembled in sections or "blocks" about 200 miles long with extra cable at the end of each block. Laying was in the direction of transmission. As cable was paid out, transmission measurements were made from shore to ship by Long Lines personnel under the direction of Laboratories engineers. Toward the end of each block (allowing enough time to permit splicing without stopping the ship), data were reviewed. The length of cable was adjusted or equalizers were added, or both, to correct transmission variations that may have resulted from slight differences in temperature or pressure, or unanticipated changes in the cable as it was laid.

On June 28, 1955, *Monarch* left her mooring at Clarenville paying out cable on the first crossing. The crossing required three loads of cable; 200 miles were laid to the edge of the continental shelf, and 43 days later, laying of the 1,400 mile stretch to Rockall Bank was started. The final span to the Scottish mainland was laid in September after several days of delay caused by hurricane "Ione." On September 26, *Monarch* steamed into Firth of Lorne and the final splice of the first crossing was completed.

On June 4, 1956, *Monarch* started the second crossing in the opposite direction. On August 14, at Clarenville, the final splice was dropped overboard to the accompaniment of an enthusiastic celebration. Six weeks later the numerous links of the 4,000-mile system, including more than 250,000 channel miles, had been tested and interconnected. Over-all line-up checks had been completed. So smoothly did the parts fit together that service was possible before final terminal equalizers could be manufactured. So, on September 25, using temporary equalizers, the system was put in service several months ahead of schedule – a tribute to the diligence and cooperation of the partners.

The success of this project is the result of much conscientious effort and close cooperation both international and internal with each member of the team playing his part well. Unfortunately, the number of people involved – literally in the hundreds – preclude individual mention in an article of this size. Satisfaction must come from the players' knowledge of their own contributions.

THE AUTHOR

E. T. Mottram received a B.S. degree from Columbia University in 1927 and an M.E. degree from the same University in 1928. He joined Bell Telephone Laboratories in 1928 and his early assignments were in the development of recording and reproducing machines and equipment. Later, he was engaged in the development of airborne radio and radar equipment, electronic computers and bombsights, and air-homing missiles. As Director of Transmission Systems development since 1950, he has been concerned with the development of transmission systems and equipment for military purposes, transmission test equipment, and television and wire transmission systems. In this capacity, he was responsible for technical liaison with the British Post Office on submarine cable matters and was in charge of Laboratories activities in this field.

The Tone Ringer

F. L. CRUTCHFIELD
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J. R. POWER
Station Apparatus Development

The transistor, because of its small power requirements, has tended to shift technological interest toward low-voltage, low-current circuits. This is particularly true, for instance, in the new electronic telephone switching systems and other transistorized equipment being developed to operate economically at low power levels. A new transistor-operated tone ringer has also been designed at Bell Telephone Laboratories as a possible replacement for the conventional telephone bell to provide equal or superior performance in supplying a pleasant but attention-attracting sound.

The ringer used in the 500-type telephone set is a direct descendant of those used 70 years ago. One reason for the persistence of this basic design is that each new ringer has had to be interchangeable with those already in service. Such compatibility is obviously desirable, but it may now have to be abandoned because in many of the switching and transmission systems currently being proposed for general use, it would be more economical to operate ringers at lower levels of power, rather than use the 90-volt, 20-cycle power presently required. This is especially true of the electronic switching system* now under intensive development at the Laboratories and, to a lesser degree, of line concentrators.

This break with the past offers a unique opportunity to make a fresh start and use modern techniques and components in the design of a ringer that will meet future requirements. Exploratory development along these lines is now underway, and the most important design objectives may be simply stated. First, the sound output must be equal or superior to that of the conventional ringers in attention-attracting qualities and in acceptance by the public. Next, the ringing signal should be within the voltage and frequency range normally provided for speech transmission in order not to impose any additional requirement on the transmission system. Another desirable characteristic would be that eight-party, full-selective ringing be available (so that each user on an eight-party line would hear only the ringing signal of his own telephone and none other). It is also desirable that this selectivity not require any ground connection at the user's telephone, because ground connections usually provide a path for the introduction of unwanted noise into the telephone line.

"Tone ringers" are being investigated as one means of meeting these requirements. On lines using

* Record, *June*, 1956, *page* 201.

such ringers, each party is assigned one of eight frequencies spaced between 478 and 1,000 cycles per second. When it is desired to ring a customer, his assigned frequency is sent out from the central office at about a + 8 dbm level. This signal excites a resonant circuit in his tone ringer which, in turn, drives a transistor amplifier. The amplifier output is converted into sound by a small loudspeaker or "sounder." The tone is given a distinctive character by interrupting the ringing voltage, and thereby the tone, about twelve times per second. The ringers of the other parties on the line remain silent because their resonant circuits do not respond to this particular ringing frequency.

A number of tone-ringer circuits are possible. They differ in detail and each is best adapted to one or another type of telephone equipment, but all perform the same functions and contain the same major elements. The most experience with field conditions and with user reaction has been obtained with the design developed for trial with the Type-P (rural) carrier system, and this ringer will be described in enough detail to illustrate the principles involved in all of them.

The circuit is shown schematically in Figure 1. The inductor L1 and capacitors C1 and C2 form a parallel resonant circuit that determines the operating frequency of the ringer. An installer can adjust this circuit to any one of the eight frequencies by making the right coil-tap and capacitor connections in the set. The ringing signal reaches the resonant circuit through a chain of components that includes the diodes CR1 and CR2 and the resistor R3. For the moment the diodes may be considered in their low impedance state, so that the controlling impedance of the chain is the resistor R3, (8,200 ohms). Near resonance, the impedance of the resonant circuit is high compared with R3, and most of the ringing

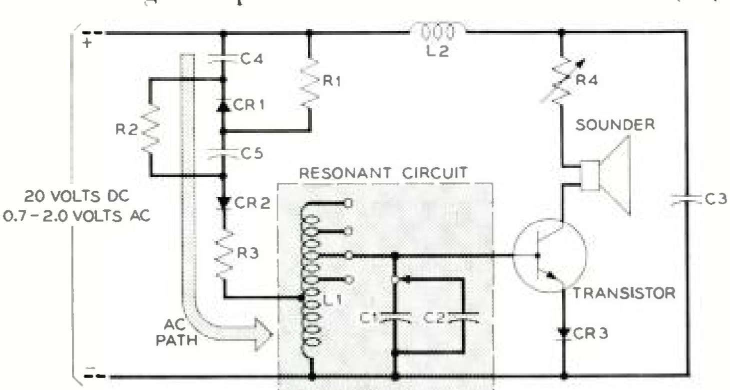


Fig. 1 — One of several possible tone-ringer circuits; different coil and capacitor taps indicated in the shaded area provide resonance to one of eight frequencies.

Fig. 2 — The sounder of the tone-ringer circuit — receiver is shown in palm of hand and double tube resonator appears above.

signal is available to drive the resonant circuit. Under these conditions, the positive peaks of the voltage wave on the base of the transistor are greater than the sum of the forward breakdown voltage of the transistor and of the diodes CR3. A pulse of current then flows through the transistor and, in fact, its collector is driven to saturation. These pulses of current also flow through the sounder and generate the ringing tone. If resistance R4 is added in the collector circuit, it absorbs some of the available power and the sound level is reduced. Volume control is provided by making this resistance variable.

At a signal frequency differing widely from the resonant frequency, the impedance of the resonant circuit is low compared to R3 and the voltage developed at the base of the transistor is not sufficient to produce current in it. The ringer will then remain silent. However, ringer frequencies are only 10 per cent apart, and at this spacing the change in resonant circuit impedance is not by itself sufficient to assure complete selectivity when maximum signal voltage is present on the line (the "zero loop" condition, approximated when a telephone is geographically very close to the central office). It is therefore necessary to regulate the current that can flow through the input circuit. This is the function of the diodes CR1 and CR2. A 60-microampere direct current flows through these diodes via R1, R2 and R3. If the peak signal current is less than 60 microamperes, the diodes have a low impedance and have negligible effect on ringer operation. However, if the signal current tries to exceed this level, the net current in one or the other diode is driven to zero and the diode blocks. As a result the maximum signal current is a clipped sine wave, approaching a square wave, with 60-microampere amplitude. When the signaling frequency is within 2 per cent of the resonant frequency, this current is sufficient to generate a tone of the same sound power as that of a conventional ringer. However, at the frequencies of the adjacent parties, it will not activate the transistor and the tone ringer remains silent.

The sounder is shown in Figure 2. It consists of a modified telephone-type receiver coupled to a double-tube acoustic resonator. Its response is characterized by three peaks, one due to the receiver and two to the double resonator. This characteristic is shown in Figure 4. The sounder achieves good efficiency over the frequency band from about 850 to 2,400 cycles per second. Most of the signaling frequencies are below this band, but the pulses of current delivered by the amplifier to the sounder are very rich in harmonics. It is these harmonics that are converted into sound. This permits the use of smaller resonators than would be required to radiate the fundamentals (i.e., the 478-1,000-cycle signaling frequencies). It also places the sound energy in a range where it is less likely to be masked by background noise. The tone still sounds low in pitch, however, because the ear and brain partially restore the missing fundamental.

The amplifier network, sounder and volume control are mounted in a 500-type telephone set as

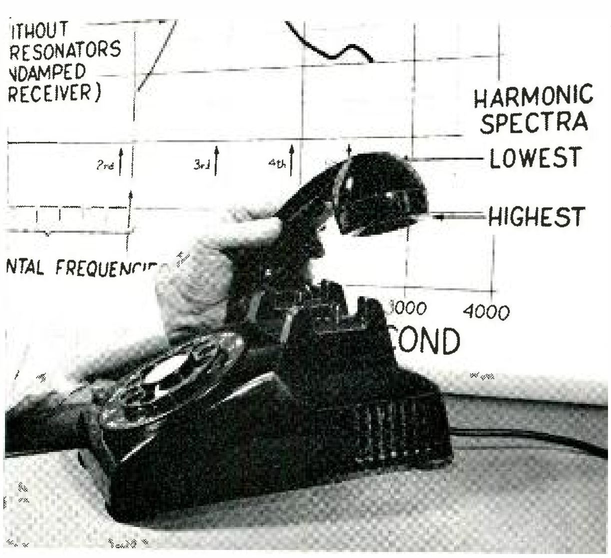


Fig. 3 — 500-type set modified for tone-ringer operation; sounder is behind louvres in base.

shown in Figure 3. The only innovation in external appearance is the row of slots in the side of the housing. These provide free egress for the sound. The volume control appears as a knob in the front lefthand corner.

The sound emitted by the tone ringer does not resemble the familiar sound of the telephone bell except that the 2-second ON, 4-second OFF repetitive cycle has been retained. In a change of this sort, it is essential to know whether there have been any important changes in such acoustical factors as audibility, clarity, distinctiveness and acceptability.

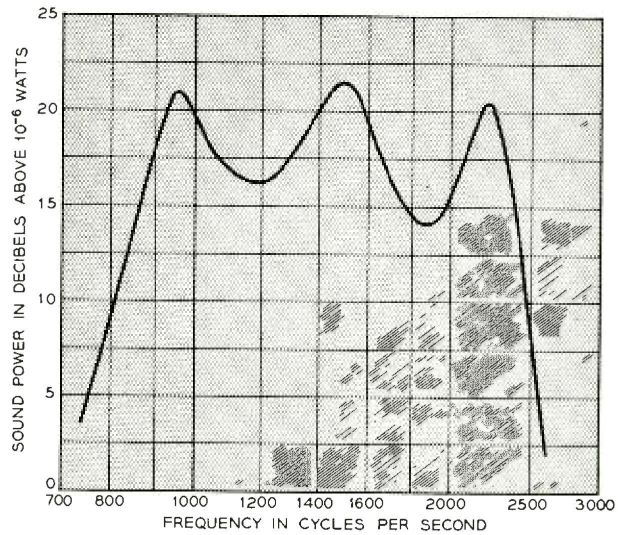


Fig. 4 — Frequency response of the sounder — the three peaks result from the telephone-type receiver and the two acoustic resonator sections.

A preliminary check of these factors was made in the Laboratories.

Models of the tone ringer were compared with a conventional ringer in the presence of background noise having an energy pattern simulating observed room noise. The level was adjustable to provide a range of noise conditions. In these tests, the masking effect of the noise was judged to be approximately the same for both ringers.

A second laboratory test was made in which the tone ringer was operated near one end of a long hallway. The observer walked away from the source until he reached a point where the signal was indistinct. The distance traversed was a measure of carrying power. Repeating the test with the conventional ringer gave a comparison in which the tone ringer was found to be somewhat more effective than the conventional ringer.

In another test, more than 200 Laboratories people served as a jury listening to the quality of the several ringer tones and expressing their opinions

Fig. 5 — J. Kocan observes the operation of an experimental photo-electric signal generator that supplies the complex tone ringer signal voltages for the development laboratory.

of them. The over-all reaction of this group was favorable to the tone ringer, but the two highest-pitched tones were less popular than the others.

After these tests, tone-ringer sets were supplied as replacement telephones to 25 people in the Laboratories for a period of two weeks and their reactions were obtained. Here the results were even more favorable to the tone ringer; they indicated that the user's preference for it increases as he becomes better acquainted with it.

At about this time a field trial of the Type-P rural carrier system was in progress in Americus, Georgia. The low-voltage, voice-frequency signaling feature of the tone ringer suggested compatibility with the carrier system, and the Laboratory tests indicated that the tone ringer could be expected to perform well. Consequently, a small-scale field trial of the tone ringer was added to the carrier trial to determine the technical possibility of incorporating a tone-ringer system in a commercial plant and to obtain further telephone-user reaction to the tone-ringer signals.

At Americus, the P-carrier installation served 28 telephones on four rural 8-party lines, ranging in length from 12 to 18 miles. A standby voice-frequency circuit was provided for each line. Normal operation in this area employed divided-code ringing (i.e., each user hears the ringing signals of four telephones). This grade of service was retained. The full-selective ringing feature of the tone ringer was therefore not tested in this trial. A tone generator capable of supplying any two of the eight ringer tones was installed at the central office for each line served — one tone corresponding to conventional ringing on one conductor of the line (the tip side) and the other tone corresponding to ringing on the other conductor of the line (the ring side). Battery voltage for both talking and ringing was supplied from the outlying terminal of the carrier system for both carrier and voice-frequency operation.

Tone-ringer sets were installed in all 28 homes and provided telephone service for 69 adults and 13 children for a period of two to six months. The opinions of the customers were obtained by interviews conducted at the beginning and at the end of the trial period. The tone ringer was preferred to the conventional ringer by 70 per cent of these people. Their reasons for their preference were that it could be heard farther, was clearer and more easily recognized. Also, to use phrases obtained in the interviews, its "calm sound" was "not as rowdy as" or was "less terrifying" than the bell.

The interviews also gave data on the relative effectiveness of the two types of ringers. Only 72 per cent of the Americus people could hear the conventional ringer in all parts of their house while 91 per cent could hear the tone ringer in all parts of the house. Thirteen customers pointed out locations where they had heard and recognized their ring and where the telephone ringer was previously in-

Fig. 6 — J. R. Power demonstrate how connections establish correct resonant frequency.

audible. Several of these locations were 300 feet or more away from the telephone instrument.

The Americus trial thus demonstrated that tone ringers can be operated over carrier lines or over long open-wire lines and that they are well liked by our customers. The economies in the case of a few carrier channels, however, are not favorable for general use at this time. A larger installation of tone ringer sets is undergoing a field trial at Crystal Lake, Ill., to establish the possibility of their use with an electronic switching system where the economic advantage would be considerable.

THE AUTHORS

F. L. CRUTCHFIELD received a B.S. degree from Guilford College in 1925. In 1926, he received an M.S. degree in Physics from North Carolina State College and joined the staff of Bell Telephone Laboratories that year. His first assignment was the development and standardization of the thermophone as a basic reference in electro-acoustic measurements. For several years, he was engaged in the design of apparatus for measuring telephone transmission and for testing telephone instruments. In 1936, he transferred into the group responsible for the design of telephone instruments. During World War II, he was concerned with the design of communication instruments for special uses by the armed forces. In 1954, Mr. Crutchfield joined the newly formed station systems engineering group which deals with the application of new arts to telephone station apparatus.

J. R. POWER received a B.S. degree from the Carnegie Institute of Technology in 1927 and joined the staff of Bell Telephone Laboratories in that same year. He was initially engaged in the development of precision voltage and speed regulators, primarily for use in the sound picture field. Following this he spent several years on miscellaneous acoustical problems and then on the electro-magnetic development of telephone ringers. During World War II he was engaged in the development of high power audio systems. After the war, he worked on hearing aids, audiometers and artificial larynges. In 1948 he returned to station apparatus development and is now concerned with the exploratory development of transistorized telephone sets.

Claude E. Shannon Receives Research Corporation Award

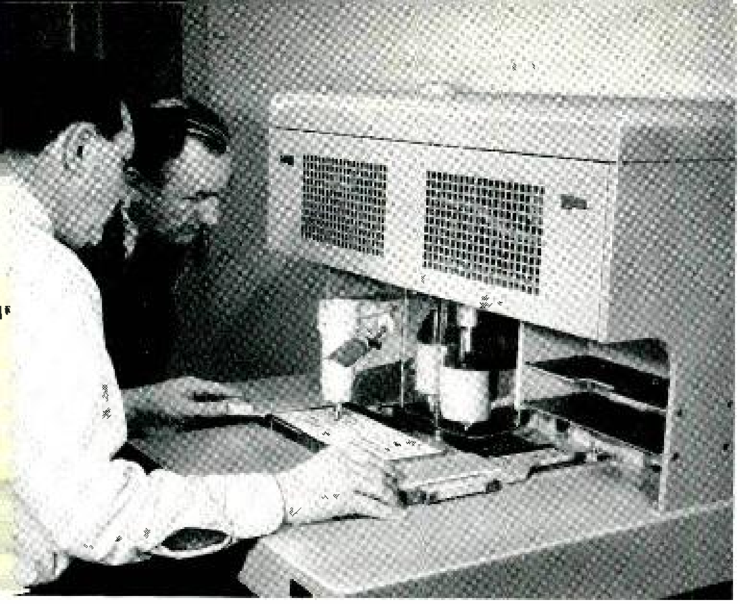
Dr. Claude E. Shannon, research mathematician at the Laboratories, has been awarded the 1956 Research Corporation Award for his work in establishing a mathematical theory of communications. His philosophic concept, known as "Information Theory," was developed by Dr. Shannon at the Laboratories. The theory has many applications in wire and radio communications and in computing machines, as well as more diverse fields.

The award consists of an honorarium of $2,500, a plaque and a citation. Dr. Shannon is the 21st recipient since the award's inception in 1925. The award honors individuals who have made notable scientific contributions which have not already received substantial recognition.

Dr. Shannon has been a member of the technical staff of the Laboratories since 1941. In January, 1956 he was appointed Visiting Professor of Electrical Communications at Massachusetts Institute of Technology. Dr. Shannon was recently appointed Professor of Communications Sciences in Electrical Engineering and Professor of Mathematics at M.I.T. He continues as a part-time member of the Laboratories.

Other award winners have included: Robert B. Woodward, Vannevar Bush, Percy W. Bridgman, Ernest O. Lawrence, Bruno Rossi, Edwin M. McMillan, Edward C. Kendall, Samuel A. Goudsmit, George E. Uhlenbeck, and H. S. Black. Mr. Black, a member of the Laboratories, received the prize in 1952 for his invention and development of the negative feedback system which is fundamental to much of science and industry.

Dr. Shannon received the Morris Liebmann Memorial Prize of the I. R. E. in 1949 and in 1955 the Franklin Institute awarded him the Stuart Ballantine Medal. He is a member of the National Academy of Sciences.



Coding Tool for Translator Cards

E. GRAF *Switching Apparatus Development*

With progress in the Bell System direct distance dialing program, more and more telephone calls are being directed to their destinations by automatic switching equipment. One important link in this operation is the card translator used in the 4A toll crossbar system to direct long-distance calls over any of a number of selected routes. Like any other machine, however, this card translator can only operate on the basis of intelligence supplied to it by a human being. In this case, the necessary intelligence is supplied in the form of sheet-steel blanks perforated by an operator using a card-coding tool.

Direct distance dialing, which is rapidly coming into general use, requires a number of automatic switching centers. At each of these centers means are provided for automatically routing calls forward, toward the next switching center, until the final destination is reached. The necessary "intelligence" for selecting satisfactory routes for the calls to follow is supplied to the switching equipment by card translators.* These translators are essentially card files from which appropriate cards are automatically selected and electronically "read" for the information required by the switching mechanism to make the desired connections. In the larger centers, as many as 10,000 such cards may be needed to supply the necessary routing information. Since these cards are selected and read automatically in the translator, the information on them must be in code.

The card blanks are made from sheets of thin, chromium-plated steel with 40 tabs on the lower edge and 118 holes arranged over the card face. To provide the necessary code for selecting the card containing the desired routing information, approximately 25 of the tabs are removed, and to provide the routing information, approximately 30 of the holes are enlarged.

New cards are necessary to meet changing traffic conditions or the addition of new switching centers. To obtain these newly coded cards promptly, a card-coding tool is required at each of the switching centers. When new routings are required, the telephone traffic department supplies the information to the operating department in the form of a printed and perforated heavy-paper template with holes and notches punched out to correspond with the holes to be enlarged and tabs to be removed from the steel blanks. This paper template is used in the machine as a pattern for coding the card blank. A sample template and card are shown in Figure 2.

The tool for coding these cards is a power operated punch press, designed for use by telephone switching personnel. Special care was taken in the design to make this machine fast and easy to operate without danger of injury to personnel or damage to the tool. Safety features include a transparent guard over the punches so arranged that the tool will not operate unless the guard is in position, and a device for holding the card in the correct position under the punches to protect the operator's hands. An interlock system is also included to prevent the wrong punch from operating if a control should fail, as well as disengaging clutches to prevent damage to the tool if undue force is applied to the movable parts. A key-operated lock secures the carriage against movement and removes power from

* RECORD, *March*, 1955, *page* 93.

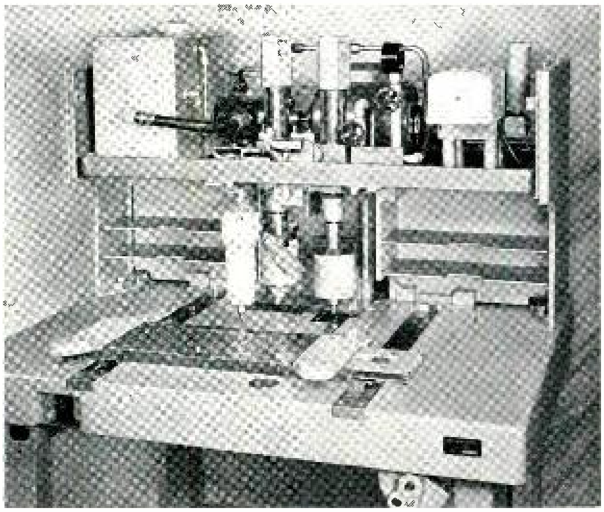


Fig. 1 — Hydraulic mechanism for coding tool.

the tool when it is not in use. Shelves are conveniently located over the table top for storage of templates, card blanks and coded cards.

To code a card, the operator unlocks the tool and places one of the prepared templates and a card blank in their respective places on the carriage. This carriage, which moves freely over the table top on ball bearings, is moved to a position where a punched out hole in the template is under a pilot pin. By depressing a foot pedal, the pin is lowered through the hole in the template into a corresponding hole in a plate on which the template rests. The pin entering the hole in the plate precisely positions the carriage so that the corresponding hole in the card, which is remotely located with respect to the pilot pin, is correctly positioned for the punch to operate. As a result, the hole in the card corresponding to the hole in the template is enlarged. In like manner each punched out hole in the template is located under the pilot pin and the operator then depresses the foot pedal.

To set the tool for removing the appropriate tabs from the card blank, a handle at the lower right corner of the table is swung to the right while the carriage is held lightly against the stops at the rear of the table. The cut notches in the template are now in position to be aligned with the tab clipping pilot. The foot pedal is again depressed once as each notch in the paper template is moved in front of the pilot. The tabs on the card corresponding to the cut notches in the template will be removed. The completed card is placed over the template and checked visually to determine that it has been correctly coded. The template is left in place on the carriage until as many cards as are required of that particular code have been completed and checked.

The two sets of punches and dies, one for enlarging holes and one for clipping tabs, are assembled in channels in the table top to facilitate replacement or sharpening when required. Each punch and die unit is assembled in a rigid steel casting. Two dowel pin receptacles and three tapped holes in the base casting are used to locate and secure these units in their correct locations in the table. Close tolerances are necessary on many parts of these assemblies to insure that the units will always be precisely located in the table, and that the punch and die members will produce cut edges essentially free of burrs. The hole punch is required to enlarge 0.375 by 0.140 inch holes in the blank to 0.375 by 0.310 inch, with the newly cut sides of the holes aligned with the sides of the precut holes to within 0.005 inch. A pilot on the punch member engages in the precut hole to align the card precisely with the punch member as each hole is enlarged. Sufficient clearance is provided in the holder to permit the card to shift the required amount for this final alignment.

To assure long life and to produce the necessary clean cut edges, tungsten carbide inserts are provided for the cutting edges of the punch and die members. The punch member is ground and lapped to fit the die member with clearances of 0.00015 to

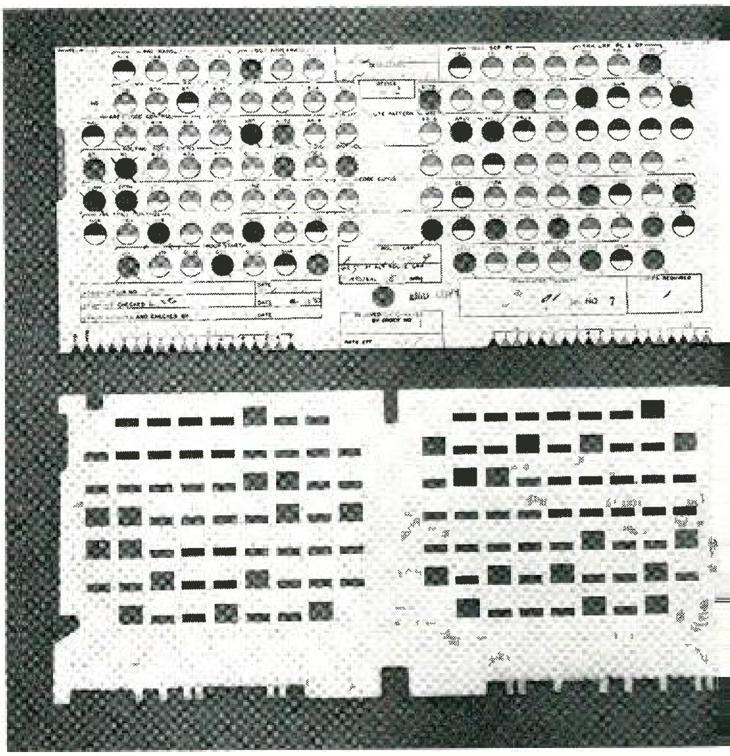


Fig. 2 — Paper template and equivalent coded card.

0.00020 inch. It is expected that the punch and die units will require replacement for sharpening after coding about 4,000 cards.

The punches are operated by a power-driven hydraulic unit assembled on a shelf over the punches as illustrated in Figure 1. Two hydraulic cylinders are mounted on the shelf directly over the punches and coupled to them with an adjustable coupling from which the punch head can be quickly disengaged. This coupling is adjusted so that the punch penetrates 0.010 inch into the die.

Power for operating the hydraulic cylinders is supplied by a ¼ horsepower motor driving a rotary pump that has a capacity of 1.5 gallons of oil per minute. This oil is normally circulated freely through the system with no appreciable pressure being required. A double solenoid-operated valve controls the application of pressure to the cylinders. When this valve is operated, pressure is applied to one or the other of the two cylinders depending upon which of the two solenoids is operated. With the valve operated, the free flow of oil through the system is blocked and pressure builds up in the cylinder to operate the punch. The maximum pressure in the system is limited to 350 pounds per square inch by a pressure release valve. Pressures approaching this value are developed only momentarily when the punch is penetrating the card blank. Immediately after the punch reaches its fully operated position, the solenoid valve releases and the pressure returns to normal. The valve is released by the operation of a microswitch which removes power from the solenoid just before the punch is fully operated. Relays prevent the valve from being re-energized until the foot pedal is released. When the pressure is released, the punch is restored by a spring in the operating cylinder.

A carriage, provided to locate and hold the card blank under the punches, consists of two essential parts; a card nest for holding the card, and a template holder for accurately locating the card under the punches. The card nest consists of two jaws mounted on arms extending forward from the template holder. These jaws are spaced to hold the card loosely with about 0.010 inch clearance between the sides of the jaws and the sides of the card. The card is supported in the nest by narrow thin ledges at the four corners of the nest. The sides of the jaws are notched in such a way that the card can be placed in the nest in only the correct position. These details are illustrated in Figure 3.

The template holder consists of a heavy steel plate having accurately located round pilot holes which

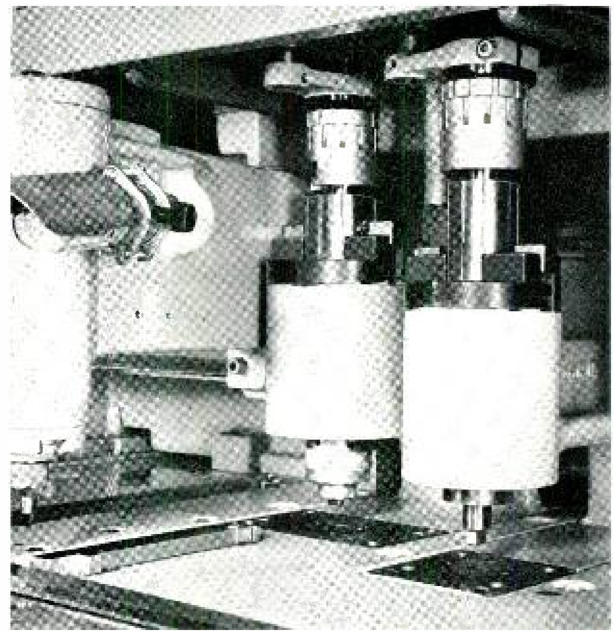


Fig. 3 — Close-up view showing punch and carriage section of card-coding tool.

correspond precisely with the positions of the holes in the card blank to be enlarged. Likewise, notches in one edge correspond to the tabs on the card blank. Means are provided on the template holder for securing the paper template in a position so that the holes and notches in the template will line up with those in the holder. The template holder and card nest are accurately located with respect to each other so that each hole and each notch in the template holder bear the same relationship to each hole and each notch in a card blank located centrally in the card nest.

The carriage is secured to the table top through two sets of ball-bearing raceways mounted at right angles to each other to provide free movement in a back and forth direction on one set of raceways and crosswise on the other set. With this mounting, the carriage may be moved freely over the top of the table, without rotation. In this way, the card may be aligned under the punches by accurately locating the template holder plate with respect to two pilot positions.

Two pilot control units are provided, one for hole enlarging and one for tab clipping. The hole enlarging unit is suspended over the center of the table on a rigid arm secured to one of the hydraulic unit shelf supports. This pilot unit contains a pin moved in an up and down direction under control of a foot pedal. The pin is accurately located with respect to the hole enlarging punch in such a way that when the pin is lowered into a hole in the template holder plate, a corresponding hole in a card will be correctly located under the hole enlarging punch. A switch in the pilot unit is closed, when the pin is near its fully extended position, to operate the valve which controls the punch action.

The tab clipping control unit is mounted in the table top flush with the surface. When the tool is set for tab clipping, however, a pilot having a "V" shaped tip is extended above the table surface with the tip just in front of the notches in the steel plate on the carriage. This pilot tip moves forward into the "V" notches on the plate when the foot pedal is depressed. When the tip is fully engaged with a notch in the plate, a switch closes to operate the control valve for the tab clipping punch. The foot pedal motion provided by the operator is transmitted to the control units by hydraulic pressure.

The card-coding tool is set for tab clipping or hole enlarging by a handle at the right of the table. When this handle is in its left position the tool is set for hole enlarging, and in its right position, for tab clipping. Except when the handle is in one or the other of its extreme positions, the punches are inoperative. Switches associated with the handle position control this condition.

With this tool, cards can be coded accurately and quickly. Limited tests indicate that, with a little experience, an operator should be able to code cards at a rate of at least 200 a day. Thirty-five of these tools have been made by the Western Electric Company and are now in service. Approximately thirty more will be required when the present plans for the nationwide dialing system are completed.

THE AUTHOR

E. GRAF joined the Laboratories after receiving a B.S. degree in Electrical Engineering from the Alabama Polytechnic Institute in 1925. Prior to World War II, he was primarily engaged in the testing and analysis of telephone apparatus. During the war he was engaged in work for the military services on tank radio sets and gun directors. Since the war, he has been primarily concerned with development and current engineering problems associated with automatic message accounting machines, the card coding tool and card translators.

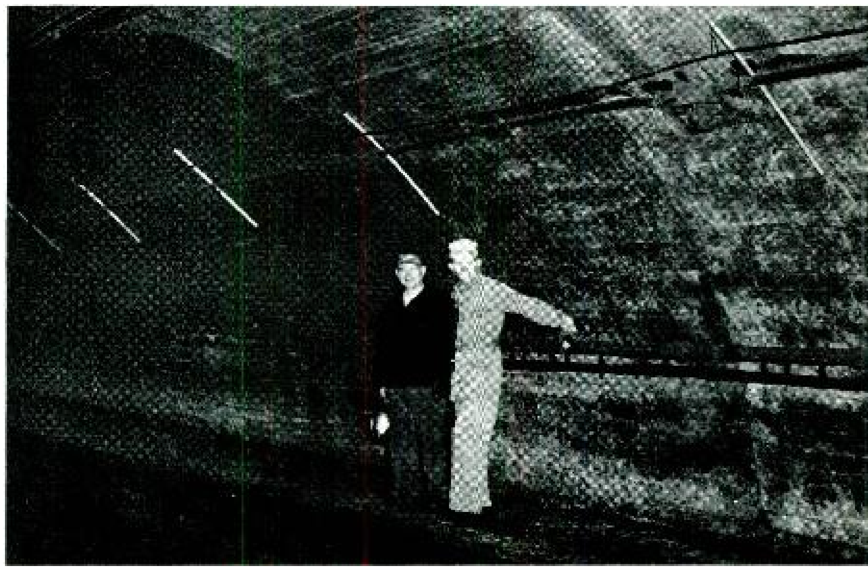
Members of the Laboratories Receive New I. R. E. Award

Two members of the Laboratories have been named recipients of a newly established I.R.E. award, known as the W. R. G. Baker Award. R. L. Trent, Transmission Systems Development I and D. R. Fewer, Transmission Systems Development II, with R. J. Kircher of Hughes Aircraft Company, will receive the award jointly for their series of papers which appeared in the *I.R.E. Transactions on Audio.*

The new I.R.E. award will be given annually to the author of the best paper published in the Transactions of the I.R.E. Professional Groups. Named for Dr. W. R. G. Baker, Vice President of the General Electric Company, the award consists of a certificate and a cash award from the income of a fund donated by Dr. Baker.

The papers in the award winning series are: "Properties of Junction Transistors" by R. J. Kircher, *I.R.E. Transactions on Audio,* No. 4, July-August, 1955; "Design Principles of Junction Transistor Audio Amplifiers" by R. L. Trent, *I.R.E. Transactions on Audio,* No. 5, September-October, 1955; and "Design Principles for Junction Transistor Audio Power Amplifiers" by D. R. Fewer, *I.R.E. Transactions on Audio,* No. 6, November-December, 1955.

Radio communication between fixed stations and moving trains, or between locomotives and cabooses of freight trains, is widely used today. Until recently such communication has been impossible while a train was traveling through a tunnel. A study by the Laboratories of radio transmission in a Pennsylvania Railroad tunnel under the Hudson River has resulted in the concept of radiation from a continuous transmission line along the tunnel instead of from separate antennas.



Radio Communication in Railroad Tunnels

H. S. WINBIGLER *Special Systems Engineering I*

Radio is used extensively today by the nation's railroads in the conduct of their daily operations. In particular, radio communication between freight-train locomotives and cabooses, and between these units and wayside stations, has been found to save time and expedite shipments. Much of the radio equipment employed at present is owned and maintained by the railroads. In some instances, however, the Telephone Companies provide both radio equipment and maintenance.

In radio systems of the type currently in use, communication is not possible when the locomotives and cabooses are in tunnels. To assist the Telephone Companies in engineering railroad systems requiring communication under such conditions, the Laboratories recently conducted a study that disclosed a practical solution to the problem. The study was made in the Pennsylvania Railroad's North River tunnel, with the cooperation of the railroad's engineers and other personnel. This tunnel, which extends under the Hudson River between New York and New Jersey, is some 13,400 feet long. It comprises two tubes with a single track in each. In addition to the portals, access to the tunnel is provided by stairways in two shafts, one at 11th Avenue in Manhattan – 700 feet from the east portal – and one in Weehawken, New Jersey – 6,000 feet from the west portal.

Frequencies in the 159-162-mc band have been authorized by the FCC for use in railroad operational radio systems. Fortunately for the Laboratories study, the public radio-telephone installations operating adjacent to this frequency range on certain of the railroad's trains* were available for use as mobile test stations. These trains pass through the North River tunnel daily. In addition, a mobile station installed in one of the Pennsylvania Railroad's electric locomotives for radio survey purposes could also be used.

To work with the trains, a base station was set up in a room adjacent to the foot of the Manhattan shaft immediately over the north, or outbound, tube of the tunnel. From this location, a short length of coaxial cable was connected to a test antenna or other radiator within the tube. The base-station test equipment is shown in Figure 1. A radio transmitter,

* RECORD, *January*, 1948, *page* 9.

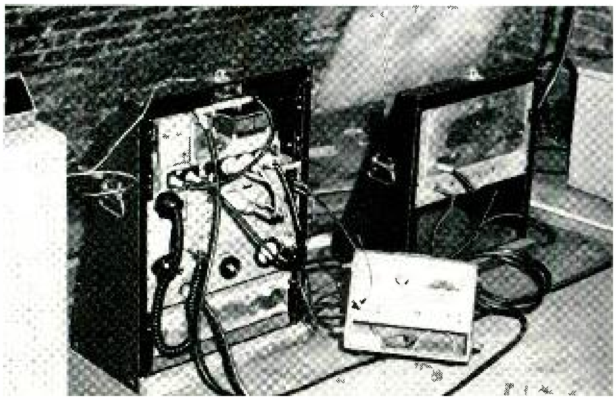


Fig. 1 — Radio equipment used at the North River tunnel base station in the tests.

control panel, and power panel are mounted in the larger rack and a radio receiver in the smaller one. Talking and listening tests to and from the trains were made with a variety of types, heights, polarities, and orientations of base antennas over a range of transmitter output powers.

No significantly different coverage distances were observed for the various antenna arrangements. The results of the variable output tests, Figure 2, show the distance over which commercially acceptable communication was obtained for several values of transmitted power, using a vertically-polarized dipole antenna at the base station. A straight line through the measurements intersects the power axis at −120 dbw.* This is approximately the received power required to produce a voice signal of minimum acceptability above the electrical noise conditions encountered during the tests. The slope of the line indicates that radio signals over the test path were attenuated at an average rate of about 18 db per 100 feet.

During these tests the radio-equipped car occupied a variable position in the train. For the majority of runs, the position was such that all or most of the tunnel between the transmitting and receiving antennas was occupied by cars of the train. The attenuation figure, therefore, more nearly represents a train-occupied tunnel than an empty one. The curve also shows that the radio coverage with a transmitter having a typical output of +15 dbw — 30 watts — was approximately 750 feet. Where a base-station antenna can be located at least 750 feet inside the portal of a long tunnel, a total coverage distance of approximately 1,500 feet can be obtained. This, however, is only one-ninth the total length of the North River tunnel so that an impracticably large number of distributed base stations would be required to provide continuous coverage.

Since the observed attenuation rate of 18 db per 100 feet was considerably greater than that of typical small-diameter coaxial cables, it was decided to explore the possibility of using a combination of feeder cable and multiple antennas to obtain tunnel coverage. A 3,000-foot length of solid-dielectric coaxial cable was installed high along one wall of the tube, with provisions for connecting ⅛-wavelength (9-inch) antenna rods to the cable's center conductor at 500-foot intervals for the first 2,000 feet and at 250-foot intervals for the last 1,000 feet. The base station was connected directly to one end of this cable, the distant end being suitably terminated at the last antenna location.

Tests indicated that satisfactory two-way communication was maintained for a distance of 2,600 feet from the base station end of the cable. By progressively reducing the number of antennas, it was learned that with no antennas the circuit still was satisfactory for a distance of 2,000 feet. Antennas were required only at the 2,000 foot location and every 250 feet beyond, to obtain the maximum communication range of 2,600 feet.

Electrical coupling between the coaxial cable and the train's antenna resulted from the nature of the cable's outer conductor. This conductor was not a solid copper tube as in most coaxial cables using air

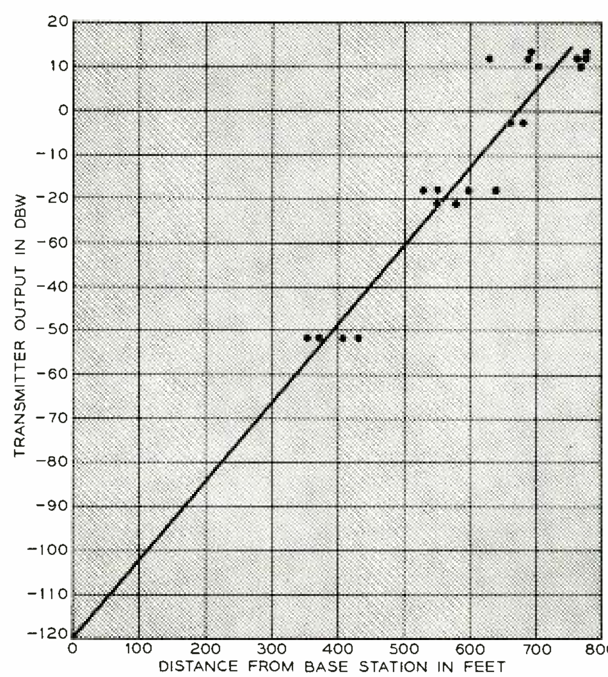


Fig. 2 — Transmitted power versus distance for a constant received signal from the base station.

* The term dbw means db based on a zero level of one watt.

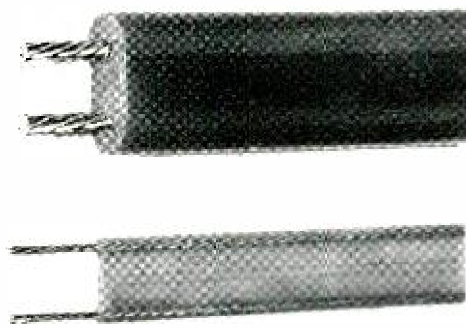


Fig. 3 — Twin-lead used in the tests (top) compared with standard twin-lead aerial wire commonly used with television receivers.

as the dielectric; it was composed of many fine strands of copper wire, braided into a tube around the solid dielectric material of the cable. This construction permits an appreciable amount of the electric field of the cable, ordinarily pictured as being entirely confined within the cable sheath, to escape into the surrounding space.

Where a base-station radio set can be located at an intermediate point in a long tunnel and connected to two branching cables, the coverage can be almost doubled. The branching cables add a loss equivalent to that of only about 100 extra feet of cable. For maintenance reasons, it is necessary to confine the location of base-station sets to the tunnel portals and shafts. Unfortunately, in the case of the Hudson River tunnel, the shafts are too far apart to obtain complete coverage from these locations with ordinary small-diameter coaxial cable such as used in the tests. A lower-loss cable of similar construction would probably provide complete coverage but at a higher cost than could be justified. Thus, while coaxial cable might be used successfully in shorter tunnels, it was impractical for use in the Hudson River tunnel.

The results obtained with the coaxial cable suggested that a two-wire line running the length of the tunnel might provide a means for obtaining the desired continuous coupling to a train's antenna. It was believed that the design of an optimum line might be predicted. However, a theoretical investigation failed to provide a conclusive answer, chiefly because of the lack of information on the absorption loss encountered by a two-wire line in close proximity to a tunnel wall. It was decided, therefore, that an experimental line should be installed in the tunnel for testing purposes.

From the available types of commercial low-loss solid-dielectric two-wire cable, the one selected was similar to but of heavier construction than ordinary television twin-lead cable. A short length of this cable is shown in Figure 3 along with a length of standard television cable. A 1,000-foot length of cable was mounted on the tunnel wall, as shown in the headpiece, suspended from the tips of dowel rods thrust behind the tunnel lighting conduit. In this position, the cable was 4 to 5 inches from the wall and 13½ feet above the rails. Its two conductors were mostly in the horizontal plane. The mobile antenna, mounted on the roof of a car or locomotive, was approximately 14 feet above the rails and six feet from the cable. The relative positions of the antenna and cable are indicated in Figure 4. The cable was as high on the wall and as close to the moving train as clearance restrictions would permit, in what was considered to be the best available location. It was not possible to locate the cable on the tunnel ceiling, directly over the train antenna, because of the 11,000-volt trolley.

Coverage tests were made in which either the output of the base transmitter or the input to the base receiver was attenuated until a definite coverage boundary somewhere along the 1,000-foot cable was determined. From the resulting data the effective coverage distance for a transmitter output of +15 dbw was determined to be the equivalent of 6,000 feet of cable.

It was appreciated that a cable or open-wire line having more nearly optimum characteristics for this particular application might be determined by further experimentation. However, in view of the satis-

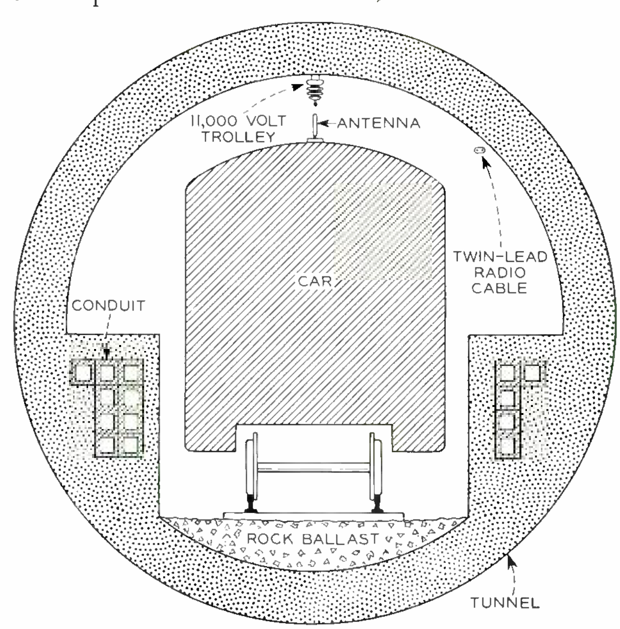


Fig. 4 — Cross-section of tunnel showing relation between base-station and mobile-station antennas.

ments of all units to be tested, and a plug-in adapter to provide the dual functions of accepting only one unit type and programming all tests for that type. These adapters are box-like structures that are inserted into the test set, and each contains a receptacle that will accommodate only the packaged unit to be tested by that adapter. Both items are pressed

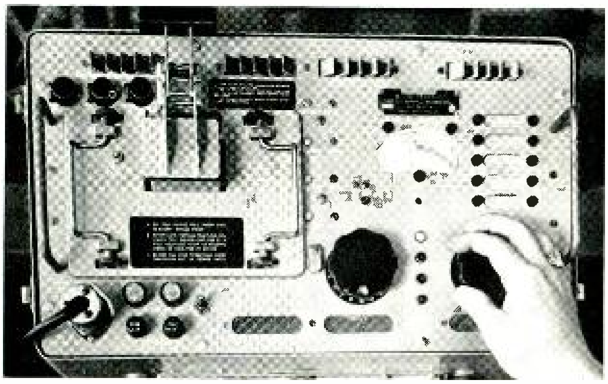


Fig. 1 — Panel view of the test set. The operator's hand is shown on the ADJUST *knob.*

firmly into contact with the test set by a toggle-action clamp as shown in Figure 2. This firm pressure insures proper heat transfer from the packaged unit through the conducting bottom surface of the package. The connectors on the bottom of the adapter either make contact directly to the proper voltages, or are connected to specific terminals of a 10-deck, 18-position TEST switch in the test set proper. As the TEST switch is rotated step by step, the proper connections are made to fulfill the requirements of each test that are specified for that particular packaged unit.

With the test steps and correct voltages selected for the operator by the adapter, the next problem was a suitable test indicator. It was decided that the meter should have colored zones on the scale, similar to many tube testers in widespread use. This simplifies the testing procedure for unskilled personnel, and an additional numerical scale permits recording test results when desired. Since the packages to be tested are complex circuits, they may require tests of such characteristics as ac or dc gain, automatic volume control voltage, phase shift, frequency response and noise level. Some tests permit a nominal reading plus or minus a tolerance. Others require the test reading to be either below or above a predetermined limit. For this reason, three colored zones (green, yellow, and blue, respectively) are used. The left half of the scale is yellow, the right half is blue, and a second scale – green – is centered above the first. Circuits in the adapters and on the TEST switch insure that the meter is correctly connected for each test, and an appropriately-colored lamp lights on the panel to tell the testman which scale is to be used for that test.

To test the amplifier packages, accurate adjustable voltages must be applied. Normally, many different controls would be required, but eight or ten different knobs on the test set to handle all contingencies would clutter the panel and cause confusion. Only one "ADJUST" knob was desired, with metering circuits to display all adjusted values at exactly midscale. The solution was to connect the single ADJUST knob to four double potentiometers and a variable transformer through a chain drive and five magnetic clutches. The TEST switch is arranged to energize one clutch at a time, and connect the ADJUST knob to the proper control for the step desired. Equally important, each control is completely disconnected at all other times so that it is impossible to inadvertently disturb any control setting that is not to be adjusted on the test step being examined. This combines tamper-proof adjustments with simplicity of operation and a minimum number of panel controls. The resultant subassembly of clutches, potentiometers, and chain drive, Figure 3, has a control response not discernibly different from a directly mounted knob. Because of the independ-

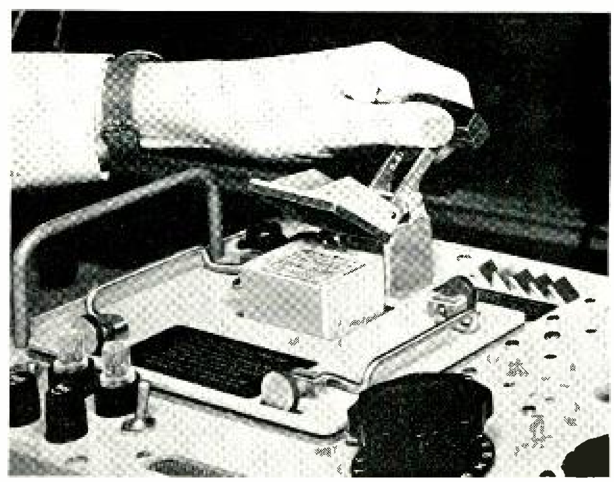


Fig. 2 — Amplifier unit being tested is held firmly in adapter by a toggle-action clamp.

ent subassembly structure, it can easily be mounted below the panel to provide free panel area that can be used for other apparatus.

Internal design of the complete test set was based on a multiple shelf assembly, Figure 4. The power supply is on the lowermost deck. The middle deck contains an audio oscillator with power amplifier,

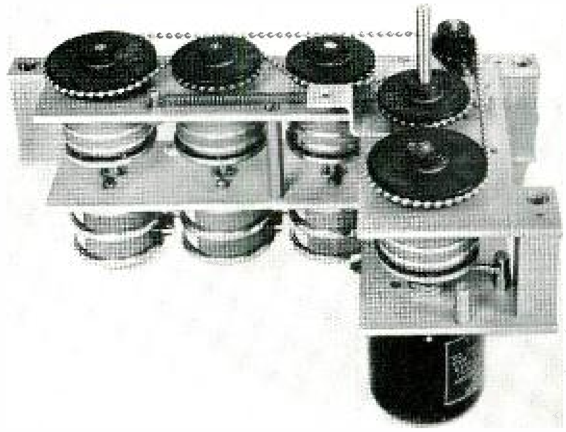


Fig. 3 — Magnetic clutch assembly to individually control multiple potentiometers from a single knob.

and both ac and dc vacuum-tube voltmeter circuits. Each of these lower decks may be removed or replaced for maintenance. The upper deck is reserved for relays, switches, transformers and other non-electron-tube items. Air flow for cooling and circulation is brought down to the lower deck by a duct, and baffles are so built into the case that the air flows over each deck before escaping out the exit louvers.

Each of the adapters contains components and circuits to fulfill all test requirements for one type of packaged unit. Specification test limits for each packaged unit are used to calculate the ac or dc vacuum-tube voltmeter sensitivities and resistance dividers required to display the expected output in the proper colored zone on the meter. Hermetically-sealed precision resistors in the adapters are used in each divider; a change in package requirements, if it is ever found desirable, can be taken care of in the test equipment by replacing one or more resistors. All adapter components are mounted on hinged terminal boards that fold down and are hence made available for easy maintenance.

In addition to the general features of the test set, a number of minor design features have been included to meet test requirements of the packaged units. To make certain that the temperature of the encapsulated units is up to its normal operating value, a thermal time-delay relay prevents a test being made until the unit has been heated for two minutes. On tests of a dual-channel package, completion of a test on one channel gives the testman an indication that he should repeat all tests for the other channel. When the TEST switch is returned to the first position, reversing relays automatically make the proper connections for repeating the same procedures on the second channel of the unit.

One relatively new item in this equipment is the use of a small vibrator to loosen the meter movement and minimize the effects of "roll" in the rugged meter. "Roll" is the tendency for the meter movement pivots to ride up the sides of their jeweled bearings, which adds to the usual permitted meter error. Because of problems in making the meter sufficiently rugged for field use, the additional roll error is normally about four per cent. By the combined use of the vibrator and the zero adjustment control, the test set permits duplication of readings to within one per cent.

Since the testman expects one of the colored lights to be energized on each step, it is necessary to provide some indication for any step that does not conform to the use of one of the meter scale instruction lights. Such indication is provided by backlighted translucent labels on the front panel, which give instructions such as REPEAT STEPS 1 AND 2, or indicate such things as TEST COMPLETE or PREHEAT 2 MIN. during the warmup waiting period.

Most of the electrical design problems involved were of a conventional nature. The methods of test of the original specifications were adapted only as required to transform all tests into forms to permit

Fig. 4 — Internal view of the test set.

a meter display of the test limits. No difficulty was experienced in designing circuits in which all variables to be measured, from phase shift to frequency change, produced linear meter deflections. To make limits of varying percentages conform to the fixed green zone of the meter, appropriate circuits provide for depressed-zero operation of the meter to produce suitable scale deflection and scale factor.

In addition to adapters for each packaged unit to be tested, field maintenance has been facilitated by a special adapter-like switch box that plugs into the same receptacle. This switch box is arranged to permit testing of all voltage outputs, lights, and clutch operations. Sensitivities of the ac and dc vacuum-tube voltmeters are both displayed on the test-set meter and also made available on test binding posts. A separate suitcase-type carrying case is provided for storage of all the adapters and this switch box. The combined weight (130 lbs.) and size (5 cu. ft.) of the test set with its accompanying adapter case are comparable to the other items of field test equipment designed for the airborne radar system and are only fractions of the weight and bulk that would have been necessary had eight separate test sets been designed.

It is hoped that field use of this equipment will permit a new simplicity in the handling of military components and come closer to the military needs for wider use of non-specialized personnel. New package types, when they are created, should not cause test-set obsolescence because only a new adapter need be provided to extend the testing ability of the equipment. Of course, the concept of a fool-proof self-programming test set cannot always be used with items as complex as these amplifier subassemblies without unduly increasing its own design requirements. It is felt, however, that this equipment does satisfactorily achieve the desired operational simplicity. At the same time the set itself should be relatively simple and easy to maintain.

THE AUTHOR

J. W. Balde received his B.E.E. degree from Rensselaer Polytechnic Institute in 1943. Employed first by Bell Telephone Laboratories as a summer employee in 1942, he joined Western Electric Company in 1944 and was assigned back to the Laboratories in 1948. Since then he has been engaged principally in design of military electronic equipment at Murray Hill, Whippany, and, since 1950, at Winston-Salem. He has worked on a number of projects including the development of aircraft radar, bombing, and navigational systems; and military apparatus design. He is presently occupied in developmental work on navy projects.

Contents of the January Bell System Technical Journal

The January, 1957, issue of The Bell System Technical Journal contains the following articles:

Transatlantic Communications – An Historical Resume by Mervin J. Kelly and Sir Gordon Radley.

Transatlantic Telephone Cable System – Planning and Over-All Performance by E. T. Mottram, R. J. Halsey, J. W. Emling and R. G. Griffith.

System Design for the North Atlantic Link by H. A. Lewis, R. S. Tucker, G. H. Lovell and J. M. Fraser.

Repeater Design for the North Atlantic Link by T. F. Gleichmann, A. H. Lince, M. C. Wooley and F. J. Braga.

Repeater Production for the North Atlantic Link by G. W. Meszaros and H. H. Spencer.

Electron Tubes for the Transatlantic Cable System by J. O. McNally, G. H. Metson, E. A. Veazie and M. F. Holmes.

Cable Design and Manufacture for the Transatlantic Submarine Cable System by A. W. Lebert, H. B. Fischer and M. C. Biskeborn.

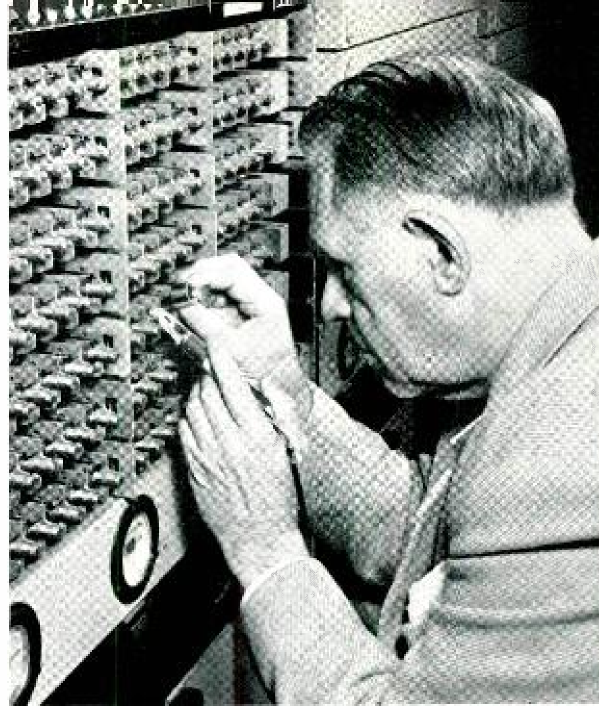
System Design for the Newfoundland-Nova Scotia Link by R. J. Halsey and J. F. Bampton.

Repeater Design for the Newfoundland-Nova Scotia Link by R. A. Brockbank, D. C. Walker and V. G. Welsby.

Power-Feed System for the Newfoundland-Nova Scotia Link by J. F. P. Thomas and R. Kelly.

Route Selection and Cable Laying for the Transatlantic Cable System by J. S. Jack, Capt. W. H. Leech and H. A. Lewis.

Relay Contact Life in Central Offices



A. P. GOETZE

Switching Systems Development III

When relay contacts open or close to control the current in a circuit, there is always some degree of erosion. The amount of erosion per operation is proportional to the amount of energy dissipated at the contacts. Since the objective of adequate life is paramount for relays in telephone service, the erosion characteristics of various contact metals need study and evaluation. The results of such studies provide data from which contacts can be engineered for adequate life and a high degree of reliability.

Objectives in the design of contacts for relays used in central offices are high reliability, so that the contacts will require little, if any, maintenance, and a life expectancy equaling that of the central office. Both of these objectives are important from an economic standpoint because of their effect on the cost of maintenance. Only the life aspects of contacts in central offices will be dealt with here.

In early telephone systems, electrical loads on contacts were relatively light, the number of relay operations was generally low, and a fifteen-year office life was considered adequate. Under these conditions, engineering a contact for general-purpose relays that would last for the life of the office was comparatively easy. With the development of newer telephone systems, contact conditions have become progressively more severe. The efficient use of common control circuits has greatly multiplied the number of relay operations. In addition, office life expectancy has been raised considerably. The present goal for the No. 5 crossbar system, for instance, is a life of forty years.

The number of relay operations in manual systems rarely exceeded two million in fifteen years. In panel systems, relay operations reached a maximum of 100 million for only a small number of relays. In crossbar systems, relay operations are still higher. In the No. 5 system, some relays must operate in the neighborhood of one billion times in forty years.

Efforts to decrease circuit holding time have led to the use of lower-resistance relay and magnet coils in the newer systems. In terms of contact requirements, these trends have meant increasingly higher current loads coupled with many more operations.

In all telephone systems, capability requirements,* economy in the use of precious metal and mechanical limitations of relay design largely determine the minimum size of a contact, the useful life of a contact being limited by the volume of metal available for erosion. This is the volume of metal intercepted by one member of a contact pair as it wears into the opposite member, and is only a part of the total volume of precious metal of a contact pair.

Capability requirements, economic considerations and reliability concepts of early telephone systems with light current loads and few operations led to the practically universal use of small point-and-disc

* Capability requirements of a system are established by the range of loads and the number of operations a contact must control during the life of the office.

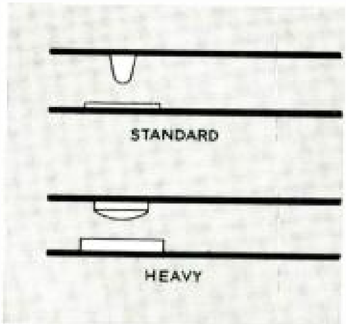


Fig. 1 — Two sizes of point-and-disc contacts. Lower pair has thirty times the erodible volume of small contacts at the top.

contacts on general-purpose relays. Larger point-and-disc contacts, with thirty times the erodible volume of the small contacts, were later provided for use in special cases where the small contacts were found to be inadequate. Figure 1 illustrates these contacts, called "standard" and "heavy" point-and disc contacts, respectively.

The advent of the panel system, with its more severe contact conditions, made heavy point-and-disc contacts more commonplace. But, even these were found to be inadequate for some of the more severe conditions. Still larger contacts would have been uneconomical, because too many contact sizes would have increased the manufacturing cost of relays. Instead of larger contacts, protective circuits have been used. These circuits usually consist of a capacitor and a resistor in series across the contact or load. A properly designed protection circuit limits the peak voltage on contact opening and the current on closure to values that result in large gains in contact life. This "protection" has become commonplace in modern relay circuits.

General-purpose relays for crossbar systems were designed with the objective of insuring both greater contact reliability and longer contact life. A bar-type twin contact was provided for use on general-purpose relays, such as the U- and Y-types, in these systems. Originally, two sizes of contacts, both made entirely of precious metal, were specified. The smaller size twin bar contact had almost the same capability as the large point-and-disc contact, while the heavy twin bar contact had about four times the capability of its smaller counterpart. These two sizes of contacts have been superseded by a bimetal contact consisting of a layer of precious metal superimposed on a nickel base. The bimetal contact has an erosible volume intermediate between the former heavy and small contacts. This is the present standard contact on U- and Y-type relays. All three types of contacts are shown in Figure 2.

This trend toward a higher number of contact operations and more severe current loads in the control circuits of the newer systems is paralleled by the constantly increasing use of contact protection. This is particularly evident in a comparison of the number of protections used in the No. 5 crossbar system with that of its predecessor, the No. 1 crossbar system. The number of protections in a 10,000-line office was less than 5,000 in the original version of the No. 1 system, but approaches 20,000 in the present No. 5 system — nearly four times as many. Increased central-office maintenance costs are, however, partly responsible for the present-day wider use of protection, inasmuch as it not only reduces contact erosion but also reduces the incidence of contact locking.

The cost of precious metal used as contact material is a sizable item in the cost of a relay — about 5 per cent. In view of the large number of contacts involved, substantial savings can be realized in the cost of an office by good contact engineering. Such engineering involves first, determining contact requirements and second, determining the erosion characteristics of the metal or metals proposed for use as relay contacts of a given system.

Contact requirements are determined from a detailed study of the circuits. Such a study provides data on the range of contact loads and on the number of relay operations for these loads. The erosion or wear characteristics of the precious-metal contacts proposed for use on general-purpose relays are obtained primarily from extensive laboratory tests. These are made for a variety of contact loads to be found in the system and with a contact size estimated to meet the necessary requirements. The choice of the ultimate size or sizes of contacts is arrived at by balancing the estimated first cost of contact metal against the estimated cost of maintenance.

The results of laboratory erosion tests form the

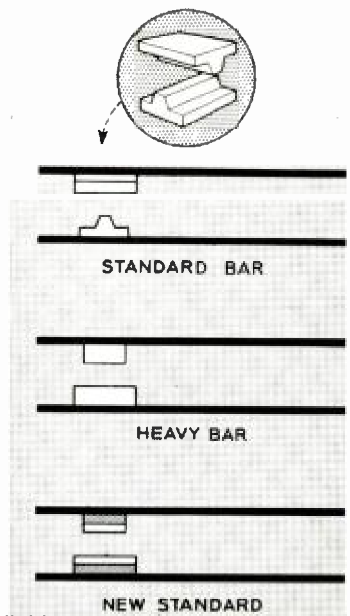


Fig. 2 — Evolution of the bar-type contact. The bimetal contact shown at the bottom has an erodible volume intermediate between the former heavy and the standard bar contacts.

basis of capability data presently used in the engineering of contacts, in terms of life in millions of operations plotted as a function of both the electrical energy and the current controlled by test contacts. In evaluating the results of life tests, it has been found that by combining the current and energy factors and plotting the combined factor against life estimates, a smooth curve is obtained.

Among factors that affect contact life is the length of lead between a contact and its load. With palladium contacts, a shorter life is obtained with long leads (over 20 feet); with silver contacts, length of leads is not significant.* For this reason, two capability curves are generally provided for palladium contacts, one for short leads and one for long leads. The lower capability figures are used for silver contacts irrespective of lead length. Each set of capability curves applies to several types of relays but only for a specific contact size.

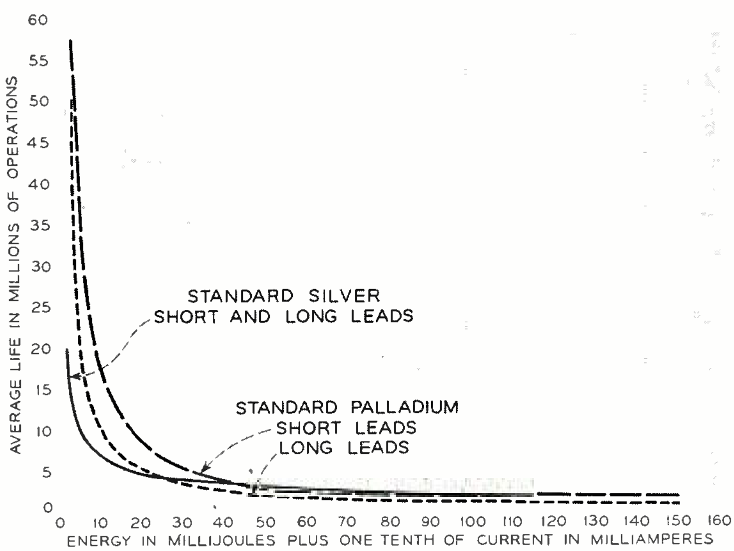


Fig. 3 — Contacts of silver and palladium have different life characteristics which are a function of lead lengths.

Figure 3, for instance, represents the capability of bar-type twin contacts of silver and palladium of an old standard size originally specified on U- and Y-type relays. Figure 4 shows the capability data of twin palladium contacts used on the new wire-spring relay. The erosible volume of the wire-spring relay contact, Figure 5, is only about half that of the present standard bimetal contact on a U-type relay. However, due to a higher speed of contact separation on opening and less chatter on closure, the rate of contact erosion on the wire-spring relay is somewhat less than that of the U-type relay.

* On short leads, the transient consists primarily of a glow discharge rather than an arc. Silver erodes about the same for both conditions while palladium erosion is insignificant for a glow discharge.

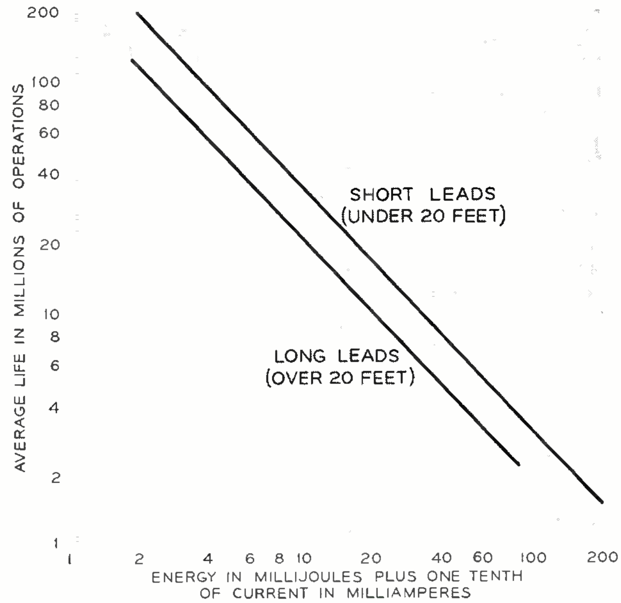


Fig. 4 — Life characteristics of palladium contacts on wire-spring relays are a function of lead lengths.

Tests of contact metal in laboratory and field observations have shown that a number of factors affect contact life. A high speed of contact separation on opening reduces erosion, as exemplified by comparing the erosion rate of U-type and wire-spring relay contacts. However, high operating speeds on closure can increase shock chatter, and therefore contribute to increased wear. Two other factors are the environment in which the contacts operate and the rate at which they are operated. Contacts on relays confined in enclosures usually wear much faster than contacts operated in open air.* A slow rate of operation can result in a much higher erosion rate, compared with a fast rate of operation. Original laboratory capability tests of silver contacts, for example, run at three operations per second, resulted in erosion of only about one third that obtained on later tests run at two operations per minute. The results of these various tests indicated that the erosion rate under most conditions was doubled when the operating rate was reduced by a factor of ten. Laboratory tests are usually run at an accelerated rate, and unless proper compensation is made for this factor, such test results can yield overly optimistic results.

Evaluation of the effect on contact life of more or less known factors alone presents a rather complex problem. It is further complicated by some circuit conditions that can seriously affect contact life, but

* RECORD, *June*, 1954, *page* 226.

may not always be anticipated at the time the circuit is designed. Contact reclosures during a critical time period can result in unexpected energy dissipation, with consequent excessive contact wear. Grounding of leads charged to battery potential, or the dissipation of even higher-potential charges trapped on leads or networks can, on contact closure, also result in unexpected severe contact erosion. Such unfavorable circuit conditions are sometimes overlooked in the original contact engineering and their effect on contact life is usually disclosed by unsatisfactory reports from the field. The cause of short contact life in such cases is seldom apparent from circuit analyses, but is generally disclosed by laboratory study with the aid of an oscilloscope.

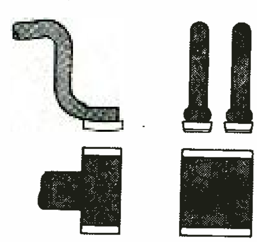


Fig. 5 — On wire-spring relays, two "twin - wire" contacts ensure good electrical connection using only a single "stationary" contact.

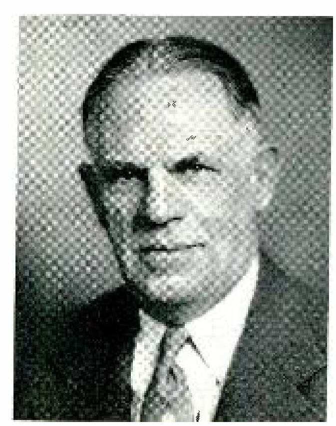
An awareness of the difficulty of reproducing in the laboratory a proper balance of all factors affecting contact life has led to the practice of verifying in the field the results of contact engineering efforts. Field contact surveys serve such a purpose. They are generally undertaken on new systems after an office has been in service a year or two. After a service period, it is usually possible to determine by visual inspection whether an over-all satisfactory life can be expected on relays in this type of office.

The primary purpose of a survey is to determine whether the rate of wear on relay contacts with severe loads conforms to the erosion rate obtained for similar loads in laboratory tests. Circuit design records will usually point out those contacts with the more severe circuit conditions and many operations. The secondary purpose of the survey is to find contacts on which excessive wear is occurring that was not anticipated at the time of the circuit design. Such contacts are generally disclosed by an examination of office trouble records, through discussions with maintenance personnel, or by examination of contacts in the more important circuits. The value of a contact survey is two-fold. It affords a comparison between field and laboratory contact performances, and is a practical medium for disclosing unsatisfactory contact conditions not anticipated in the original circuit design.

In view of the large number of relay contacts in a central office, it is impractical in a survey to examine all contacts. A large majority of contacts in a central office do not make or break current and therefore should not be subject to electrical erosion. Consequently, a survey is usually planned with the view of examining only "working" contacts that make or break current. Examination of the contacts is made with a ten-power glass and a concentrated light source, as in the illustration at the head of this article. A record is made of all contacts that show signs of wear, with the amount of wear estimated by the observer in thousandths of an inch.

Recorded results of these examinations are later used to compute life estimates for the respective contacts. A study of this record will point out cases of inadequate life which are then corrected, where possible, by design changes. Unsatisfactory contact conditions that do not lend themselves to simple design changes become a subject of study in the laboratory for possible corrective measures. The infrequent cases of contacts with inadequate life that would not be improved by the application of presently known design techniques are generally taken care of in the field on a maintenance basis.

THE AUTHOR



A. P. Goetze, a native of Finland, joined the Bell System with the Western Electric Company in 1922, a few years after receiving his E.E. degree from the University of Lausanne, Switzerland. Transferring to the Laboratories when it was organized, Mr. Goetze had been in the Switching Apparatus Development Department until his recent retirement. He had been concerned with relay design, contact metal studies and central office cost reduction studies.

Carrier-Frequency Transformers for P1 Carrier

DORIS RIBETT *Component Development*

In carrier telephone systems, miniaturization of components coupled with the use of transistors and other modern devices is expected to reduce the size and cost of terminals sufficiently so that carrier can be used economically between customers and a central office. Special carrier-frequency transformers developed for the new rural carrier system have achieved a substantial gain in miniaturization yet they permit wideband transmission.

To realize the design objectives of the P1 carrier system with its neat, compact, and inexpensive printed-wire circuitry, many apparatus components had to be especially adapted to meet highly restrictive space, mounting and cost requirements. Carrier-frequency transformers fall in the category of components that required entirely new designs.

These transformers handle frequencies in the band between 8 and 100 kc, and their use in the P1 System makes it possible to add 4 two-way conversations to the existing voice frequency over a single pair of wires. The transformers are used to match impedances for maximum energy transfer and to furnish isolation where needed. They are used in a variety of equipment, including the transmitting and receiving amplifiers, and in modulator, oscillator and regulator circuits.

As finally developed, the new carrier-frequency transformer structure conforms strictly to the P1-carrier requisites of small size and low cost. The structure is about half a cubic inch in volume and weighs only half an ounce. It has less than one-third the volume of a transformer structure designed some years ago for similar use in the N1 carrier system, Figure 2. Until now the N1 structure has offered the smallest and least expensive carrier-frequency transformer available. The final cost of a P1-carrier transformer is expected to be about two-thirds that of an equivalent N1-carrier transformer designed in accordance with the P1 electrical requirements.

This one new structure accommodates all the low-voltage carrier-frequency transformers required for P1 carrier with only minor variations in the windings. It consists, Figure 1, of a molded nylon spool on which the windings are wound, a manganese-zinc ferrite core made of two identical U-shaped pieces, a molded terminal-plate assembly and a cylindrical metal can.

The short, stubby wire terminals molded into the phenolic terminal plate are especially intended as mountings for the transformer in printed-wire circuitry. Although they are arranged in a circle to enclose the winding assembly, they are not spaced at equal distances around the circle. Instead, they lie on the intersections of a square grid, 0.2 inch on a side. This is the modular grid spacing that governs the location of all terminal connections on the P1-carrier printed-wire boards, in anticipation of pos-

In the illustration above, the author checks a transformer. This transformer indicated by the arrow, is dwarfed by the test equipment.

sible future automatic assembly and testing of the P1 equipment. The terminal circle is slightly eccentric to the center of the completely-assembled transformer. The eccentricity points up the importance of a fraction of an inch in a structure as small as this because, although the displacement is only 0.035 inch, it permits a 30-per cent larger transformer winding.

The basis of the design, and also one of its more novel features, is the cage-like arrangement of the terminals around the spool and winding assembly. A substantial reduction in size cannot be obtained, nor can full advantage be taken of the performance capabilities of the design, unless fine wire is used for the windings. To do this, a way must be found to minimize the danger of breaking the wire, particularly where the wire is brought out of the spool and over to the terminals. Most previous designs used either terminal leads – separate pieces of heavy wire connecting the fine wire of the winding with the terminals – or a somewhat heavier wire for the winding itself. Neither of these methods is conducive to size reduction, and the use of terminal leads would have had the added disadvantage of increasing the cost of this structure by about 25 per cent over current estimates.

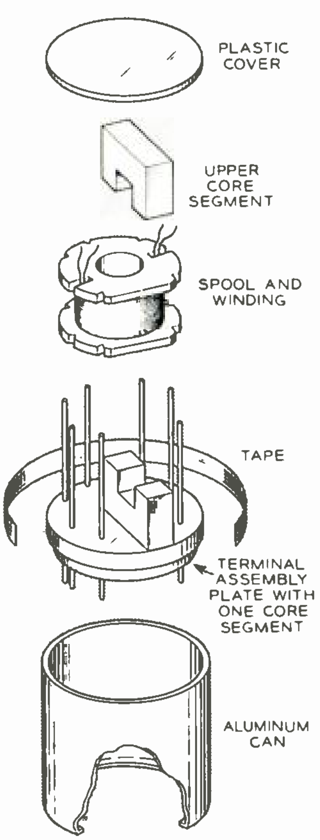


Fig. 1 — Exploded view illustrating the various components that make up the new carrier transformer.

Fig. 2 — F. J. Sweney compares the new transformer with its predecessor used in N1 carrier. Five of the new transformers can be seen on a P1-carrier printed-wire board.

In the new structure, short ends of the wire terminals extend from one side of the terminal plate for use in mounting the unit in equipment, while the other and much longer ends form a kind of wire cage on the opposite side of the terminal plate. The rims or heads on either end of the nylon spool on which the winding is wound are notched around their outer periphery to correspond to the terminal locations, so that the spool and winding assembly can be nested snugly within the cage-like structure without bending the terminals.

The order in which the various parts of the transformer are assembled is generally governed by manufacturing considerations. To demonstrate the method of using the cage-like structure, however, assume that the transformer is assembled as follows: one U-shaped core piece is first located in a positioning groove molded into the terminal plate. The spool and winding assembly is then inserted within the terminal cage with the terminals seated in their respective notches, and pushed down over a leg of the core piece. At this point, a band of pressure-sensitive tape is slipped over the terminals around the winding assembly and pulled tight to hold the terminals firmly against the spool. The notched spoolheads prevent rotational slippage of the winding with respect to the terminals, and the band of pressure-sensitive tape keeps the spool from sliding up and down inside the terminal cage.

Immobilization of the spool with respect to the terminals permits the fine wire of the windings to be brought through slots in the spoolhead nearest the open end of the terminal cage and wrapped directly around the ends of the proper terminals. With no motion between spool and terminals, there is no tendency for the wire to snap. Since the terminal ends extend beyond the spool, all winding connections can be made at once by dipping the terminal ends in molten solder. The assembly is completed by cementing the second U-shaped core piece to the first so as to form a rectangular core with the spool and winding encircling one leg.

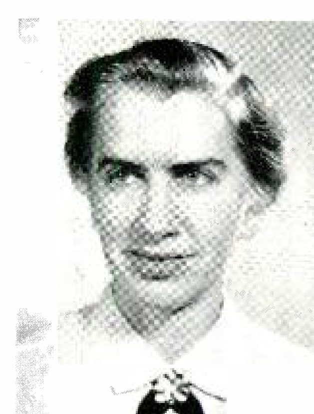
The completed cage assembly is dried, impregnated in wax, and potted in an asphaltic compound in an aluminum can, in accordance with inexpensive, proved procedures for moisture protection. For the first time on carrier-frequency transformers, an anodized finish is specified to provide electrical insulation between the terminal cage and the inside of the can. This finish is an aluminum oxide film on the surfaces of the aluminum can that is electrically formed in a sulphuric acid solution. It is only a few ten-thousandths of an inch thick but withstands up to several hundred volts. It is inexpensive, space-saving and eliminates the need for a separate can liner of insulating material.

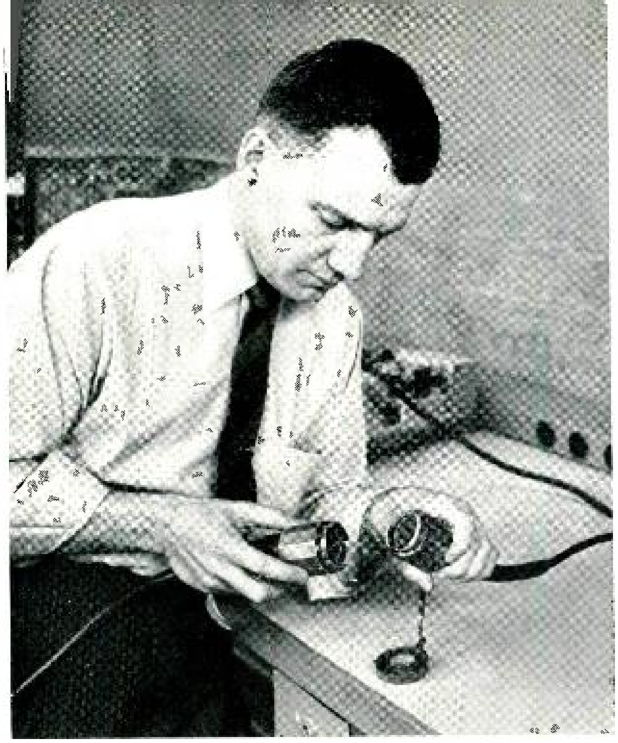
Small transformer windings offer certain problems. Large coils, using heavier wire and having layers of insulation between layers of wire, can easily be wound, a number at once, on a single long tube or arbor and then cut apart. After the coils have been separated the wire ends are fished out of each winding. This is usually done with a small probe, and fine wire is likely to be damaged or broken, especially if the winding is too small to handle easily. The P-transformers are designed with spool-type windings where the winding ends are brought out of slots in the spoolheads as the winding progresses, completely eliminating the "fishing" operation. Generally, spools are hand-wound one at a time. Windings for the P1-carrier transformers, however, are designed for automatic machine distribution of the turns so that it may be possible to wind more than one spool at a time.

Although this new carrier-frequency transformer structure was developed specifically for the P1 carrier needs, it is sufficiently versatile to perform satisfactorily in many diverse applications. For example, the P1 carrier transformers transmit a comparatively low-frequency band, but the structure should be equally suitable in the megacycle frequency range because its small size readily permits the design characteristics necessary for high-frequency transmission. In addition to broadband transmission, the high Q (figure of merit) obtainable with the ferrite core should permit the design of tuned transformers. In yet another field, the structure is being used for two pulse transformers in private-line teletypewriter switching units. One of the pulse transformers, used in a transistor circuit, transmits a 30-microsecond pulse; the other, operating in the plate circuit of a triode electron tube, transmits a pulse of only a few microseconds duration. In all probability, therefore, this structure will be used for many telephone applications where low cost and small size are required.

THE AUTHOR

Doris Ribett received a B.A. degree and certificate in mathematics from Barnard College, and joined the Laboratories in 1942. During the war years, she worked on audio frequency transformers for military applications and following the war she transferred to a group responsible for the design of carrier transformers. While in this group, she worked on the design of transformers for the N, O and P carrier systems as well as various types of test equipment. At present, she is working on the design of transformers for submarine cable systems.





Equalization of Military Carrier Telephone Systems

C. L. SEMMELMAN
Transmission Systems Development

In a transmission system, equalization is the correction of signal distortions caused by the unequal attenuation or amplification of some frequencies with respect to others. These departures from uniform transmission arise not only from the inherent characteristics of the cable and from temperature effects, but also from a variety of other sources. In each case, the correction requires careful engineering and design. Excellent equalization has been achieved in two Laboratories-developed military carrier telephone systems by the use of a combination of fixed and adjustable equalizers and temperature-compensating regulators.

The Laboratories has recently designed two carrier telephone systems for use by the Armed Forces as parts of a coordinated military communications network.* One of these is a four-channel system using a band of frequencies from 4 to 20 kilocycles per second, and the other is a twelve-channel system using a band of frequencies from 12 to 60 kilocycles per second. Both systems also transmit an additional channel at voice frequencies for maintenance (order-wire) purposes.

The two systems use the same "spiral four" cable – a four-conductor cable in which separate pairs of conductors are used for the two directions of transmission, as shown in the illustration above. As in all cable systems, signal strength decreases with transmission over a length of cable, and in addition, the higher frequency signals are attenuated to a greater extent than are the lower frequencies. Thus, it is necessary to "equalize" the system – to restore the gain characteristic to the desired "flat" condition.

* RECORD, *August*, 1955, *page* 290; *October*, 1955, *page* 382; *January*, 1956, *page* 21.

In the military carrier systems, this equalization is performed in three steps. First, the bulk of the equalization is accomplished by fixed equalizers, which are designed to equalize the received signal under standard conditions of cable characteristics and temperature. Second, since cable sections cannot all be manufactured absolutely alike and since many installations will require an amount of cable for which no fixed equalizer is available, adjustable equalizers are included to correct for such variations. Third, cable loss characteristics change when the temperature of the cable changes, and these variations are corrected by means of regulators.

This general plan of equalization applies to both the four- and twelve-channel systems, but there are several differences. Cable is supplied in quarter-mile lengths, and in the four-channel system, loading coils are inserted at each point where two lengths are joined. "Loading" the cable with inductors in this manner reduces loss and distortion. The twelve-channel system, however, does not use loading coils, since they would be impracticable with the wider range of frequencies. For this and other reasons, the equalizers and regulators required are quite different in the two systems.

In the twelve-channel system, the maximum amount of cable allowed between amplifiers is limited by crosstalk to 5.75 miles. Unattended repeaters are therefore spaced at this distance. As many as six unattended repeaters may be used between two terminals or between attended repeaters. Thus the cable loss characteristic to be equalized at each repeater or terminal is that of 5.75 miles of cable. A "basic" equalizer is used for this purpose, and its effect on the gain-frequency characteristic of a 5.75 mile span can be seen in Figure 1. In this illustration the central or cable-loss curve shows the greater attenuation in the higher-frequency portion of the band. The basic equalizer curve at the bottom is complementary to the cable-loss curve, so that the sum of the two curves is the essentially flat curve at the top. (A magnified scale is used for the top curve to show minor deviations.)

Deviations from the true flat characteristic could have been reduced by using a larger and more expensive basic equalizer, but size, weight, and cost would have been prohibitive. Instead, the accumulated distortion from a number of 5.75-mile cable spans is corrected by a "deviation" equalizer located at each attended repeater and terminal.

Attended repeaters and terminals must of course be placed in militarily advantageous positions, which will seldom coincide with the end of a 5.75-mile span. For this reason, another type of equalizer, called a "building-out" network, is provided to avoid stacking many reels of cable at the terminal or repeater. This network is used to insert additional loss to simulate the missing cable, and is adjusted in steps to simulate any cable length up to 5.75 miles within ¼ of a mile. The ¼-mile deviation is tolerable because it is further reduced by adjustable equalizers that will be described later.

Temperature change is the next variable that must be dealt with, and the regulator used for this purpose employs a thermistor ("thermally sensitive resistor") — an element whose resistance changes widely with small changes of temperature. Each unattended repeater of the twelve-channel system employs a regulator in which the thermistor resistance is automatically controlled by the ambient air temperature and is used to compensate for cable variations with temperature. Figure 3 shows the thermally sensitive behavior of this regulator.

At the attended repeaters and terminals, however, a somewhat different scheme is used. Above the 60-kc upper limit of the band of message channels, a 68-kc "pilot signal" is transmitted. The strength of this signal will be affected both by temperature changes in the cable and inaccuracies in unattended repeater regulation. At each attended repeater and terminal, the strength of this received pilot signal is used to adjust the temperature and resistance of another thermistor. This controls the loss of a regulator which corrects for almost all of the residual temperature effects up to that point.

Distortion from several other sources will also be present. As mentioned earlier, for example, unavoidable variations in cable manufacturing processes are one source of distortion. Also, in very long systems, the automatic temperature regulation may not be sufficiently accurate. Further, in some tactical situations it may be necessary to operate the system over lines other than the spiral-four cable for which it was designed. Each of these three factors can cause gain-frequency distortion of unknown and unpredictable shape and magnitude. For this reason, the adjustable equalizers required to compensate for such distortion must be capable of equalizing almost anything.

It is well known in mathematics that almost any curve, no matter how complex, can be approximated by adding a number of more elementary curves obtained from simple equations. The analysis of a complicated wave form into a fundamental fre-

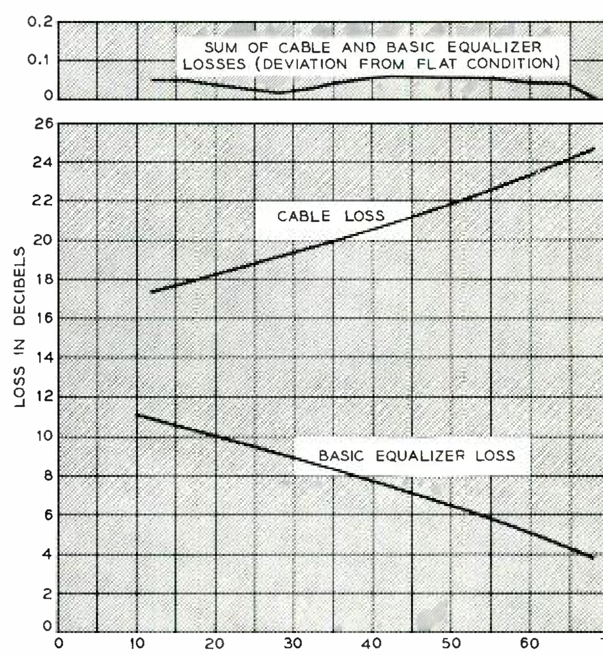


Fig. 1 — Effect of basic equalizer on the cable loss characteristic of the twelve-channel system.

quency and its harmonics is a familiar example of this process. The mathematical expression called a "power series" may also be employed. Usually, the first few terms of such a series will also approximate any required curve.

The power series method can be used as a tool for designing equalizers that are adjustable to match

Fig. 2 — The author adjusting an equalizer.

a non-predictable shape. The terms of the series, beginning with the first, yield a sequence of equalizer "shapes" — a constant, a sloping straight line, a parabola and, for the subsequent terms, more complex curves.

This is a straightforward mathematical process, but its use in the two military systems depended upon three additional requirements. First, the person adjusting an equalizer must have an indication that tells him when the controls are properly set. A test tone is therefore used, and the output level of this tone, as read on a meter, is used in finding the correct equalizer setting. Second, when two or more equalizers are used, they must be so designed that adjusting one will not make it necessary to readjust another. Third, the adjustable equalizers must of course have no effect on the pilot tone at 68 kc, because this would be mistaken by the temperature regulator as a temperature change. Thus, the constant term of the power series is not used for field adjustment. It turns out that only the linear and parabolic terms are needed, and each is arranged to produce zero loss change at 68 kc. The linear or "slope" term pivots on 68 kc and swings through a range of values in the low-frequency end. The parabolic or "bulge" shape pivots on two frequencies, 12 kc and 68 kc.

A complete 200-mile, twelve-channel system contains two terminals, four attended repeaters, and thirty unattended repeaters. Transmission over this system can be made flat with frequency to well within ±3 db for at least a 30°F temperature change in any portion of the —30° to +130°F region. Five such 200-mile systems can be connected in tandem to form a multi-link circuit which meets the established performance standards for Bell System long-distance circuits.

By contrast with the twelve-channel system, the four-channel carrier system is intended for use in forward areas where lighter traffic and shorter transmission distances are expected. Cable loss per mile is lower than with the twelve-channel system, because of the lower range of frequencies and the use of loading coils. Repeaters can therefore be placed 25 miles apart, or even 35 miles apart under special circumstances. Many short systems will not need any repeaters, and longer systems will have only

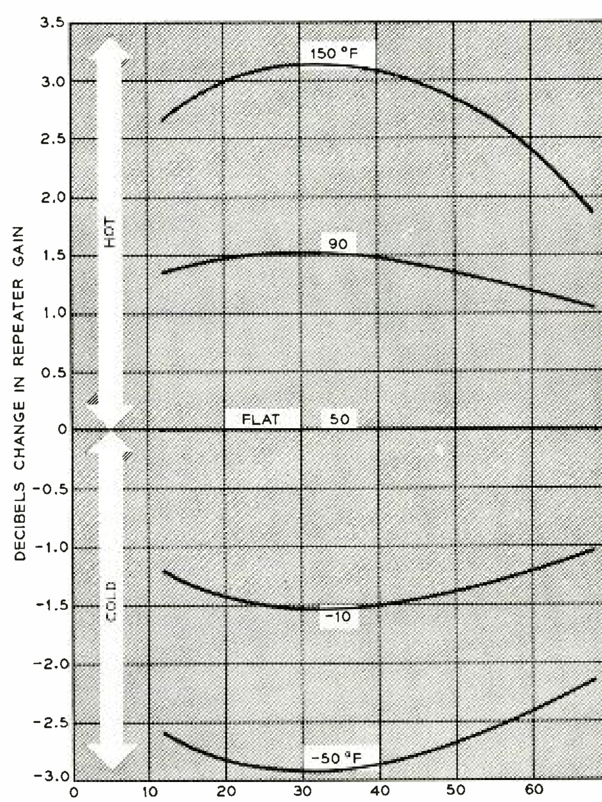


Fig. 3 — Regulator characteristics which compensate for temperature changes; curves are the inverse of change in cable loss with temperature.

attended repeaters. As a result, no fixed spacing comparable to the 5.75 miles of the twelve-channel system can be expected. For this reason, it was not possible to design a fixed equalizer comparable to the "basic" equalizer of the twelve-channel system.

In addition to temperature regulation, therefore, the four-channel system needed equalization to correct for variations in cable length. Figure 4 shows a number of calculated loss curves over the 20-kc range, for different lengths of cable and different temperatures. The shapes of these curves suggest how equalization may be accomplished. It should be noticed that if we change the length of cable, the loss curve shifts up or down on the scale with not too much change in overall shape, at least over the 1 kc to 10 kc region. This is also true for changes in temperature. Thus, below 10 kc a "flat" adjustable equalizer compensates approximately for changes both in cable length and temperature. Actually, the "flat" equalizer is flat above 1 kc and equalizes cable loss down to 300 cps. A 1-kc test tone (in the order-wire channel) is used in lining up the system or in correcting for temperature changes.

Above 10 kc, however, we notice in Figure 4 that the loss curves begin to turn upward rather sharply. To correct for this increased attenuation, an adjustable "slope" equalizer is used. It is adjusted by means of a 19-kc signal transmitted over the cable and used at the receiving point to correct the transmission level at this frequency. The adjustment does not change the response of the system at 1 kc. These "flat" and "slope" equalizers perform the functions of the basic equalizer, the building-out network, the temperature-compensating regulators, and the slope equalizer of the twelve-channel system.

Finally, the four-channel system also includes a "bulge" equalizer to compensate for manufacturing deviations in the cable and to permit the use of the system over other types of cable or even over open wire. The "bulge" equalizer is similar in function to the bulge equalizer of the twelve-channel system; it is adjusted to result in a variety of bulge shapes pivoting on 1 kc and 19 kc, and is adjusted with an 11 kc tone.

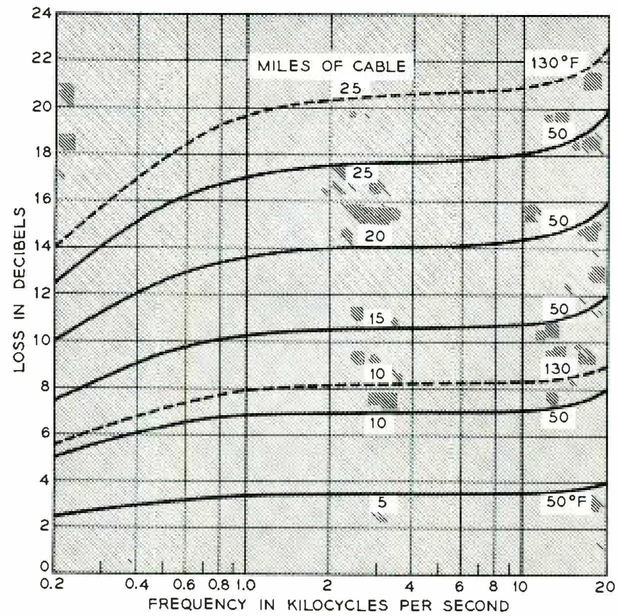


Fig. 4 — Calculated loss curves, over 20-kilocycle range, of loaded cable used in four-channel system, for different cable lengths and temperatures.

The system of equalization is sufficiently accurate that when a 25-mile, four-channel system in lined up at any temperature in the —30° to +130°F range, transmission will be flat to within ±0.5 db across all the carrier bands. Because temperature regulation is not automatic in this system, large temperature changes require manual adjustments. For ±15°F changes, however, transmission remains within ±1.5 db of flat. Thus the transmission quality is comparable to that of the twelve-channel system and to long-distance Bell System circuits.

THE AUTHOR

C. L. Semmelman received the B.S. in Physics and the B.E.E. degrees from Ohio State University in 1939. After an additional year of graduate work at Ohio State, he joined the Laboratories in 1940, where he was initially engaged in the design of equalizers for television systems. During the war years he was engaged for a time in work on power transformers for radar systems, and then entered the services as a reserve officer for four years' duty with the Signal Corps. Following his return to the Laboratories in 1946, Mr. Semmelman was concerned with experimental work on filters for the Nike system, with filters and equalizers for the twelve- and four-channel military telephone systems, and with equalizers for the A2A local video system. More recently, he has been concerned with exploratory work on equalizers in the 70-mc frequency band and with programming computers for network calculations.

Engineering Societies Hold Joint Conference Over Transatlantic Cable

M. S. Coover, right, opens the joint conference. Other speakers are from left: Dr. M. J. Kelly, T. F. Gleichmann, BTL; J. S. Jack, Long Lines; and H. A. Lewis, A. N. Lebert, and E. T. Mottram, BTL.

Dr. M. J. Kelly joined with other members of the Laboratories, representatives of the British General Post Office and the Canadian Overseas Telecommunication Corporation in a three-way conference carried over the transatlantic telephone cable on January 24. Links through the cable and over land lines joined the Winter General Meeting of the A.I.E.E. in New York City, the Engineering Institute of Canada in Montreal and the Institution of Electrical Engineers in London. Speakers in New York, Montreal and London were heard over public address systems in all three locations.

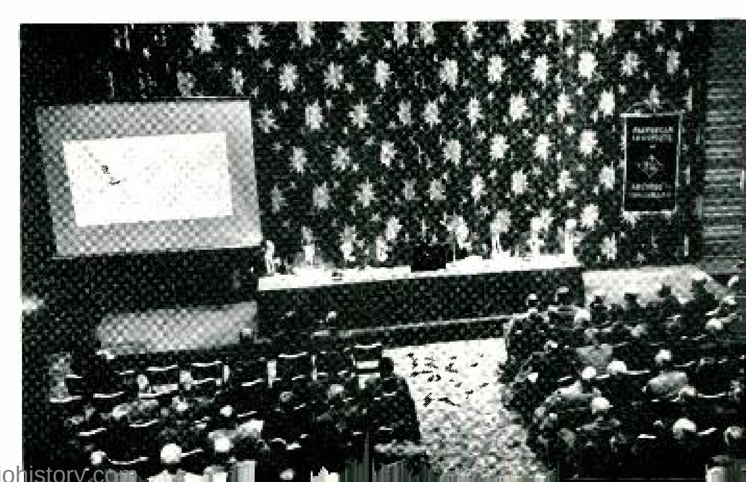
Presidents of the three engineering societies, M. S. Coover of the A.I.E.E., V. McKillop of the E.I.C. and Sir Gordon Radley of the I.E.E. opened the three-way, hour-long conference. After an introductory address by Dr. Kelly, the following scientists and engineers from the United States, Canada and Great Britain spoke on the design, engineering and manufacture of the cable:

R. J. Halsey, Assistant Engineer in Chief of the British General Post Office; E. T. Mottram, Director of Transmission Systems Development at the Laboratories; R. G. Griffith, Chief Engineer of Canadian Overseas Telecommunication Corporation; Capt. W. H. Leech, Submarine Superintendent of the British Post Office; J. S. Jack, Long Lines Department of the A.T.&T. Company; H. A. Lewis, Director of Outside Plant Development; A. W. Lebert of the Outside Plant Development Department; T. F. Gleichmann of the Transmission Systems Development at the Laboratories; and R. A. Brockbank of the British Post Office.

Following these talks, brief addresses were delivered by Sir Archibald Gill, former Engineer in Chief of the British Post Office; T. W. Eadie, President of the Bell Telephone Company of Canada; D. F. Bowie, President of the Canadian Overseas Telecommunication Corporation; and C. Lawton, General Plant Engineer — International Communications, Western Union Telegraph Company.

During the conference, authors of other technical papers on various aspects of the cable were also introduced to audiences in the three countries.

Below, left, some members of the Laboratories who delivered papers at the meeting: Second row, H. A. Affel; first row from left — H. B. Fischer, J. O. McNally, E. A. Veazie, F. J. Braga, J. W. Emling, R. S. Tucker, M. C. Wooley, J. M. Fraser, M. C. Biskeborn, H. H. Spencer and G. W. Meszaros. Below, right, Grand Ballroom of the Hotel Statler in New York City during the transatlantic joint conference.



President F. R. Kappel Describes Need for Three-Dimensional Engineers at A.I.E.E. Winter General Meeting

Frederick R. Kappel, president of the American Telephone and Telegraph Company, said recently that business needs "three-dimensional" engineers and that business can do much to help develop such engineers.

In a talk before the Winter General Meeting of the American Institute of Electrical Engineers on January 21, Mr. Kappel said, "The first dimension we'll say is what you got in college, that showed you how to move in a straight line in your first particular field. The second dimension is in continued training and self-study, that broadens a man – or a woman – and keeps him up-to-date with technological changes so he can solve problems in broad areas and new areas of engineering.

"The third dimension is the height that comes from the mixing and mingling of engineering and management ideas, so that the engineer's understanding of the problems and requirements *of* the business makes him more effective *in* the business. This understanding comes not only from study but from shoulder-to-shoulder association and contact and interaction between engineering, operating, financial and merchandising people. And we need this third dimension not here and there among engineers but everywhere – so they will have a volume effect on the business. If engineering is to be solid, it's got to have this volume."

"Industry can contribute much, especially to the second and third dimensions," Mr. Kappel stated. He said that putting engineers in compartments and shutting them off from the rest of the ship will not produce the engineers industry is looking for to take on responsible management jobs.

"In this dynamic and expanding world," he said, "the competent engineer has to lead a dynamic and expanding life. In my judgment there is simply no room left for any routine approaches to engineering, or for standing still with the mental equipment we've got. The engineer has to grow and change with the times and constantly equip himself to handle new problems. He has to nourish his mind and broaden his outlook to make sure that neither gets obsolete.

"Obviously we need the most in creative imagination, ability to take on new assignments, and selective judgment. I think the growing tendency in the schools to concentrate on fundamentals is very helpful to this, because the first need is to develop the basic mental equipment. There remains to industry the great responsibility to provide not only first-rate technical training but also to make sure the able engineer never gets locked in his technical closet.

"To be sure, he always remains an engineer, with a sound grasp of engineering fundamentals that never grow obsolete. But he also becomes something more. As he applies ever-changing arts he is also thoughtful of their effects. He gains and uses knowledge of marketing and finance. He interprets between designer and salesman. He perceives and understands the general wants and particular problems of other people, whether he holds a supervisory position or not."

"The Bell Companies," Mr. Kappel said, "are attempting to provide engineers with full opportunity for education and growth. Special training courses have been set up within the Bell System and in certain cases tuition is paid by the companies for study in colleges and universities.

"Over the next ten years we foresee that more than 80,000 Bell System people – engineers included – will be moving into new positions in management. In the same ten years we shall be going a long, long way in the transformation of our physical telephone system. New art and new applications will bring new convenience in service and new forms of service. In fact we expect the time is coming when we'll be able to communicate anything you want in just about any way you want, and over any distance, long or short. With people changing, management changing, technology changing, and service changing, it is unthinkable not to use every means in our power to improve our competence and at the same time our understanding of the world around us and our place in it.

"Because of the effort we're making," he pointed out, "we're getting a wonderful amount of fine engineering work done that otherwise could never have been done so soon or so well. More than that, with a wider appreciation by other people in management of the engineer's contribution, I'm confident we're getting a better team and a better over-all job. And I am equally confident that our engineers are profiting in prestige, promotion, and salary rewards as a result."

Ben S. Gilmer Elected President of Southern Bell

Ben S. Gilmer was elected president of the Southern Bell Telephone Company effective January 1. He succeeds Fred J. Turner, who was elected Chairman of the Board of Directors.

Mr. Gilmer, a native of Montgomery, Alabama, has had extensive experience in a variety of telephone jobs. He joined the Bell System in 1926 after being graduated from Alabama Polytechnic Institute. His first assignments were in plant and commercial departments. In 1942, he entered military service with the Army Air Force and became a lieutenant colonel. On returning from the Air Force, Mr. Gilmer worked in Southern Bell's general offices as general development and revenue engineer, and as assistant vice president before becoming Louisiana commercial manager with headquarters in New Orleans.

In 1950, he was appointed Southern Bell's general commercial manager, and in 1952 was elected vice president of the Northwestern Bell Telephone Company. He directed operations in the Minnesota area of that Company until his election to the vice presidency of the Pacific Telephone Company in 1953. He was vice president in charge of the California operations of that Company when he was elected operating vice president of Southern Bell in early 1956.

Mr. Turner, who has been president since 1951, has headed Southern Bell during its period of greatest growth. The Company now serves nearly 5½ million telephones in 1,070 communities in nine southern states and has almost 70,000 employees.

M. H. Cook Elected Vice President of Sigma Tau

Vice President M. H. Cook was elected Vice President of Sigma Tau, all-engineering honor society at its recent meeting in Boulder, Colorado.

Mr. Cook has served the group on the National Council since 1952 and from 1928 to 1938. Sigma Tau, with 31 chapters, recently celebrated the 50th anniversary of its founding at the University of Nebraska. Mr. Cook is a member of the Theta Chapter at the University of Illinois.

Patents Issued to Members of Bell Telephone Laboratories During November

Anderson, W. A., and Harrison, C. W. – *Saw-Tooth Generator* – 2,771,556.

Black, H. S. – *Reduction of Interference in Pulse Reception* – 2,769,861.

Brown, J. T. L., and Pollard, C. E., Jr. – *Mercury Contact Switch* – 2,769,875.

Dalton, J. F., Fisher, C. A., and Turnbull, W. G., Jr. – *Snap Switch* – 2,770,692.

Dudley, H. W., and Harris, C. M. – *Synthesis of Speech from Code Signals* – 2,771,509.

Fischer, C. A., see Dalton, J. F.

Fuller, C. S. – *Method of Fabricating Semiconductors for Signal Translating Devices* – 2,771,382.

Gardner, L. A., and Hysko, J. L. – *Carrier Telegraph Switchboard Supervisory System* – 2,770,670.

Harris, C. M., see Dudley, H. W.

Harrison, C. W., and Nielsen, G., Jr. – *Power Amplifier for Television* – 2,771,517.

Harrison, C. W., see Anderson, W. A.

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

King, J. H., and Kleinfelder, W. C. – *Splice Closure for Sheathed Cable* – 2,771,502.

Kleinfelder, W. C., see King, J. H.

Mattke, C. F. – *Non-Intermittent Projector for Motion Picture* – 2,770,163.

Meszaros, G. W. – *Current Supply Apparatus* – 2,771,576.

Mumford, W. W. – *Non-Reciprocal Wave Transmission Networks* – 2,769,960.

Nance, R. C. – *Routine Trunk Test Circuit* – 2,771,519.

Nielsen, G., Jr., see Harrison, C. W.

Parks, C. O. – *Time and Traffic Controlled Trunking System* – 2,769,846.

Pfann, W. G. – *Semiconductor Translators Containing Enclosed Active Junctions* – 2,770,761.

Pollard, C. E., Jr., see Brown, J. T. L.

Schott, J. T. – *Test Probe* – 2,771,580.

Shockley, W. *Negative Resistance Device* – 2,772,360.

Stansel, F. R. – *Negative Impedance Transistor Circuits* – 2,769,908.

Thomas, D. E. – *Frequency-Controlled Transistor Oscillators* – 2,771,584.

Turnbull, W. G., Jr., see Dalton, J. F.

Talks by Members of the Laboratories

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

FIFTH ANNUAL SIGNAL CORPS WIRE AND CABLE SYMPOSIUM, ASBURY PARK, N. J.

Jahn, A. P., *C Rural Wire.*

Lanza, V. L., *The Effect of Radiation on Polyethylene.*

Lundberg, C. V., see Vacca, G. N.

Vacca, G. N., and Lundberg, C. V., *Aging of Neoprene in a Weatherometer.*

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, NEW YORK CITY

Arnold, S. M., see Treuting, R. G.

Hamming, R. W., *Harnessing the Digital Computers.*

Morin, F. J., *Diffusion in Semiconductors.*

Pfann, W. G., *Growth of Single Crystals of Germanium and Silicon.*

Treuting, R. G., and Arnold, S. M., *Growth and Structure of Spontaneous Whiskers.*

OTHER TALKS

Augustyniak, W. M., see Bemski, G.

Bemski, G., and Augustyniak, W. M., *Annealing of Electron Bombardment Damage in Silicon Crystals*, American Physical Society, Monterey, Cal.

Bogert, B. P., *Bandwidth Conservation Techniques*, Dept. of E.E., University of Wisconsin, Madison, Wis.

Bozorth, R. M., *Scientific Visit to Russia* and *Domain Structure of Magnetic Materials,* Reed College, Portland, Ore.; *Russian Research Activities: Magnetism*, Endicott House, Massachusetts Institute of Technology, Dedham, Mass; *Visit to Russian Conference on Magnetism*, Pacific Telephone and Telegraph Company, Portland, Ore.

Brattain, W. H., *Physics of Semiconductor Surfaces,* Royal Swedish Academy of Sciences, Stockholm, Sweden, and Societe Française de Physique, Sorbonne, Paris, France; *Demonstration Lecture on Circuit Aspects of Transistors,* Royal Academy of Engineering Sciences, The Society of Electrical Engineers and the Society of Technical Physics in a Joint Meeting, Stockholm, Sweden; *Simpler Semiconductor Circuits,* Neils Bohr Institute, Copenhagen.

Braunwarth, W. W., and Taylor, R. H., *Industrial Supervisory Techniques,* Rutgers University, New Brunswick.

Burger, M. J., *Using Electronic Computers,* Joint Student Branch Meeting A.I.E.E.-I.R.E., Notre Dame University.

Burke, P. J., *Some New Developments in Queuing Theory,* Twelfth Annual Princeton Conference, Metropolitan Section, American Society for Quality Control, Princeton University, Princeton, N. J.; *The Output of a Queuing System,* Seminar on Mathematical Statistics, Columbia University, New York City.

Buschert, R. C., Geib, I. G., and Lark-Horovitz, K., *Electrical and Structural Investigations of Liquid Semiconductors,* Symposium on Structure of Liquid and Vitreous Materials, Southside Chemical Conference, Memphis, Tenn. (Messrs. Geib and Lark-Horovitz are from Purdue).

David E. E., *Perception and Coding of Auditory Information*, Physics Colloquium, Harvard University, Cambridge.

Deutsch, M., *Experiments on Trust*, Psychology Club, Brooklyn College, Brooklyn, N. Y.

Dudley, H. W. *Speech Production by Human and Electronic Methods,* New Jersey Division, New York Section A.I.E.E., Arnold Auditorium, Murray Hill, N. J.

Feinstein, J., *Status of the Coaxial Magnetron*, AGET-MW High Power Tube Conference, Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Mass.

Githens, J. A., *The Tradic Leprechaun Computer*, Eastern Joint Computer Conference, New York City.

Hamming, R. W., *Bell Telephone Laboratories Use of the IBM-650's*, IBM Engineering Executive Class, Poughkeepsie, New York.

Harvey, F. K., *Speech, Hearing and Music,* Engineers' Club of the Lehigh Valley, Packard Laboratory, Lehigh University, Bethlehem, Pa.

Hough, R. R., *Problems and Progress in Guided Missiles,* Harvard Engineering Society, New York City.

Hutson, A. R., *Semiconducting Properties of ZnO,* American Physical Society, Monterey, Cal.

Irvin, H. D., *Customers' Preferences and Telephone Systems,* Men's Club, Westfield Presbyterian Church, Westfield, N. J.

Kompfner, R., *Recent Advances in Microwave Tubes,* Boston Chapter I.R.E. Sylvania Electric Products, Inc., Boston.

Koontz, D. E., *The Role of Research Chemistry in Electronics,* Chemistry Department Seminar, University of Tennessee, Knoxville, Tenn.

Kramer, H. P., *A Generalized Sampling Theorem*, American Mathematical Society, Rochester, N. Y.

Lovell, C. A., *Mechanized Logic and Some Applications,* Student Branch of A.I.E.E., Louisiana State University, Baton Rouge, La.

McDavitt, M. B., *Transatlantic Submarine Telephone Cable*, Massachusetts Institute of Technology Club, Northern New Jersey, East Orange, N. J.

Pierce, J. R., *Information Theory and Writing*, Dinner of Technical Writers and Editors Association, Boulevard de Paris, New York City.

Raisbeck, G., *The Bell Solar Battery*, Stamford Engineering Society and the Southwestern Connecticut Section of the Optical Society of America, Norma Hoffmann Bearings Corporation, Stamford, Conn.

Riesz, R. R., *Human Engineering*, Western Electric Engineering Symposium, Western Electric Company, Winston-Salem, N. C.

Talks by Members of the Laboratories, Continued

Rose, D. J., *Some Recent Advances in Gaseous Electronics,* Physics Colloquium, University of Washington, Seattle, Wash., also at the University of British Columbia, Vancover, B. C., Canada.

St. John, G. E., *Microwave Amplification and Noise,* Physics Department Colloquium, University of Toronto, Toronto.

Schelkunoff, S. A., *Conversion of Maxwell's Equations Into Generalized Telegraphist's Equations,* Colloquium, University of California, Berkeley, Cal.

Schimpf, L. G., *Transistor Circuits High Frequency Design Considerations,* A.I.E.E. Basic Science Group, Western Union Auditorium, New York City.

Suhl, H., *Some Novel Aspects of Ferromagnetic Resonance,* Microwave Colloquium, Columbia University.

Tanenbaum, M., *Semiconductors – A New Insight Into Solid State Chemistry,* Maryland Section, American Chemical Society, Johns Hopkins University, Baltimore, Md.

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