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THE COVER: Alfred Fox of the Metallurgical Research Department applies load weights to a lead alloy specimen being tested for creep—the effect of steady, prolonged stress. Some of the samples in this temperature-controlled laboratory have been under constant test for twenty years. (See opposite page.)

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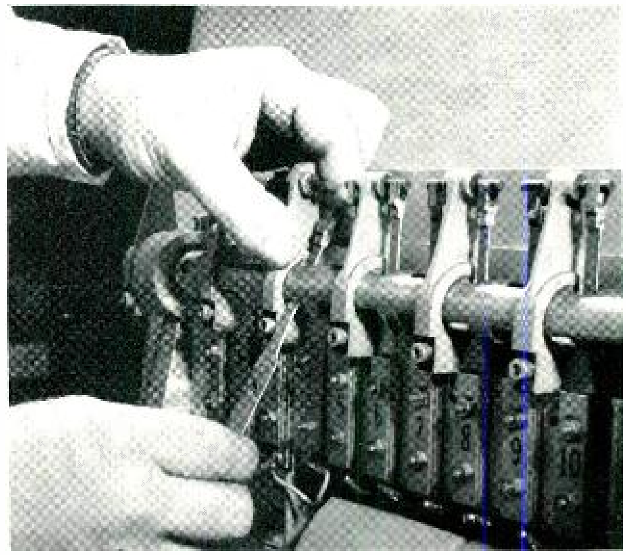
Fatigue, Creep, and Relaxation in Metals



G. R. GOHN *Metallurgical Research*

The inevitable deterioration of metals can be divided broadly into two types — actual physical wear and loss of initial strength or properties. The first type of deterioration, primarily due to friction and corrosion, can be prevented by controlling the design and operating environment of the metal parts, or by coating or lubrication. How long a material retains its initial properties however is something inherent in the particular base metal or alloy. Fatigue, creep and relaxation are indications of how well-suited a metal is to the operating stresses it will encounter in a particular application.

Our aim in the Bell System is to provide the best possible telephone service at all times. To achieve this aim, we must design and build telephone apparatus and equipment that will give long trouble-free service throughout a life expectancy of as much as 40 years. Unfortunately, various deterioration processes are continually operating to reduce the service life. If these processes are not properly evaluated and compensated for, premature failure of valuable equipment may occur.

The principal causes of failure of metallic parts are corrosion, wear, fatigue and creep. Corrosion depends primarily on the chemical constituents of the materials and environment. Wear is a problem of machine design and lubrication. Fatigue is the behavior of a material under repetitive stress and is the decisive factor in the life of many machines; it causes more than 80 per cent of the failures in machine elements. Creep is the behavior of a material under continuous load. While important at room temperature only in special applications, creep becomes more decisive as the operating temperature or load increases. One result of creep – relaxation – is also of interest in certain applications of interest to the telephone industry.

Fatigue in metals, like fatigue in people, results from repeated stresses. Such stresses exist in springs, diaphragms, rotating shafts, structures that are alternately loaded and unloaded, and in apparatus subjected to shock or thermal changes. Although the phenomenon of fatigue has been recognized for more than one hundred years, comparatively little study was done on the subject until the late 20's, and that mostly in Europe. At that time, the Engineering Foundation under the leadership of the late Frank B. Jewett, former president of Bell Telephone Laboratories, initiated a scientific study of fatigue. Much has since been done by many investigators to explain the causes of fatigue and to develop mechanical designs with greater life expectancy. Only recently, however, have physical metallurgists and research statisticians offered what appears to be a plausible explanation of fatigue.

It now appears that fatigue is usually associated with the progressive strain-hardening of the material, particularly in areas of high stress concentrations. Strain-hardening is familiar to anyone who has repeatedly bent or stressed a piece of metal and found that it offered more and more resistance as the bending continued. When repeated stress

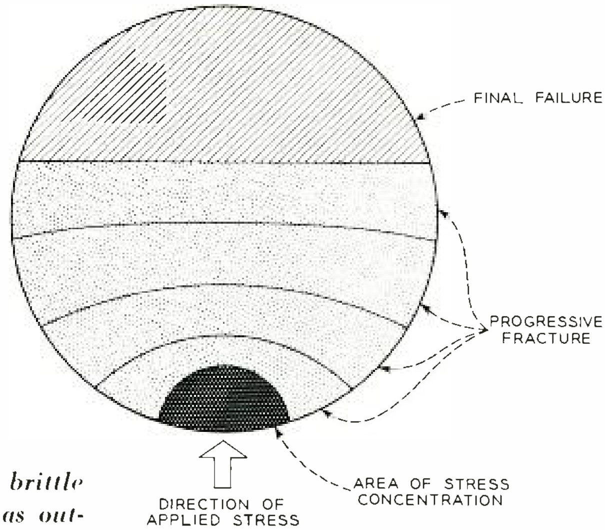


Fig. 1 — Photomicrograph shows typical brittle crystalline fracture at origin of failure as outlined in cross section drawing at the right.

is applied to a metal piece, such as the automobile axle of Figure 1, stress is concentrated in certain areas rather than being evenly distributed. This may lead to overstressing in some areas, starting a small crack. The corresponding reduction in area produces higher stresses; under repeated stressing, the crack increases progressively to the point where the cross-section of the part can no longer carry the load. Sudden failure then occurs without advance warning. The failure is usually characterized by a nonductile, crystalline-appearing fracture in which the failure path ignores crystal boundaries, Figure 2. This type of fracture is the hallmark by which fatigue failures of most metals except lead can be identified upon detailed metallographic examination of the piece.

While the preceding example will explain many fatigue failures, it has been observed that certain cold-worked materials, such as copper, lead alloys, and aluminum, soften to a degree during cyclic stressing and that areas of lower hardness develop at or near the point of failure. The strain-hardening theory does not adequately explain this phenomenon, which may be associated with recrystallization or thermal effects.

In a few instances where data are available on similar alloys, the fatigue properties of a material can be determined from a knowledge of the chemical composition and the tensile properties. Since fatigue strength is an independent mechanical property of a material, however, the precise fatigue properties required for engineering design must usually be determined by laboratory tests made on carefully machined specimens. A typical specimen used to determine the bending fatigue properties of metal sheets and strips is a tapered cantilever beam. This specimen simulates in size and shape the springs used on many flat-type relays. Some fatigue studies on lead-alloy cable sheath make use of specimens designed on the same principles of size and shape simulation.

Fatigue specimens are tested to failure by repeated bending at various initial stress levels, as shown in the headpiece. This machine automatically counts the number of bends and records failures. The results of tests on 5 per cent tin bronze, a material widely used in the manufacture of telephone apparatus springs, are shown in Figure 4. The maximum value of the repeated stress is plotted against the average number of

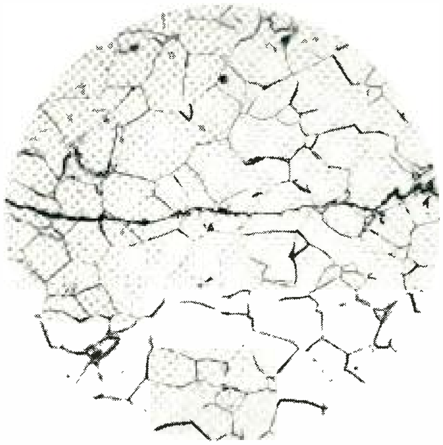


Fig. 2 — Nonductile transcrystalline fracture is characteristic of metal failures due to fatigue.

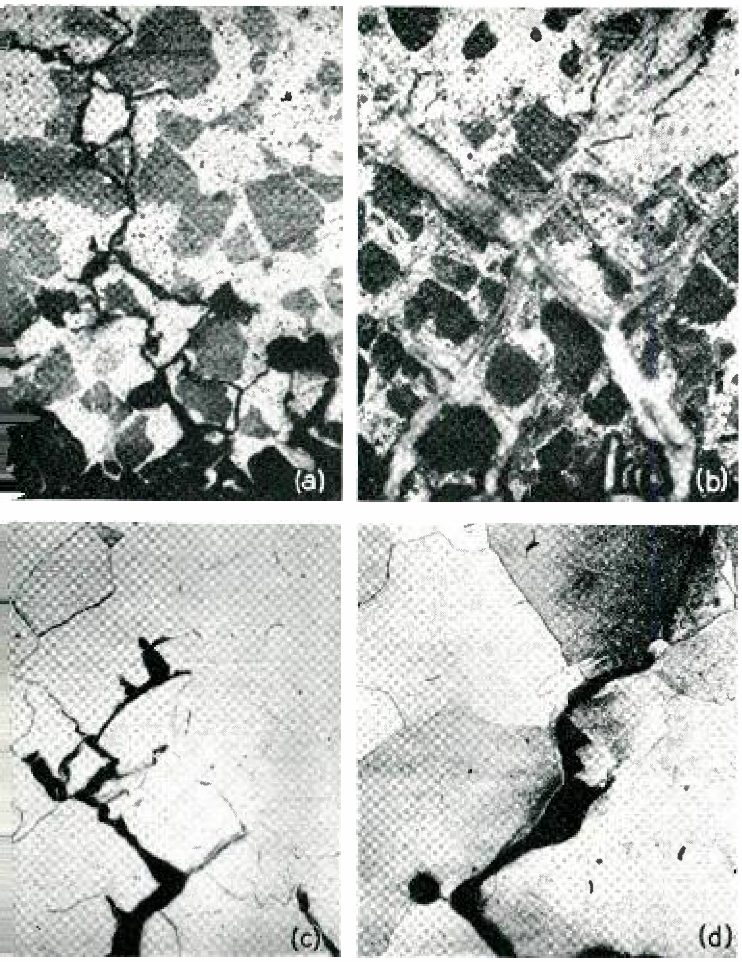


Fig. 3 — Slow cycle-rate failure of lead-1 per cent antimony cable sheath is shown in a laboratory-produced failure (a), and a field failure of experimental cable after eight years of service (b). High cycle-rate failure of lead and 0.010 per cent silver alloy sheath is shown in (c), a laboratory test-to-failure, and (d), a failure in cable sheath from a reel of cable shipped across the continent by rail.

stress cycles required for a failure to take place.

At high stresses but at values well below the tensile (breaking) strength, and usually below the proportional limit, failure occurs after only relatively few cycles. At lower stresses, a point is reached at which no failure occurs, even after an almost infinite number of cycles. In the past, one hundred million cycles has been considered as a satisfactory end point for spring materials used in Bell System relay designs. When the introduction of crossbar switching systems and the subsequent need for more relay operations extended the life requirement, one hundred million cycles was no longer sufficient. Today, with wire-spring relays designed for a life of forty years, one billion cycles would be a more representative end point.

In the telephone plant, fatigue failures have been observed in diaphragms, relay springs, terminal leads, coil springs, rotating shafts, open-wire lines, cable sheaths, and other parts. However, our studies on fatigue have given us a better knowledge of the fatigue properties of the commonly used engineering materials and of ways to eliminate many factors that raise stresses and start fatigue failure.

Machine switching, because of the increased demands on the relays, made spring failure a problem. Changing the spring material from brass to nickel silver or phosphor bronze resulted in longer life since these two materials have higher fatigue strengths. Voids and inclusions of nonmetallic particles were reduced through better manufacturing processes and controlled by the use of more definitive raw material specifications, eliminating many factors that increase localized stresses. Fatigue failure has been further reduced by changes in manufacturing processes to produce finer-grained materials, by the elimination of stress-raisers such as tool marks or die stampings in highly stressed areas, by more careful adjustment of springs in the field to avoid nicking, and by designing the springs within safe stress limits established from various test procedures.

Fatigue failures in open-wire lines have been caused by vibrations set up by winds or road shocks. Although a high-pitched humming sound can sometimes be heard from open-wire lines in windy areas, the amplitude of such vibrations is usually too low to cause trouble. The damage is done by vibrations at a much lower rate – around 30 cycles per second. Changes in the wire tension and the use of external damping devices* have been successful

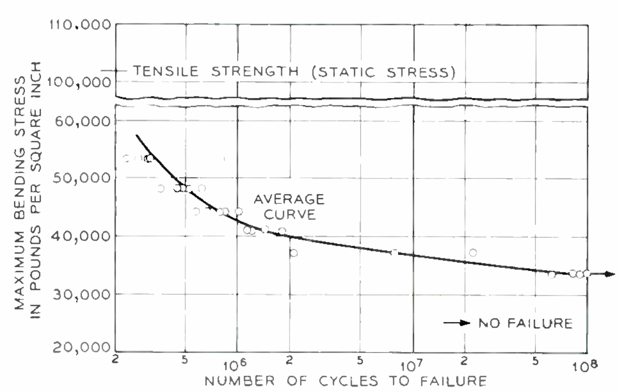


Fig. 4 — Typical stress versus cycle-life (S-N) diagram. Reversed fatigue test data for spring temper, 5 per cent tin, phosphor bronze strip.

* Record, *May*, 1956, *page* 173.

in reducing such vibrations and the resulting fatigue failures in open line wires.

Two interesting types of fatigue failures can occur in cable sheath. Extremely slow cyclic stress changes occur in aerial cable as a result of daily and seasonal temperature changes. Early laboratory tests showed that an alloy of lead and 1 per cent antimony had fatigue properties equivalent to the more expensive tin alloys and superior to other lead alloys then in service, so the lead-antimony alloy became the standard cable sheathing material. To date, no better lead alloy sheath has been developed for this application.

The second type of cable sheath failure occurs from higher-frequency (30-cycle) vibrations. Such conditions do not occur in the field, but are found, for example, when reeled cable is transported on freight cars with slightly flattened wheels. Fatigue failures of this type are absent in lead-antimony sheath. They have been observed, however, in lead-silver alloy sheath extruded by newer presses introduced for the continuous sheathing of long lengths of cable. This alloy was substituted when it was found that lead-antimony alloy could not be extruded on the new presses. Figure 3 compares sections near the fracture from both field and laboratory failures in lead-antimony and lead-silver alloy cable sheath.

As the opposite of fatigue, we have creep. Whereas fatigue occurs because of repeated stresses, creep results from continuously applied, unchanging loads. It is defined as the permanent extension of a material under constant load. Except for lead and lead alloys, creep of significant magnitude seldom occurs in metals at room temperatures.

Creep first became a problem in the Bell System when toll cables were gas pressurized to prevent the entrance of moisture. Cuts in the sheath resulting from friction between the cable and its supporting rings, or cracks of any kind, would permit moisture to enter the cable and lower the insulation resistance if internal pressure was not used. Cable sleeves, used to protect splices and to continue the cable sheath, have diameters somewhat larger than the cable itself. Because of the larger diameter, internal pressure produced greater stress in the sleeve material, and this increase in stress caused creep in the lead sleeves.

Laboratory studies of creep showed that cable sheathing materials, used for both sheath and sleeves, had poor creep resistance. A much lower creep rate was found for Chemical lead – a natural lead alloy containing small percentages of silver and copper, found only in the southeast Missouri district. Today, therefore, we use Chemical lead for sleeves where creep is predominant, and lead-antimony alloy for sheathing where fatigue is more of a problem. Figure 5 compares creep rates for several sheath and sleeve materials.

Physical metallurgists have shown that creep occurs as a result of viscous flow in the grain boundaries, "slip" along crystallographic planes, and rotation of the grains. Any one of these mechanisms may predominate under a given set of field conditions – in single crystals, for example, creep is obviously due to slip alone – but in general, all three

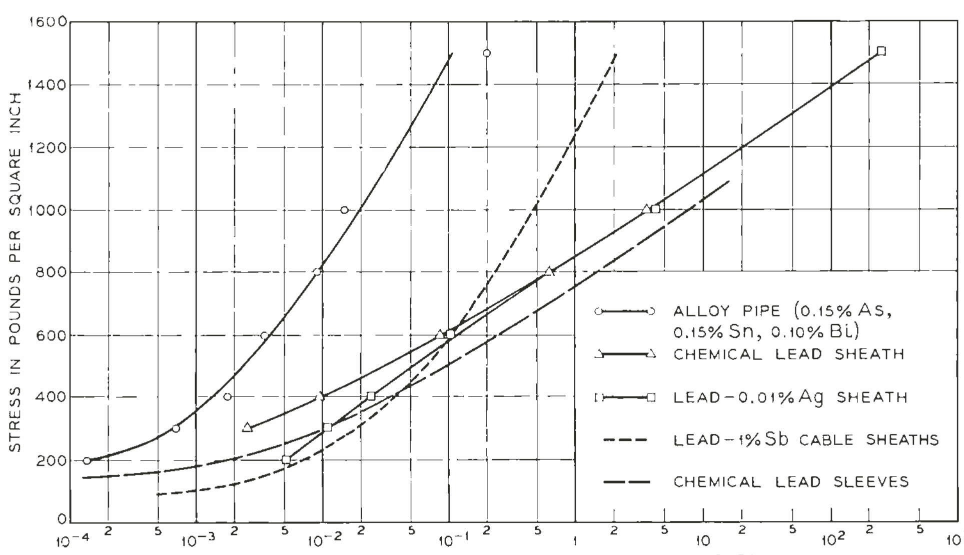


Fig. 5 — Creep rate data for some commercial cable sheath and sleeving alloys.

factors contribute somewhat toward the total effect.

Fatigue and creep properties of a material can be improved by alloying, by cold working, or by heat treatment. Of these, the most effective is alloying. Fatigue properties are improved by using finer-grained materials, while creep properties are improved by using coarser-grained materials. Where both fatigue and creep are factors in the service life of apparatus, a compromise must be effected. Where both constant and repeated stresses are superimposed, the creep rate will be accelerated by fatigue failure, and the life of the component part is generally shortened.

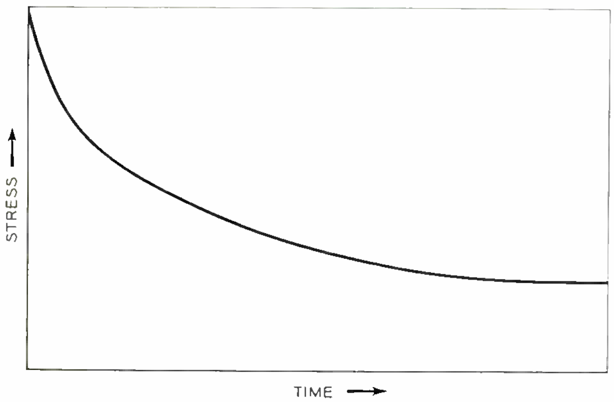


Fig. 6 — Theoretical stress relaxation curve showing decrease in stress with time under load.

Relaxation, a possible result of creep, is the name given to the loss of stress in a structural member held at constant length. For example, the loss in tension of a staybolt used to hold a boiler together or the leakage that occurs around a gasket are manifestations of relaxation. Loss of stress occurs rapidly for a short time, Figure 6, then becomes slower until a stress level is reached at which further change is very small. Except in the boiler and turbine industries, relaxation has played so small a part in deterioration processes that little work has been done in this area. During the development of solderless wrapped connections,* studies of relaxation in copper switchboard wire were made at the Laboratories to insure that relaxation would not adversely affect the reliability of the connections.

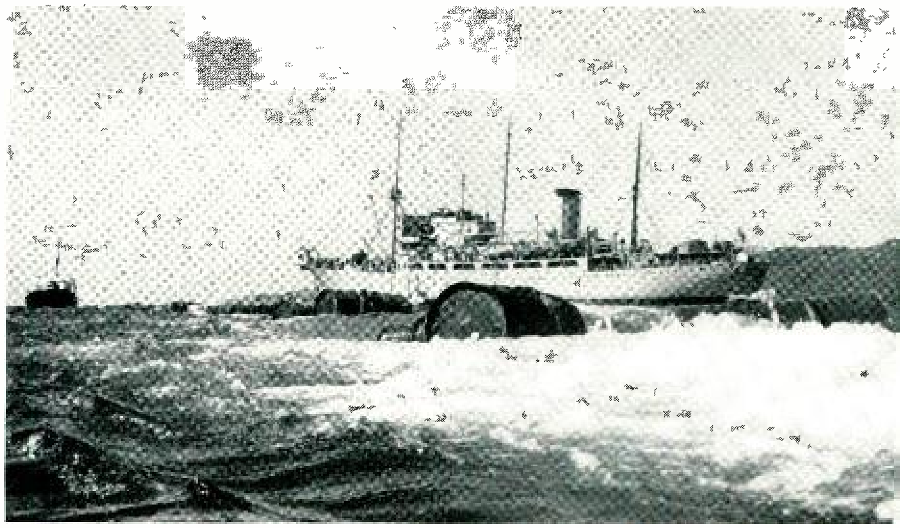
All of the deterioration processes discussed — fatigue, creep, and relaxation — may affect the life of telephone apparatus, but fatigue is the most commonly encountered. In that area, our studies have given us a background of knowledge so that if the stress conditions are known or can be accurately determined by analysis or from photoelastic studies, designs can be made that will be relatively free from fatigue failure. Increasing miniaturization and weight limitations that require the use of smaller factors of safety have led to a newer statistical approach to the problem which, it is hoped, will reduce the probability of failures even under extreme conditions of use.

* RECORD, *February*, 1954, *page* 41.

THE AUTHOR

G. R. GOHN came to the Laboratories in 1929 after receiving the degrees of B.S. in Engineering and Met. Eng. from Columbia University. He also holds a B.A. degree from Otterbein College. His work at the Laboratories has been concerned with the physical properties of metals, the application of die casting to Bell System manufacturing processes, procurement specifications, and since 1945, responsibility for fatigue and creep studies. Mr. Gohn is a former Director of the American Society for Testing Materials, and a member of the British Institute of Metals, American Society for Metals, American Society of Mechanical Engineers, Tau Beta Pi and Sigma Xi.

Evolution of the Transatlantic Cable



O. B. JACOBS, *Retired*
Formerly Transmission Systems Development II

A project that is as technically complex as the transatlantic telephone cable system is the culmination of many years of research and development by engineers and scientists in a wide variety of fields. The continuing problem of developing ever better submarine cable systems has been studied by Laboratories and other Bell System personnel since well before 1921, when three cables capable of transmitting telephone messages were put in service between Key West and Havana. Research and development are continuing, so that additional transatlantic cable service can be provided in the future.

The two telephone cables of the system which links Newfoundland and Scotland embody the results of technical advances in the submarine telephone cable art contributed by Bell System engineers. About forty years ago, preparations were made to provide voice communication between Key West, Florida, and Havana, Cuba. The intervening maximum depth of about one mile and distance of slightly more than 100 nautical miles made it impracticable to use multi-conductor cables such as those then existing in shallow water between England and the continent. On the other hand, the type of deep sea cable structure used for telegraph service had excessively high attenuation at telephone frequencies. The first step in solving this problem was a study by J. R. Carson and J. J. Gilbert which showed that cable attenuation could be reduced greatly by providing a coaxial return conductor over the insulation surrounding the central conductor.

Three cables linking Key West and Havana were placed in service early in 1921. These are coaxial in structure and have an iron wire wrapping on the central conductor to increase the inductance. Each still provides one two-way voice-frequency circuit. Originally each of these three coaxial cables was used to furnish two carrier telegraph channels above the voice band and a dc telegraph circuit.

In 1923 two cables were laid across the 23 nautical mile gap between the California mainland and Catalina Island. These cables have a non-loaded central conductor, rubber insulation, developed by Dr. R. R. Williams, and a return conductor with the usual jute and armor wires. Initially, each cable provided a voice-frequency circuit and a telegraph circuit. In 1926 carrier equipment was provided whereby one cable could furnish six two-way telephone channels, plus a voice-frequency circuit and a dc telegraph circuit. This system uses the same frequency band for both directions of transmission. Later the other cable was similarly equipped.

In the early 1920's, Dr. O. E. Buckley showed how to apply a newly discovered alloy, permalloy, to the inductive loading of telegraph cables, thereby increasing their message capacity fourfold. In 1924 Dr. Buckley directed the engineering and manufacture of such a cable and the newly developed operating equipment. This cable was laid for the Western Union Telegraph Company between New York and the Azores. Experience gained in the design, manufacture and laying of this cable, and others laid in 1926, provided valuable background for future work by Laboratories engineers.

Further developments in magnetic materials resulted in perminvar, an alloy suitable for loading a voice-frequency cable. At about the same time the Laboratories, under the leadership of Dr. Williams, developed a new insulating material called paragutta, a mixture of deresinated balata (a hydrocarbon obtained from the sap of tropical trees) and deproteinized rubber, which had a lower dielectric constant and less leakage than was found in older types of insulation.

Studies showed that it would be possible to provide a voice-frequency circuit over an 1850 nautical mile cable between Newfoundland and Ireland using these new materials. In the period between 1928 and 1931 negotiations were started with the British Post Office, and factories in Germany and England were shown how to fabricate the materials and manufacture the cable.

Trial lengths of cable were laid at a depth of 2½ miles in the Bay of Biscay, their transmission characteristics measured with shipboard equipment, and the cables recovered from the bottom. Proposed landing points were selected and noise measurements made on sample cables laid seaward from the Irish location. The Laboratories designed terminal equipment for the proposed cable and tested it using an artificial line. This line simulated the entire length required, and had an attenuation of 170 db at 3,000 cycles. Voice-frequency switching arrangements were required to control the direction of transmission.

Between Newfoundland and Nova Scotia, there was to be a single non-loaded paragutta insulated cable with two intermediate land-based repeaters for two-way carrier operation. The considerable expense for attendants and power equipment at the repeater points led to a plan to supply power to each intermediate repeater by direct current from the adjacent terminal via the central conductor of the cable. This conductor carries telephone currents in both directions of transmission.

Work on the proposed cable was actively in progress in 1929 when an urgent need arose for additional circuits to Cuba. This was met in 1930 by a non-loaded, paragutta-insulated cable which provided three channels in each direction of transmission by means of modified type-C carrier equipment at the terminal stations. In 1941 this equipment was replaced by modified type-K carrier equipment which provided seven channels each way by using filters and a receiving amplifier at each landing hut.

Negotiations with the British Post Office terminated in 1931 when, due to improvements in transatlantic telephony, a cable carrying a single conversation could no longer be justified. Even while the loaded cable project was active, however, the possibilities of other methods of transatlantic wire communication were not overlooked. Floating islands, called seadromes, spaced at intervals of about 375 miles, were being considered in 1929 for an airplane route across the ocean and this suggested their use as repeater stations. A transmission study concluded that possibly as many as eight circuits might be obtained with two cables, each transmitting in only one direction, using an output level of +40 db at each repeater and a gain of 140 db at the highest frequency.

The fact that seadromes would drift around their

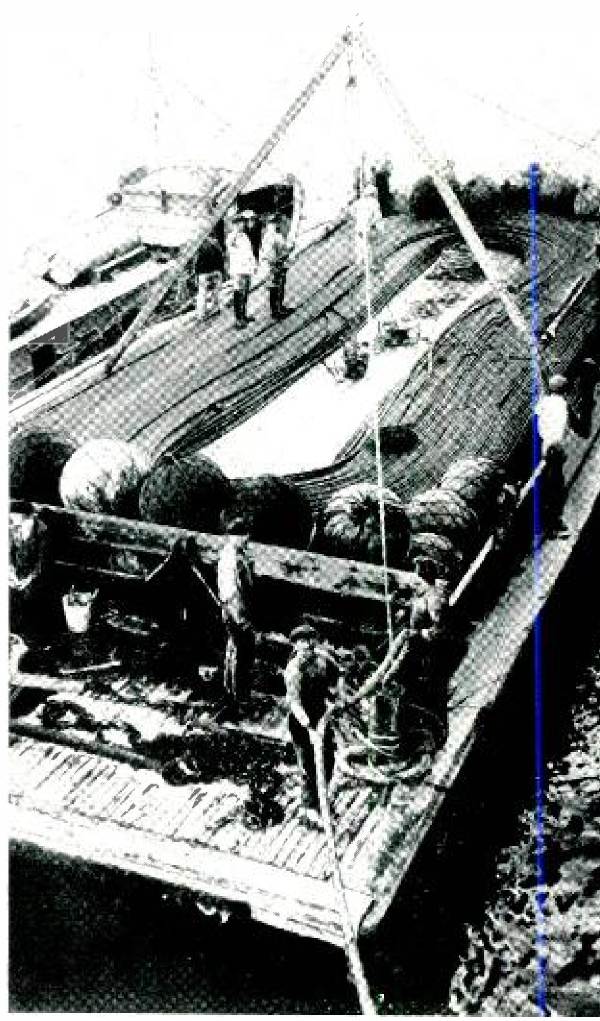


Fig. 1 — A photograph taken in 1930 shows a cable-laying barge with balloon buoys used in placing the shallow water portion of the Key West-Havana telephone cable laid in that year.

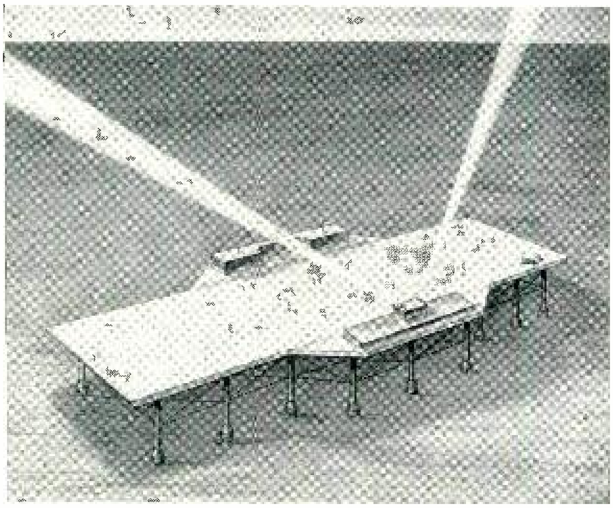


Fig. 2 — In 1929, seadromes of the sort sketched here were being considered for an airplane route across the Atlantic ocean. It was suggested that they might also be used to house repeaters for a proposed transatlantic cable.

anchorages in a six-mile circle and might have to be cut loose in severe storms posed a baffling problem for cables leading to and from them, and therefore other methods were explored. One called for a globe with batteries sufficient for six months, supported well below the surface by a buoy. Repeaters nearest land were to be energized by dc supplied from the shore stations over the cable itself.

Later, it was proposed to supply power to all of the fourteen submerged repeaters in an 1,800 nautical mile cable using potentials of the order of 1,800 volts at each shore station. This system would provide four circuits over a single cable using different bands of frequencies for the two directions of transmission. Each submerged container was to hold two high-output power repeaters, only one of which would be energized at a time, according to the polarity of the direct current supply.

In June, 1932, Dr. Buckley summarized various proposals and the costs involved, concluding that it would be reasonable to supply power to the repeaters from the shore stations at potentials as high as 2,000 volts. Repeaters having high output powers were contemplated, possibly with duplicate equipment controlled by the direction of the dc supply. Containers floating on the surface were ruled out because of the severity of wave action; sea-bottom locations were preferred if the repeaters could be made small enough to be attached to the cable even though it would take longer to raise them to the surface for servicing. Submerged containers thus appeared to afford the most promising solution. It was thought that electron tubes having a probable life of 7,000 hours could be made, and that not more than one or two interruptions due to tube failure would be expected in a period of ten years if the repeaters were serviced twice a year. A route via Greenland was also given serious consideration.

Early in 1933 Dr. Buckley and the writer proposed the use of a comparatively large number of low output power repeaters on the sea-bottom, enclosed in flexible containers incorporated in the cable under the armor and using a separate cable for each direction of transmission. Repeaters operated at low outputs with low currents and potentials should permit a much longer period of satisfactory operation than if higher power repeaters were employed. Preliminary consideration indicated that, by applying the latest electron tube art, the tubes could be made to have a reasonably certain life of twenty years or more.

Incorporation of small diameter bendable repeaters in the cable would permit laying and recovery at ocean depths using conventional cable ship machinery. When cable is payed out the tension is high and the spiral form of the armor and other components of the cable cause untwisting as the cable leaves the ship. As the untwisted portion approaches the bottom the tension decreases and the cable twists up again, but a bulky container would tend to impede this action and cause loops of cable on the bottom. Kinks would result when the loops are pulled and this damages the cable. Continuous laying with a small diameter repeater minimizes such hazards, making the job not more difficult than for a cable without repeaters.

Development work on rugged electron tubes having long life was begun at once under the direction of Dr. M. J. Kelly. The first tubes for this purpose were of the filamentary type, but improved cathode coating materials soon became available and made it possible to develop heater type tubes having satisfactory characteristics. The use of a large cathode area with low space current and low screen and plate potentials provided conditions conducive to long life. A rugged tube structure was devised to withstand shocks during the handling and laying operations. Some of the essential features of the tubes result from contributions made by J. R. Wilson, C. Depew, W. Gronros and V. L. Ronci of the Laboratories. Groups of tubes were made from time to time; about half of each group were placed on life test, others laid aside for future use if their counterparts proved good, and a few used in repeater development work. All tubes were aged by operation for 5,000 hours and tested several times during the process.

Development work on other repeater circuit components, as well as containers and seals, also was undertaken promptly. New advances were made in components, especially transformers and capacitors and their mounting arrangements, to which W. M. Bishop, E. M. Boardman and M. C. Wooley made important contributions.

The first container design was developed by J. F. Wentz who proposed the use of a closely wound spiral of steel wire of square cross-section, supporting an impermeable outer sheath. Steel rings were later substituted for the wire, and thin rings were placed over the joints between inner thick rings. A glass seal, impervious to moisture, for closing each end of the container, was developed by W. T. Read, Jr., and V. L. Ronci. Although this seal is capable of withstanding sea-bottom pressures, tension or pressure on its central conductor is avoided. For this purpose each glass seal is supplemented by a rubber seal which resists such forces successfully. Means for bonding rubber to cable insulation were also developed. Protection of the rubber seal against the deteriorating effect of sea water was obtained by providing a flexible tube which extends about seven feet beyond the seal along the cable and is filled with a viscous insulating liquid. Important contributions in developing containers and seals were made by W. M. Bishop.

Work on a repeater circuit continued until the beginning of World War II. By that time a three-stage amplifier for the 12- to 60-kc range had been developed using components suitable for enclosure in a flexible container. The gain was 61 db at 60 kc and the feedback exceeded 43 db throughout the range. The gain versus frequency characteristic was a close match for the loss versus frequency characteristic of 56 nautical miles of cable having a structure like that of the 1930 Key West-Havana cable. The circuit was designed by I. E. Wood using a modification of the technique developed by H. W. Bode for repeaters in the coaxial system, with the shaping divided about equally among the input, output and feedback circuits. Important assistance was contributed by D. E. Thomas who devised special measuring circuits for determining the performance of the amplifier. Based on the progress made up to that time, Dr. Buckley prepared a paper discussing the future of transoceanic telephony, which was presented as the 33rd Kelvin lecture before the British Institution of Electrical Engineers at their annual meeting in 1942.

Concurrent with repeater development work, studies of other methods of providing a transatlantic system were under way, with emphasis on methods requiring only one cable. Because of cable impedance variations with temperature, depth, and the strains resulting from stresses during laying, there was little likelihood of obtaining the high degree of impedance balance required at repeaters using the same band of frequencies for both directions of transmission. Also, if separate frequency bands were used for the two directions, the added complexity of the repeaters, the problem of enclosing them in small diameter flexible containers and the narrower useful frequency band obtainable per cable made a two-cable system more attractive. All things considered, a two-cable system was more attractive than one using a single cable, in spite of the fact that failure of one cable would interrupt all of the circuits.

Development work on cable structures was also active. This included armorless cables having a copper-clad steel central conductor; others having high-strength bronze central conductors or bronze

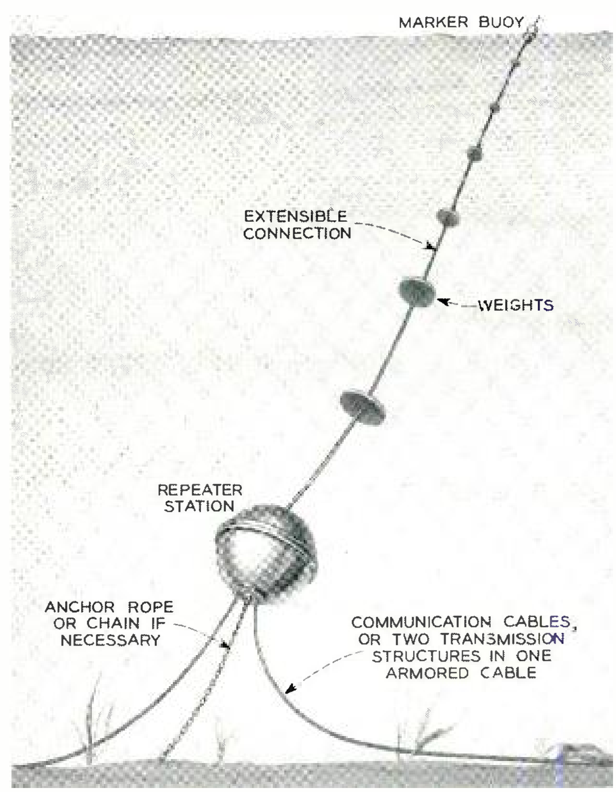


Fig. 3 — An alternative proposal for housing submarine repeaters was for semi-buoyant, water-tight globes of the type shown in this sketch.

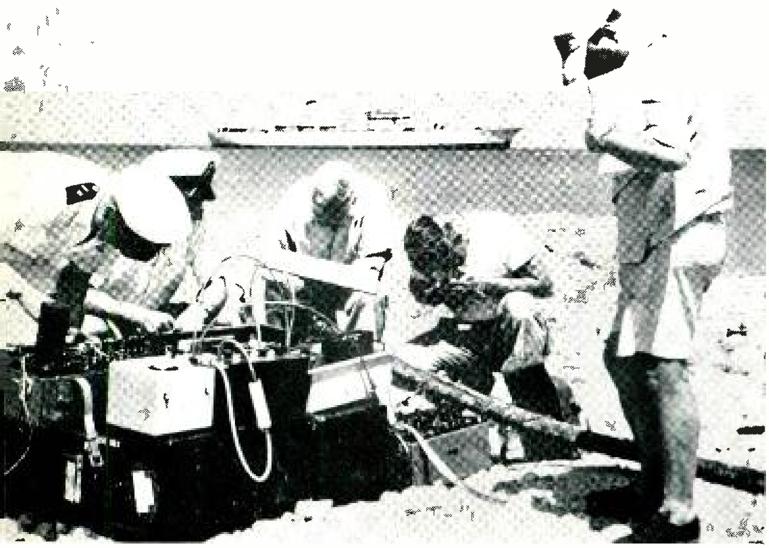


Fig. 4 — J. J. Gilbert, center, R. J. Tillman and ship's officers test insulation resistance of Air Force Missile Test Range submarine cable laid in 1953.

return conductors; armored cables with insulated return conductors for supplying power to repeaters; spiral-four structures; and the use of a braided fine-wire (Litzendraht) central conductor. In many cases specimens were made and tested.

After World War II, development work on the amplifier and container was resumed, and the problem of identifying defective repeaters in a system by tests from shore stations was explored. L. M. Ilgenfritz and R. W. Ketchledge solved this problem by adding a crystal with a different resonant frequency in the feedback path of each repeater. These crystal frequencies were located just above the useful transmitted band where the feedback is deficient. The crystal greatly reduces the feedback in a very narrow band, resulting in a peak of gain, the magnitude of which is dependent upon the activity of the electron tubes. Thus, over-all measurements of a multi-repeater system at the peak frequency of each repeater will disclose the condition of the tubes in each one.

A further advantage of the crystal arrangement is the means it affords for identifying a repeater in case it fails to transmit altogether. If the dc path for the energizing current is still intact, the peaks of noise at the crystal frequencies from repeaters between the defective one and the receiving stations can be detected, thus disclosing the location of the trouble.

By this time, polyethylene insulation for cables had been developed by the British and used successfully to provide cables having lower attenuation than was obtainable with paragutta. Based on this material, a cable structure was designed by J. J. Gilbert, using the smallest size which cable experience indicated could be laid safely at the depths encountered on a transatlantic route. The central conductor was made larger than the theoretical optimum for lowest attenuation to reduce the total voltage for such a system with negligible sacrifice in transmission. This design called for the use of a special polyethylene compound to fill the voids in the composite central conductor.

About this time there was a strong demand for additional circuits to Cuba which afforded an opportunity to obtain a trial installation of a transatlantic-type system on a small scale. As the requirements called for more than the twelve circuits provided by the repeater previously developed, its design was modified to provide twenty-four channels in the range from 12 to 108 kc, with a gain of 65 db at the highest usable frequency. This work was carried out principally by L. M. Ilgenfritz and Q. E. Greenwood.

Advance preparations for new cables to Cuba

THE AUTHOR

O. B. Jacobs graduated from Worcester Polytechnic Institute in 1910 with a B.S. degree and joined the AT&T Company in that year. At first, he was concerned with equipment maintenance, and later with the preparation of toll installation specifications. He served overseas in the Signal Corps from 1917 to 1919, and returned to the Long Lines as Division 1 Transmission Engineer. In 1921, Mr. Jacobs transferred to the Operation and Engineering Department where he worked on various transmission problems. In 1929, he joined the staff of the Laboratories where he worked on submarine cable system development, participating in work on undersea repeaters, cable power supplies, equalization methods, test procedures and over-all system design. Interruptions during World War II included coordination of work on the Signal Corps spiral-four cable system, liaison between that organization and the Laboratories and work on visible speech. Since retiring in 1954, he has continued submarine cable work as a resident visitor.

included sea trials and transmission measurements of lengths of cable, with and without repeaters, laid at depths as great as 2½ miles. Laboratory tests were also conducted on short specimens having various widths of surround tapes and directions of lay. Electron tubes for the repeaters were selected from the stock which had been made at Bell Telephone Laboratories.

The energizing current supplied to the repeaters has to be kept within narrow limits to avoid shortening the life of the electron tubes. Equipment for regulating the dc supply to the cables in the presence of large differences in earth potentials between landing points, was designed and built by the power group under the direction of J. M. Duguid, H. H. Spencer and D. E. Trucksess with important contributions by G. W. Meszaros and J. A. Potter. Cables Nos. 5 and 6 to Cuba were laid in 1950 with complete success. Precision measurements of attenuation at that time and in subsequent years have shown no appreciable deterioration in cable or repeater performance.

The next cable project undertaken was a two-way single cable carrier system for the U. S. Air Force Missile Test Center, extending from Cape Canaveral, Florida, to Puerto Rico via intervening islands in the Bahamas and the north coast of the Dominican Republic. By using the largest size cable considered suitable at that time for laying at ocean depths, it was possible to locate all of the repeaters on land and to supply power to those at unattended points from the various missile tracking stations established by the Air Force at the other repeater points. The cable structure was designed by J. J. Gilbert, employing the same size of central conductor used for the new Key West-Havana cables – slightly smaller than the optimum diameter. The sacrifice in attenuation was negligible, however, and the delay and difficulty of developing new manufacturing methods and techniques was thereby avoided. The insulation for this cable is a compound of high molecular weight polyethylene with 5 per cent of butyl rubber. Also, no filler was used in stranding the central conductor. Measurements of the attenuation of the various lengths of cable in this system, both in the factory and after laying, provided valuable information for future projects.

The continued satisfactory performance of the new Key West-Havana system and the accumulated experience and data provided a solid foundation for the work of the many Laboratories' personnel involved in making transatlantic telephone communication by cable a successful accomplishment.

Cleo F. Craig Resigns as Chairman of A T & T Board

Cleo F. Craig resigned May 15 as Chairman of the AT&T Company's Board of Directors, effective May 31. He will continue as a director of the company and a member of the Executive Committee.

Mr. Craig started his telephone career as an equipment man in St. Louis in 1913, after graduating from the University of Missouri with a degree in electrical engineering. He rose through various positions, primarily in the plant department of Long Lines, until he became Vice President in charge of Long Lines in 1940. The following year he joined the General Departments of the AT&T Co. and served at different times as Vice President in charge of Personnel Relations; Operation and Engineering; Revenue Requirements; and Finance.

Mr. Craig was elected President of AT&T on July 2, 1951, and served in this capacity until September 19, 1956, when he was elected Chairman of the Board of Directors.

Cleo F. Craig

One of the Laboratories' continuing jobs is to adapt older equipment to new communications techniques. Direct distance dialing requires, for example, central office equipment that can handle ten digits — 3 for the area code and 7 for the local number. To be incorporated into the existing direct distance dialing network, older switching systems such as panel and No. 1 crossbar must therefore be modified to increase their capacity from 8 digits to 10. Using existing design techniques, an economical and mechanically practical way of incorporating these older switching systems into the Bell System direct distance dialing network has been developed.

Direct Distance Dialing from Panel and No. 1 Crossbar Offices

J. W. KIRCHHOFF *Systems Engineering, and* **C. O. PARKS** *Switching Systems Development*

Expansion of direct distance dialing (DDD) service for long distance calls is one of the major objectives of the Bell System. The basic idea is not new, but the tremendous growth of long-haul toll traffic since World War II, coupled with a continuing rise in the cost of handling such traffic by means of operators, has made the provision of DDD extremely desirable. This service is already available to many Bell System customers.*

The technical planning behind DDD dates back to the 1920's when exploratory studies of operator toll dialing were made. Operator toll dialing has been in use by Operating Companies having step-by-step toll networks since the late 20's. An important stride in the direction of nationwide operator toll dialing was taken with the installation introduced at Philadelphia in 1943, but because of the war, no further installations were possible until 1948. In 1950, the present comprehensive program was begun, and by the end of 1958 there will be nearly 120 large operating centers equipped for operator toll dialing.

* RECORD, *January*, 1954, *page* 11.

During the development of the nationwide operator toll dialing plans, the country was divided into numbering areas, each designated by a 3-digit code. These codes differ from the 3-digit codes used for local central offices in that an area code always has a 0 or a 1 as the second of the three digits. Within one numbering area, there are theoretically 640 possible office codes, although the practical limit is closer to 540. These office codes never use a 0 or a 1 for the second digit and there are no duplicate office codes within one numbering area. To reach any customer, the originating toll operator need only dial the numbering area code, followed by the directory number, a total of 10 digits. This plan lends itself to direct distance dialing of toll calls by customers, especially those served by common control switching systems (panel, No. 1 crossbar or No. 5 crossbar). Provision must be made for registration of 10 dialed digits, for the identification of a calling customer's number for charging purposes and for automatic routing of the call. If the step-by-step system is senderized, customer toll dialing may also be done on a 10-digit basis, but in the meantime an additional 2- or 3-digit access code is prefixed to the 10-digit number to provide access to the toll dialing network.

Panel and No. 1 crossbar systems were developed for use in metropolitan areas where the emphasis was on customer dialing of local calls. Consequently, the sender circuits which record the digits dialed by the customer were designed to accept only a maximum of eight dialed digits.

In panel offices and in most No. 1 crossbar offices, customer billing is based on message units recorded by means of message registers. Over the years, means have been provided to extend the dialing range of customers served by these offices within this charging limitation. To relieve the load on the operators for short-haul toll calls, provision has been made for multiple registration on the message register (zone and overtime registration) for calls having initial period charges of not over six message units. Provision has also been made since the war for permitting panel and No. 1 crossbar customers to dial into one adjacent numbering area by prefixing 1-1 to the called directory number. Such calls are routed through a crossbar tandem office arranged for centralized automatic message accounting (CAMA)* for recording of the calling and called telephone numbers and the time duration of the call.

Since DDD was in the planning stage when No. 5 crossbar was in the process of development, this system was arranged to accept 10 dialed digits with minimum modification. Direct distance dialing is now available to many customers served by No. 5 crossbar offices. The remaining big problem was, therefore, to provide DDD service for the more than 15,000,000 telephones in metropolitan areas served by panel and No. 1 crossbar systems. An obvious solution to the problem was the method used in No. 5 crossbar – to modify the registers and senders to handle 10 dialed digits. However, the existing 60,000 panel and No. 1 crossbar originating sender units do not have enough spare mounting space for the additional apparatus required for the new features, and furthermore, the cost of such an elaborate change would be excessive. Another possibility would be to provide a new originating sender for panel and No. 1 crossbar, with all the features now required, but this would be even more expensive. Systems engineering studies showed that while the number of 10-digit customer-dialable toll calls would be very large, these calls would actually be less than 2 per cent of the total calls handled by the originating senders. These findings made the provision of some less expensive facilities for DDD a necessity.

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

The plan finally adopted is one using a relay-type auxiliary sender. In this approach, a decision-making function was put into the originating sender to recognize any call with a "0" or "1" for the second digit as one which requires an auxiliary sender for registration of the last two digits of the 10-digit number. These auxiliary senders are provided in small groups (maximum of 10 per group) and are connected to originating senders as required through a high speed, crossbar switch link frame. After dialing is completed, these auxiliary senders receive the first eight digits from the originating sender by the signaling method known as panel call indicator (PCI), and in turn outpulse these digits plus the two registered in the auxiliary sender by the multifrequency (MF) method of signaling.* A block diagram of the auxiliary sender

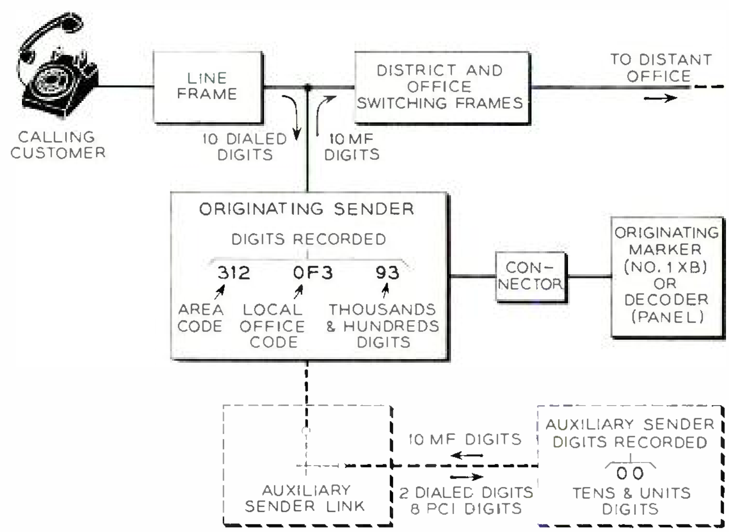


Fig. 1 — Block diagram of auxiliary sender applied to panel or No. 1 crossbar central office.

applied to both panel and No. 1 crossbar systems is shown in Figure 1.

Substantial economy in the auxiliary sender was achieved through use of the "overlap" method of outpulsing the called number to the distant office. At first glance it would seem that 10 digit registers would be required in the auxiliary: 8 for the digits in the originating sender and 2 for the digits dialed directly into the auxiliary. The originating sender would then PCI pulse all of its 8 digits into the auxiliary before the auxiliary could outpulse any digits to the distant office. The final design of the

* Record, *December* 1945, *page* 466; *June*, 1954, *page* 221.

auxiliary sender, however, used only 4 digit registers. Two of these are required for the last 2 dialed digits, the other two are dual purpose circuits which are capable of both registering PCI pulses from the originating sender and controlling the MF outpulsing of these same digits to the distant office. Thus, while the "odd" register is receiving a PCI digit, the "even" register will be controlling the MF outpulsing of the preceding digit and preparing to receive the next PCI digit. This "overlapping" of PCI and MF pulses is illustrated in Figure 2.

Although this method of outpulsing results in a considerably simpler auxiliary sender with shorter holding time, there is one relatively minor drawback: the first 8 digits are MF outpulsed at the PCI

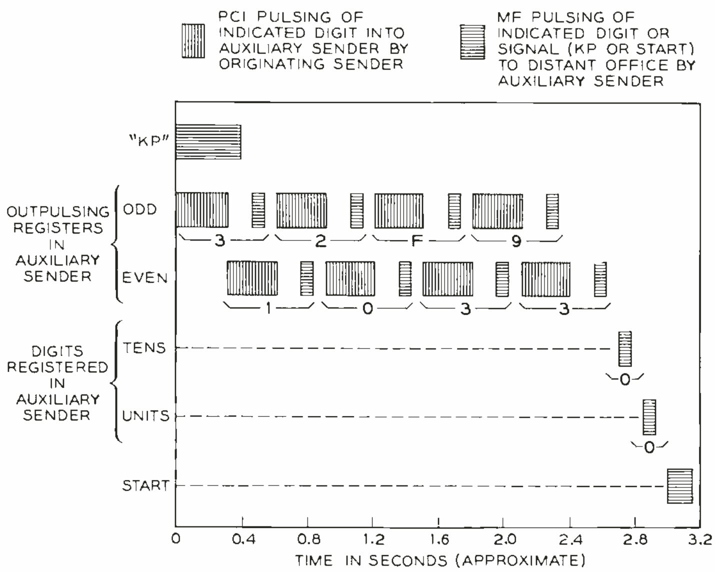


Fig. 2 — Graphic presentation of "overlap" method of out-pulsing the digits for 3-1-2-OF 3-9300.

rate of about 3 digits per second rather than the standard MF rate of about 7 digits per second. This slowing down of outpulsing results in slightly greater holding time of the distant office incoming sender, and therefore more of these senders will be required. An engineering study of this problem showed that the reduction in price of the auxiliary sender outweighed by far the cost of the additional distant office senders required.

If an MF power supply is not available in the central office, an individual supply for each auxiliary sender can be installed. These supplies employ transistors and occupy only the mounting plate space required for one row of relays.

The auxiliary sender is used in the following way on 10-digit calls. Suppose a New York customer wishes to call the Chicago number, OFficial 3-9300. After receiving dial tone, indicating an originating sender is attached, he dials 3-1-2 (the Chicago numbering plan area code) followed by OF 3-9300. From the "1" for the second digit, the originating sender recognizes that an auxiliary sender is required to complete the call. When the customer has dialed the "thousands" digit of the directory number (in this case, "9"), the originating sender makes a bid for an idle auxiliary sender through the link frame. This is normally completed before the dialing of the eighth digit in time for the last 2 digits to be registered in the auxiliary. After the tenth digit has been dialed into the auxiliary, a sender is called for in the distant office. When one is connected, outpulsing begins and on completion of outpulsing, both circuits release.

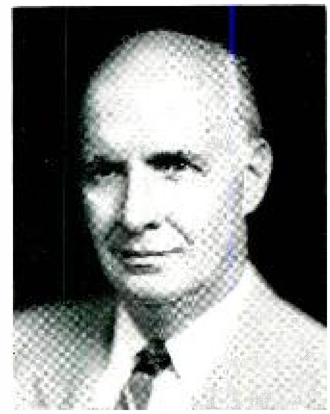
Should heavy traffic conditions prevent an auxiliary sender from being connected in time to accept the ninth digit, the originating sender releases and the customer is given an overflow tone. This can happen only if all auxiliary senders are busy or if an excessive number of simultaneous start signals are made by originating senders. The auxiliary senders have been so engineered, however, that the probability of a call going to overflow for these reasons is very small.

Another application for the auxiliary sender is to use its MF outpulsing feature for 7-digit calls. This extends the use of MF pulsing to all common control systems. The decision to use the auxiliary sender in this fashion is made by the decoder in panel offices and by the originating marker in No. 1 crossbar offices when determining the route for the call. The route selected is based on a translation by the decoder or marker of the particular office code dialed, and this translation process has been expanded to include a decision as to whether or not an auxiliary sender is required for MF outpulsing. If one is required, the decoder or originating marker tells the originating sender to call for an auxiliary sender after dialing is completed and outpulsing proceeds as previously described. The auxiliary sender thus solves simply and economically the problem of expanding the central office capacity to ten dialed digits and of providing MF outpulsing.

Very briefly, this is the method of charging the customer for DDD calls. All 10-digit DDD calls from panel and non-AMA No. 1 crossbar offices will be routed first to a switching point (usually a crossbar tandem office) equipped with centralized AMA facilities for recording of customer billing information, such as the calling and called number and the duration of the call. Initially, these centralized AMA offices will employ operators to obtain the calling customer's number, but an automatic number identification system is now being developed which will ultimately do this automatically without the aid of operators.

Since 1951, direct distance dialing has been one of the major trends in communications. With the addition of facilities for DDD service from panel and No. 1 crossbar dial local offices, another large segment of the Bell System has been added to the direct distance dialing network.

THE AUTHORS



C. O. PARKS joined the Western Electric Company as a panel tester in 1921, and from 1923 until 1944 was an engineer on the installation engineering staff. In 1944 Mr. Parks was transferred to the Laboratories and since that time has been engaged in transmission test circuit design, field studies for automatic number identification, design of an auxiliary sender for direct distance dialing, and is currently running field trials on DDD and ANI installations in Newark.

J. W. KIRCHHOFF joined the Illinois Bell Telephone Company in 1950 as a co-op student while attending Northwestern University. Upon receiving the B.S.E.E. degree in 1952 he entered the plant department rotational training program and was later assigned to the plant extension group. Mr. Kirchhoff came to the Laboratories in January, 1955, under the borrowee plan and was assigned to systems engineering studies on direct distance dialing arrangements for panel and No. 1 crossbar, DDD from coin boxes and the application of new coin collectors and push-button dialing to existing systems. In January of this year Mr. Kirchhoff left Bell Laboratories to accept a position with another company.

National Academy of Sciences Elects H. W. Bode

H. W. Bode, Director of Research – Physical Sciences at Bell Laboratories, has been elected a member of the National Academy of Sciences. Dr. Bode was one of thirty new members named at the 94th annual meeting of the Academy held in Washington, D. C., on April 23.

Dr. Bode, a member of the Laboratories Technical Staff since 1926, received his bachelor's and master's degrees from Ohio State University in 1924 and 1926, respectively, and his Ph.D. from Columbia University in 1935. During his first three years at the Laboratories, Dr. Bode was engaged in electric filter and equalizer design. He joined the Mathematics Research group in 1929, and specialized in research on electric network theory and its application to long distance communication facilities. After the outbreak of World War II, he turned to the development of electronic fire control devices, and in recognition of his contributions in this field was awarded the Presidential Certificate of Merit.

Dr. Bode was placed in charge of the Mathematics Research group in 1944, and in 1952, he became Director of Mathematical Research. He assumed his present position as Director of Research – Physical Sciences, in October, 1955. He is the author of *Network Analysis and Feedback Amplifier Design*, a volume in the Van Nostrand Bell Laboratories series, and is also a Fellow of the Institute of Radio Engineers, the American Institute of Electrical Engineers and the American Physical Society, and a member of the American Mathematical Society and Phi Beta Kappa.

Other Laboratories members of the Academy are President M. J. Kelly; Executive Vice President J. B. Fisk; J. R. Pierce, Director of Research – Electrical Communications; and Claude E. Shannon, research mathematician, now a professor at M.I.T. and consultant to the Laboratories.

The P1 carrier system marks a new approach to rural telephone service. The use of carrier operation between the customer and a central office has been accompanied by development of new designs and manufacturing techniques for miniature components. These new P carrier components have been a considerable challenge to the ingenuity of Laboratories design engineers. This was especially the case in achieving the required transmission characteristics with audio frequency transformers of a size suitable for terminals and repeaters mounted on poles.

Miniature Audio Transformers for the P Carrier System

C. E. LUFFMAN *Apparatus Development*

The features emphasized in the design of the audio frequency transformers for the P carrier system* have been dictated largely by the unique objectives established for the system – namely, low cost, small size and provision for outdoor mounting in sealed cabinets.

To make the P systems attractive to Telephone Companies, it is necessary that the cost per channel be relatively low. Since there are 22 audio transformers involved in each telephone conversation, low cost of these components is likewise important. Because the system equipment was designed to be contained principally in small cabinets suitable for pole mounting, the basic units are miniaturized components, printed wiring and transistors. Consequently, the transformers had to conform to this design pattern. In addition, the outdoor mounting of these transformers imposes severe temperature conditions. To maintain electrical stability under such conditions, as well as to protect the transformers with their fine wire prior to sealing in the cabinets and during the time when the cabinets are opened, it was necessary to provide an adequate protective encapsulation.

The Bell System has for some time employed partially automated methods in manufacturing apparatus such as resistors and relays. The P carrier system, however, is the first telephone system scheduled to make use of mechanized techniques in assembling equipment elements. In line with this, the P carrier audio transformers were designed to make them suitable for a greater degree of mechanized manufacture than has been possible with transformers in the past.

Attempting to reduce the size of any audio frequency transformer introduces special problems and penalties. Physically, the present concept of a

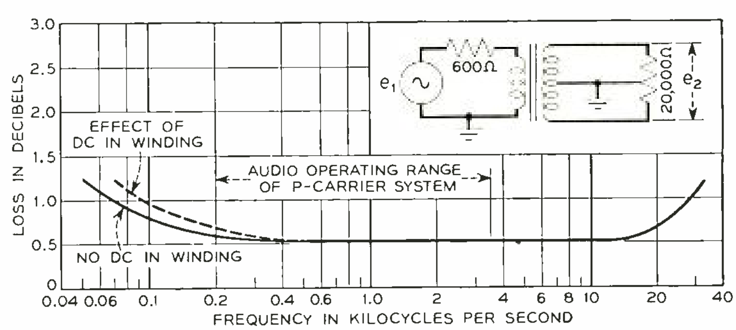


Fig. 1 — Loss versus frequency characteristics for a typical P carrier audio transformer.

* RECORD, *August*, 1956, *page* 281.

transformer does not readily lend itself to extreme miniaturization because, unlike other components, it is an involved aggregate of parts. The assembly of windings, laminations, lead-out wires and associated parts becomes complicated as the parts are made smaller. New techniques undoubtedly will solve many of these difficulties, but one pressing problem which currently is proving a block to further transformer miniaturization is the inability to wind coils commercially with fine enough wire. Direct current flow through the windings of transformers is also a deterrent to miniaturization since its effect is to cancel a part of that important element – mutual inductance of the windings. This causes additional loss, as shown by the dashed line in Figure 1. To compensate for the loss of inductance, other than by increasing the size of the transformer, more turns must be used in the windings, usually at the expense of resistance losses. In general, the amount of direct current through transformers in audio transistor circuits has not been appreciably less than that in like electron tube circuits. Also if reduction of transformer size to match other miniaturized elements is required, it can be accomplished only at the expense of efficiency, frequency response or distortion. Contrariwise, if the transformer designer is presented with a circuit having little or no direct current flow through the windings – such as in push-pull circuits – or if dc bypass circuits are used, the job of minimizing transformer size is facilitated, since the electrical loss factors, such as leakage, capacitance, resistance and magnetic reluctance, normally decrease in almost direct proportion with size reduction.

There are eight types of audio transformers in the P carrier system. These are used in the compressor,* modulator and expandor* circuits of the system. The transformers function to match the impedances to the transistor amplifiers and provide feedback paths; make connections to the 600-ohm line; provide correct termination; and serve as part of the control circuit for the variolossers.† The final size of these transformers was dictated by the magnitude of the allowable loss that they could introduce in the circuit, plus the fact that to obtain lowest manufacturing cost, a single structure for all types had to be used. This meant that some of the transformers were not used to full design capacity, but in such cases, this extra margin was employed to improve the over-all efficiency of the system. Typical transmission characteristics of one of the types of audio transformer are shown in Figure 1. On two of the transformers, the required electrical balancing between halves of the 600-ohm windings was obtained in one case by means of a split winding – a physical arrangement to equalize the dc resistance of the two halves. The other case,

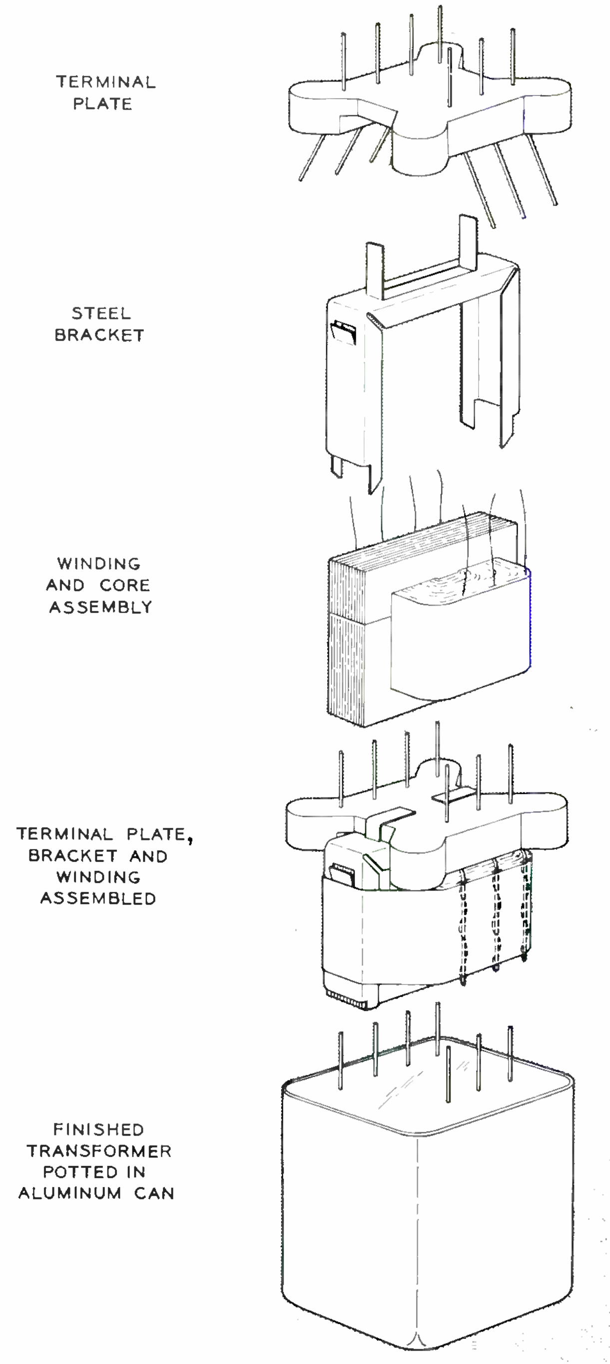


Fig. 2 — Exploded drawing of transformer showing the major parts and construction details.

* Record, *November*, 1954, *page* 411; *November*, 1953, *page* 452. † Record, *December*, 1953, *page* 501.

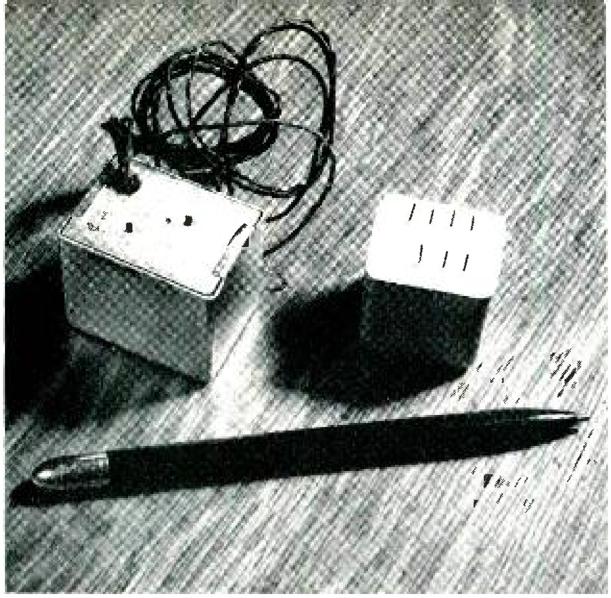


Fig. 3 — N carrier audio transformer, left, and new P carrier transformer, side-by-side, show comparison in size and construction details.

having more rigorous balance requirements, employs a parallel pair winding.

An epoxide resin casting* in an aluminum can is used for weatherproofing. This resin has been a boon in transformer engineering because it penetrates thoroughly into parts, has low shrinkage in curing and hardens at relatively low temperatures. Moreover, it forms a tough, durable cover which withstands temperature variations such as will be encountered with P carrier installations. The resin also resists moisture, chemicals, fungi, vibration and shock, and has very good electrical insulating properties. A can is employed because the unit cost of this item is less than the *pro rata* costs associated with molds for shaping the epoxy resin. This procedure also permits some degree of mechanization.

To minimize costs, the design has been made simple and amenable to a fairly high degree of mechanization in manufacture as Figure 2 illustrates. The terminal plate is inexpensively made by mass molding from styrene polyester. The windings are wound in groups by machine and the wire of the windings, which has solder-through insulation, serves also for leads. This permits connections to be made to the tin-plated terminals after wrapping merely by dipping groups of terminals in a solder bath. This obviates the need for additional terminal lead wires, stripping of insulation and hand soldering. The core laminations, selected for their high permeability at the low signal levels involved, are made from molybdenum permalloy (4 per cent molybdenum, 79 per cent nickel, remainder iron and manganese) and are of a commercial double-E type. The winding and lamination assembly and the terminal plate are fastened together in the steel bracket by means of bent tabs. When the assembly is inserted in the aluminum can, the spurs on the bracket gouge into the side of the can and ground the core to the can.

Straight wire terminals serve to provide electrical connection and means of fastening the transformers to the printed boards. All transformers have seven terminals, three on one side, four on the other, for orientation during automatic assembly to the printed wiring boards.

These transformers weigh about two ounces and are approximately 1$\frac{3}{16}$ inch long, 1$\frac{1}{32}$ inch wide and 1$\frac{3}{16}$ inch high, excluding terminals. This represents a reduction of about fifty per cent over the volume of the N- and O-type voice frequency transformers, previously the smallest audio transformers for a carrier system. Figure 3 shows the relative sizes of these transformers.

Although the general structure of this transformer was designed specifically for the P carrier, it should have wide use in the telephone plant because of its small size and comparatively low cost in large quantities. It is currently employed in several other communication systems, including the 1A speakerphone system.

* Record, *December*, 1954, *page* 447.

THE AUTHOR

C. E. Luffman joined the Laboratories in 1926 and was associated with the Inspection Engineering (Quality Assurance) Department prior and subsequent to World War II. In this department he was primarily concerned with quality matters relative to telephone system circuits and equipment. During the war he designed power apparatus for the armed forces. In 1951 he joined the apparatus development group responsible for transmission transformers and is currently engaged in transformer development for military applications. Mr. Luffman received a B.S. in M.E. degree from Cooper Union in 1932 and a B.S. in E.E. degree from New York University in 1935.

Chairs for Telephone Operators

W. W. BROWN
Switching Systems Development

To the Bell System, supplying good equipment for use by Telephone Company employees is as important as supplying good service to customers. Nothing is neglected in designing the things employees use so that work can be performed efficiently and safely. A new operator's chair, developed to incorporate many improvements over older designs, should prove a welcome addition to the furniture used in Bell System telephone offices.

Chairs are important items of home or office furniture, and they can be well or poorly designed. A chair may be expertly adapted for its special use, or it may fail in one or more particulars. At Bell Telephone Laboratories, studies are made of posture, comfort and appearance, so that the chairs used by operators will tend to make their tasks easier and their working conditions more pleasant. The overall result will be a contribution to better service to the customer. Involved in these studies are both the mechanics of materials and the structure of the human body, and the goal is to produce a design that will be strong, durable, and well-proportioned posture-wise to support comfortably a person performing specific operations.

Switchboard operation requires that the operator sit at a level which gives her access to such equipment as customer lines and inter-office trunks located in the face of the switchboard as shown above and in Figure 1. The number of lines or trunks varies, depending on the type of service furnished, and the switchboards accordingly vary in height. The operator may have to reach to the right or left or upward to connect to these lines or trunks. In contrast, desk operation is somewhat different than switchboard operation, but the necessary movements of the operator are about the same. An information-desk operator may require access to records in front and at each side of her as shown in Figure 3. Figure 2 illustrates how a rate-and-route operator may have to reach upward for toll tickets filed in cabinets in front of her. To insure that these functions can be performed comfortably and efficiently, the seating must be ample and the seat height must be adjustable. The chair must be rugged and stable to give the occupant a feeling of safety as she moves about. These in general are the mechanical requirements, and in the design of chairs they can be engineered with reasonable accuracy.

The posture requirements are somewhat less definite. In medical parlance they are divided into "static" and "dynamic" conditions. The static condition occurs during the periods when the operator is sitting still, and in this case the chair design must provide the kind of support to cause the least amount of strain on the body muscles. The dynamic condition occurs while the operator is moving about, and the chair design should encourage the operator to assume the most efficient position for the necessary motions. These conditions are generally obtained by the proper relationship between the seat, the backrest and the foot rest or support for the feet. To attain a high degree of perfection in this respect would not be very difficult if the chair were built to order for a single person. However, chairs stay with the switchboard position, while operators are assigned to positions depending on traffic conditions, so that a girl may not necessarily occupy

The result was a design change to use backrests of molded bakelite. This change eventually resulted also in cost savings. The raw material was a little more costly and there was an initial expenditure for molds, but the result was fewer parts to assemble. As styles often do, this one faded out of the picture after several years but the new backrest was retained.

Another illustration of how chair design is affected by extraneous events is the change in floor wax for linoleums in central offices. Originally, the chair rest or caster on the bottom of each leg was made of bakelite and was designed to provide generous load distribution and thus prevent indentations in the linoleum. It also had to permit sliding the chair – but not too easily – because the inadvertent movement of a chair while an operator was reaching a distant jack in the switchboard multiple might cause an accident. However, for floor-maintenance reasons it was found desirable to change to an improved floor wax, and with the new wax the coefficient of friction was somewhat greater than with the old. This resulted in sticking between the bakelite casters and the linoleum, and as a result, new steel casters were designed to obtain the right degree of freedom.

Changes in design will undoubtedly continue for combinations of the reasons given above, and the tendency of such changes is to provide better seating or to reduce the cost of the product. New materials and new industrial processes generally tend to reduce costs, and by adopting them when they prove sound, the ultimate overall costs are kept at nominal levels.

THE AUTHOR

W. W. Brown received a B.S. degree from M.I.T. in 1921. He joined the Western Electric Company Engineering Department at 463 West Street which later became Bell Telephone Laboratories. After short training periods with the New York Telephone Company in central office maintenance and with the Western Electric Company in central office installation he was assigned to the engineering group engaged in equipment design. In the period preceding World War II he was engaged in the design of switchboards, information desks, local test desks, and No. 1 crossbar. During the war he took part in the development of crew trainers for Navy PBM and Army B24 planes. Since the war he has taken part in the development of No. 5 crossbar, the 23 operating room desk, time-of-day equipment and chairs for telephone operators and supervisors.

New High-Power Transistor Announced By Laboratories Engineers

An experimental silicon power transistor, capable of providing an output of five watts at ten megacycles, either as an oscillator or an amplifier, has been developed at Bell Laboratories under the sponsorship of the Joint Services. Details of this development were revealed in a talk prepared by J. C. Iwersen, J. T. Nelson, and F. Keywell of the Device Development Department, and delivered by Mr. Iwersen at the National Conference on Aeronautical Electronics in Dayton, Ohio, on May 15.

Unilateral gain in excess of 20 db and a collector efficiency of better than 40 per cent have been achieved in the construction of this device. The unit is a p-n-i-p diffused emitter and base transistor, in which a near-intrinsic or "neutral" layer of silicon separates the collector from the other elements. Introduction of an intrinsic layer to improve the high-frequency performance of transistors was announced by the Laboratories in 1954.

Alpha cutoff is about 100 mc per second, and some laboratory samples have provided as much as one watt output when used as a 100-mc oscillator. Input and output impedances are on the order of 20 ohms and 300 ohms, respectively.

Original design objectives have been met in the laboratory models and development work on this unit is continuing. Steady improvements in the diffusion process, packaging, and other features are expected to result in a transistor which is reliable and relatively easy to manufacture.

Laboratories-designed four-channel and twelve-channel telephone systems, along with coordinated radio service, have recently become available to the armed forces. Because of its integrated nature, and especially because of its high level of performance and portability, this equipment comprises a major contribution to military communication. The four-channel system for the shorter, light-traffic routes uses a terminal housed in only two transporting cases and a repeater which is housed in a single case.

Four-Channel Military Carrier Terminal and Repeater

G. E. HARPER *Military Communication Systems Engineering*

A new four-channel military carrier system has recently been developed by the Laboratories under Signal Corps sponsorship. This system consists of a terminal, designated the AN/TCC-3 telephone terminal, a repeater, designated the AN/TCC-5 telephone repeater, and a suitable transmission medium of either wire or radio. Some of the features stressed in the design are improved system performance, simpler operating techniques, greater circuit reliability, and ease of maintenance. An additional circuit has been provided, while reducing weight and volume to less than one-third that of earlier equipment of this type.

The terminal, repeater, and connecting transmission media permit simultaneous transmission and reception of four carrier telephone channels plus an order wire (maintenance) channel. Each carrier channel is capable of handling as many as sixteen teletype circuits. Wide-band signals, such as those used for facsimile and data transmission, can also be substituted for the four message channels.

The new carrier system was designed for cable operation over distances up to 100 miles between terminals while operating within the temperature range of −40°F to +130°F. This temperature range applies to both the system equipment and the associated cable. The cable, of the "spiral-four" type, contains two pairs of conductors wound in the form of a spiral — one pair provides a path for one direction of transmission, while the other pair serves as a medium for transmission in the other direction. Each cable section includes a loading coil to add inductance to the cable, which reduces the cable attenuation over the frequency range of the system. Although this carrier equipment has been designed for use over loaded spiral-four cable, the amplification and equalization provided by the terminal and repeater permit its use on other types of transmission media. It will function over open-wire lines and also operate into a number of military radio links. In the military communication system such flexibility is essential.

The AN/TCC-3 terminal, Figure 1, is composed of two major units, each in a separate transit case, called the amplifier power supply and the telephone modem. The amplifier power supply contains the power supply, line amplifiers, equalizer, and crystal-controlled carrier supply. It also contains an order-wire circuit, oscillator and transmission measuring set for line-up and maintenance, a ringer-oscillator for signaling purposes, and a 4-kc terminal-to-terminal system alarm. The telephone modem case houses the four channel modem (modulator and demodulator) units. The AN/TCC-5 repeater, Figure 3, is a major unit with self-contained power supply, line amplifiers, and equalizers. Similar to the terminal, the repeater also contains an order-wire circuit, a transmission measuring set, and a ringer-oscillator. This repeater unit is completely housed in a single transit case.

The metal transit cases used to house the two major elements of the carrier telephone terminal, and the single case which contains the carrier telephone repeater, are of the shock-mounted type. The electrical circuits contained within each case have been mounted on a drawer-type chassis attached to the front panel. This type of design makes the electrical circuits readily accessible for maintenance. Another feature which simplifies maintenance is the use of plug-in units. The transmitting and receiving amplifiers, ringer-oscillator, carrier supply, and channel modems are of the plug-in type. The terminal transmitting and receiving amplifiers, and the repeater line amplifiers, are all interchangeable units. This interchangeability feature between terminals and repeaters is also incorporated in the ringer-oscillator. The channel modem units are somewhat similar in physical appearance but have different electrical characteristics. A mechanical design feature permits the removal of each channel unit for maintenance or replacement without the possibility of the occurrence of errors in reassembly.

As previously mentioned, the telephone modem case contains four individual channel modems. This unit has been designed following the modern military "building block" concept, whereby an entire unit of equipment, or elements of it, serve as an important adjunct or portion of another unit of equipment or of the system. An associated twelve-channel system capitalizes upon this principle by using three telephone modem boxes to obtain the twelve channels.

Each individual channel modem contains a transmitting and receiving section. The voice frequencies applied to the transmitting section modulate the carrier frequency, thus producing upper and lower sidebands. Since the same intelligence is contained in both the upper and lower sidebands, band filters can be used to eliminate the upper sidebands and pass only the lower sidebands. This well known "single-sideband" method conserves considerable frequency space in the transmission medium. The carrier frequency is also suppressed in the transmitting section of the channel modem and resupplied at the receiving terminal to demodulate the lower sideband frequencies. The demodulation process converts these signals to their original audio-frequency forms.

Carrier frequencies of 8, 12, 16 and 20 kc are used for channel modems one through four, respectively, each having a bandwidth of approximately 3,200 cycles. The four carrier frequencies

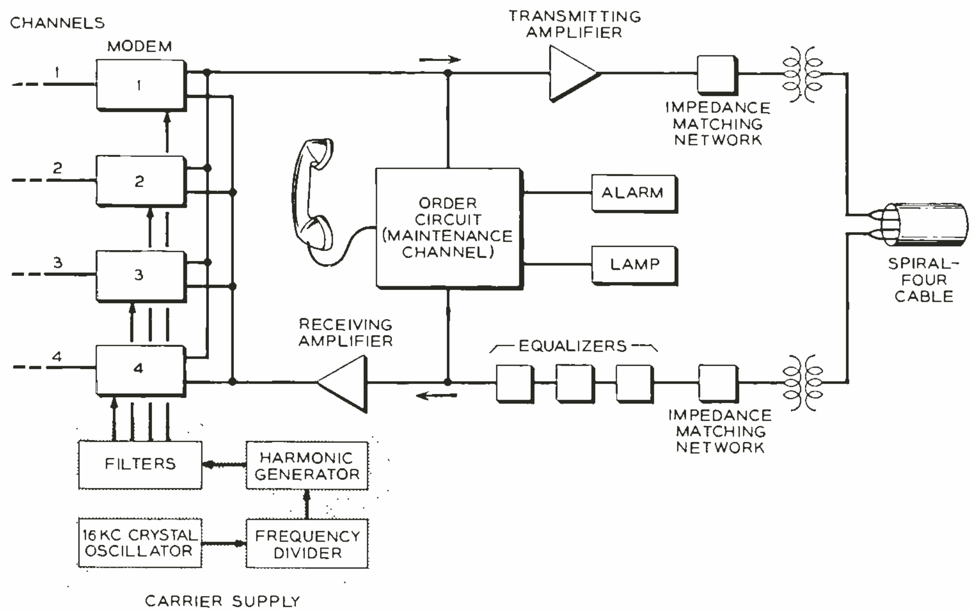


Fig. 1 — Simplified block diagram of the AN/TCC-3 terminal, showing carrier-frequency supply for the four channel modem equipment units.

Fig. 2 — The author, left, tests a complete AN/TCC-3 terminal in the laboratory. Four-channel modem in the top case and the amplifier-power supply in the bottom. At the right, J. O. Replogle works on amplifier-power-supply pulled out of its case; internal design permits ease of maintenance.

are obtained from a carrier supply, represented in the lower left part of Figure 1. To develop the carrier frequencies, the crystal oscillator of the carrier supply generates a 16-kc frequency, which is applied to a frequency-division circuit. This frequency is divided to 8 kc, and then to 4 kc. A constant 4-kc frequency output is obtained, and this is applied to a saturable inductor to produce a wave shape that is rich in odd harmonics. The 4-kc odd harmonics – 12 kc and 20 kc – are selected by filters and applied to the appropriate channel modems. The 4-kc even harmonics – 8 kc and 16 kc – are obtained from two fullwave varistor rectifiers and are similarly selected by filters. The 4-kc output, in addition to providing a constant frequency from which the carrier frequencies are obtained, also serves as a pilot frequency. Changes in the line characteristics large enough to decrease the pilot frequency below a predetermined level, will bring in an audible and visible alarm at the terminal.

The amplifier circuit, which serves as either a transmitting or receiving amplifier, is a two-stage, wide-band, plug-in amplifier with negative feedback. A switch is provided to alter the amplifier gain. An equalizer network* precedes the terminal receiving amplifier and each of the two line amplifiers contained in the attended repeaters. Three manually adjusted equalizers enable equalization of the cable at 1, 19 and 11 kc. With these, it is possible to apply a relatively "flat" input to the amplifier over the band of received frequencies.

Transformer coupling is used to connect the transmitting and receiving sections of the terminal to the spiral-four cable. Transformer leakage inductance is used as part of a network to provide an appropriate impedance for junction with the cable.

The amplifier power supply part of the terminal contains a built-in signal generator and detector. The signal generator is a one-tube oscillator which produces an adjustable 1-kc output. This frequency

* RECORD, *February*, 1957, *page* 72.

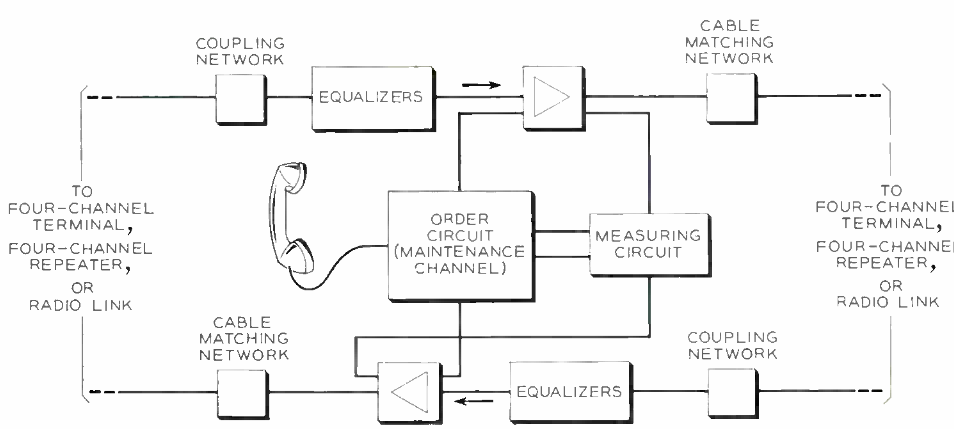


Fig. 3 — Simplified block diagram of the AN/TCC-5 repeater.

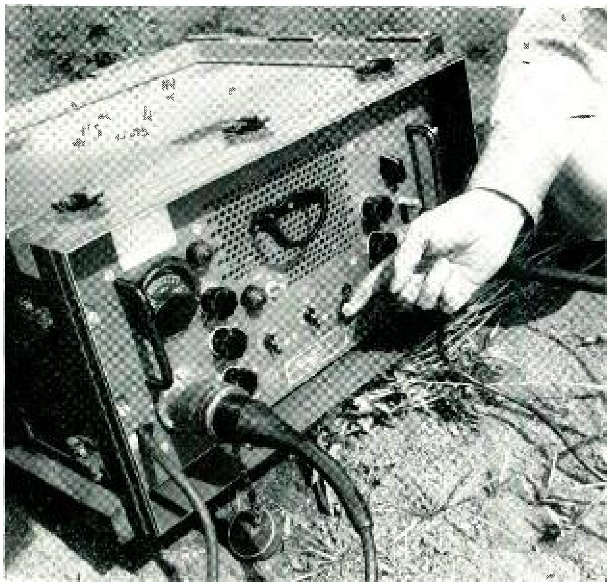


Fig. 4 — The complete AN/TCC-5 repeater.

can be applied to a channel modem, where it modulates any one of the channel carriers to develop frequencies used for equalization and other frequencies that aid in checking the performance of the terminal transmitting section. The measuring circuit (detector) contains a rotary switch and a selective filter. These permit the application of selected test frequencies to a copper-oxide rectifier and the application of the rectified output to the measuring meter. The terminal receiving circuits may be checked by switching the measuring circuit to the output of the receiving amplifier and by switching to the receiving side of any channel modem. A measuring circuit test probe is available for checking the output of the carrier-supply 16-kc oscillator and for measuring the 4-kc output. Test jacks are provided for performing this test.

The separate order-wire circuit makes a voice-frequency telephone channel available for communication between terminal or repeater attendants. It is primarily used for maintenance or operational purposes, and it can be used at any time without interfering with traffic over the four carrier channels. The order-wire circuit functions similarly for attendants of intervening radio links. The band of this circuit extends from 300 to 3,100 cycles.

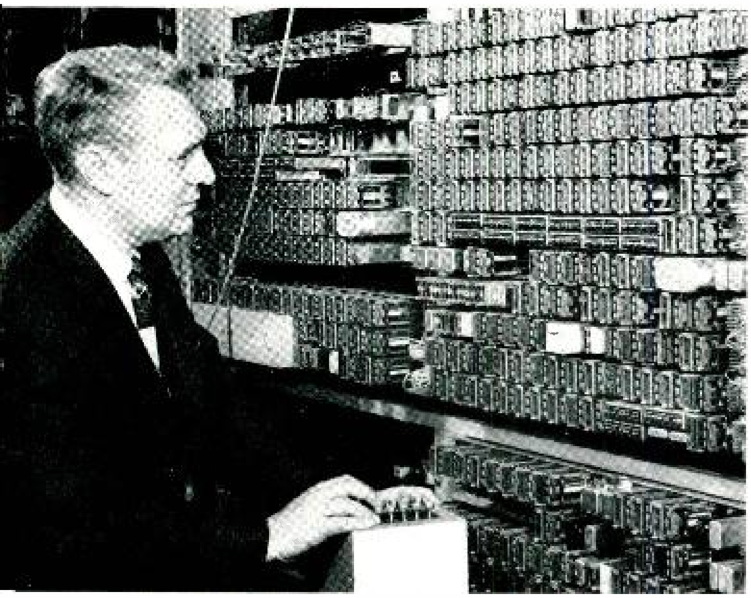
A ringer-oscillator circuit is used in conjunction with the order wire to establish contact between equipment attendants. When the ringing switch is nonoperated, the ringer acts as a selective detector to receive incoming 1,600-cps ringing signals from other system attendants. When the ringing switch is operated, the ringer-oscillator functions as an oscillator, generating a 1,600-cps signal for alerting other associated system attendants. When operated as a ringer, a guard-channel circuit provides a safeguard against false ringing.

All terminals and repeaters have their own internal power supplies, designed to operate on 50 to 60 cycles ac at either 115 or 230 volts plus or minus 10 per cent. The terminal power supply delivers 125 watts to the terminal. The repeater power supply delivers 75 watts of power. Double-diode, full-wave rectifiers, connected in parallel, are used to produce the high voltage +200 volts dc output required by both the terminal and repeater. The power supplies also develop a 6.3 volts ac filament voltage and negative voltages of −5 and −10 volts dc. The negative voltages are obtained from varistor rectifiers, and are used as biasing voltages in the ringer-oscillator and order-wire circuits.

The AN/TCC-3 and AN/TCC-5 carrier equipment is now in use by a number of military organizations. In several field tests, it has been subjected to adverse climatic conditions, and subsequent reports have indicated very satisfactory performance.

THE AUTHOR

G. E. Harper was graduated from the Capitol Radio Engineering Institute in 1949. He then served as a technical advisor at the Signal School, United States Mission Aid to Turkey, for two years. During World War II, Mr. Harper served as an officer in the European Theater of operations. He is presently active as a Major, Signal Corps, United States Army Reserves. After joining Bell Telephone Laboratories in 1952, Mr. Harper worked on military carrier systems for several years, and is presently working on a military communication system study project.



The relay is today such a common item that few people realize just how important it is. Relays are, in fact, indispensable tools in Bell System switching systems. On a single inter-office call in the No. 5 crossbar system, for example, there are more than 1,200 separate relay operations. More than three-hundred million relays of about a hundred different types are presently in use in the Bell System's far flung telephone plant.

R. MUELLER *Switching Apparatus Development*

Relays in the Bell System: Facts and Figures

Antedating the telephone by some years, the relay was used by Samuel Morse in 1836 in his electric telegraph. The device took its name from the service it performed in the telegraph – relaying a message from one circuit to another. It consisted of an electromagnet operating an iron "clapper" or armature which also acted as the moving element of a switch. The term "relay" is now more broadly defined in the electrical industry as an electro-mechanical device that uses a change of current or potential in one circuit to produce a change in the electrical condition of another circuit. This is much broader than the Bell System meaning of the word, since it includes such things as panel, step-by-step, and crossbar switches. In the Bell System, a relay is usually thought of as a switch element capable of assuming one of two positions and operated by an associated electromagnet. A few relays, however, are operated by thermo-electric means.

The telephone industry was slow to adopt the relay, apparently making little use of the device until the common-battery switchboard and the Strowger dial system were introduced around 1895. In the Bell System as then constituted, line and cut-off relays and supervisory relays in cord circuits of common-battery switchboards were the chief uses. The Bell System began to use automatic switching equipment on an appreciable scale around 1919, and the uses of relays and the demand for them began to expand rapidly. Today, the relay is the work-horse of the Bell System and, at the present stage of the switching art, is the one indispensable tool in a switching system.

Since first used in the Bell System, the relay has

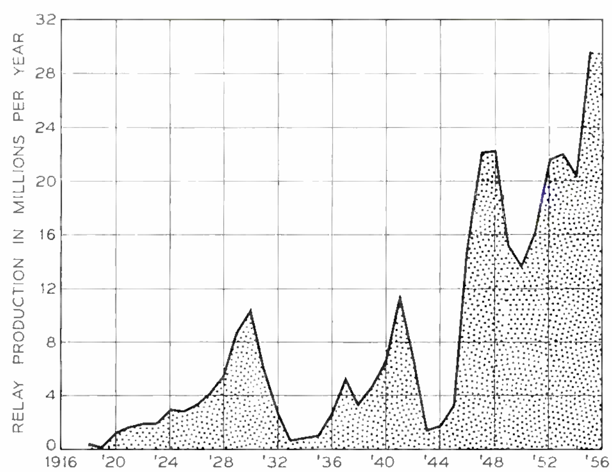


Fig. 1 — Chart of Western Electric Company relay production through the years.

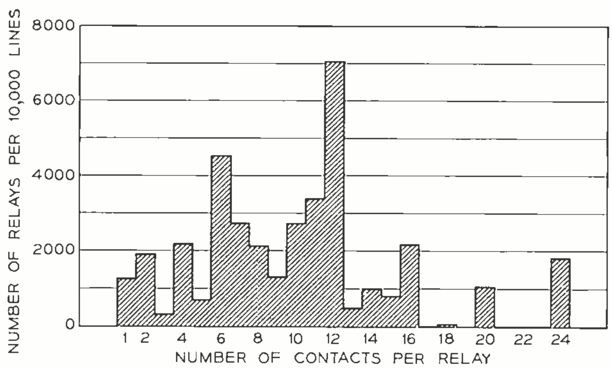
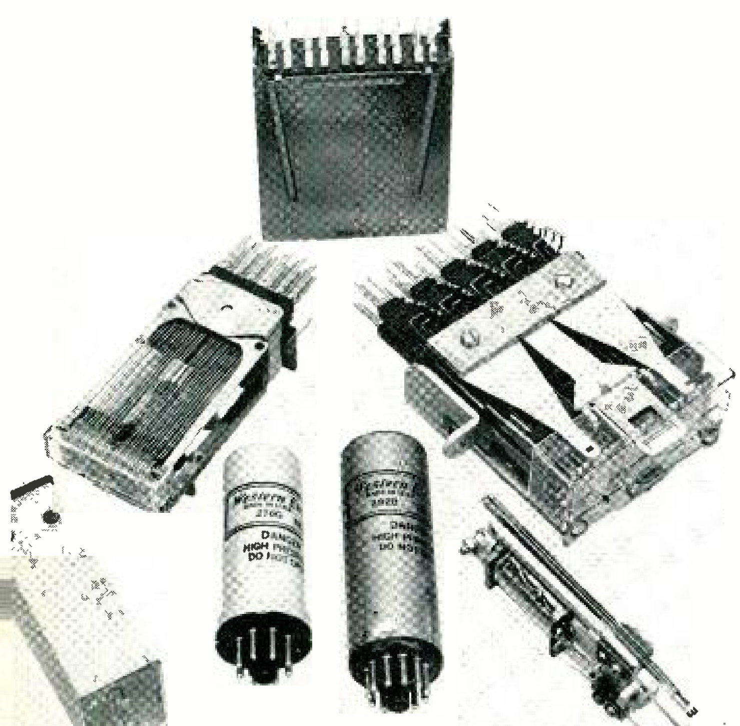


Fig. 2 — Number of wire-spring relays per 10,000 lines versus number of contacts per relay.

gone through a considerable evolution and numerous types have been made. Many of the early types, however, are still being manufactured by the Western Electric Company for replacements in older switching equipment. In all, Western Electric manufactured 98 types and a total of about 6,400 different codes in 1955. Yearly production of relays from 1918 to 1955 is shown in Figure 1. Production descended during the depression of the thirties, rose to new heights, and again dropped during World War II. The pent-up demand for telephone service caused relay production to increase rapidly at the end of the war. It is estimated that as of mid-1956 there are over 300 million relays in use in the Bell System, with the total still on the increase at the rate of about 20 to 30 million per year.

Production of 30 million relays of 98 different types in 1955 varied from a single relay in some older types to as many as 6 million for the U type,

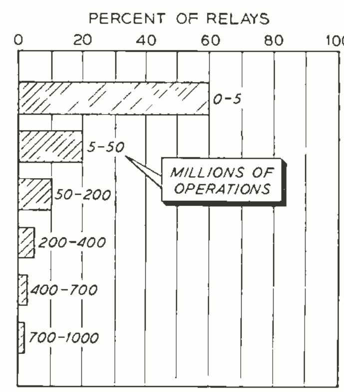
Fig. 3 — Representative relay types used in a modern telephone office.



the commonly used general-purpose type before the advent of the wire-spring type. Figure 3 shows several types of relays in use today. Each type is usually made in a number of minor variations or codes. About 5 to 7 thousand different codes of relays are manufactured in one year. Here again, annual production varies widely, from a single relay for some codes to as many as a million for another, more frequently used, code.

Although relay production runs to large numbers, spreading the production over 6,400 different items, many of low demand, increases Western Electric's cost of administration and manufacture. This aspect of relay production was given much consideration by the Laboratories, culminating in an effective

Fig. 4 — Operating life requirements of relays for the No. 5 crossbar system.



code-reduction program in 1947 when the No. 5 crossbar system was being developed. This program held the number of needed codes to 489, compared with 705 codes required by No. 1 crossbar. Continuation of the program during design of the wire-spring relay resulted in coordination of systems needs with the relay design so that the wire-spring redesign of No. 5 crossbar requires only about 170 general-purpose wire-spring relay codes. This appreciable reduction in codes permits substantial savings in administrative and manufacturing costs. The large demand for many of the codes makes the use of highly mechanized assembly methods possible.

Uses to which these relays are put vary widely; some relays switch only a single circuit, others as many as 30 circuits. On the average, a general-purpose relay will have about 10 contacts. Figure 2 shows demand versus number of contacts for the general-purpose wire-spring relays in the No. 5 system. The peaks at 6 and 12 springs are largely fortuitous. Relays during their life are expected to perform their switching function for from only a few operations in some circuit applications to a billion operations in other applications.

The great bulk of the relays, however, are used in circuits requiring a few million operations. A chart of operations versus number of relays for the No. 5 crossbar system is shown in Figure 4.

It is interesting to compare relays in various local switching systems from the standpoint of the number used and the number of operations. In manual switching, operators make the actual connections, while in step-by-step and No. 5 crossbar, switches make the connections. Step-by-step is a simple system using switches that follow the dial pulses. No. 5 crossbar is a highly developed system using crossbar switches and common-control equipment to direct the switch operations. The number of relays per line for these systems is shown in Table I.

On seeing the comparatively large number of relays in automatic switching systems, one unfamiliar with the art immediately wonders why the extra relays are used when the switches supposedly replace the operator. The reason is that an operator does far more than merely go through the mechanical operation of switching a call. She performs many additional functions requiring logic and memory, such as selecting the lines of customers requesting service, selecting the called customers, ringing the called station, checking for busy indications and keeping records of charges. In automatic systems, these functions of logic and

Table I — Number of Relays per Line

System	*Relays per Line*
Step-by-Step	7.0
Manual	2.5
No. 5 Crossbar	6.5

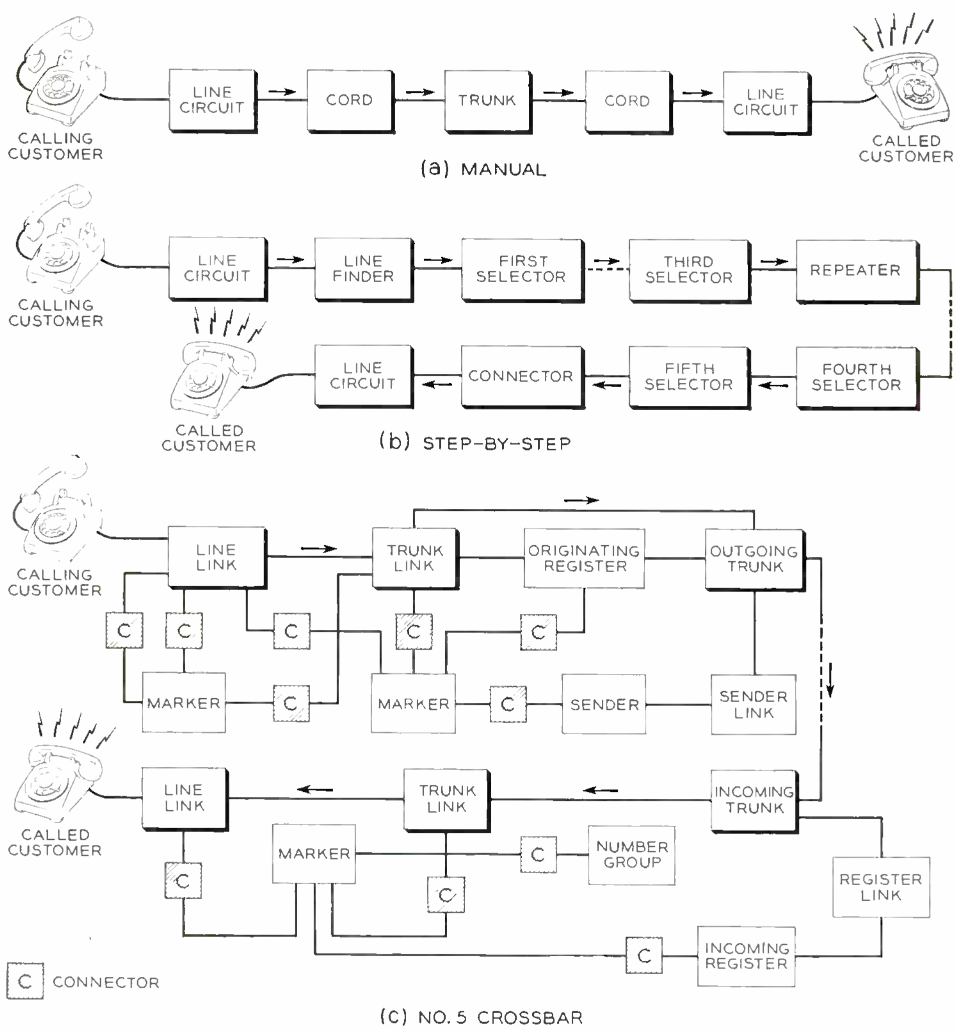


Fig. 5 — Comparison of the amount of equipment used for an inter-office call in three different types of systems for the switching of telephone calls.

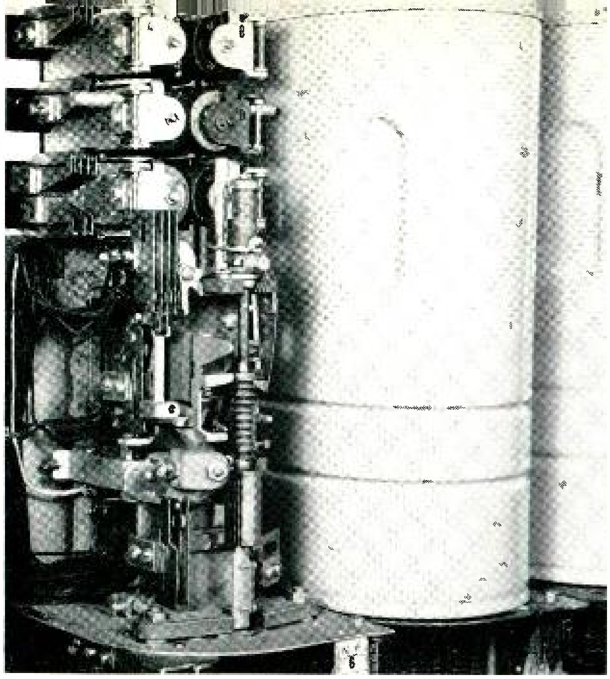


Fig. 6 — Even a step-by-step switch requires several control relays for successful operation.

memory are performed largely by a group of relays.

Circuits involved in setting up inter-office calls in the three systems are illustrated in Figure 5. It can be seen from Table II that about 30 times as many relays and 12 times as many relay operations are involved in a call in No. 5 crossbar as in step-by-step. In No. 5, however, only a few relays are held during a conversation while the other several thousand are used only for short intervals — a few milliseconds to a few seconds — and are then free to handle other calls; in step-by-step, practically all relays are held for the duration of a call. It is apparent that some relays have very high usage in No. 5 compared to step-by-step but the added features and versatility of the system make this greatly increased relay use worthwhile.

High usage of cross-bar common-control equipment requires that a large proportion of the relays

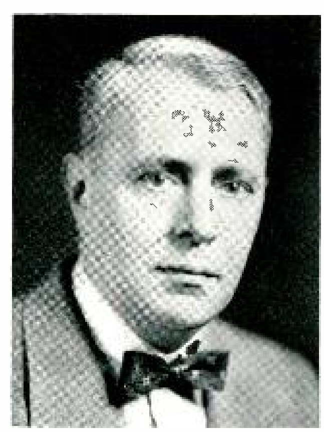
TABLE 2 — COMPARATIVE USE OF RELAYS IN AN INTER-OFFICE CALL

System	Number of Relays: In Circuits	Number of Relays: Used per Call	Number of Relay Operations per Call	Number of Relays held for Duration of Call
Manual	16	15	15	16
Step-by-Step	48	44	97	47
No. 5 Crossbar	4871	1200	1278	24

have an operational life far in excess of that required in older automatic systems. This resulted in development of the U-type relay as a heavy-duty, high-performance relay for use in common-control systems such as No. 1 crossbar. Although the U relay permitted the design of an economical system, it soon became evident that for many applications a faster, longer-lived relay was desirable. Subsequently, the wire-spring relay was developed to fill this need. The operating speed and superior characteristics of this relay in combination with advances in the circuit art permitted substantial cost reduction in the new wire-spring redesign of No. 5 crossbar. Improvements in performance and life and reductions in maintenance costs can also be expected through use of wire-spring relays.

From the standpoint of capital investment, relays represent a substantial part of the investment in a central office. About 20 per cent of the cost of installed equipment is for relays. The number of relays used in the Bell System has been steadily increasing and will no doubt continue to do so for some time. Future developments in the electronic switching field probably will gradually reduce the rate of increase and eventually the total number of relays in use but, at present, the relay is indispensable in modern telephone switching systems.

THE AUTHOR



R. MUELLER graduated from the University of Minnesota with the B.E.E. degree in 1929 and immediately joined the Systems Development Department of the Laboratories. Shortly thereafter he transferred to the Apparatus Development Department, designing transformers for carrier and radio telephone applications, and for various radar equipments during World War II. Since that time, Mr. Mueller has been engaged in the evaluation and testing of new electromechanical apparatus and in contact studies.

Experimental "Drive-In" Coin Telephone

Experimental model of the new "drive-in" telephone. The instrument, housed in a weather-protective hood, is easily accessible to the driver.

Drive-in arrangements are becoming familiar services at libraries, banks and post offices, and now outdoor telephones are also being adapted for use from automobiles. Experimental "drive-in" telephones have been developed at Bell Laboratories and are presently undergoing a field trial to determine customer approval. These phones, mounted on metal stands beside roadways, could provide "road service" for telephone users. Installed along curbs, safety islands and at road-side cut-offs, drive-in coin telephones can supplement the service presently provided by existing outdoor telephone booths installed at convenient locations.

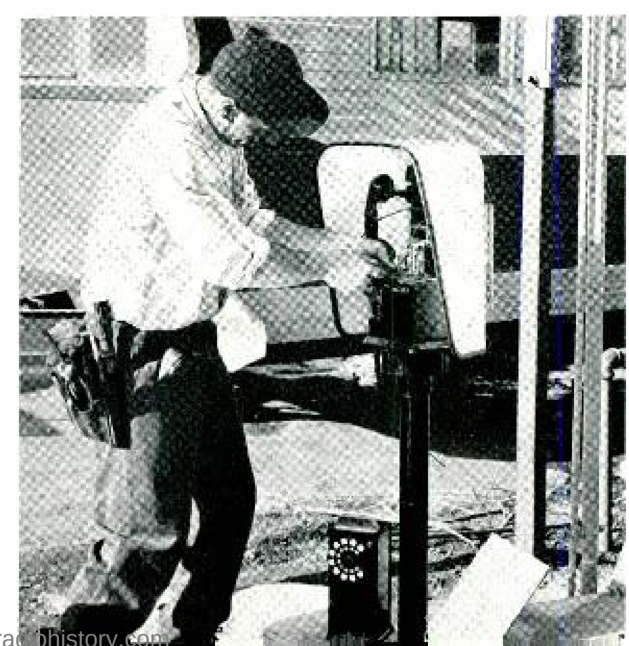
The experimental units consist of three sub-assemblies: a base, a post and a hood. Each is designed with specific service requirements in mind. A concrete block, approximately 2 cubic feet in volume, rigidly supports the post assembly, and extra strong steel pipe with suitable mountings secures the hood assembly. For ease of operation by the customer, the unit is positioned with the dial two-thirds of the way up the average car window opening, a little over four feet above road level. The latest coin telephone – equipped with retractile handset cord and extra weatherproofing – is fastened to a very tough and durable manganese-bronze support plate. A bright-colored plastic hood partially encloses the unit and offers protection from bad weather. Hoods for the trial models were made in green, yellow, orange and blue.

The hood – vacuum formed from a cellulose acetate butyrate material – presents an eye-catching, flexible and translucent assembly. A telephone directory is supported in a square metal box below the instrument. The directory is secured with a ten-foot retractile cord. For night-time use, the "drive-in" telephone is illuminated either by spot lights mounted on adjacent structures or by lights imbedded in the concrete base.

The development of this unit at the Laboratories involved a number of problems in the choice of materials and in structural design for both durability and convenience of use. Prior to the field trial, preliminary tests, including exposure to weather, were conducted at the Laboratories to verify that initial design requirements had been met. The field trial of this new telephone equipment – presently in progress at Mobile, Alabama, and at Chicago, Illinois – will produce user preference information. Favorable response to the use of this experimental equipment can forecast a new convenient service for telephone customers.

W. J. KENNEDY *Station Apparatus Development*

Illinois Bell employee installing field-trial "drive-in" telephone set in Chicago location.



Frederick R. Kappel Addresses AT&T Annual Meeting

At the AT&T Annual Meeting, held April 17 at 50 Varick Street in New York City, President Frederick R. Kappel stated that the business was in sound condition and was carrying on a large construction program. He also discussed the long-run question of Bell System earnings. "As to the present state of business," Mr. Kappel said, "here are some of the facts that give me confidence.

"To begin with, people want our product. They want it very much. Our service is the best it has ever been, and the better we make it the more people want and use it. The basic fact is that we have a tremendously popular and expanding line of services, and their quality and value are continually increasing. This is the first condition for a healthy business, and we have that.

"Along with this, our financial structure is sound and our credit is good. We are not overloaded with debt. We continue to gain more share owners — in fact we now have about 80,000 more than a year ago, and half a million more than in the spring of 1951 (only six years back) when we welcomed our

Part of the record group of share owners who attended the Annual Meeting.

one-millionth share owner. All these factors gave the business strength.

"Still another point of great consequence is this: We are all the time gaining new knowledge that is tremendously important for the future. No matter how well we might be doing at this present moment, I couldn't say we were in good shape if I didn't feel confident that the scientific and technical advances we are making would equip us for great progress in the years ahead."

Additional quotes from Mr. Kappel's talk are as follows: "We're spending a great deal of money to enlarge and modernize our physical facilities, and to do this we must continue to raise very large amounts of new capital. . . . We must provide the services people expect and are entitled to receive. The whole welfare of the business is wrapped up in this undertaking.

"Every cent we obtain from investors and use to build telephone plant must, of course, be earned on. . . . The first necessity in these days of creeping inflation is to keep ahead of rising costs. We do everything we can to hold costs down. We develop and install more efficient equipment. We devise new tools. We are continuously working out more economical methods for handling all the many different jobs that go into the rendering of telephone service. But in spite of these savings, our costs, in which wages are much the largest element, continue to go up. So this is one factor in our requests to the regulatory commissions for rate increases: we must have higher revenues to cover higher costs.

"A second factor is equally important," Mr. Kappel continued. "This is the need to assure successful financing on a scale never before attempted by any business. . . . We must obtain great sums of money from investors – more new capital than ever before. We must do this at a time when money is tight and interest rates are high; and in doing it we must win and keep the favor of investors in competition with all industry, including nonregulated companies which earn two or three or more times as much on their investment as we have been able to earn under public regulation. This clearly means that the Bell System, in order to have reasonable assurance of attracting all the capital it needs, should have earnings substantially above the present level.

"I'd like to end, as I began, on a strong note of confidence," Mr. Kappel said. "Our service is good, the public wants more and more of it, and I'm sure people are willing to pay for good service what it reasonably costs. Telephone people know their jobs and are continually learning how to improve performance. Our construction program is carefully planned to meet practical needs. Finally,

At the close of AT&T's Annual Meeting, President Kappel greets one of the company's share owners.

we are extremely fortunate in our share owner group, now a million and a half strong, and we are determined to do everything that should be done to promote the progress of your business and assure the integrity of your investment."

At the meeting, which had a record attendance of about 3,000 AT&T share owners, the proposal that AT&T shares be split four-for-one was defeated by vote of the share owners, with 91.84 per cent against and 8.16 per cent for. Two other proposals – for ceilings on officer's pensions and for televising or broadcasting annual meetings – were also defeated.

P. Andreatch, Jr. adjusts delay-line test equipment as R. N. Thurston and W. P. Mason look on.

New Type of Delay Line Developed at Laboratories

Torsional wave delay lines with delay times per unit length as much as twenty-five times greater than those of conventional lines have been constructed by members of the Bell Laboratories' Mathematical Research Department. Based on theoretical work by W. P. Mason, P. Andreatch, Jr. and R. N. Thurston have developed lines which can be useful in applications where accurate, predictable delays are required. Their chief advantage is the small space required for a given delay.

The delay in a line or rod depends on the velocity of propagation of the torsional wave. This velocity can be greatly decreased by the use of disc loading, wherein the delay-line rod is composed of alternately positioned large and small diameter sections.

A delay line of this type, which consists essentially of a series of equally spaced discs along a smaller diameter axial rod, is a low-pass filter for torsional waves whose cutoff frequency decreases with increase in the diameter, the thickness, or the spacing of the discs. To obtain high cutoff frequencies, therefore, small dimensions are necessary; but the delay for a given length increases roughly as the square of the ratio between disc and rod diameters. Large delays at reasonable operating frequencies thus require small diameter rods, and these must be precisely machined.

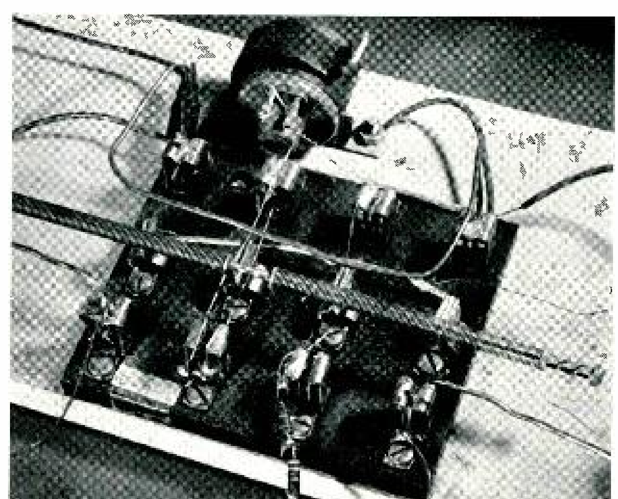
Two delay lines, machined from solid brass rods, were studied—one having diameters for disc and rod of 0.180″ and 0.045″; the second 0.220″ and 0.044″ (ratios of 4 to 1 and 5 to 1, respectively). The cutoff frequency for these lines was about 50 kc, and a frequency of 32 kc was employed to check the characteristics of the lines.

Special low-frequency torsional transducers, produced from barium-lead-calcium titanate, were designed for the tests. One, a "split tube" type, was 3.14 cm long and 0.255 cm in diameter. A second "dumbell" or "disc-loaded" type, analogous to the line itself, was only 1.43 cm long. These transducers were incorporated by soldering them to the ends of the brass delay lines.

The delays were measured by first determining the delays in the transducers themselves and then soldering the lines between them. The line delay was taken as the difference between that for the coupled transducers and that for the line-transducer assembly.

For the 4-to-1 line with 0.020″ discs and spaces and a total length of 2½″, the delay was 43 microseconds per centimeter with an insertion loss of 1.7 db. Bandwidth was 4.6 kc, determined by the transducers. The delay in the 5-to-1 line with 0.015″ discs and spaces and a total length of 3″ was 114 microseconds per centimeter, the insertion loss about 1 db, and the bandwidth 6.3 kc.

The torsional wave delay in a brass rod of uniform diameter is only 4.5 microseconds per centimeter, so that the 5-to-1 disc-loaded line offers a 25-fold improvement in delay time.



Experimental torsional wave delay line developed by research team at Bell Telephone Laboratories.

Laboratories to Establish Graduate Study Center

A graduate study center will be established by New York University at Bell Laboratories this fall, making it possible for members of the Communications Development Training Program to obtain credit toward advanced degrees.

The New York University program, offered under the Graduate Division of the College of Engineering, will replace that part of C.D.T. consisting of courses in mathematics, physics and engineering, and will carry graduate credit. C.D.T. will continue and will offer courses in areas of specific Bell System technology. The new program will constitute an integrated system of graduate study and training in industry.

All of the courses will be given during regular working hours, and the Laboratories will provide funds for the entire cost of instruction. Participants in the program will receive full salary and will work part time in technical departments as they now do.

In recent years, New York University has cooperated with the Laboratories in teaching certain mathematics and physics courses of the C.D.T. Program. The present development is an extension of this earlier cooperation and sets up, at the Laboratories, a branch of the university, authorized under the New York State Charter of the institution, to give residence credit toward academic degrees on the same basis as is done at its campus on University Heights. The university will have a full time resident director of the branch at the Laboratories, and the courses offered for graduate credit will be taught by regular members of the New York University faculty.

The courses planned initially will lead to a Master of Electrical Engineering (M.E.E.) degree which may be obtained in two years by those able to satisfy the requirements of the College of Engineering of the university. Those who already have master's degrees, and those who wish to qualify for degrees in fields other than electrical engineering, may also accumulate graduate credits toward a doctorate or toward other graduate degrees. To complete the requirements for such degrees, courses in any field may be taken on the New York University campus under the Laboratories' Graduate Study Plan, which provides tuition refund and limited time off with pay for employees attending universities near Bell Laboratories locations.

Dr. M. J. Kelly (right) and New York University President Carroll V. Newsom approve final plans for the graduate study center at the Laboratories.

The first C.D.T. class to enter fully into the new program will be the class of 1957 which begins its graduate studies this fall. Some courses carrying academic credit will be made available to members of the class of 1956 in their second year. For those new recruits lacking full prerequisites for the program, New York University will provide special courses during the summer months. Classroom and office space is planned in the new administration building now under construction at Murray Hill. Until this space as available early in 1958, classes will be held in New York City.

Inventors of Transistor Address Physical Society

At the invitation of the American Physical Society, inventors of the transistor Walter H. Brattain and John Bardeen delivered talks at the Society's Washington, D.C., meeting on April 27. Mr. Brattain, member of the Physical Research Department at Bell Telephone Laboratories, gave a talk entitled "Physics of Semiconductor Surfaces." Mr. Bardeen, former member of the Laboratories and now Professor of Electrical Engineering and Physics at the University of Illinois, gave a talk entitled "Semiconductor Research Leading to the Point Contact Transistor."

These talks were, in essence, the same as the ones presented to the Swedish Academy of Sciences in Stockholm in December, 1956. On this occasion, Messrs. Brattain and Bardeen, along with William Shockley, Director of the Shockley Semiconductor Laboratory of Beckman Instruments, Inc., received the 1956 Nobel Prize in Physics for work at the Laboratories leading to the discovery of the transistor.

H. Kraft (left) and K. B. McAfee, Jr., engage in measurement of gaseous diffusion through glass and high-alumina ceramics. Mr. Kraft is pouring liquid air into cold trap of high-vacuum apparatus.

Properties of Ceramics Discussed At Convention

Several members of the Laboratories discussed diffusion of gases and properties of ceramics at the recent national convention of the American Ceramic Society, held May 6-8 in Dallas, Texas.

As one of the speakers at the convention, K. B. McAfee, Jr., of the Chemical Research Department presented information on the ability of certain gases to diffuse through glass and various ceramic materials. For most practical purposes, glass is a good envelope for gases, but if there is a difference of pressure between the inside and the outside of the envelope, gas may pass through the glass walls by a process known as diffusion.* This is especially true of helium. It has been found that the actual quantity of gas which will diffuse through the glass is very small, but it can be appreciable in many investigations and where high pressure differences and long periods of time are involved.

Certain other ceramic materials may be many thousands of times more resistant to diffusion than glass, Mr. McAfee reported. Materials known as high-alumina ceramics are particularly resistant to diffusion, even under conditions of high temperature and pressure.

* Record, *January, 1955, page* 1.

Other properties of high-alumina ceramics were discussed by E. D. Tidd and J. C. Williams of the Military Electronics Development and Chemical Research Departments at Bell Laboratories. Such ceramics, used for many years as electrical insulators by the spark plug industry, are now being employed in the construction of hermetically sealed electrical terminals.

To realize the full advantages of these ceramics – from such standpoints as hermetic seal, insulation resistance, corona and flashover, mechanical strength, and working temperature limits – careful attention must be given to the microstructure of the material, and quality control must be maintained in all stages from fabrication to final installation in the component or device.

Information relative to sealing metals to high-alumina ceramics was presented by J. C. Williams and J. W. Nielsen, Chemical Research, of Bell Laboratories. The ability of various molten brazing solders to wet both the original and metallized surfaces of such ceramics is one of the more important factors in forming a satisfactory seal.

The electrical properties of some ceramic semiconducting oxides were discussed by H. A. Sauer and S. S. Flaschen, also of the Chemical Research Department at Bell Laboratories. In studies of such properties, results can be considerably influenced by the electrodes employed, a fact which has not been properly recognized in many cases.

A new indium alloy electrode has been developed which gives good results with certain semiconducting materials, for example, titanium dioxide and barium titanate.

Winner of Laboratories Graduate Fellowship

The May, 1957, issue of the Bell Laboratories Record carried an announcement of the winners of the 1957-58 Laboratories college fellowships. The name of one recipient was inadvertently omitted. The list of winners should have included Robert E. Baron of Chicago, who will pursue his graduate studies at the University of Chicago. His field of study will be physics.

Talks by Members of the Laboratories

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

Annual Meeting of the Eastern Psychological Association, New York City

Bricker, P. D., *Display Size and Performance on Simple Perceptual Tasks.*

Griffith, B. C., *The Use of Phoneme Labels in Distinguishing Speech Sounds: An Effect of Learning on Perception.*

Solomon, L., *The Influence of Some Types of Power Relationships and Motivational Orientations Upon the Development of Trust.*

American Chemical Society, Spring Meeting, Miami, Florida

Brady, G. W., and Krause, J. T., *Structure in Ionic Solutions.*

DeCoste, J. B., Howard, J. B., and Wallder, V. T., *Weathering of Poly (Vinyl Chloride), Effect of Composition.*

Frisch, H. L., *The Adsorption of High Polymers from Solution.*

Giuliano, C., see Schwartz, N.

Howard, J. B., see DeCoste, J. B.

Knox, K., Tyree, S. Y., Srivastava, R. D., and Coffey, C. E., *Chlorides of Technetium and Rhenium.*

Krause, J. T., see Brady, G. W.

Matthias, B. T., and Morgan, S. O., *Ferroelectrics and Pyroelectricity.*

Morgan, S. O., see Matthias, B. T.

McCall, D. W., *A Cell for the Determination of Pressure Coefficients of Dielectric Constant and Loss of Liquids and Solids to 10,000 pounds per square inch.*

Schwartz, N., Giuliano, C., and Wilmarth, W. K., *Persulfate Chemistry: I. The Free Radical Induced Hydrogenation.*

Thurmond, C. D., *The Chemistry of Semiconductors.*

Wallder, V. T., see DeCoste, J. B.

Wilmarth, W. K., see Schwartz, N.

American Mathematical Society, New York University, New York City

Fleischer, I. B., *Maximality and Ultracompleteness in Normed Modules.*

Gilbert, E. N., and Pollak, H. O., *A Maximum Problem Connected with Trees.*

Miranker, W. L., *The Reduced Wave Equation in a Medium with a Variable Index of Refraction.*

Pollak, H. O., see Gilbert, E. N.

American Physical Society Meeting, Washington, D. C.

Brattain, W. H., *Physics of Semiconductor Surfaces.*

Dillon, J. F., Jr., *Optical Transparency and Faraday Rotation in Yttrium Iron Garnet.*

Garrett, C. G. B., *High Frequency Relaxation Processes in the Field-Effect.*

Geller, S., see Gilleo, M. A.

Gilleo, M. A., and Geller, S., *The Magnetic Moment of $3Y_2O_3$ x M_2O_3 (5-x) Fe_2O_3 Garnet for $M = Al$, Sc and Ga.*

Jaccarino, V., and Shulman, R. G., *Superexchange Effects on the F^{19} NMR in Paramagnetic Fluorides.*

Jaccarino, V., and Stroke, H. H. (Princeton), *Effect of Nuclear Configuration Mixing on Hyperfine Structure Anomalies.*

Krusemeyer, H. J., and Thomas, D. G., *Adsorption and Charge Transfer on Semiconductor Surfaces.*

Shulman, R. G., see Jaccarino, V.

Stroke, H. H., see Jaccarino, V.

Thomas, D. G., see Krusemeyer, H. J.

Thomas, D. G., *Surface Semiconduction in ZnO.*

International Symposium on the Theory of Switching, Computation Laboratory, Harvard University, Cambridge, Mass.

Chen, W. H., see Cragle, W. B.

Cragle, W. B., and Chen, W. H., *A New Method of Designing Low Level, High-Speed Semiconductor Logic Circuits.*

Holbrook, B. D., *Some Logical Requirements for the Control of Switching Networks.*

Karnaugh, M., *Magnetic Selectors.*

Kudlick, R. A., *Circuit Considerations and Logical Design with Direct Coupled Transistor Logic.*

Lewis, W. D., *Microwave Logic.*

Moore, E. F., *The Shortest Path Through a Maze.*

A.I.E.E.-I.R.E. Special Technical Conference on Solid State Dielectric and Magnetic Devices, Catholic University, Washington, D C.

Armstrong, J. H., *A Study of Deviations in Polarization and Coercive Voltage of Multibit $BaTiO_3$ Crystal Units.*

Schwenzfeger, E. E., *A Ferroelectric Crystal "And" Gate.*

Stadler, H. L., *The Ferroelectric Tachometer.*

Talks by Members of the Laboratories, Continued

Other Talks

Almquist, M. L., *The Responsibilities, Objectives, and Methods of Systems Engineering in the Bell Laboratories,* Engineering Management Forum on Systems Engineering, American Management Association, Hotel Statler, New York City.

Baker, W. O., *Perspectives on Atoms, Bonds and Crystals,* New England Section, American Chemical Society, New Haven, Conn.; American Chemical Society, Kingston, R. I.; and Conn. Valley Section, Hartford, Conn.

Bavelas, A., *Communication Networks and Learning,* Dept. of Psychology, Graduate Seminar, New York University, New York City, and Ramo-Wooldridge Corporation, Redwood City, Calif.

Beck, A. C., *Waveguides for Long Distance Communication,* Garden State Amateur Radio Association, Middletown, N. J.

Bell, D. T., *Application of Digital Computers to Transmission Networks Development,* IBM-650 Seminar, Endicott, N. Y.

Bennett, W. R., *General Properties of Noise,* Joint A.I.E.E.-I.R.E. Study Group on Information Theory, New York City.

Bricker, P. D., *Some Problems and Methods in Engineering Psychology,* Psychology Club, Lafayette University, Easton, Pa., and Bucknell University, Lewisburg, Pa.

Budlong, A. H., *Switching Logic,* Student Branch, I.R.E. City College of New York.

Chapin, D. M., *Bell Solar Battery,* Couples Club, Presbyterian Church, Basking Ridge, N. J.

Dillon, J. F., Jr., *Optical and Ferromagnetic Resonance Properties of Yttrium Iron Garnet,* Virginia Institute for Scientific Research, Richmond, Va.

Drenick, R., *A Statistical View of Reliability,* Working Conference on Reliability, New York University, Ardsley-on-Hudson, N. Y.

Dudley, H. W., *Nuclear Speech,* Washington Audio Society and Washington Section I.R.E. Washington, D. C.

Edens, C. D., and Jewett, W. E., *Application of Silicon Diodes in Series Array in High Voltage Power Supplies,* Seventh International Symposium of Microwave Research Institute, New York Ctiy.

Ehrbar, R. D., *The Transatlantic Submarine Cable System,* Summit Association of Scientists, Celanese Auditorium, Summit, N. J.

Felker, J. H., *Mechanized Memory — What Electronics Can Do,* Bi-Annual Meeting of District 4 of A.I.E.E., Jackson, Miss.

Findeis, A. F., *Determination of Rubidium and Cesium by X-Ray Fluorescence,* American Association of Spectroscopy, Eighth Annual Symposium on Spectroscopy, Chicago, Ill.

Fletcher, R. C., *Physical Phenomena of the Solid State,* Polytechnic Institute of Brooklyn.

Gambrill, L. M., *System Applications of Beyond-Horizon Radio,* A.I.E.E., Communications-Electronics Group, Denver Section, University of Denver.

Garrett, C. G. B., *Experiments on the Physics of Germanium Surfaces,* U. S. Naval Ordnance Laboratory, Silver Springs, Md.

Geils, J. W., *Problems of Recruitment of Scientists and Engineers,* Rutgers University, New Brunswick, N. J.

Gerard, H. B., *Conflict and Social Conformity,* Psychology Dept. Colloquium, University of Buffalo.

Gerdsen, W. D., *Bell Solar Battery,* Tri-County Amateur Radio Association, Plainfield, N. J.

Gibbons, D. F., *Dislocations and What They Mean to the Practical Metallurgist,* New Jersey Chapter, American Society for Metals, Newark, N. J.

Guttman, N., *On How We Control Our Speaking,* Evening Session Psychology Society, City College of New York.

Gyorgy, E. M., *A Rotational Model of Flux Reversal in Square Loop Ferrites,* Armour Symposium on Relaxation Phenomena in Ferromagnetic Materials, Armour Research Foundation, Illinois Institute of Technology, Chicago, Ill.

Gyorgy, E. M., *Magnetization of Ferrite,* Case Institute of Technology, Cleveland, Ohio.

Haines, A. B., *Research and Development at the Bell Telephone Laboratories,* 8th Annual Engineering Conference, Virginia Polytechnic Institute, Blacksburg, Va.

Hagstrum, H. D., *The Surface Auger Effect,* Physics Colloquium, Brown University, Providence, R. I.

Hamming, R. W., *Introduction to a Theory of Automatic Coding,* Symposium on Recent Improvements in Programing Techniques, Ohio State University, Columbus, Ohio.

Harvey, F. K., *Speech, Hearing and Music,* Harrisburg Chapter of the Engineering Society of Pennsylvania, Harrisburg, Pa.

Hearn, A. H., *Moderate Retention of Creosote in Poles,* American Wood Preserver's Association Convention, Chicago, Ill.

Herbert, N. J., *What Can be Done with Transistors Now,* Washington Section, A.I.E.E., Washington, D. C.

Herring, C., *Temperature Dependence of the Piezoresistance of High-Purity Silicon and Germanium,* Physics Colloquium, Texas Instruments Corporation, Dallas, Texas.

Howard, J. B., *Some Considerations in the Selection of Thermoplastics for Submarine Telephone Cable,* 15th Annual Conference, Society of the Plastics Industry, Ottawa, Ontario, Canada.

Humphrey, F. B., *Pulsed Flux Reversal of Deposited Nickel Iron Films,* Armour Symposium on Relaxation Phenomena in Ferromagnetic Materials, Chicago, Ill.

Huyett, Miss M. J., and Sobel, M., *Selecting the Best One of Several Binomial Populations,* Philadelphia Section, I.R.E., Philadelphia, Pa.

Jensen, A. G., *Coding of Television Signals,* National Association of Radio and Television Broadcasters Convention, Chicago, Ill.

Jewett, W. E., see Edens, C. D.

Kompfner, R., *Some Recollections of the Early History of the Traveling Wave Tube,* Burroughs Corporation Branch of Research Society of America, Paoli, Pa.

Levenbach, G. J., *Models in Electronic Components Qualification Studies,* Working Conference on Reliability, New York University, Ardsley-on-Hudson, N. Y.

Lewis, H. A., *Transatlantic Telephone Cable*, Sigma Xi, Cornell University, Ithaca, N. Y.

Mallina, R. F., *Automation in Communication*, Eastern Sociological Society, Hotel New Yorker, New York City; and A.S.M.E., Newark College of Engineering, Newark.

Mason, W. P., *Ferroelectrics and Electric Circuit Theory*, Symposium on Role of Solid State Phenomena in Electric Circuits, New York City.

Matlack, R. C., *Communications: Present and Future*, Symposium on Systems for Information Retrieval, Cleveland.

Miller, R. P., *A Three-Watt Transistor Audio Amplifier for Home Use*, I.R.E. Student Paper Contest, Polytechnic Institute of Brooklyn.

Pearson, G. L., *Electrical Energy from the Sun*, Sigma Phi Honorary Scholastic Fraternity, Drew University, Madison, N. J.

Read, W. T., Jr., *The Dislocation Determined Properties of Metals*, National Academy of Sciences, Washington, D. C.

Reed, Miss S. J., *The Role of the Mathematical Assistant at Bell Telephone Laboratories*, Barnard College, New York City.

Shea, J. F., *A Study of the Wind Induced Vibrations in Aerial Cables and Related Structures*, Professional Division, A.S.M.E., University of Delaware, Wilmington, Del.

Slepian, D., *Information Theory*, New York Section, I.R.E., and Basic Science Division, A.I.E.E., New York City; and IBM, Poughkeepsie, N. Y.

Smith, K. D., *Transistors – Theory and Applications*, Amateur Radio Club, Irvington, N. J.

Smith, W. L., *A Transistorized Crystal Controlled Oscillator and Frequency Divider for Very Low Frequencies*, Seventh International Symposium of the Microwave Research Institute, New York City.

Sobel, M., see Huyett, Miss M. J.

Storks, K. H., see Wright, J. P.

Suhl, H., *A Proposed Ferromagnetic Microwave Amplifier*, Microwave Seminar, Columbia University, New York City.

Tanenbaum, M., *Dissolved Gases in Germanium and Silicon*, Basic Sciences Group, Science and Electronics Division, Philadelphia Section, A.I.E.E., Philadelphia, Pa.

Thomas, D. E., *Early Repeatered Submarine Telephone Cable Systems Development*, Long Island Section, I.R.E., Garden City, L. I.

Thomas, U. B., *Applications of Electrochemistry at Bell Telephone Laboratories*, Cleveland Section, Electrochemical Society, Cleveland, Ohio.

Tidd, W. H., *White Alice – A Tropospheric Scatter Radio System*, A.I.E.E.-I.R.E. Evening Student Section, Polytechnic Institute of Brooklyn.

Weisbaum, S., *Nonreciprocal Microwave Ferrite Devices*, IBM Research Seminar, Poughkeepsie, N. Y.

Wilder, G., *Theory and Application of Point Contact Transistors*, University of Florida, Gainesville, Fla.

Wright, J. P., and Storks, K. H., *X-Ray Fluorescent Spectra for the Analysis of Preservatives in Wood and Paper Products*, American Wood Preserver's Association Convention, Chicago, Ill.

Patents Issued to Members of Bell Telephone Laboratories During March

Branson, D. E., and Rea, W. T. – *Number Display Device* – 2,784,397.

Budenbom, H. T. – *Hybrid Ring Coupling Arrangements* – 2,784,381.

Buehler, E. – *Method of Growing Quartz Crystals* – 2,785,058.

Chase, A. J. – *Telephone Set with Amplifier* – 2,785,231.

Fuller, C. S. – *Method of Fabricating Semiconductor Bodies for Translating Devices* – 2,784,121.

Goddard, C. T. – *Electron Discharge Devices and Method of Fabricating* – 2,784,480.

Goddard, C. T. – *Wave Amplifier Electron Discharge Device* – 2,785,338.

Goddard, C. T. – *Wave Amplifier Electron Discharge Device* – 2,785,339.

Harley, J. J., Henneberger, T. C., and Watling, R. G. – *Installation of Overhead Transmission Lines* – 2,785,217.

Henneberger, T. C., see Harley, J. J.

Holdaway, V. L. – *Method of Preparing Cathodes for Discharge Devices* – 2,785,093.

Hopper, A. L. – *Microwave Device* – 2,784,377.

Kingsbury, E. F. – *Electro-Optical System* – 2,785,316.

McKay, K. G. – *Signal Translating Device* – 2,786,880.

Mitchell, D., and Vroom, E. – *Recording Systems* – 2,784,049.

Ostendorf, B., Jr. – *Electronic Regenerative Repeater* – 2,785,225.

Rea, W. T., see Branson, D. E.

Scaff, J. H., and Theuerer, H. C. – *Rectifier and Method of Making it* – 2,784,358.

Sumner, E. E. – *Welding Circuit* – 2,785,283.

Theuerer, H. C., see Sumner, E. E.

Thiel, F. A., Jr. – *Statistical Card Handling Tool* – 2,784,026.

Von Gugelberg, H. L. – *Multicathode Gaseous Discharge Devices* – 2,785,355.

Vroom, E., see Mitchell, D.

Watling, R. G., see Harley, J. J.

Weiss, M. T. – *Non-Reciprocal Directive Antenna Arrays* – 2,786,999.

Wood, E. A. – *Stable Liquid Electrodes* – 2,785,322.

Yager, W. A. – *Magnetically Controlled Microwave Structures* – 2,784,378.

Zuk, P. – *Method of Fabricating an Electrical Connection* – 2,784,300.

Zupa, F. A. – *Relay* – 2,786,915.

Papers Published by Members of the Laboratories

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

Anderson, O. L., see Andreatch, P.

Andreatch, P., and Anderson, O. L., *Teflon as a Pressure Medium*, Rev. Sci. Instr., **28**, p. 288, April, 1957.

Boyet, H., see Seidel, H.

Bozorth R. M. *Review of Magnetic Annealing*, Proc. of 1956 A.I.E.E. Conference on Magnetism and Magnetic Materials, **T-91**, pp. 69-75, April, 1957.

Boyet, H., see Seidel, H.

Bozorth, R. M. *Review of Magnetic Annealing*, Proc. of 1956 A.I.E.E. Conference on Magnetism and Magnetic Materials, **T-91**, pp. 69-75, April, 1957.

Cioffi, P. P., *Rectilinearity of Electron-Beam Focusing Fields from Transverse Component Determinations*, Commun. and Electronics, **29**, pp. 15-19, March, 1957.

Cook, R. K., *Absorption of Sound by Patches of Absorbent Material*, J. Acous. Soc. Am., **29**, pp. 324-329, March, 1957.

Cook, R. K., *Variation of Elastic Constants and Static Strains with Hydrostatic Pressure: A Method for Calculation from Ultrasonic Measurements*, J. Acous. Soc. Am., **29**, pp. 445-449, April, 1957.

Dewald, J. F., *The Kinetics of Formation of Anode Films on Single Crystal Indium Antimonide*, J. Electrochem. Soc., **104**, pp. 244-251, April, 1957.

Foster, F. G., *The Unconventional Application of the Metallograph*, Focus, **18**, pp. 16-20, April, 1957.

Garn, P. D., *An Automatic Recording Balance*, *Anal. Chem.*, **29**, pp. 839-841, May, 1957.

Geller, S., *Crystallographic Studies of Perovskite-Like Compounds, IV – Rare Earth Scandates, Vanadites, Galliates, Orthochromites*, Acta Crys., **10**, pp. 243-248, April 10, 1957.

Geller, S., *Crystallographic Studies of Perovskite-Like Compounds V – Relative Ionic Sizes*, Acta Crys., **10**, pp. 248-251, April 10, 1957.

Grossman, A. J., *Synthesis of Tschebycheff Parameter Symmetrical Filters*, Proc. I.R.E., **45**, pp. 454-473, April, 1957.

Heidenreich, R. D., and Nesbitt, E. A., *Stacking Disorders in Nickel Base Magnetic Alloys*, Phys. Rev., Letter to the Editor, **105**, pp. 1678-1679, March 1, 1957.

Holden, A. N., see Wood, Elizabeth A.

Karp, A., *Backward-Wave Oscillator Experiments at 100 to 200 Kilomegacycles*, Proc. I.R.E., **45**, pp. 496-503, April, 1957.

Kelly, M. J., *The Work and Environment of the Physicist Yesterday, Today, and Tomorrow*, Phys. Today, **10**, pp. 26-31, April, 1957.

Law, J. T., and Meigs, P. S., *Rates of Oxidation of Germanium*, J. Electrochem. Soc., **104**, pp. 154-159, March, 1957.

Liehr, A. D., *Structure of $Co(CO)_4H$ and $Fe(CO)_4H_2$*, Zeitschrift für Naturforschung, **12b**, pp. 95-96, Feb., 1957.

Liehr, A. D., *Structure of π-Cyclopentadienyl Metal Hydrides*, Naturwissenschaften, **44**, p. 61, Feb. 1, 1957.

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

Lundberg, J. L., and Nelson, L. S., *The High Intensity Flash Irradiation of Polymers*, Nature, Letter to the Editor, **179**, pp. 367-368, Feb. 16, 1957.

Marrison, W. A., *A Wind-Operated Electric Power Supply*, Elec. Engg., **76**, pp. 418-421, May, 1957.

Meigs, P. S., see Law, J. T.

Nelson, L. S., see Lundberg, J. L.

Nesbitt, E. A., see Heidenreich, R. D.

Seidel, H., and Boyet, H., *Form of Polder Tensor for Single Crystal Ferrite with Small Cubic Symmetry Anisotropy Energy*, J. Apl. Phys., **28**, pp. 452-454, April, 1957.

Seidel, H., see Boyet, H.

Slichter, W. P., *Nuclear Magnetic Resonance in Some Fluorine Derivatives of Polyethylene*, J. Poly. Sci., **24**, pp. 173-188, April, 1957.

Smith, K. D., see Veloric, H. S.

Suhl, H., *Proposal for a Ferromagnetic Amplifier in the Microwave Range*, Phys. Rev., Letter to the Editor, **106**, pp. 384-385, April 15, 1957.

Swanekamp, F. W., see Van Uitert, L. G.

Vacca, G. N., and Lundberg, C. V., *Aging of Neoprene in a Weatherometer*, Wire and Wire Products, **32**, pp. 418-457, April, 1957.

Van Uitert, L. G., and Swanekamp, F. W., *Permanent Magnet Oxides Containing Divalent Metal Ions*, J. Appl. *Phys.*, **28**, pp. 482-485, April, 1957.

Veloric, H. S., and Smith, K. D., *Silicon Diffused Junction Avalanche Diodes*, J. Electrochem. Soc., **104**, pp. 222-227, April, 1957.

Weibel, E. S., *An Electronic Analogue Multiplier*, Trans. I.R.E. PGEC, EC-6, pp. 30-34, March, 1957.

Wertheim, G. K., *Energy Levels in Electron-Bombarded Silicon*, Phys. Rev., **105**, pp. 1730-1735, March 15, 1957.

Willis, F. H., *Some Results with Frequency Diversity in a Microwave Radio System*, Comm. & Elec., **29**, pp. 63-67, March, 1957.

Wood, Elizabeth A., and Holden, A. N., *Monoclinic Glycine Sulfate: Crystallographic Data*, Acta Crys., **10**, pp. 145-146, Feb., 1957.