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Systems Engineering in Bell Telephone Laboratories

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Director of Systems Engineering

The unprecedented demand for toll telephone service following World War II was not limited to communication between the larger cities but extended to the less densely settled areas served largely by open-wire facilities. Much of the new demand was for short haul toll service involving distances as short as twenty miles. The companies could, of course, string more wire, build completely new open wire lines or install cable, but this would involve large outlay of capital and use scarce material such as copper and lead.

Another approach would be to add carrier systems, which make it possible for many conversations to share a pair of wires. However, to prove in, carrier systems must cost less than stringing new wire or building new pole lines. The available carrier systems proved in easily for the longer haul circuits but not for circuit lengths measured in tens of miles. Moreover, on many lines carrier had already been applied so extensively for the longer hauls that adding more channels would mean going to higher frequencies and thus introduce serious crosstalk problems. The question then was: Could a new carrier system be designed which would be low enough in cost to be economical for distances as short as twenty miles and which could be operated on the existing open wire lines without expensive rearrangement of the wires?

Analyzing comparative costs and current advances in the technological art, Laboratories systems engineers predicted that the job could be done. On paper they broadly outlined what such equipment would have to consist of, how it would have to perform transmission-wise and how little it would have to cost. Then, as actual development of the system was begun, they worked closely with the specialists who would develop the equipment and the many apparatus components involved, specifying in more detail what the system would have to accomplish in cost and performance. At the same time, they conducted detailed studies of crosstalk and other transmission properties of the open wire lines. Thus, the teamed efforts of systems engineers and development specialists produced the new Type-O carrier system, which puts up to sixteen voice circuits on a single open wire pair and operates economically over distances down to twenty miles or less.

This valuable new carrier system is but one example of the varied activities of Laboratories systems engineers. In a world of specialists the systems engineer is a non-specialist; his field of interest is the entire field of telephone technology. Sometimes he has only to advise on operational problems in terms of what he already knows; at others, he must propose an elaborate new system involving radically new principles. Always he must be in touch with the latest developments as he keeps a sharp lookout for practical ways to match them with new telephone needs. Conversely, he uses new demands for service as a basis for spurring new developments. As he sees to it that promising new products of research receive fair consideration, he must make equally sure that developments likely to cause trouble are strictly kept out of the telephone system. Confronted by tempting alternatives he must decide as to which development holds the greatest promise.

In studying a major project, the systems engineer may have to make a mathematical analysis, confer with research, development, and operational people, conduct an economic survey, embark on field tests far from home or make studies with complex testing devices which he has first had to devise and develop. To evaluate a proposed development he usually starts with an exploratory study. Here, whenever possible, he takes advantage of mathematics and physical theory which have frequently demonstrated their capacity to save him time and money. There are notable instances in which mathematical studies have effectively disclosed in quantitative terms basic controlling factors of complex problems without any practical experimentation at all. Mathematical analysis has proved a powerful tool, for example, in clarifying the philosophy of the transmission of information and in the application of statistical theory to telephone trunking.

Mathematics has its limitations, however. Existing theory could not show, for example, how to calculate with sufficient detail the performance of a modern crossbar system in handling the various demands of telephone subscribers. To conduct studies of this type, systems engineers have developed a complex testing device that is able to do what mathematics could not. It has been nicknamed the throwdown machine.

The throwdown machine solves the problem by reproducing and displaying the *functions* of a modern automatic telephone office. "Calls" are fed into the machine according to statistical patterns of calling habits, and the passage of a call is controlled and observed as it passes through the office from one part of the system to another. Real time is slowed down so that calls which need only a few seconds to be put through a real office may remain in this special machine

Fig. 1—A machine to simulate functions of a cross bar system. Pegs at right represent subscribers. Selected by random sampling, a peg is removed, attached to a report card, then routed through the various positions. At each, a girl records details for subsequent analysis.

for hours. The effects of telephone traffic loads on the loading of the various paths in the office may thus be conveniently observed and studied in detail. Results are proving valuable in indicating ways to make switching systems handle more calls for their size.

In ascertaining the qualities of a new system or of a prospective change in an existing one, systems engineers base their judgment wherever possible on standards of service quality which are expressed in a quantitative way. For this purpose the Laboratories maintains a transmission standards laboratory in which all the varieties of telephone instruments and types of connections are critically judged by "juries"—teams of experts and laymen. From such tests come methods of evaluating and measuring the effects of such things as loss, noise, crosstalk, and frequency band-width restriction. Corresponding activities are carried on in telegraphy, television, and other fields of communication.

In his exploratory studies, the systems engineer can never be sure which way the cat will jump. In the cases of microwave radio relay, coaxial cable, crossbar switching, and toll-line dialing, exploratory studies established the practicability of worth-while new systems. Such was not the outcome in the case of "pulse" code modulation* (PCM) as a modulation technique for microwave radio relay.

Following its successful use in war time

* RECORD, *July*, 1947, *page* 265.

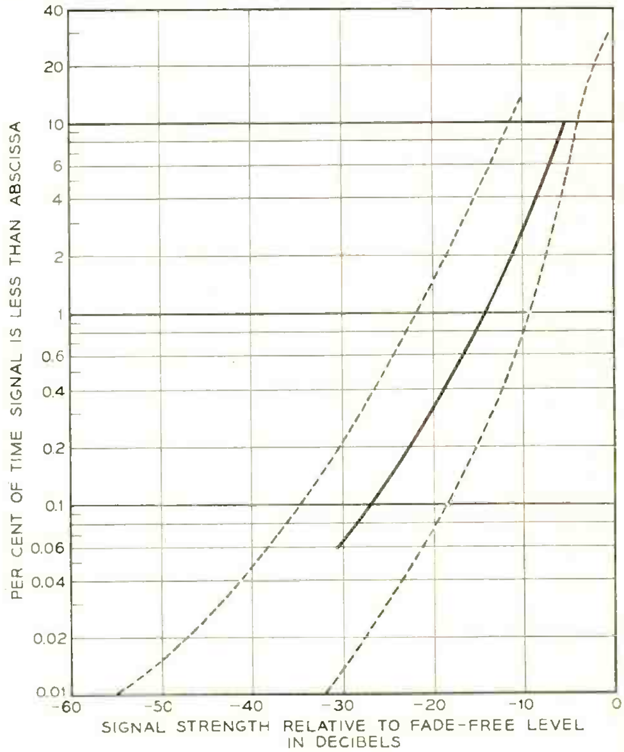
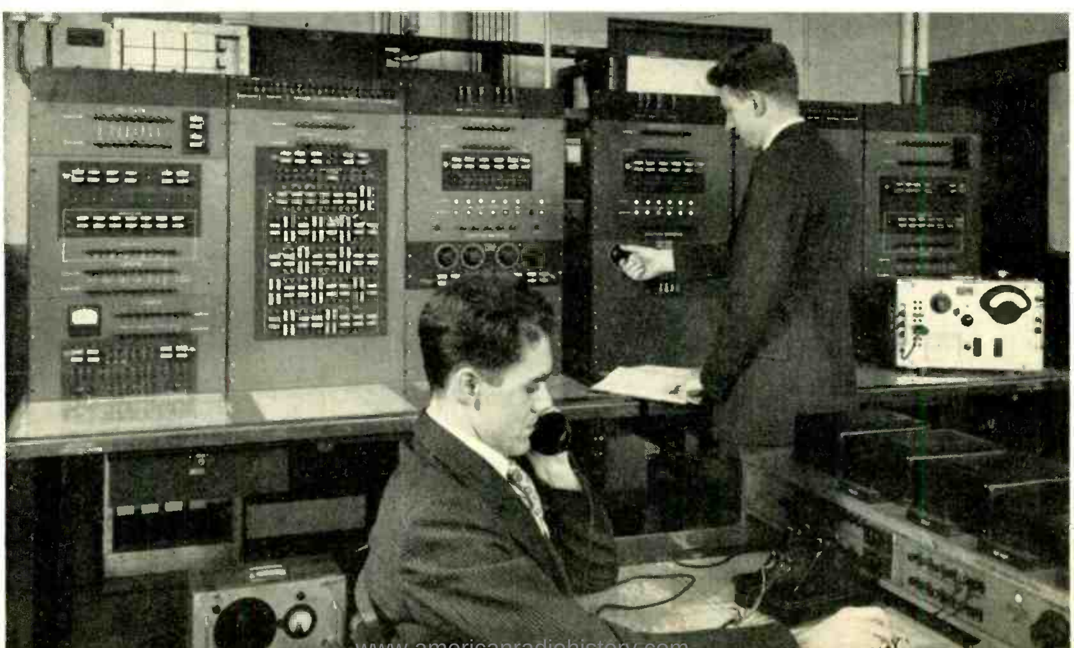


Fig. 2—Curves summarizing 4000-megacycle fading tests over individual repeater sections during worst month. Solid line shows typical fading; broken lines denote spread of data. Even in worse fading periods, which are confined to the summer, fading is less than 6 db during 90 per cent of the time. Curves revealed the fading that the system had to be engineered to tolerate.

Fig. 3—Transmission standards laboratory. Panels at rear provide means for simulating a wide variety of transmission paths. Test subject in foreground judges comparative quality of two such paths which engineer at rear has set up.



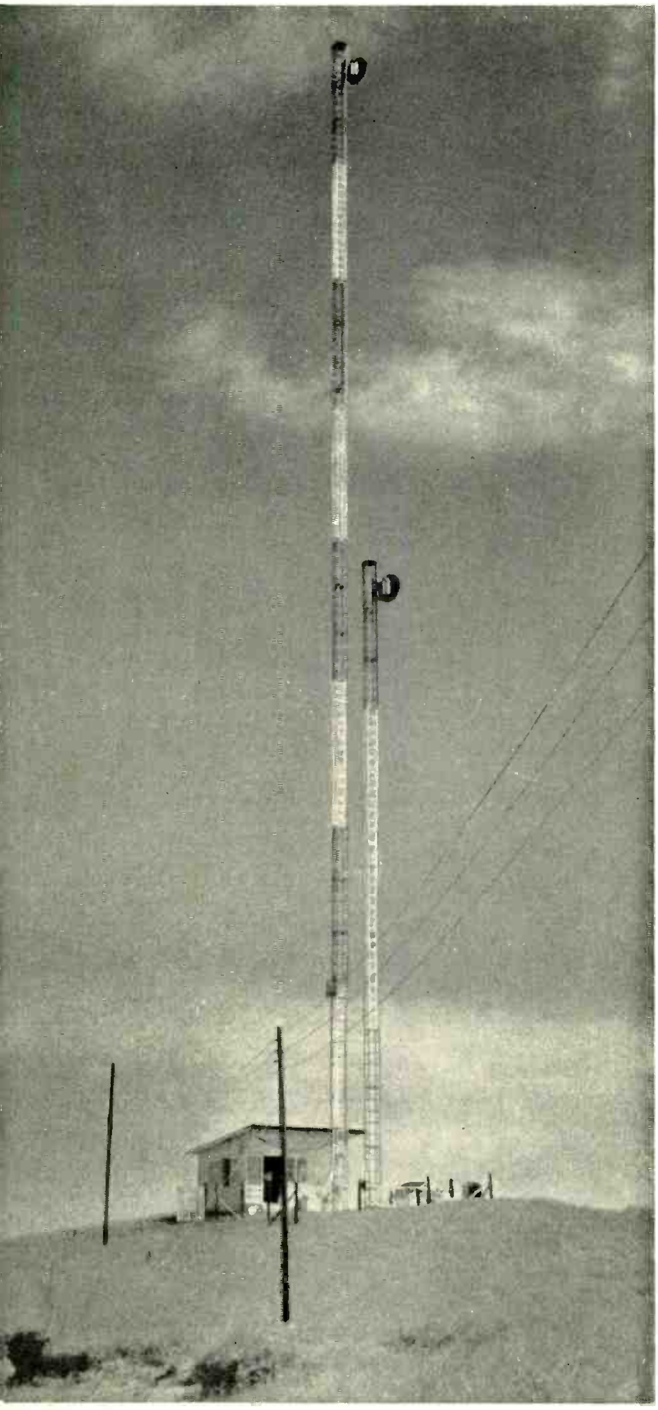


Fig. 4—At St. Libory, Nebraska, parabolic dishes perched on portable towers received microwaves at different elevations in path-loss tests. Day and night, equipment in the shack automatically recorded signal level in exploratory tests for the practicability of a transcontinental system.

radio communication pulse modulation had appeared at the close of the war as a serious rival for the older methods of amplitude and frequency modulation. The pulse method, in which speech is modulated, not on a steady carrier wave but on pulses of radio signal, offered attractive possibilities in one or more of the several forms in which it could be applied. Of these, the latest and most popular was PCM.

In PCM the voice signal is sampled many thousands of times per second, and data as to the amplitude of the signal at each instant of sampling are encoded and sent toward the distant terminal of the system as a kind of high-speed telegraph signal. At the end of these "telegraph" signals are decoded and the original speech signal is reconstructed. At repeater points, such crisp on-off signals, being accurately decipherable in the presence of noise, could be recreated in perfect form for retransmission. In spite of the speed and apparent complexity of the process, it turned out to be entirely practicable, and as part of the appraisal of PCM, laboratory equipment was constructed to demonstrate the method.

Statistical and analytical studies, however, disclosed that PCM offered no substantial advantages over its FM rival under actual conditions of use. Economic comparisons also were not favorable. After several months of intensive study, it was decided that FM rather than PCM would be used in developing the microwave radio relay system. This experience, however, does not rule out PCM for good. Through new developments the PCM system may one day again be in the running for important applications in the telephone system.

The type of modulation to be used was only one of many questions that had to be answered in the exploration of microwave radio relay which, after wartime interruption, was resumed in 1946. Would, for example, such a system be good for unrestricted operation over any distance? How serious was the risk of systems failure due to radio fading?

It was well known that microwaves, like other forms of radio, are subject to fading because of certain fine-grained changes in the temperature and humidity gradients of the lower atmosphere. It was known too, that each successive link of a relay system would be subject to disturbance from this cause. The systems engineering problem was to describe in advance, in a quantitative manner, how the 3,000-mile transcontinental system would behave under all conditions of fading with 100 such links connecting end-to-end.

Unlike studies of crossbar system performance, which can be conducted in the Laboratories with a throwdown machine, microwave fading had to be studied under actual conditions far from home. Special 200-foot aluminum towers, built in sections for transportation, had to be designed and constructed as well as remotely steerable antennas, radio measuring gear and automatic data analyzers. Extensive field surveys were made in the east, midwest, mountain states, and on the west coast; over 100,000 man-hours of measurement went into a statistical evaluation of the probable performance of the system.

From this investigation came methods for predicting the statistical chance of excessive noise or of complete interruption, the probable severity and nature of interruptions, and the trend with season and time of day. It was determined for example that fading would be most severe in late summer during the period between midnight and 4 a.m. and that it would appear to the listener, if he happened to notice it at all, as an increase in noise, or a "hit" lasting at most for a few seconds. Experience to date with fading in the commercial system has closely confirmed the predictions. This exploration of radio fading was one of the most extensive of recent studies made by the systems engineering group.

Not all exploratory studies involve the development of new systems. Some seek to improve operational results through the application of new technical knowledge. Studies of this kind are carried out in the field cooperatively with operating organizations. An example is a recent field experiment carried out in New Jersey to study the use of gas pressure in exchange cables as a means of minimizing service interruptions and to reduce maintenance costs.

Once the exploratory study has demonstrated the economic and technological feasibility of a project, a specific development plan is laid out. Even with the background of exploratory studies, the preparation of a development plan usually involves several months of work in collecting data in the analysis of objectives, and the securing of agreements on points of controversy. So complex are the considerations that enter into the planning of a new system that it is generally found most effective to collect all the data into a single document which becomes a charter for the development. This "prospectus" nails down the objectives, scope, and boundaries of the job; it indicates how the project can be accomplished within the time and resources that are to be put aside for it. Prospectuses are now a formal part of development control. Essentially fluid, they serve as a guide, subject to modification by mutual agreement among the interested engineers, and they are framed to provide the greatest possible opportunity for the interplay of ideas and for originality of execution in the various development departments.

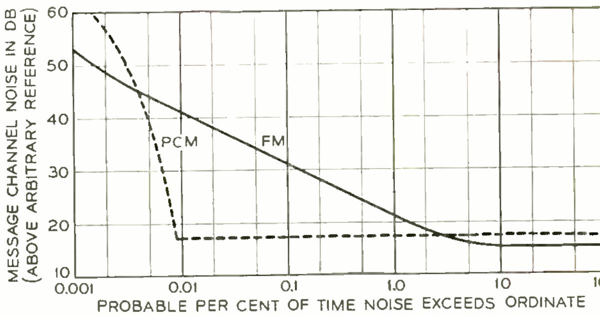


Fig. 5—Comparison of predicted message channel noise for typical PCM and FM multichannel systems, between 8 P.M. and midnight in worst month for fading. The curves show that PCM and FM noise are nearly equal about 97 per cent of the time during which fading is least. FM has the advantage under the severe fading conditions represented by the extreme left of the curves. PCM is superior during moderate fading.

A recent example of engineering project planning at Bell Telephone Laboratories involved participation in the Bell System experiment to determine customer acceptance of Foreign Area Customer Dialing. In FACD, as it is called, the subscriber is given the opportunity to dial distant telephones in other parts of the country without the in-

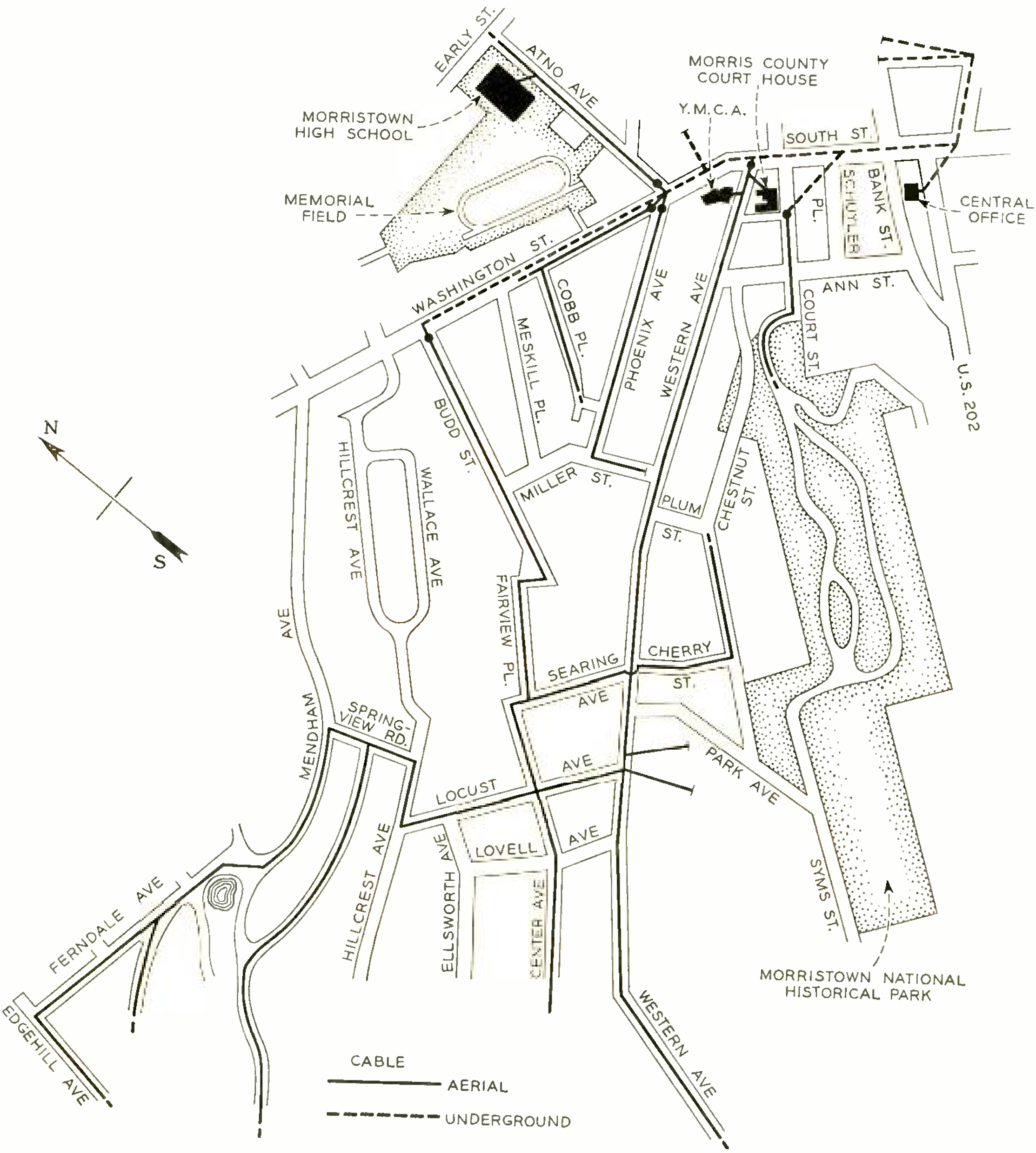


Fig. 6—At Morristown, New Jersey, this exchange area cable system was tested for advantages of gas pressure as an economical means of keeping out moisture and detecting sheath leakage. Successful results led to more extensive tests now in progress in Caldwell, New Jersey. Formerly only toll cable was pressurized.

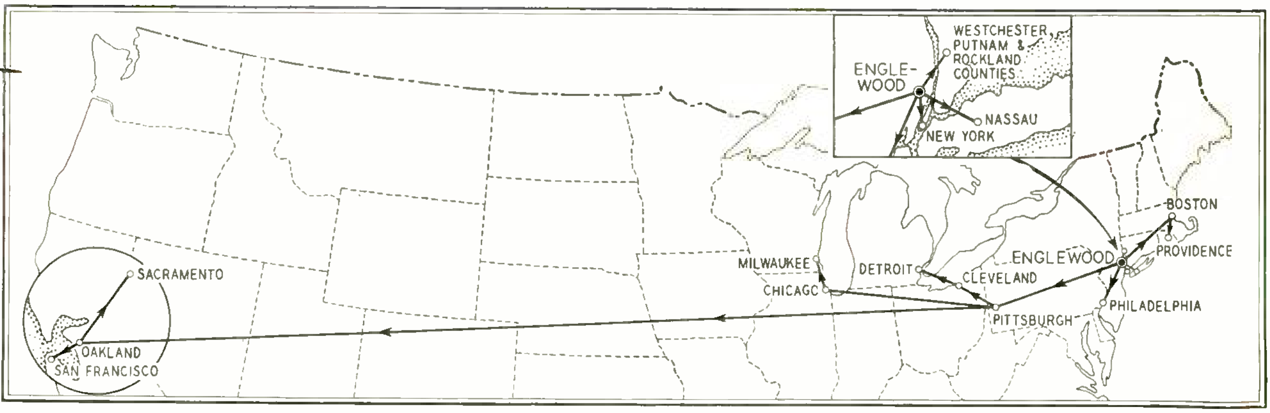


Fig. 7—Englewood customer toll dialing trial. Shows points which can be directly dialed by Englewood subscribers.

tervention of an operator. To carry out this investigation a crossbar switching office in Englewood, New Jersey, was modified so as to permit individual and two-party subscribers to participate in the experiment. There had to be an automatic arrangement for billing the calls. Data for calculating call charges are automatically registered on punched tapes which are subsequently processed at a nearby accounting center. Numerous modifications of the central office itself had to be foreseen and described. Means had to be provided for observing performance. This trial is still in progress.

As a development project matures, factors brought out in the earlier studies frequently need further clarification, and entirely new ones may turn up. The systems engineer must be in constant touch with the changing situation and ready to negotiate changes in the original prospectus with interested parties. The development departments may require additional information on the operating environment which the system will encounter. For example, in anticipation of the extension of long distance dialing, recent carrier telephone systems have been designed with built-in signaling and dialing facilities. Little, however, was known about the performance of these signaling and dialing features in the presence of static noise, particularly when applied to open-wire lines.

Static and lighting noises are not only elusive but also extremely variable with season, time of day, location, and type of lines. At first it appeared that the experimental models of the carrier systems would have to be taken into the field for test over a long period under the actual conditions

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He became Assistant Technical Representative in Europe for A T & T in 1938. He had previously served on the Pacific Coast, in the Far East, and in Hawaii during the establishment of Trans-Pacific telephone service.

In 1940 Mr. Gilman became Radio Transmission Engineer, and in 1944 he was made Director of Transmission Engineering. During World War II, he served as a consultant to the National Defense Research Committee. He was a guest lecturer in electrical engineering at Massachusetts Institute of Technology in 1950 and was appointed to his present post as Systems Engineering Director in 1951.

to be expected. Removal of models from the laboratory would interrupt design work. If continued, design work might be later invalidated by the field test findings. The better solution would be to bring the static into the laboratory.

Systems engineers went thunder hunting. In areas where storms are most frequent and intense they recorded typical static noises on wide band recorders. In the laboratory this captive lightning is now proving a valuable time saver in testing carrier telephone and telegraph systems.

A duty of systems engineers is to assist operating organizations in their planning for future additions to plant. Long before a development is perfected, prospective systems engineers worked with planners in the operating organizations, and in the development and manufacturing groups in predicting not only the performance and the costs to be expected but also the time when the new system would become available.

In the latter stages of a development, plans are laid for the introduction of the first systems in the field. Usually these initial systems are tried out under the severest operating conditions. This exacting test procedure promptly discloses hidden weaknesses, and hence speeds final standardization of the system as a new facility for the use of operating organizations.

Though standardization ends a development project, it does not end the responsi-

Fig. 8—Thunder hunting equipment on location near Madison, Florida. Loop antenna picks up static which is fed into wide band recorder.

users must be kept informed of what is in the making. The importance of such advance information is nicely indicated by Type-N carrier which strongly influenced the planning of cable sizes because of the opportunities it offered to make wires carry more service. Very early in the program,

bility of the engineers, who continue to stand watch on the operations of the new system as well as those of all other existing systems. As they keep up to date on the Bell System as a whole, systems engineers thus gather new data to guide their quest for still better facilities.

"B" Lineman's Wrench

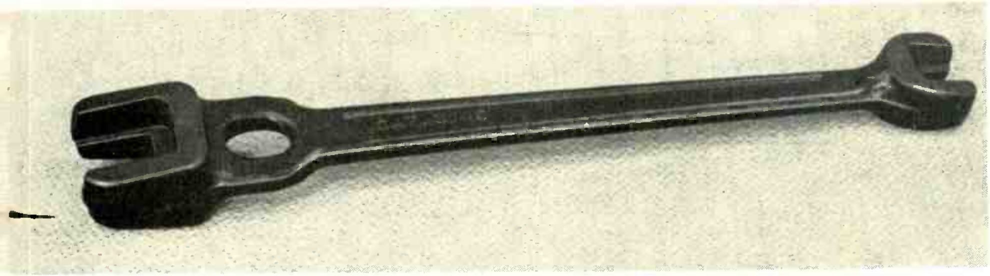

Fig. 1—"B" lineman's wrench showing two sizes of openings at each end. The elliptical hole is used to orient steel pole steps.

Fig. 2—One end of the wrench showing two sizes of openings and the elliptical hole.

As a result of continuing standardization of the bolts, nuts, and drive screws used in pole line construction, it is possible for the lineman to install almost all such devices with a single "B" lineman's wrench (Figure 1). This "one item tool kit" is a product of sound mechanical design, selection of proper steel, excellent drop-forging practices, and improvements stemming from daily use by the construction forces throughout the System.

The "B" lineman's wrench, thirteen inches long and weighing one and three-quarter pounds, is of the open-end double-end type with four sizes of openings, two on each end, as evident in Fig. 2. These openings accommodate ⅜-, ½-, ⅝- and ¾-inch nuts and the heads of ½-inch drive screws over the wide range of tolerances in effect for rough and semi-finished galvanized bolts and nuts. The faces of each wrench opening taper with respect to the shank and thus permit the shank to clear adjacent work at a sufficient angle to permit the wrench to be turned without obstruction and provide adequate clearance for the workman's hand, as shown in Figure 3. To broaden the utility of this tool still further, an elliptical hole is forged in the large end of the wrench to be used either for orienting steel pole steps after they have been driven, or for removing them.

Fig. 3 (left)—Tapered faces of "B" lineman's wrench set wrench shank at an angle to the work so that the shank and the workman's hand clear obstructions as the wrench is turned. Fig. 4 (right)—With the end of the steel pole step in the elliptical hole in the shank, the wrench becomes a lever either for turning the step into proper position or for unscrewing it from the pole.

Test Set for the M1 Carrier System

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Formerly Transmission Systems Development

At the present time there are nearly 10,000 stations of M1 (Rural Power Line) carrier* in service, and about 4000 channels of its modifications, the M1A and M1B. These latter systems provide extra channels over existing open-wire lines between central offices and between attended offices and community dial offices. Since M1 is employed primarily in outlying districts, away from most of the maintenance personnel trained in carrier techniques, special facilities for maintaining the system have been required. Chief among these is the KS-5785 test set shown in Figure 1.

The design of the KS-5785 test set was based on an earlier set built by the plant engineering personnel of the Oklahoma area of the Southwestern Bell Telephone Company to help maintain the M1 systems in that territory. Although this set did not contain all the circuits incorporated in the present set, it did include the major ones, and it served to emphasize the need for such a test set for general use throughout the Bell System.

The KS-5785 set is provided with three major units: an oscillator with output level calibration for all the frequencies used by the M1 system; a variable phase shifter; and a meter circuit with shunts, multipliers, and rectifiers that permit it to measure ac and dc voltages, dc current, and carrier output power. A selector switch at the upper left of the test set permits the circuit to be set for any of seven different tests. Other controls on the front panel are used in conjunction with one or more of these tests.

Controls for the oscillator are mounted immediately beneath the meter. They include a crystal selecting switch, at the right,

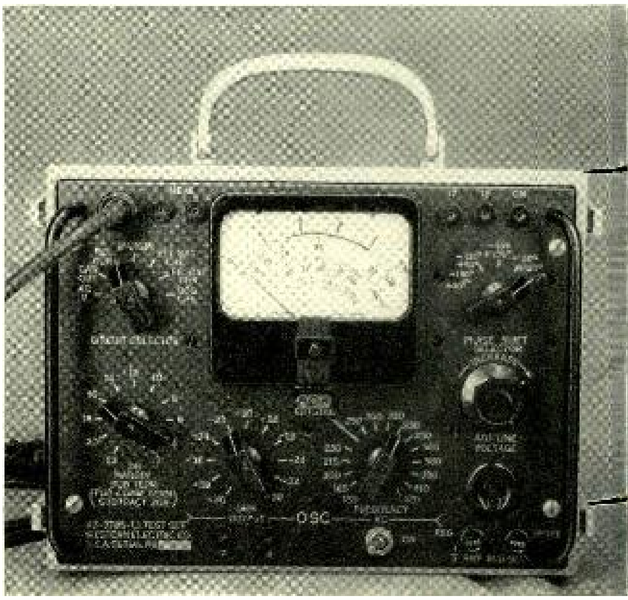


Fig. 1—The KS-5785 test set designed for maintaining M1 carrier terminals.

and an output control, at the left, together with an on-off switch below the frequency selector, which is made non-locking "on" to conserve battery power. The output jacks are below the output control. The frequency switch may be set to any of fifteen crystals that give the frequencies used by the M1 carrier or to a crystal socket, immediately beneath the meter, into which may be plugged a crystal from an M1 terminal for checking its condition.

The circuit of the oscillator is shown in Figure 2. A flashlight cell supplies the filament and a 67½-volt minimax battery is used for the plate. The output is thermistor regulated to compensate for aging batteries, for tube variations, and for temperature changes, and the output control is calibrated in 2 db steps from −20 to −40 dbm. Besides its use as a signal generator for a variety of transmission-type measurements on the ter-

* Record, *October*, 1947, *page* 363; *November*, 1947, *page* 413; *January*, 1948, *page* 2; *February*, 1948, *page* 77; *March*, 1948, *page* 101.

minals, the oscillator is used for checking the condition of the crystals used with the M1 terminals.

In the lower part of Figure 2, the meter and the three arrangements in which it is used for oscillator "self-testing" measurements are indicated. The meter itself is a 1-MA milliammeter, and when the selector switch is in the OSC CHK position, it indicates plate current to determine oscillation and crystal condition. In the FIL BAT and PLT BAT CHK positions it reads dc voltage. In checking the filament battery in this manner, if no reading is obtained on the meter, it indicates an oscillator tube with an open filament.

When the selector switch is turned to the AC-V position, the meter circuit is arranged as shown in Figure 3. This allows the 120-volt 60-cycle line voltage applied to an M1 terminal to be measured, and also allows it to be reduced (by means of a rheostat) to permit checking the operation of the terminal at lowered line voltages. Power for the test is provided through the cord at the left of Figure 3 and evident at the upper left of Figure 1. The circuit is extended from the cord through a fuse and a rheostat, controlled by the dial at the middle right of the test set, to a polarized receptacle at the lower right corner of the set, just beneath the rheostat. The meter, in combination with a full wave rectifier, is bridged across the circuit, and reads the ac voltage at the polarized receptacle, into which the power cord to the M1 terminal is plugged.

By turning the selector switch to the CAR OUT position, the meter is connected to act as a 100-ohm carrier-frequency voltmeter, and reads carrier voltage across the red and black MEAS jacks just to the left of the upper left corner of the meter. This test arrangement, which is shown in Figure 4, is used for reading carrier output power in dbm of the carrier equipment.

Still another use of the meter is for checking the received relay current in the carrier terminal. For this test, the 3000-ohm plug-in relay is removed. One end of a patch cord furnished with the test set is plugged in place of the relay, and the other end into the two MEAS jacks at the upper left of the meter. The selector switch is turned to the REL CUR position, which sets up the circuit shown in Figure 5. There is a 3000-ohm resistance in the circuit to take the place of the relay winding, and the current indicated by the meter is thus that which would flow through the relay under operating conditions.

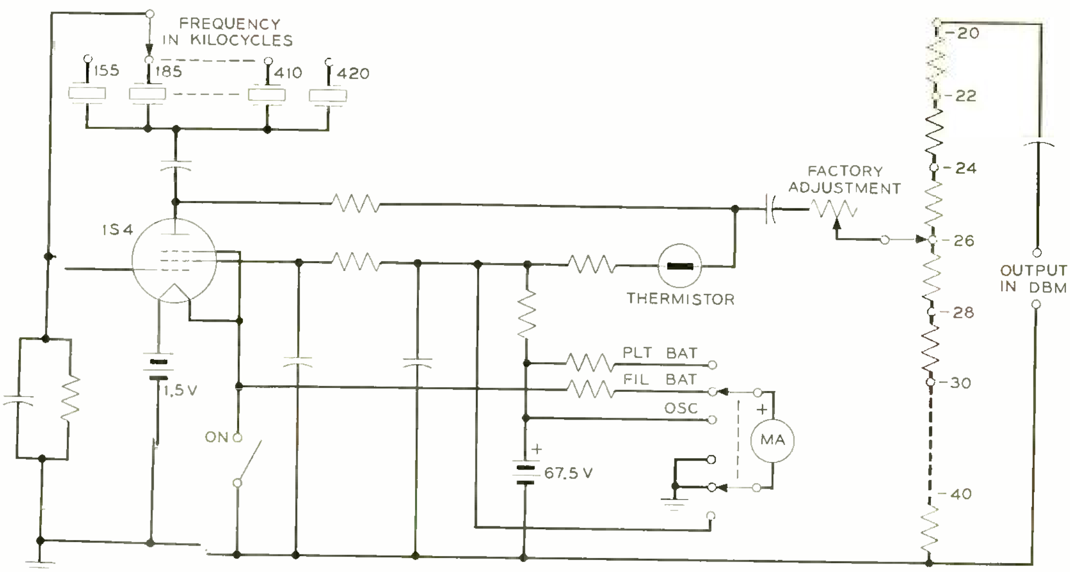


Fig. 2—Simplified schematic of the oscillator circuit of the KS-5785 test set.

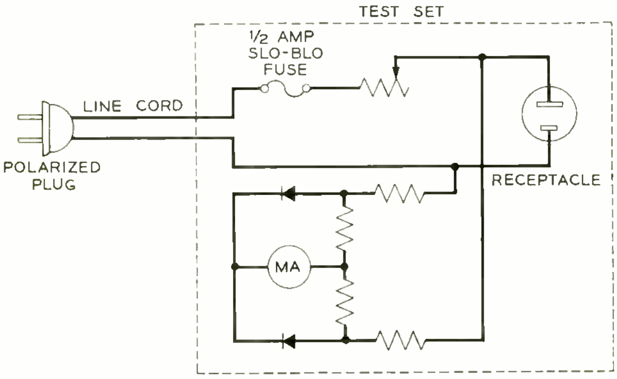


Fig. 3—Circuit established when the selector switch on the front of the test set is turned to the AC-V *position.*

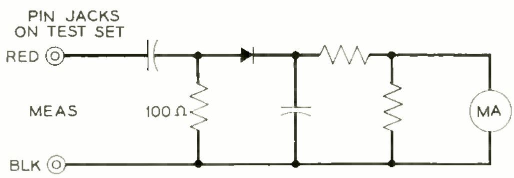


Fig. 4—Circuit established when the selector switch is turned to the CAR OUT *position.*

To check signaling margins, the carrier output of a terminal is reduced until the circuit fails. For this test the selector switch is turned to the MARGIN position, which establishes the circuit shown in Figure 6. An adapter furnished with the set is inserted between the transmitter output amplifier tube of the M1 terminal and its socket, and cords from the adapter and from a ground connection on the terminal are connected to the two MEAS jacks of the test set. Beneath the selector switch is the margin dial by which the carrier output may be reduced in 2 db steps. The same arrangement is used for both subscriber and common terminals, but for tests on the common terminal, a correction factor is subtracted from the reading of the dial.

Semi-selective ringing with the M1 system* is accomplished by sending over the line a sequence of carrier pulses synchronized with either the positive or negative half pulses of the 60-cycle commercial power supply at the common terminal. The screen grid of the output tube of the subscriber terminal receiver is supplied – while the handset is on the hook—with 60-cycle ac from the commercial supply. The tube, then, conducts only during that half cycle when the ac voltage on the screen grid is positive, thus providing "gating" action. With the ac supply plug at the terminal inserted in one position, the screen grid will be positive for one set of half cycles, and with the plug reversed, it will be positive for the other set of half cycles. By this simple expedient, therefore, a terminal may be made to receive either of two sets of ringing codes sent out.

It sometimes happens that the power sup-

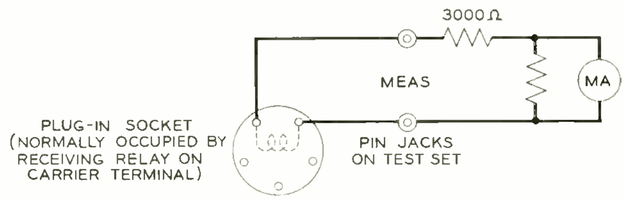


Fig. 5—Circuit established when the selector switch is turned to the REL CUR *position.*

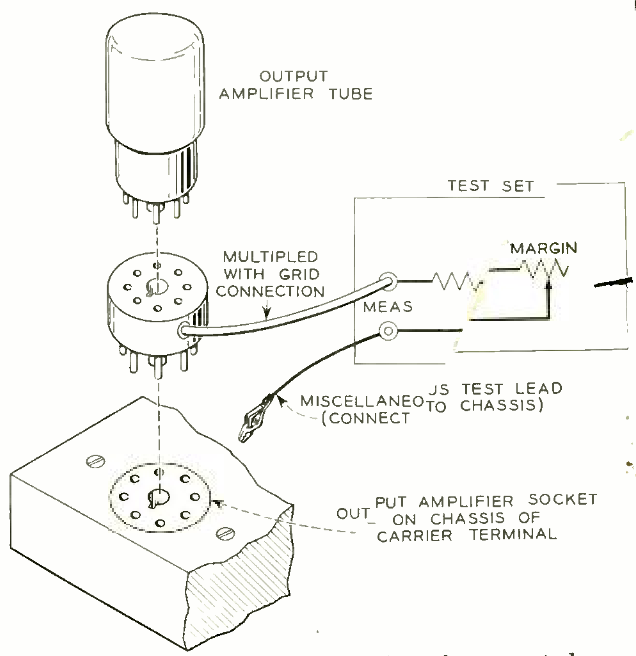


Fig. 6—Circuit established when the selector switch is turned to the MARGIN *position.*

* RECORD, *November*, 1947, *page* 413.

When normal service power is again available after a failure, the engine continues to carry the station load for a predetermined time to insure that the normal voltage condition is not temporary. Unless the engine has been running for some time, it continues to operate long enough to raise its temperature and thus prevent undue condensation dilution of crankcase oil. At the end of this period the fast acting contactor again operates to connect the commercial power supply to the load, the engine then stops and the circuit is in readiness for the occurrence of the next power failure.

Engine room ventilation in unattended stations required careful design to maintain desirable operating temperatures. Three automatically operated shutters are provided in the air system. The air intake louvers open when the engine starts and close when it stops. The air exhaust shutters do not begin to open, however, until the radiator cooling solution reaches about 135 degrees F. The position of these shutters is determined by a mechanism controlled by the cooling solution temperature, the exact position being changed as required to maintain the desired temperature. The third set of louvers is controlled by an engine-room thermostat; these louvers are arranged to recirculate some of the warm radiator air if needed to maintain the desired room temperature during engine operation, since engine rooms generally are not heated.

A simplified block diagram of the essential features of the control system is shown in Figure 1. Since there is usually no attendant within a number of miles of the station, it is important, in case of trouble, to stop the engine before damage is done. If the speed becomes too high, oil pressure too low, or cooling solution too hot, controls are arranged to stop the set and transmit alarm signals to maintenance people at a control center. If the engine should fail to start during the cranking period, cranking is stopped after a predetermined period to avoid complete discharge of the starting battery. This is a separate storage battery with a rectifier to keep it in a fully charged condition. Similarly, if the heavy initial inrush of starting motor current persists – as it would, for example, if the bearings seized – the attempt to crank the engine is discontinued so as to avoid damage to the starting motor. Signals are also given to indicate power failure, to show when the engine set is carrying the station load, and to warn

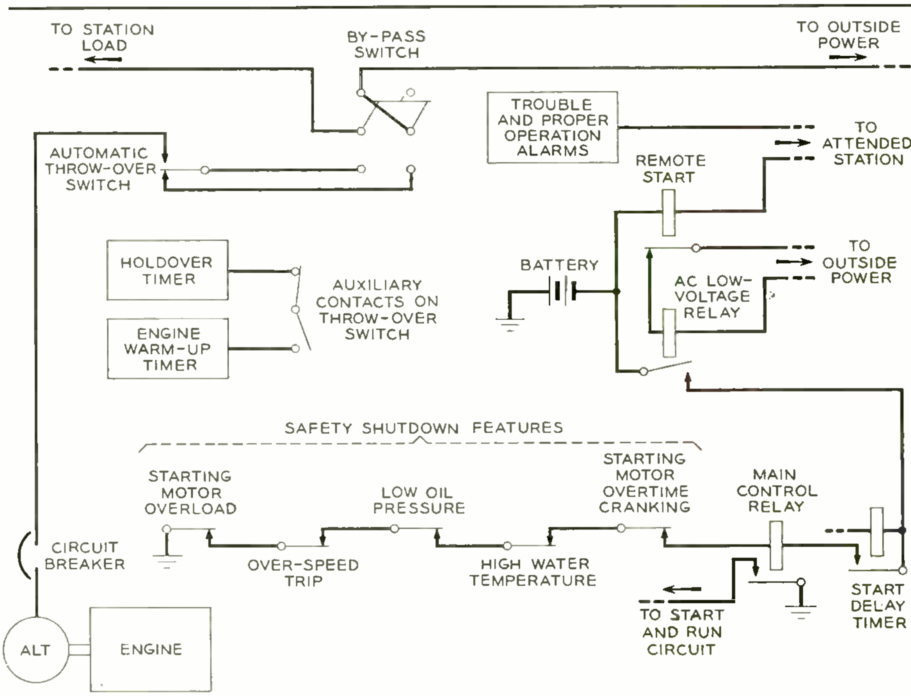


Fig. 1 – Block schematic diagram for the automatic control system.

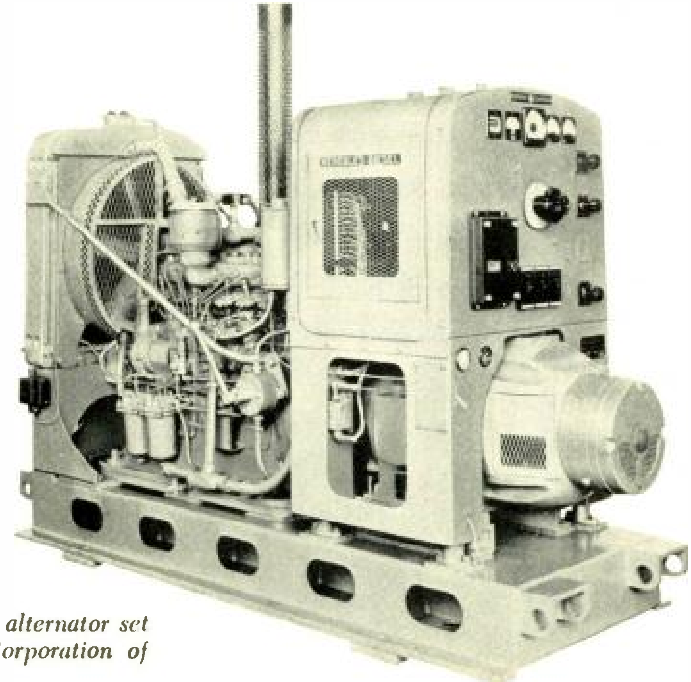
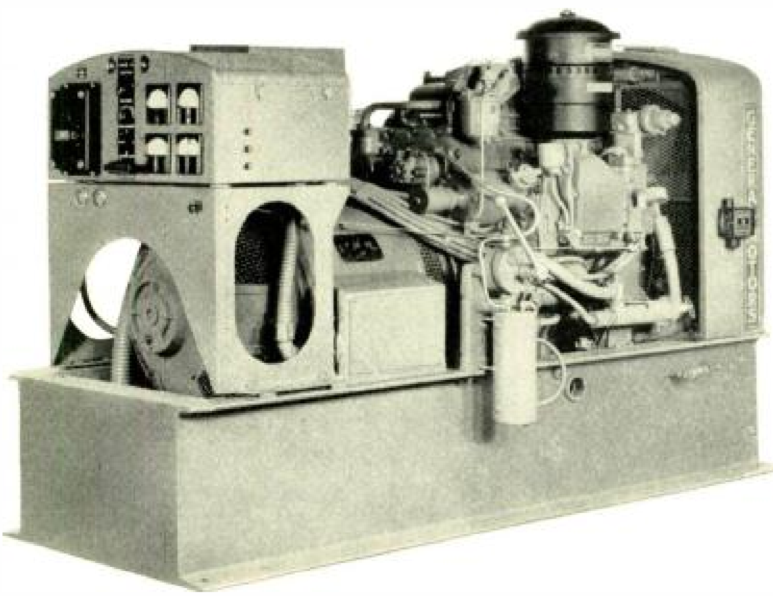


Fig. 2—The 20-kw Diesel engine alternator set furnished by Hercules Motor Corporation of Canton, Ohio.

Fig. 3—The 40-kw Diesel engine alternator set supplied by General Motors Corporation.



ply for the common terminal may be obtained from a different power phase from that supplying a subscriber terminal, and thus the voltage applied to the screen grid of the tube to "gate" the ringing may be out of phase with the ringing pulses. Because of the phase relationship of the Δ and Y transformers, the difference in phase between any two phases is always some multiple of 30 degrees, lagging or leading. To provide for correcting this difference in phase when it is encountered, the J98701N phase shifter has been developed and is installed on the terminal strip of the carrier terminal as shown in Figure 7. Circuitwise, this device is a high impedance phase shifting RC network which operates directly on the screen grid voltage previously referred to. The pigtail leads with spade lugs on the shifter permit it to be set for the various values of phase difference that may be encountered.

If the new test set were not available, the amount of phase shift required would have to be tediously determined on a trial-and-error basis. Arrangements are provided in the test set, however, for measuring the required phase differences so that the phase shifter may be set to the proper value before installation.

To accomplish this a separate phase shifter in the test set, controlled by the dial in the upper right-hand corner, is inserted in the screen circuit of the receiver output tube of the subscriber terminal by three cords running from the three jacks at the upper right of the test set to two similarly marked terminals on the subscriber terminal and to one of the cord leads from the telephone set. With ringing applied to the terminal, the phase shifter dial is turned until the proper signals are heard. The setting of the dial then indicates how the J98701N phase shifter should be set.

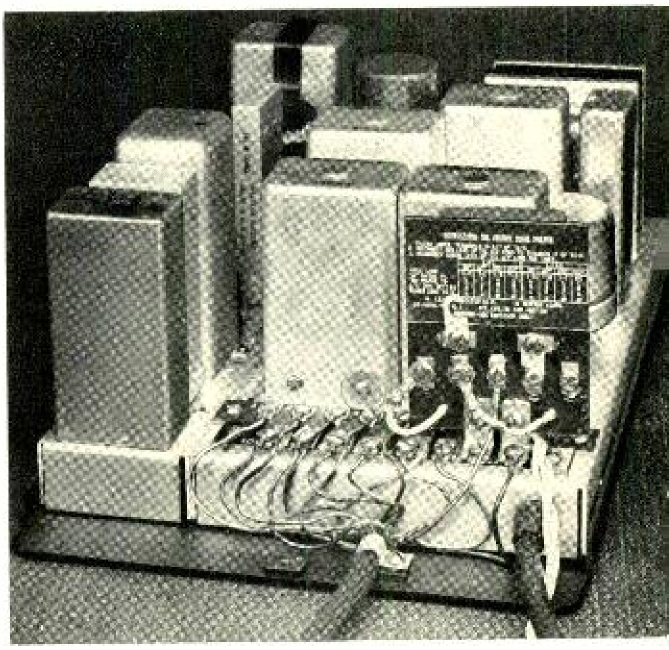


Fig. 7—The J98701N phase shifter mounted on an M1 carrier terminal.

The entire test set is housed in a 12 inch wide by 9 inch high by 7 inch deep gray enameled metal cabinet with removable cover and carrying handle. The inside of the cover provides storage space for the

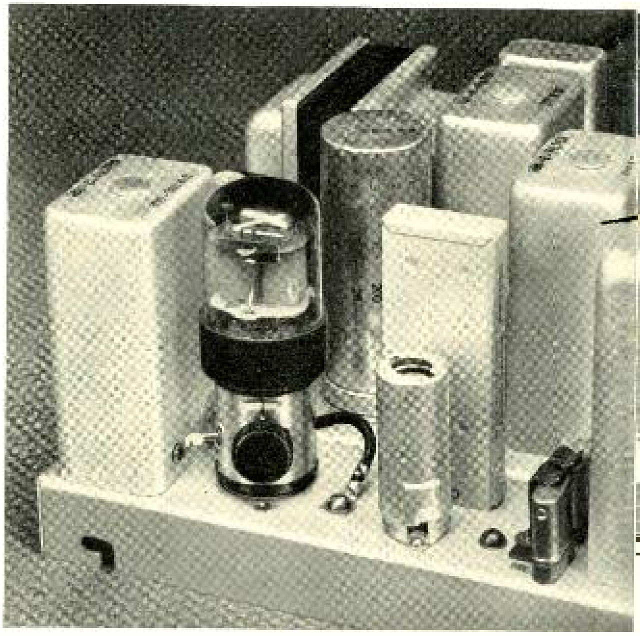
THE AUTHOR: John W. Geils, who recently set up the Personnel Department's technical employment group at Murray Hill, has since World War II been primarily concerned with the development of Type-M and various other carrier systems. Mr. Geils joined the Laboratories in 1941, after graduating from Rensselaer Polytechnic Institute with a B.E.E. degree. After a brief assignment in the trial installation of emergency service equipment for community dial offices, he worked on the design of military equipment, including spiral-4 telegraph, a pulse modulation system, radar, and a bombing computer. In 1945 he made a trip overseas with the 20th Air Force to instruct the military in the installation and use of the computer.

various test leads furnished with the set and for other accessories. To maintain the economy consistent with all M1 carrier designs, this test set is usually equipped only with crystal units having frequencies corresponding to the carrier systems in the area in which the set is to be used. The batteries and the oscillator tube—the only components expected to be replaced from time to time—are standard items, commercially available anywhere for a total cost of about three dollars.

A Carrier-Level Adjuster for M1 Carrier Terminals

M1 carrier* terminals were designed to have fixed output, but some adjustment of carrier level has been necessary under certain conditions. The distance between subscribers, and between subscriber and common terminal, varies over a wide range – one subscriber may be one mile and another as much as twenty miles from the common terminal. To take care of this situation, a certain fixed adjustment was originally provided in the power line coupling unit.† To supplement this, a pad has been used in some areas to provide a fixed loss in the carrier terminals themselves. In many areas, moreover, two or more M1 carrier systems using like channels may terminate in the same central office. To reduce crosstalk and cross signaling from a channel of one system into the like channel of another, reduction of the carrier power transmitted from the nearer of the distant terminals is required so that the levels received from all the like channels are approximately equal. This also has been accomplished by inserting pads in the necessary terminals to reduce their outputs.

Primarily to take care of this latter situation, the 8GC adapter was recently developed by J. W. Geils and D. T. Osgood to provide a continuously variable adjustment from zero to maximum output. It is inserted between the tube and socket of the 398A output tube of either the subscriber or common terminal. All the tube leads pass straight through the adapter from tube to socket except the grid lead, which is connected to the slider of a miniature potentiometer mounted on the side of the adapter. One side of this potentiometer is connected to that socket terminal formerly supplying the grid, while the other side is returned to ground by a pigtail strap fastened under a nearby screw on the chassis. The potentiometer then forms a signal grid voltage divider, permitting the output to be controlled over the range from zero to maximum. This accessory is inexpensive to buy and extremely simple to install. The terminal protruding radially from the side of the adapter permits margin measurements with a KS-5785 test set, described in the preceding article, without disturbing the adjustment of the adapter.



* Record, *October*, 1947, *page* 363.
† Record, *January*, 1948, *page* 2.

Dial-Tone and Completing Markers for No. 5 Crossbar

G. S. BISHOP
Switching Systems Development

Only one type of marker* was provided originally for the No. 5 crossbar system and it was designed to handle nine types of calls. These are dial tone, intra-office, outgoing, incoming, through tandem, through toll, inter-marker group, reverting, and pulse conversion calls. In studying the possibilities of cost reduction in the No. 5 crossbar system, it was found that savings could be made in offices requiring more than four markers by providing markers of two types—one, to be used to connect a calling subscriber to an originating register, which would send dial tone to the subscriber, and the other to handle all other types of connections. The former is called a dial-tone marker and the latter, a completing marker. Although the total number of dial-tone plus completing markers may be increased by the use of two types of markers, each of these markers is simpler and less expensive than the original marker. Also, in general, the total connector cost is appreciably reduced, since each dial-tone or completing marker need connect with only the frames it serves. Since the original marker remains less expensive for the smaller offices, it has been retained and is now called the combined marker. Provision is made, however, to install a small office with a single group of combined markers and to convert to dial-tone and completing markers as the office size expands. This conversion may also be made in offices which were initially installed with combined markers prior to the development of dial-tone and completing markers.

The first installation with dial-tone and completing markers went into service at Turtle Creek, Pa., early this year, while the first conversion from combined markers to dial-tone and completing markers was made at Englewood, N. J., last November.

Of the various frames comprising a combined marker, the common-equipment frame and the translator and route-relay frame, shown in Figures 1 and 2, are individual to each marker. One trunk frame test-lead-connector frame, shown in Figure 3, is common to six or twelve markers depending on the number of routes and trunk-link frames used by the office. One class-of-service frame, shown in Figure 4, is common to four markers. An additional single bay of route relays is sometimes used when the number of route relays exceeds the 100 shown in the right-hand bay of Figure 2.

In an average office, dial-tone calls require about thirty-five per cent of the total usage time for a group of combined markers. For each connection between a calling subscriber line and an originating register, the marker must connect to the line-link frame, through the associated line-link connector and line-link marker connector, and to the trunk-link frame and orginating register through the trunk-link connector. These are shown in Figure 5. The functional units used for dial-tone connections in the combined marker include most of the apparatus of Figure 1, but only one route relay in Figure 2, and only two trunk-frame test-lead-connector relays in Figure 4. These latter three U-type relays are used in the selection of originating registers. Altogether, only a little more than one-third of the U-type relays in a combined marker are used for dial-tone connections.

Completing calls, on the other hand, account for about sixty-five per cent of the

* RECORD, *November*, 1950, *page* 502; and *September*, 1950, *page* 396.

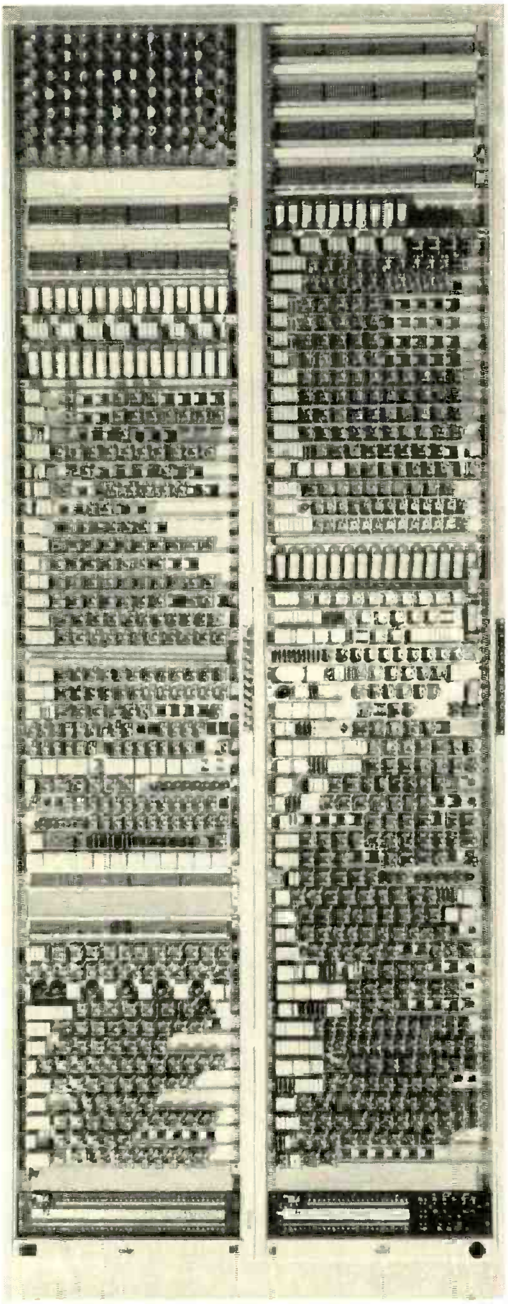


Fig. 1—A common equipment frame for the combined or completing marker.

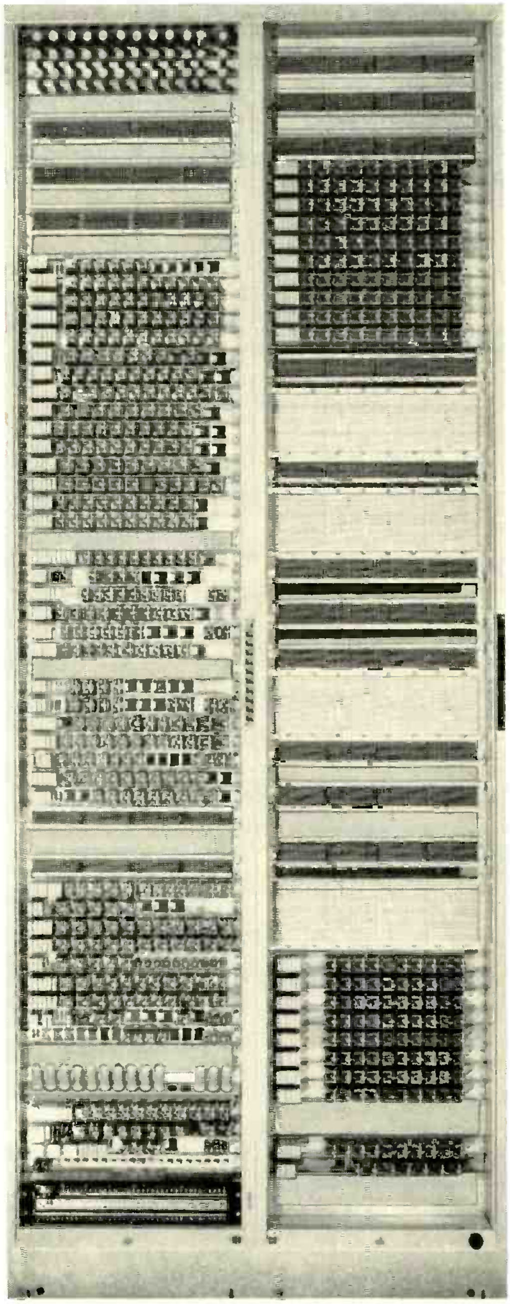


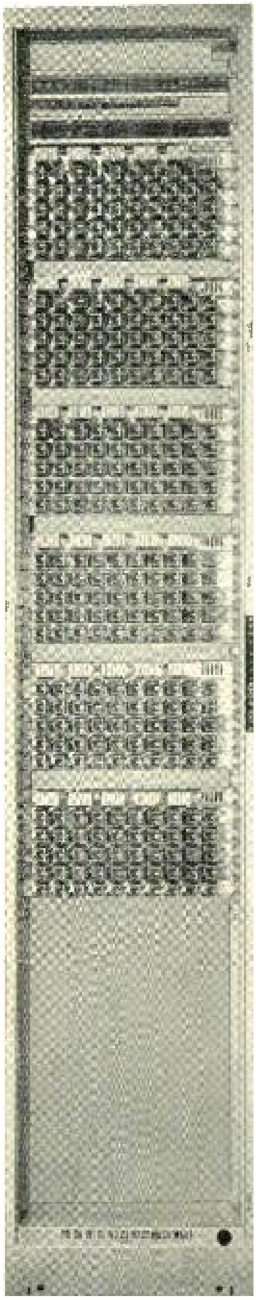
Fig. 2—A translator and route-relay frame for the combined or completing marker.

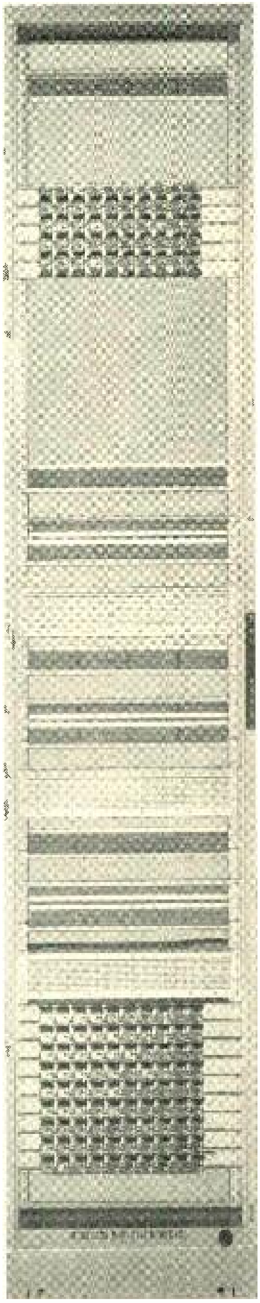
marker usage time of a group of combined markers. The various frame and connector circuits associated with a completing marker are shown by the block schematic of Figure 6. All but from thirty to fifty U-type relays of the units on the four frames of a combined marker are in some way used in setting up completing connections. The relays used only for dial-tone calls are scattered over a number of functional units in the marker common-equipment frame, and in no case make up a complete unit. This division of the relays of a combined marker for dial-tone and completing calls is indicated approximately in the block schematic, Figure 7.

In providing markers, it is standard procedure to equip a minimum of two combined or two dial-tone and two completing markers in each marker group. Thus, one marker of each type is available for handling traffic while the other may be out of service for maintenance. On this basis the use of dial-tone and completing, instead of combined, markers generally does not prove economical except in offices which require more than four combined markers.

For the conversion of a small office initially equipped with combined markers to dial-tone and completing markers, the combined markers will normally be used as completing markers, and the new dial-tone markers will be added. Sometimes, however, one or more of the combined markers may be used either temporarily or permanently for dial-tone traffic. In converting from combined to completing markers, no changes need to be made except to deny access to the marker from line-link marker connectors, while for converting from combined to dial-tone markers, access from originating and incoming register-marker connectors, and access to the number-group and outgoing-sender connectors is denied. Where a combined marker is to be used permanently as a dial-tone marker, provisions can be made to disconnect the associated translator and route relay frame and remove it from the marker group if desired. The circuits of the marker are not arranged to permit the use of dial-tone, completing, and combined markers in the same group, and thus when a conversion is to be made, every combined marker in the group must be changed to either a completing or a dial-tone marker.

The expected savings that stimulated the development of dial-tone and completing markers were a combination of both a reduction in the total amount of marker equipment and a reduction in the number of multicontact relays in the associated connectors. Marker equipment savings result primarily from using the smaller dial-tone markers. Since only about one-third of the relays of a combined marker are used for dial-tone connections, a dial-tone marker is comprised of only two twenty-three inch bays. This frame, as shown in Figure 8, has the same equipment arrangement as a combined-marker common-equipment frame, but with twenty plates of U-type relays and associated apparatus omitted. The completing marker has the same number of bays and the same





Figs. 3 and 4—Left, The trunk frame test lead connector for a combined or completing marker, shown above, is equipped for five markers, ten trunk-line frames, and sixty routes. Right, a class-of-service frame, shown above, is equipped for three markers.

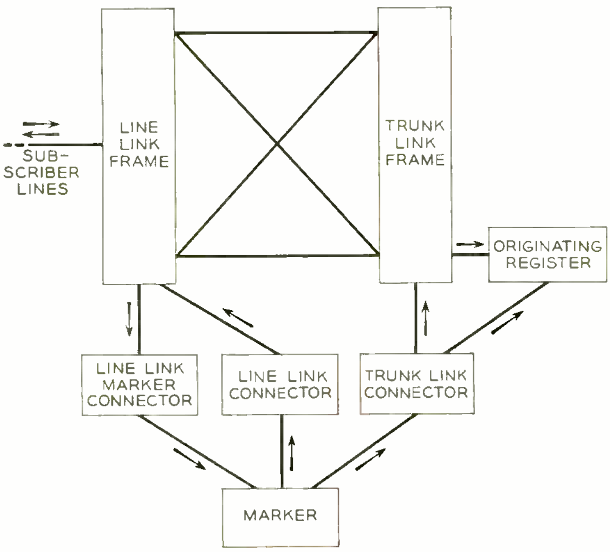


Fig. 5—Block diagram showing circuits required for a dial-tone call.

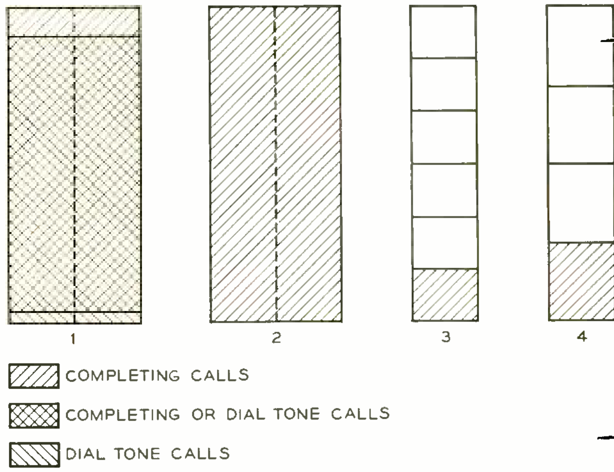


Fig. 7—Block diagram of the four frames of a completing marker with an indication of the amount of equipment on them required in handling the two types of calls.

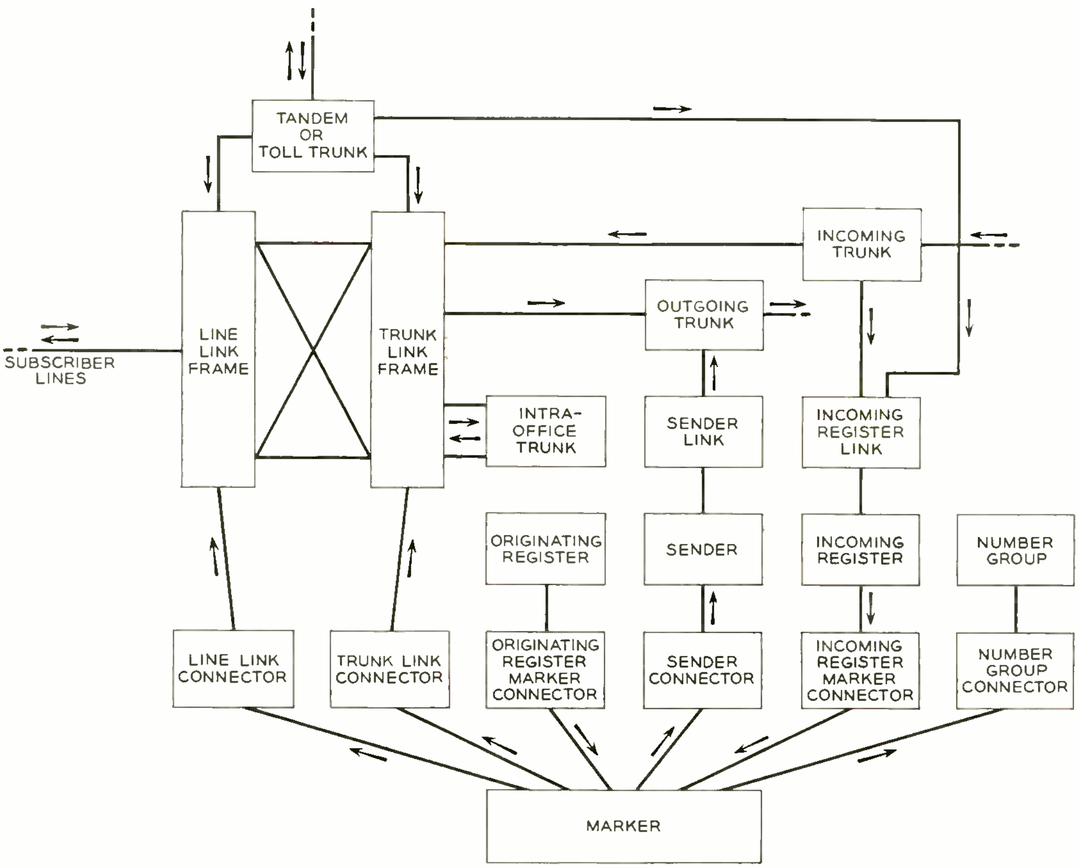


Fig. 6—Block diagram showing circuits required for a completing call.

equipment arrangement as a combined marker except that from thirty to fifty U-type relays, as determined by certain optional features, are omitted from the common equipment frame.

For a given traffic-carrying capacity, the number of dial-tone plus completing markers will ordinarily exceed the equivalent number of combined markers, but the total number of equipment bays for dial-tone and completing markers will be fewer. For example, a group of nine combined markers might be replaced by four dial-tone and six completing markers. The net savings in equipment for this example would amount to a minimum of six twenty-three inch bays fully equipped with relay units and associated cross connecting terminal strips.

Saving in connector equipment can be estimated by referring to the block schematics of Figures 5 and 6. Consider that the blocks designated MARKER represent a group of nine combined markers. All seven different types of connectors* must be arranged with nine sets of connector relays to accommodate all nine combined markers. Replacing the group of nine combined by a subgroup of four dial-tone and a subgroup of six completing markers, the block designated MARKER in Figure 5 would represent four dial-tone markers and the one in Figure 6 would represent six completing markers. The trunk link and line-link connector equipment would then have to be increased to accommodate a total of ten markers, since both dial-tone and completing markers use these connectors. On the other hand the line-link marker connector equipment would be reduced to accommodate only the four dial-tone markers, and the originating register and incoming register marker connectors and number group and outgoing sender connectors would be reduced to accommodate only the six completing markers. Also on the master test connector frame, which is used only for connections to circuits in the master test frame, only eight multicontact relays are required for each dial-tone marker whereas sixteen multicontact relays are required for each combined or completing marker.

Altogether a reduction of about 304 multicontact relays would be made by replacing nine combined markers by four dial-tone and six completing markers. This is given in Table I, which shows the number of connectors and multicontact relays when nine combined markers are used and when four dial-tone and six completing markers are used for an assumed set of conditions. Since the number of connectors is determined pri-

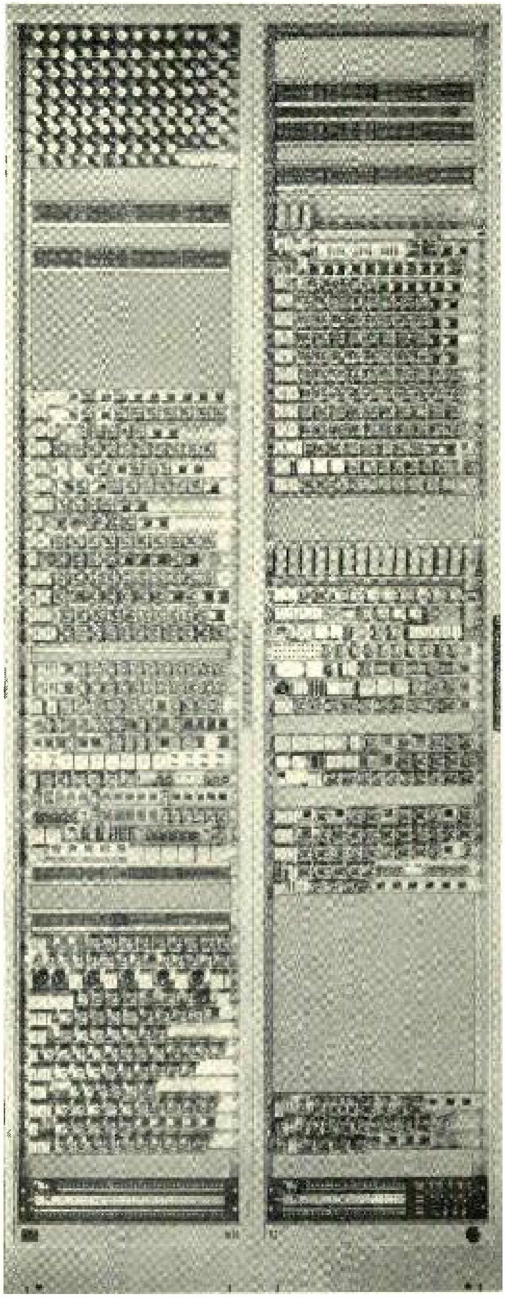


Fig. 8—A dial-tone marker.

* RECORD, *February*, 1950, *page* 56.

TABLE I—COMPARISON OF EQUIPMENT REQUIREMENTS FOR A GROUP OF NINE COMBINED MARKERS AND A GROUP OF FOUR DIAL-TONE AND SIX COMPLETING MARKERS.

Connectors		*Group of 9 Combined Markers*		*Group of 4 Dial Tone and 6 Completing Markers*	
Type	*Number*	*Connector Bays*	*Multicontact Relays*	*Connector Bays*	*Multicontact Relays*
LLMC	29	12	396	8	176
LLC	29	12	522	16	580
NGC	15	8	360	5	240
OSC	2	2	36	1	24
TLC	15	19	540	23	600
ORMC	7	3	126	2	84
IRMC	2	2	36	1	24
MTC	1	3	144	3	128
Totals		61	2160	59	1856

marily by the number of the office frames and not by the number of markers, the number of connectors for the two cases remains the same, but the number of multicontact relays in the connectors varies as indicated.

Although dial tone and completing markers are considered as separate subgroups, collectively they are one marker group. The total number of dial-tone plus completing markers is limited to twelve in a marker group. Within each subgroup, the number of markers will vary according to the number of dial-tone or completing calls, but it is not expected that subgroups will exceed six dialtone or nine completing markers. Accordingly the maximum number of markers for which the connector frames need be arranged takes these limits into account. Trunk-link and line-link connectors are arranged to serve twelve dial-tone and completing markers. Line-link marker connectors are arranged to serve six dial-tone markers, and the register marker connectors and outgoing sender and number group connectors are arranged to serve nine completing markers.

THE AUTHOR: G. S. BISHOP was graduated from Iowa State College in 1942 with a B.S. degree in electrical engineering. He then joined the Technical Staff of the Laboratories and worked one year with the trial installation group of the Systems Development Department. He enlisted in the Marine Corps in 1943 and returned to the Systems Development Department in 1946. Since then he has been active in the design of equipment for No. 4 toll crossbar and No. 5 crossbar systems.

The Howling Telephone

For longer than most telephone engineers can remember, the howling telephone has been a familiar and always-to-be-reckoned-with phenomenon. In many situations precautions have to be taken to avoid howling, while in others, a howling circuit is used to advantage. A copy of what might appear to be the first mention of the howling phenomenon in print has recently been sent to us by Lloyd Espenschied. It is from *The Electrical Engineer* of September 3, 1890, and reads, under the title of *A Novel Telephonic Reaction,* as follows:

"We have recently had our attention called to an interesting phenomenon in connection with the telephone, which might be looked upon with suspicion by the uninitiated. While Messrs. Hibbard and Pickernell were conversing recently over one of the lines of the Long Distance Telephone Company, the former, in order to shut out some conversation, placed the receiver with the diaphragm end over the mouth-piece of the long distance transmitter. The receivers at both ends at once began to give out a musical sound, which continued until the receiver was withdrawn from the mouthpiece of that transmitter. Investigation proved that the effect was due to an action quite similar to that employed in the well-known buzzer or vibrating bell. An original impulse imparted to the transmitter is conveyed electrically through the primary and secondary circuits to the receiver, which in turn throws it back upon the transmitter through the intervening air, thus constituting a complete electric and acoustic cycle. This battledore and shuttlecock action between receiver and transmitter is continuous as long as the receiver is held against the transmitter, and gives rise to a musical note of high pitch and great uniformity. Of course it requires a powerful transmitter to produce the phenomenon, the ordinary Blake instrument being incapable of demonstrating it. The effect produced is decidedly novel and the experiment is well worthy of repetition."

A fortnight later the *Telegraphic Journal and Electrical Review* (London) quoted the paragraph in *The Electrical Engineer,* and then went on to point out that the phenomenon was not new, stating it had been observed some years previously by Stroh. No specific reference was given, and a search has failed to reveal any paper by Stroh affirming his discovery.

Ten years later, F. Gill discussed the phenomenon at more length in a paper entitled *Note on a Humming Telephone* read at a meeting of the Dublin Section of the Institution of Electrical Engineers on April 14, 1901, and later published.[1] Gill credits Hibbard as the discoverer.

In a paper[2] on the humming telephone by A. E. Kennelly and Walter L. Upson in 1908, Hibbard is also cited as the discoverer. In Kennelly's book *Electrical Vibration Instruments* of 1923, however, he correctly cites Prof. Hughes as the discoverer, referring to the *Journal of the Society of Telegraph Engineers and Electricians* for 1883,[3] where Prof. Hughes describes his experiments on the humming phenomenon. These experiments were apparently carried on before 1879, because in that year Harper Brothers brought out a translation of *The Telephone, Microphone, and Phonograph* by Count du Moncel in which Hughes' experiment is referred to.

A more complete discussion of the phenomenon was given by Harvey Fletcher, in 1926,[4] but there had been other discussions in the intervening years.

Although howling has thus been continually with us for over seventy years, unchanged in its nature and invariable in its appearance under suitable conditions, the name by which it is designated has apparently suffered a metamorphosis: from the "musical tone" of Hibbard, through the "humming" of Gill and Kennelly, it becomes "howling" with Fletcher.

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[1] *Jl. Inst. Elec. Engr.*, Vol. 31, pp. 388-395.

[2] *Proc. Am. Phil. Soc.*, Vol. XXVII, pp. 329-365.

[3] Vol. XII, pp. 245-250.

[4] B.S.T.J., Vol. 5, pp. 27-49.

Early Work on Dial Telephone Systems

R. B. HILL
General Staff

The first commercial telephone exchange, employing one operator, was opened for service at New Haven, Conn., in January, 1878, and within a short time exchanges had been established in a number of cities throughout the country.* Almost immediately, and, of course, long before the requirements of the switching art were clearly envisioned, inventors in many walks of life began devising schemes for performing the switching operations by machines instead of by operators. The patented art in any new development is usually well in advance of the commercial art, and in the early work on dial exchanges, many of the fundamental ideas came from inventors who were without technical training or practical telephone experience, and whose mechanical arrangements for embodying their ideas were apt to be impractical or unworkable.

Dial telephone systems derive their name from the use of a dial, or equivalent device, operated by a subscriber or operator to produce the interruptions of current that direct or control the switching process at the central office. The use of a dial for such purposes, however, is much older than the telephone. It was suggested by William F. Cooke in 1836 in connection with telegraphy, and was first used in Professor Wheatstone's dial telegraph of 1839. During succeeding years, it was the subject of many improvements, and was employed not only in dial telegraph systems, but in fire alarm and district messenger systems. Figure 1 shows Froment's telegraph transmitting and receiving dials of 1851. When the pointer P of the transmitting dial (a) is moved to the letter D, for example, four teeth of wheel R will be moved past spring M, and four makes and breaks of the battery current will take place. These will attract the armature, a, of electromagnet b, at the distant station (b) four times, and, by means of pawl F, will give four movements to ratchet wheel G, thus advancing the pointer of the receiving dial (c) to letter D. In this way, the telegraph message was spelled out, letter by letter. The modern type of finger-wheel dial – an important mechanical improvement over the pointer type of dial – did not appear until 1896.

The first dial telephone exchange patent, No. 222,458, was applied for on September 10, 1879, and issued on December 9, 1879, jointly to M. D. Connolly, of Philadelphia; T. A. Connolly, of Washington, D. C.; and T. J. McTighe, of Pittsburgh. Although this first system was crude in design and limited to a small number of subscribers, it nevertheless embodied the generic principle of later dial systems. At each station, in addition to the telephone, battery, and call bell, were a reversing key, a compound switch, and a dial (Figure 2a) similar to that employed in dial telegraph systems, and bearing on its face the numbers corresponding to the different stations of the exchange. At the central office (Figure 2b) were ratchet wheels: one wheel for each station, mounted one above the other on a common vertical shaft and carrying wiper arms which moved with the ratchets. Actuated by the circuit interruptions made by the calling subscriber dial, an electromagnet stepped the wiper arm around to engage the contact of the called subscriber line.

Although the switching mechanism was relatively simple, various manipulations of the reversing key and compound switch

* RECORD, *February*, 1931, *page* 265.

were required by both parties to a conversation to make the necessary circuit shifts at the station, to reverse the current on the line, to operate the call bells, and to restore the switching apparatus to normal when the parties were through talking.

The Connolly and McTighe system, with eight stations connected, was exhibited at the Paris Exposition in 1881, and various modifications were made in it by its inventors in subsequent patents. It was never employed in commercial service.

Between 1879 and 1900, a great many patents covering dial switching systems were issued, but except for the Strowger patent (No. 447,918) of 1891 and subsequent patents pertaining to the Strowger system, none resulted in a successful commercial system. A list of the patents falling within the Patent Office classification "Automatic Telephone Exchanges," is given in Table I. Several other patents covering automatic village, house, and factory systems, not included in the above list, were also issued during this period.

The twenty-six patents on the list that were issued between the Connolly and McTighe patent of 1879 and Strowger patent No. 447,918 of 1891 all related to the operation of small exchanges, and for the most part employed complicated electromagnetic step-by-step arrangements, constantly running synchronized clockwork mechanisms, reversals of current direction, changes in current strength, and the like. None of them can be said to have advanced the automatic switching art in any practical manner, nor did any of them, so far as is known, go into commercial use.

Patents Nos. 223,201 and 223,202, issued to George Westinghouse, Jr., in December, 1879, were the first to provide for the operation of a number of suburban, or satellite, exchanges connected to the main manually-operated exchange in a city.

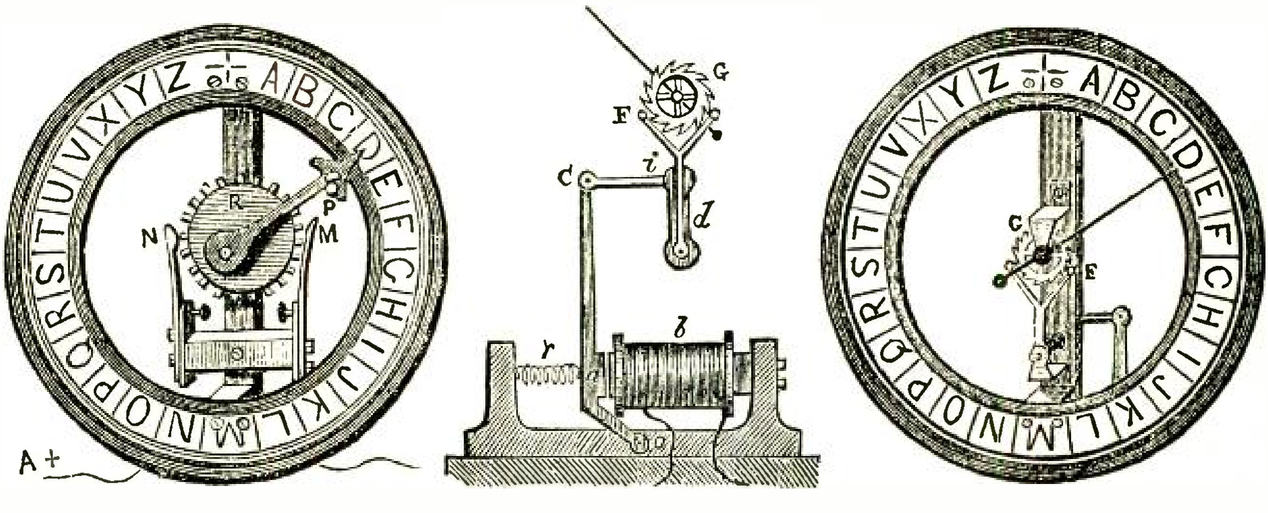

Fig. 1—Transmitting dial (a) and receiving dial (c) used with Froment's alphabetical telegraph system of 1851 (from Shaffner's Telegraph Manual) together with the electromagnet, ratchet, and pawl arrangement used with the receiving dial (b).

The Village system invented by E. T. Gilliland, of the American Bell Telephone Company, and covered by patent No. 306,-238, of October 7, 1884 (not included in Table I), with subsequent improvements, enjoyed a limited commercial use. It employed a number of main lines which entered all of the subscriber stations, thus eliminating the central office altogether. To make a call, a subscriber pushed in a knob corresponding to the line on which the desired station was located, which connected his telephone to that line. If, on listening, he found that the line was not in use, he rang the wanted subscriber with his magneto generator, and conversed with him. This Village system, which was first installed at Leicester, Mass., in 1885, and was afterward employed in a number of small towns, was exhibited at the Chicago World's Fair in 1893.

In 1886, Gilliland also patented an "Automatic Circuit Changer," patent No. 334,014, whereby the operator at Worcester could pulse a rotary selector at Leicester, six miles away, selecting and ringing any desired line of the Village system. This might be considered an embryonic form of operator dialing. It was placed in actual commercial use in 1885.

Foreshadowing the complexity of later switching systems was another patent, No. 435,295, issued to Dr. William H. Ford, of St. Louis, in August 1890. It was the result of several years' work by its inventor, and contained twenty-seven sheets of drawings and twenty-two pages of specification.

Thomas D. Lockwood, manager of the American Bell Company's Patent Department, also entered the dial switching field, and was granted two patents, Nos. 335,708 and 372,378, issued in 1886 and 1887, respectively.

In 1889, H. V. Hayes and H. D. Sears, of the American Bell Telephone Company, devised a dial system for small exchanges, which was afterward covered by patent No. 457,477, issued in 1891. It employed at the central office a motor-driven rotary commutating mechanism for each line, which could be set in motion, through a polarized relay and other intervening appliances, by plus or minus currents sent out over the line by the subscriber magneto generator. The method of operation was quite complicated, and the system never passed the laboratory stage. It represented, however, the first work of American Bell engineers on true dial exchanges.

The real advances in the dial exchange art prior to the Strowger patent of 1891 came from inventions not directly related to automatic telephone systems.

On November 2, 1889, for example, J. G. Smith, of New York City, applied for a patent on a dial switching system for telegraph lines, which was issued on August 23, 1892, as patent No. 481,247. This was the first patent to clearly disclose the use of trunks* between groups of selectors, including the automatic selection of an idle trunk, which later became an essential feature of all but the smallest dial telephone exchanges.

For the purpose of reducing the cost of giving private wire service to brokers and others who desired telegraph connection between their offices in different cities, the inventor provided only enough trunk lines to serve the maximum number of subscribers who would be telegraphing at any one time. To prevent two or more subscribers from being connected to the same trunk, he devised a mechanism for hunting for the first trunk that was not in use. At each subscriber station was a dial, with holes bearing the numbers of the distant local circuits with which communication might be desired, and means for setting in motion the central office mechanism. At the local central office, each subscriber line terminated in a switch, or selector, whose function was to select an idle trunk. The trunk lines were multipled to the bank contacts on each selector, so that each subscriber line could connect with every trunk. Each trunk line terminated, at the distant central office, in a switch, or connector, which made the connection with the desired subscriber line. All of the subscriber lines at the distant central office were multipled to the banks of all of the connectors. Power for actuating the switches was supplied by a constantly rotating shaft driven by a small motor.

The apparatus and method of operation of this system were far too complicated for an adequate description here. Briefly stated, a subscriber desiring a connection inserted a brass plug in the proper hole in his dial plate, and, by operating suitable hand switches, caused his selector clutch to engage a constantly rotating disc, which advanced the selector brushes over the trunk terminals until the test brush encountered an idle trunk, whereupon the clutch was disengaged and the brush stopped. This connected the calling subscriber line, through the selected trunk, to a connector switch at the distant central office, whose brushes ad-

* In manual switching, trunking had been employed for many years.

vanced over the terminals of the subscriber lines, one step at a time. For each of these steps, the calling subscriber dial arm made a corresponding advance until it encountered the brass plug which had been inserted in a hole, whereupon a change in the current strength took place, which stopped the distant connector on the proper terminal, and the desired connection was completed.

Although the important feature of the Smith patent was the adoption of the trunking principle, the invention also employed the principle of reverse impulse control which, in a different form, is a feature of the Bell System panel dial system.

In two later patents, Nos. 550,728 and 550,729, issued in 1895, J. G. Smith applied the features of his dial telegraph exchange to telephone exchange operation.

Patent No. 329,874, issued to Thomas Ahearn, of Ottawa, Canada, in 1885, covered a watchman's signal. In order to compel a watchman, in making his rounds, to be at each station at the proper time, the inventor provided at the central station a constantly rotating brush, driven by clockwork, which slowly wiped over the contacts of the lines to the various signal stations and closed the circuit of each for a definite period of time. If the watchman did not arrive at a station within the appointed time interval, he was unable to send in his signal, as the circuit through the central station indicator was destroyed. Instead, an alarm sounded at the central station. This patent was only a partial disclosure of the line finder principle, since no provision was made for stopping the rotating brush on a particular line. It is mentioned here because it was cited by the Patent Office in connection with the Van Size invention referred to below.

Patent No. 393,529, issued to W. B. Van Size, of Plainfield, N. J., on November 27, 1888, and subsequently reissued, disclosed an arrangement closely analogous to the line finder method of operation. To simplify the equipment at a manual operator's position, and to eliminate the annunciator drop, the

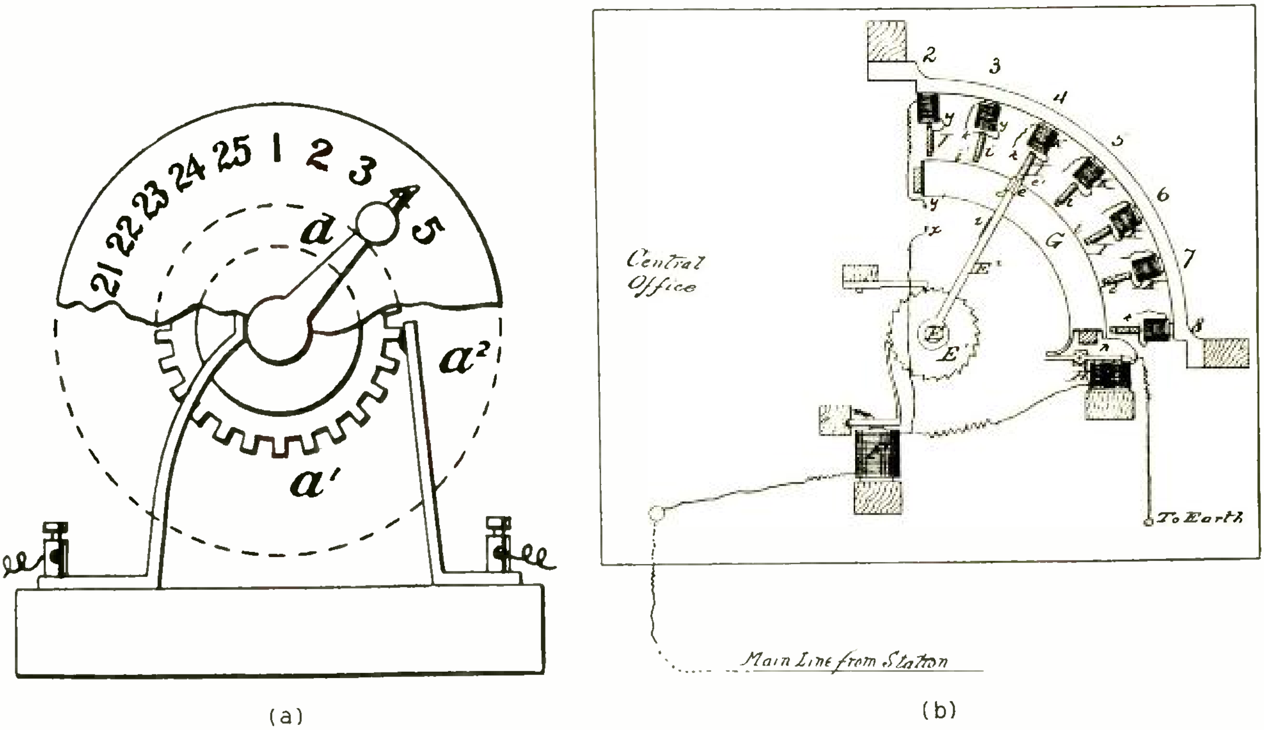

Fig. 2—Dial arrangement (a) and switching elements (b) for one subscriber's line illustrated in the Connolly and McTighe patent of 1879. *Similar switching equipment, mounted on a common shaft* E, *was provided for each line of the exchange.*

inventor provided at each position a constantly revolving radial arm or brush, connected to ground through an electromagnet and the operator's head telephone, which wiped over the circularly arranged contacts of the subscriber lines assigned to that switchboard position. When a calling subscriber operated a switch, connecting his battery to the line, it actuated the electromagnet as soon as the revolving brush reached his line terminal and, by means of a ratchet and pawl, stopped the brush on that terminal, thus connecting the operator's telephone into the circuit. The subscriber could then pass his call verbally to the operator, who completed it in the usual manner. Although the Van Size arrangement could hardly be called a simplification of the manual method of operation employed at that time, it did represent an interesting patent disclosure.

All dial switching systems prior to the early 1890's were severely handicapped by the lack of a reliable power plant. Primary cells, such as LeClanché, were the best available, and the voltage varied widely.

By 1900, only two general types of automatic telephone systems had been developed, although both had various subdivisions. In the first, and earliest, type, there was a direct connection of the calling and called line. Each subscriber line ended at the central office in the movable arm of an individual switch capable of making connection with the fixed terminals of any other line in the exchange. All of the subscriber lines were connected, or multipled, to the fixed terminals of each switch. Figure 3 illustrates this principle for an automatic exchange of eight subscriber lines. For the sake of simplicity, the multiple connections to only four of the eight lines are shown. As long as the number of lines in the exchange was small – not more than one or two hundred – this type of system was practicable. In large exchanges – several thousand lines, to take an extreme case – it is readily seen that the switches, with the necessary multiple connections, would be prohibitive in size and cost. The Connolly and McTighe system and the early Strowger installations were examples of this type.

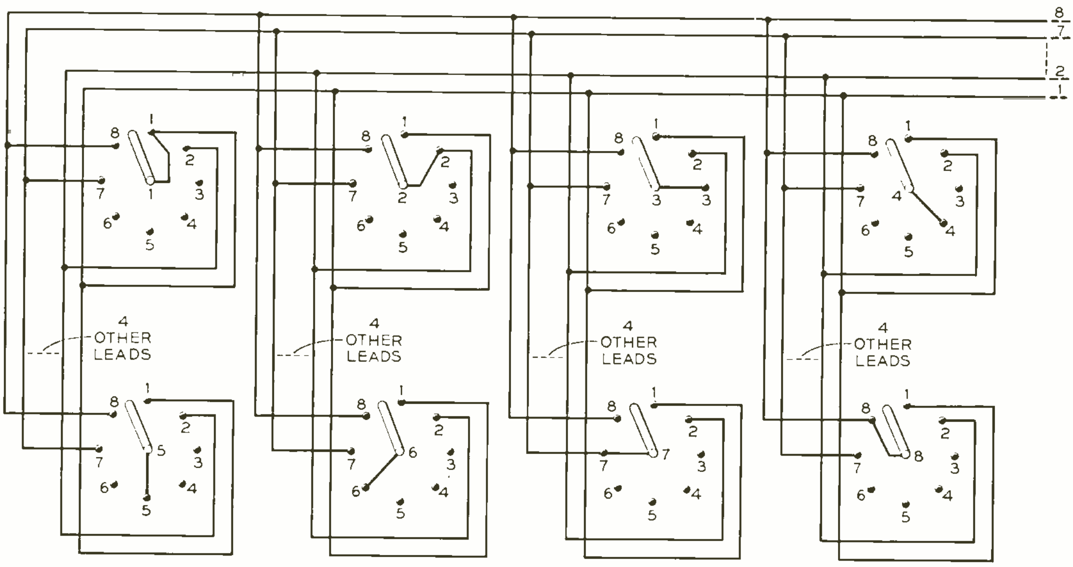

Fig. 3—Diagrammatic representation of the earliest type of automatic telephone exchange. At the central office there was an individual switch for each subscriber, to the wiper arm of which his line was permanently connected (center numbers). Each of the lines (eight shown in diagram) was also connected, or multipled, to its own peripheral contact on every switch.

The second, and later, type of automatic exchange employed the trunking, or transfer, principle, in which the direct connection between the terminals of the calling and called lines is discarded, and instead such connection is established through an office trunk, the function of the central office switches being, first, to unite the calling line to one end of an idle trunk, and then to unite the other end of the trunk to the called line. This method greatly diminished the first cost and complexity of the central office apparatus in large exchanges, since it permitted the use of switches of relatively small capacity. Only enough trunks had to be provided to handle the maximum number of calls made at any one time.

This second type of automatic system comprised two distinct classes. In one class, there was an individual switch for each subscriber line which, when operated, selected an idle trunk of a group leading to the bank of terminals in which the called line was located, and then, by means of another switch, connected that trunk to the terminals of the desired line. In Figure 3, for instance, the peripheral contacts, of which there would be 100 or more for a large exchange, are now the terminals of trunk circuits leading to the switch arms of selectors which make the final connection. In this class were included the later Strowger installations.

In the other class of the second type, the subscriber lines were not provided with individual selecting switches, and there was no such apparatus normally connected with their lines. Instead, the several trunk circuits assigned to a group of subscriber lines were each provided with a suitable selecting switch, or "line finder," at their calling circuit ends, adapted to seize upon and connect with the terminals of a calling line, to unite those terminals with an idle trunk, and then by means of suitable switching devices to join the other end of the trunk with the terminals of the called line. This "line finder" method of operation was first employed in the Lorimer and Faller systems. As there used, a constantly operating mechanism brought a switch common to a group of lines into successive contact with the terminals of the lines and detected the changed electrical condition produced when any line had originated a call. A path was then provided from the calling line to an idle selector, which the calling subscriber could actuate to complete his call. Line finders of forms not requiring continuous scanning were used in later Western Electric and Strowger Systems.

During the first twenty-five years of the telephone, up to the beginning of the twentieth century, the attempts to devise a dial switching system had been made primarily by inventors without practical telephone experience, as has already been noted. The problem was interesting in its theoretical aspects, and all over the country men of an inventive turn of mind and with some knowledge of electricity tried their hand at solving it. Some of the many bizarre proposals have already been described in the Record*. As a matter of fact, however, there was very little need for a dial system in these early years of the telephone art.

The objective in the minds of the many inventors was probably to save the cost of operators, but for the most part they knew too little about the telephone system and its requirements to realize that with an adequate dial system the saving in salaries of the operators would be largely if not entirely offset by the greatly increased maintenance expenses of the more elaborate switching apparatus and by the carrying charges on the much greater investment required. The real need for dial switching is due primarily to other and much more complex technical and economic factors, and did not arise in any appreciable intensity until well after the turn of the century.

The engineers of the Bell System had been closely following the dial system patents from the very beginning, and had carried on a little development along these lines as early as the late 1880's. They recognized the difficulties, however, and knew how little would be gained from dial switching under existing conditions. There was far greater need for developments along other lines — in instruments and station apparatus, in transmission systems and methods, and in underground distributing systems. During the 1890's and early 1900's, for example, they were very much occupied in developing and

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* RECORD, *March*, 1929, *page* 265.

Table I — List of United States Patents on Automatic Telephone Exchanges Issued During the Years 1879-1900, Inclusive.*

Number	Date Issued	Patentee	Application Date
222,458	Dec. 9, 1879	Connolly & McTighe	Sept. 10, 1879
223,201	Dec. 30, 1879	Westinghouse, G. Jr.	Oct. 11, 1879
223,202	Dec. 30, 1879	Westinghouse, G. Jr.	Oct. 13, 1879
224,565	Feb. 17, 1880	Westinghouse, G. Jr.	Oct. 27, 1879
237,222	Feb. 1, 1881	Westinghouse, G. Jr.	Feb. 7, 1880
248,138	Oct. 11, 1881	Buell, C. E.	June 15, 1881
255,766	Apr. 4, 1882	Buell, C. E.	Dec. 12, 1881
262,645	Aug. 15, 1882	Connolly & McTighe	Aug. 29, 1881
262,646	Aug. 15, 1882	Connolly, M. D.	Nov. 29, 1881
262,647	Aug. 15, 1882	Connolly, M. D.	Nov. 8, 1881
263,862	Sept. 5, 1882	Connolly, M. D.	Oct. 29, 1881
269,130	Dec. 12, 1882	Snell, F. H.	Sept. 6, 1882
281,613	July 17, 1883	Cardwell, G. A.	July 7, 1882
282,791	Aug. 7, 1883	Snell, F. H.	Feb. 28, 1883
283,806	Aug. 28, 1883	O'Donel, I. M.	June 5, 1880
290,730	Dec. 25, 1883	Bartelous, J. V. M.	June 15, 1882
295,356	Mar. 18, 1884	Connolly, T. A.	Apr. 10, 1883
310,282	Jan. 6, 1885	Jackson & Cole	Mar. 5, 1884
335,708	Feb. 9, 1886	Lockwood, T. D.	Sept. 26, 1885
349,975	Sept. 28, 1886	Bickford, J. H.	Nov. 25, 1885
349,976	Sept. 28, 1886	Bickford, J. H.	Jan. 18, 1886
367,219	July 26, 1887	McCoy, J. A.	Jan. 29, 1887
372,378	Nov. 1, 1887	Lockwood, T. D.	Apr. 11, 1887
381,938	May 1, 1888	McCoy, J. A.	July 6, 1887
408,327	Aug. 6, 1889	Smith, J. R.	Feb. 16, 1888
435,295	Aug. 26, 1890	Ford, W. H.	Dec. 31, 1889
442,734	Dec. 16, 1890	Smith & Childs	Sept. 27, 1889
447,918	Mar. 10, 1891	Strowger, A. B.	Mar. 12, 1889
457,477	Aug. 11, 1891	Hayes & Sears	Feb. 3, 1891
486,909	Nov. 29, 1892	Strowger, A. B.	Feb. 19, 1892
498,236	May 30, 1893	Clark, E. A.	Apr. 5, 1892
498,289	May 30, 1893	McCaskey, A. S.	July 29, 1892
498,291	May 30, 1893	McCaskey, A. S.	Aug. 25, 1892
499,748	June 20, 1893	McClaren, A. E.	June 13, 1892
510,195	Dec. 5, 1893	Serdinko, J.	Apr. 22, 1893
511,873	Jan. 2, 1894	Callender, R.	Apr. 24, 1893
511,874	Jan. 2, 1894	Callender, R.	May 12, 1893
511,875	Jan. 2, 1894	Callender, R.	Aug. 13, 1892
515,108	Feb. 20, 1894	Callender, R.	Nov. 2, 1893
515,109	Feb. 20, 1894	Callender, R.	Nov. 2, 1893
515,110	Feb. 20, 1894	Callender, R.	Nov. 2, 1893
520,246	May 22, 1894	Simoneau, L. E.	July 11, 1893
528,590	Nov. 6, 1894	Childs, W.	May 12, 1891
528,591	Nov. 6, 1894	Childs, W.	May 27, 1890
530,324	Dec. 4, 1894	Callender, R.	Dec. 18, 1893
533,893	Feb. 12, 1895	Hey & Parsons	Mar. 30, 1893
535,806	Mar. 12, 1895	Nissl, F.	Feb. 17, 1894
537,603	Apr. 16, 1895	Decker, W.	May 14, 1894
538,975	May 7, 1895	McDonough, J. W.	May 21, 1891
540,168	May 28, 1895	Keith, Lundquist & Erickson	Nov. 7, 1894
543,160	July 23, 1895	Shibata, W. Y.	Oct. 11, 1894
543,708	July 30, 1895	Shibata, W. Y.	Nov. 24, 1893
546,725	Sept. 24, 1895	†Berditschewsky et al.	Mar. 27, 1895
547,755	Oct. 8, 1895	Hutchins, G. K.	May 6, 1893
550,728	Dec. 3, 1895	Smith, J. G.	Feb. 18, 1893
550,729	Dec. 3, 1895	Smith, J. G.	Feb. 20, 1893
551,391	Dec. 17, 1895	Lounsbury, W. F.	Apr. 23, 1895
554,125	Feb. 4, 1896	Houts, W. A.	Dec. 24, 1894
556,007	Mar. 10, 1896	Freudenberg, M.	Jan. 10, 1896
561,377	June 2, 1896	Dean, G. Q. & J. Jr.	Aug. 3, 1895
562,064	June 16, 1896	†S. Berditschewsky	Mar. 23, 1896
570,840	Nov. 3, 1896	Brooks, M.	Jan. 26, 1895
573,859	Dec. 29, 1896	Callender, R.	Mar. 19, 1896
573,884	Dec. 29, 1896	Keith, A. E.	Sept. 16, 1893
574,245	Dec. 29, 1896	Houts & Nilson	Aug. 25, 1896
574,707	Jan. 5, 1897	Bowman, L. G.	July 18, 1896
582,578	May 11, 1897	Clark, Ellacott & Johnson	Sept. 28, 1893
584,384	June 15, 1897	Macklin, A. B.	Aug. 7, 1896
586,529	July 13, 1897	Davis, W. W.	Sept. 5, 1896
587,435	Aug. 3, 1897	Freudenberg, M.	Oct. 22, 1896
588,511	Aug. 17, 1897	Van Wagenen, A.	Apr. 30, 1896
589,798	Sept. 7, 1897	Strowger & Keith	Feb. 19, 1896
591,201	Oct. 5, 1897	Strowger, Lundquist & Erickson	July 17, 1895
597,062	Jan. 11, 1898	Keith & Erickson	Aug. 20, 1896
604,373	May 24, 1898	Decker, W.	Mar. 25, 1895
604,434	May 24, 1898	Stillwell & Barneck	Nov. 10, 1896
606,764	July 5, 1898	Lundquist, F. A.	May 19, 1897
611,974	Oct. 4, 1898	Nilson, L. G.	Mar. 9, 1896
612,681	Oct. 13, 1898	Snow, H. P.	Nov. 1, 1897
616,714	Dec. 27, 1898	Lundquist & Erickson	Mar. 28, 1893
624,666	May 9, 1899	Lundquist, F. A.	Sept. 20, 1897
626,983	June 13, 1899	Decker, W.	Aug. 3, 1896
632,759	Sept. 12, 1899	Slater, J. C.	May 23, 1898
638,249	Dec. 5, 1899	Keith & Erickson	Dec. 16, 1895
639,186	Dec. 12, 1899	Seligmann-Lui, G.	May 27, 1898

* Excludes village, house and factory systems. † Called "Apostoloff." Note:—No automatic telephone exchange patents were issued during the year 1900.

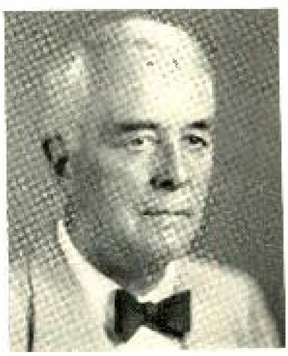
installing throughout the Bell System the common battery system to take the place of the local battery or magneto system that had been employed since the beginning of the telephone business. This system constituted one of the most important advances ever made in the telephone art, and opened the way for a tremendous expansion in telephone service. It also gave the engineers a much broader and clearer picture of the intricacies, both technical and economic, of the switching problem in large exchanges, together with all of the necessary traffic data to make intelligent plans for future requirements.

During the later years of the nineteenth century, moreover, many features were introduced to save operating effort, such as automatic ringing of a called subscriber when an operator plugged into his jack, and automatic tripping of the ringing when he answered. All of these developments and many others were paving the way for a really satisfactory dial system.

The first real need for dial operation within the Bell System arose in connection with some of the smaller communities where there was not a full time operating load for even one operator, and thus 24-hour service was very expensive. Work was accordingly started about 1900 on the development of a small dial exchange, and during 1902 a 50-line system was placed in experimental operation in Queens, Long Island. During the following year this was replaced by a 100-line system. Other such systems, of 20-line and 100-line capacity, were built during 1904 and 1905, to a total of more than 40. Experience indicated, however, that the operation of dial switching equipment in unattended offices brought in additional requirements that were difficult if not impossible to meet at that time. As a result, these installations were later reconverted to manual operation. It was not until many years later that dial switching for small unattended offices proved technically and economically practicable.

At about this same time, however, it began to become evident that before many years dial switching would be needed to meet the complex conditions in the larger cities, where it was foreseen that there would not be a sufficient number of competent operators available to do all switching manually. As a result, the development of dial switching within the Bell System had expanded into an intensive program by 1905. It resulted in the trial of a semi-automatic system at West Street in 1910, in the commercial installation of a semi-automatic panel system in Newark in 1915 and later in the full automatic panel dial system.

Although many patents had been issued on dial switching systems prior to the Bell System work beginning about 1900, and most of the elementary switching principles had been disclosed, none of the systems that were devised enjoyed any extensive commercial use except that of Almon B. Strowger and his associates. This latter system will be the subject of a forthcoming article.



THE AUTHOR: Roger B. Hill received a B.S. degree from Harvard University in 1911 and entered the Engineering Department of the American Telephone and Telegraph Company in August of that year. For several years thereafter he was engaged principally in appraisal and depreciation studies. When the Department of Development and Research was formed in 1919, he transferred to it, and since then, until his retirement in 1951, had been largely concerned with studies of the economic phases of development and operation. He had been a member of the staff of Bell Telephone Laboratories since 1934, first in the Outside Plant Development Department and later in the Staff Department. In addition to his work on the economic side of the telephone business, Mr. Hill exhibited a great interest in the early history of the telephone art, and assisted with the preparation of several books and articles dealing with that subject.

Reserve Power Generators For Unattended Stations

V. T. CALLAHAN
Power Development Engineering

Few people in the eastern United States realize that, as they watched television programs from the West Coast early last year, one of the radio relay stations had been operating on its emergency power generator for about two weeks. At Mount Rose, Nevada, high in the Sierra Nevada mountains, 1600 feet of power lines were down, along with the alarm and order circuits, completely isolating the station. With 17 to 20 feet of snow already on the ground, with more falling and high winds blowing, maintenance men could not get through for four days. Finally, using snow shoes, and "snow cats,"* the men reached the station, where they found that the engine-driven alternator, which had automatically assumed the load when the power supply was interrupted, was still working satisfactorily. With a change of lubricating oil, the engine continued to carry the load without attention until the power lines were restored, after being down fourteen days.

On earlier carrier routes, such as the Type-J and Type-K systems, reserve power is usually furnished by the repeater station storage batteries. During unusually long outages of commercial power, portable engine sets are brought up by trailers. This practice, of course, requires battery reserves sufficient for periods as long as 100 hours. A few stations that require more operating power than can economically be furnished with such long battery reserves are supplied with permanent automatically controlled engine alternators for emergency use.

Increased power demands of the broadband systems, such as Type-L carrier and radio relay, plus isolated locations of many of the radio relay stations, have made it economically feasible, in some cases, to install automatic engine-driven alternators for the primary reserve. Storage batteries are included, but limited to six- or eight-hour capacities, sufficient for the period necessary for ordinary engine repairs.

Early radio relay station installations on the transcontinental microwave radio relay system were supplied with automatic gasoline engine sets, but the later stations west of Denver have diesel engines. Development of the automatically controlled diesel engines had not been completed in time for use throughout the transcontinental system. Both gasoline and diesel automatic sets have capacities of 20 to 60 kilowatts.

Repeater stations are normally unattended, and many are in isolated locations. It has therefore been necessary to provide more elaborate controls than usually needed for commercial standby power supplies. For example, to keep the engine from starting on a temporary voltage dip (which can be taken care of by the battery reserve), a starting delay circuit is included, which requires the low voltage condition to persist for a predetermined length of time. After this delay, the engine is given its final signal to start, but does not ordinarily assume the station load until after a warm-up period to improve engine operation. During this interval, the station load is carried by storage batteries. At the end of this time the load transfer is made by a very fast operating contactor. Designed to require electrical power only when transferring the load, this contactor remains mechanically locked in one position until energized, thereby avoiding interruptions of power supply due to temporary voltage variations.

* Record, *March,* 1952, *page* 146.

that the fuel supply may be becoming low.

To be sure that the engine sets are in condition for reliable starting, arrangements are provided for exercising them each week. This may be done locally at the station, or remotely from the maintenance center, whereby the engine circuit "thinks" a power failure has occurred, goes through its regular power failure cycle, restoring the load to commercial service upon completion of the cycle.

Since they are installed in unheated rooms, the engine sets may be exposed to temperatures as low as minus 20 degrees F. Tests at that temperature have shown that positive and reliable automatic starting requires a 2500-watt thermostatically controlled heater for the cooling liquid solution. The thermostatic switch used with this heater is set to cut off the heater when the cooling liquid is 80 to 100 degrees F, and to turn on the heater at 60 degrees F or lower. Due to radiation in air temperatures at minus 20 degrees F, the heater maintains an engine cylinder combustion air temperature of 45 to 50 degrees F. The types of diesel engines used in these stations require a cylinder combustion air temperature of not less than 35 degrees F at the start of the compression stroke, so as to ignite the fuel properly by the heat of compression at the end of the stroke.

Emergency arrangements are made to stop the engine by a switch at the engine or from the control panel. Switching provisions are also included to transmit normal service power directly to the load circuits, and to remove the service power from the control circuits during periods of repair or maintenance.

Three stations on the transcontinental radio relay are in locations where no commercial power supply is available and where the provision of such a supply was economically prohibitive.* For these stations, the single engine control circuit was modified so that two engines could be operated on a continuous basis, one engine operating for twelve hours, then the other for twelve hours, continuing this way for a month, without attendance. Two-engine installations have all the features that the single engines have except that no cooling solution heaters are provided since the rooms are heated.

At the completion of a twelve-hour service period, the idle engine starts, running for five minutes under no-load. The load is then transferred to the other engine, and the first engine shuts down. The control circuits are interlocked to prevent false or improper operation of either engine generator set. If the second set should fail to start or to assume the load, the first set will continue to run, and the failure will be reported over the alarm circuit to the control center.

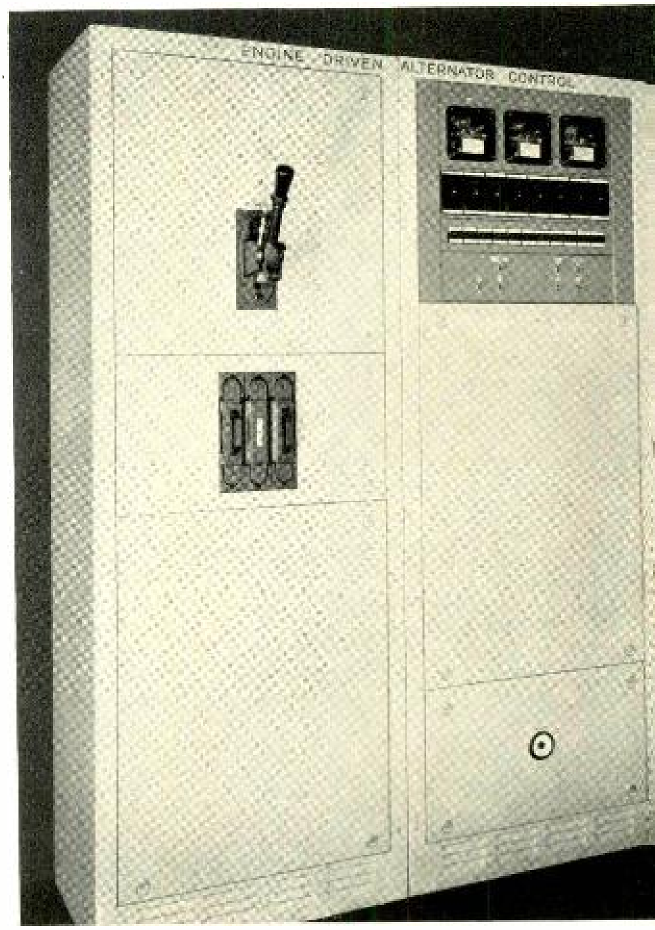


Fig. 4—Automatic control equipment is mounted in twin cabinets. This equipment is furnished by the Western Electric Company.

It is not practicable to provide an engine crankcase of sufficient size to hold enough lubricating oil for a month's continuous operation of the two-engine generator sets without attention. Therefore, to enable

* RECORD, *July*, 1951, *page* 311.

monthly maintenance, a wall-mounted tank for the lubricating oil is provided. It has pipes connecting to both engine crankcases and it also has float level valves. To avoid the possibility of flooding the engine crankcases if the float level valves should fail, a high level overflow line is connected to each crankcase. This line runs to a floor tank containing a float-operated switch used to start a small electric motor-driven pump. The pump returns the oil from the floor tank to the wall-mounted reserve tank.

Development of the reserve power plants is another example of cooperation between Bell Laboratories engineers and those of outside suppliers. Through the combined efforts of these engineers, engine alternator sets equipped with the necessary accessories for full automatic operation are now giving excellent emergency service in radio relay stations. Some of the engine-alternator sets were supplied by the Hercules Motor Corporation of Canton, Ohio. Figure 2 is a photograph of one of these. Another supplier, the Detroit Diesel Division of the General Motors Corporation, also furnished a number of the machines. Figure 3 is a photograph of this type. The automatic control equipment, built by Western, is contained in twin cabinets, Figure 4. This equipment is arranged to operate with engine-alternator sets made by either manufacturer.

THE AUTHOR: Vincent T. Callahan, a member of the power plant development group, has in his thirty years with the Laboratories been concerned with the development of gas, gasoline, kerosene and diesel engine driven generator sets for standby service in telephone offices. After graduating from Pratt Institute in 1916, Mr. Callahan had two brief jobs before joining the Lake Torpedo Boat Company in 1917. He stayed with that concern for five years, designing, constructing, and testing both electrical and mechanical equipment. In 1922 he came to the Laboratories to design reserve power plants for central offices and has been doing related work ever since.

Volume 30, Bell Laboratories Record — Bound Copies and Index

Bound copies of Volume 30 (January, 1952 to December, 1952) will be available shortly at $2.75, foreign postage 25 cents additional. Remittances should be addressed to Bell Laboratories Record, 463 West St., New York 14, N. Y. A separate index to Volume 30 of Bell Laboratories Record *is available upon request.*

New York Company to Extend Toll Dialing in Suburbs

Direct dialing of many station-to-station telephone toll calls by 50,000 individual and two-party line customers will begin in 12 Long Island and Westchester central offices during the coming year. They will be the first in New York Telephone Company's territory and among the first in the Bell System to have this service. With the use of the No. 5 crossbar central offices, including automatic message accounting equipment, these customers will be able to make calls directly to more than 4½ million telephones in downstate New York and sections of Northern New Jersey.

Following years of planning, this extended service will start early in February with customers served by the Baldwin, Freeport and Scarsdale central offices. In March will follow those in Massapequa and in April, Levittown; service will be extended to customers in Hicksville and Peekskill in the late spring and to Amityville and Wantagh later in the year. By the end of 1955, about 300,000 customers in 25 communities in Nassau, Suffolk and Westchester counties will have similar service.

Operators will still play an important part in handling many calls. All station-to-station calls made to places beyond downstate New York and Northern New Jersey, as well as all person-to-person and collect toll calls, will require the usual operator assistance. So will calls from coin telephones and calls from telephones with more than two parties per line to points beyond their local calling area.

Although there will be no change in the way Westchester and Long Island customers within the New York metropolitan service area are now dialing each other, in dialing toll points outside this area, a directing code number will be used. For example, when a subscriber in Freeport or Scarsdale calls Cranford (N. J.) 6-9970, he will actually dial ten digits–201 CR6 9970, and, if the number happens to be a party line ending for example in "J," he would add that letter with the eleventh pull of the dial.

Distances covered by direct dialing of toll calls will at first range up to about 60 miles. With later development of the dial program, more distant places will be included. At first, direct dialing will reach about 61 different communities in New Jersey, including large cities such as Newark and Jersey City; also Patterson, Elizabeth, New Brunswick, Plainfield, and other places as far away as Somerville and Dover. On Long Island, it will reach points as far east as Lake Ronkonkoma, and north of New York City, as far as Greenwood Lake, West Point, Carmel, and Greenwich.

Years of research by Bell Telephone Laboratories and planning by Telephone Company engineers have paved the way for customer toll dialing. An important preliminary step was the development of operator toll dialing in recent years, speeding short-haul as well as long distance calls as these were increasing in volume. Besides, the development of the metropolitan area telephone networks, such as the present one in the New York City area interconnecting hundreds of central offices, has been a major advance.

Conference on High-Frequency Measurements

The Third Conference on High-Frequency Measurements is scheduled to be held in Washington, D. C., January 14, 15, and 16. This conference, as were the two previous conferences held in 1949 and 1951, is devoted solely to the problems of high-frequency measurements, measuring apparatus, and closely related problems. It is under the joint sponsorship of A. I. E. E., I. R. E., and the National Bureau of Standards. Four technical sessions, an evening demonstration session, inspection trips to government laboratories and a group luncheon have been planned.

Several Laboratories engineers are taking a prominent part. At the *Session on Measurement of Power and Attenuation,* with E. W. Houghton presiding, R. W. Lange will present a paper entitled *40-4,000 Microwatt Power Meter.* At the same session, D. H. Ring will give his paper *A Microwave Double Detection Measuring System with a Single Oscillator.* The evening session on January 15 will consist of demonstration lectures by A. G. Fox on *Microwave Propagation on Dielectric Rods and in Ferromagnetic Media* and *A New Transistor for High-Frequency Use* by R. L. Wallace, Jr. The *Session on Measurement of Transmission and Receptions,* includes papers by H. E. Curtiss, and J. B. Maggio, *Frequency Consideration in the Transcontinental Radio Relay System* and *A Note on the Stability of Microwave Noise Generators* by W. W. Mumford. At the luncheon on January 15, E. P. Felch will preside. Invited guests at this luncheon include J. W. McRae, who is President of I. R. E., and D. A. Quarles, President of A. I. E. E. E. P. Felch is Chairman of the Joint A. I. E. E.-I. R. E. Committee on High-Frequency Measurements which is one of the working groups responsible for setting up the conference and E. W. Houghton and B. M. Oliver are members of the I. R. E. group on this committee. Mr. Houghton is also a member of the Technical Program Committee for the conference.

Papers Published by Members of the Laboratories

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

Alsberg, D. A., Principles and Applications of Converters for High-Frequency Measurements. I.R.E., Proc. 40, pp.1195-1203, Oct., 1952.

Briggs, H. B., Infrared Absorption in High Purity Germanium. Opt. Soc. Am., Jl., 42, pp.686-687, Sept., 1952.

Briggs, H. B., and Fletcher, R. C., New Infrared Absorption Bands in p-Type Germanium. Letter to the Editor, Phys. Rev., 87, pp.1130-1131, Sept. 15, 1952.

Clark, A. B., and Osborne, H. S. (A T & T) Automatic Switching for Nation-Wide Telephone Service. A.I.E.E., Trans. Commun. and Electronics Sec., 2, pp.245-248, Sept., 1952.

Conwell, E. M., see P. P. Debye.

Debye, P. P., and Conwell, E. M., Mobility of Electrons in Germanium. Phys. Rev., 87, pp.1131-1132, Sept. 15, 1952.

Fine, M. E., Evidence for Domain Structure in Anti-Ferromagnetic CoO from Elasticity Measurements. Phys. Rev., 87, p.1143, Sept. 15, 1952.

Fletcher, R. C., see H. B. Briggs.

Fox, A. G., see M. T. Weiss.

Hopper, A. L., see J. R. Pierce.

Hornbeck, J. A., Charge Transfer and the Mobility of Rare Gas Ions. Jl. Phys. Chem., 56, pp.829-831, Oct., 1952.

Jakes, W. C., Broad-Band Matching with a Directional Coupler. I.R.E., Proc., 40, pp. 1216-1218, Oct., 1952.

Keller, A. C., New General-Purpose Relay for Telephone Switching Systems. Elec. Eng., 71, pp.1007-1012, Nov., 1952.

Merz, W. J., Domain Properties in $B_aT_iO_3$. Phys. Rev., 88, pp.421-422, Oct. 15, 1952.

Miller, S. E., Notes on Methods of Transmitting the Circular Electric Wave around Bends. I.R.E., Proc., 40, pp.1104-1113, Sept., 1952.

Miller, S. E. and Mumford, W. W., Multi-Element Directional Couplers. I.R.E. Proc. 40, pp.1071-1078, Sept., 1952.

Mumford, W. W., see S. E. Miller.

Munson, W. A. and Wiener, F. M., In Search of the Missing 6 Db. Acoustical Soc. Am., Jl., 24, pp.498-501, Sept., 1952.

Osborne, H. S., see A. B. Clark.

Peters, H., Hard Rubber. Ind. & Eng. Chem., 44, pp.2344-2345, Oct., 1952.

Pfann, W. G., Principles of Zone-Melting. Journal of Metals, 4, pp.747-753, July, 1952, and A.I.M.E. Trans., 194, pp.747-753, 1952.

Pierce J. R. and Hopper, A. L., Nonsynchronous Time Division with Holding and with Random Sampling. I.R.E., Proc., 40, pp.1079-1088, Sept., 1952.

Reynolds, F. W. and Stilwell, G. R., Mean Free Paths of Electrons in Evaporated Metal Films. Phys. Rev., 88, pp.418-419, Oct. 15, 1952.

Schlaak, N. F., Single-Sideband System for Overseas Telephony. Electronics, 25, pp.146-149, Nov., 1952.

Shipley, F. F., Automatic Toll Switching Systems. A.I.E.E., Trans., Commun. and Electronics Sect., 2, pp.261-269, Sept., 1952, and Elec. Eng., 71, pp.889-897, Oct. 1952.

Stewart J. A., Traffic Engineering Design of Dial Telephone Exchanges. Telephony, 143, pp.13-16, 41-42, Oct. 18, 1952.

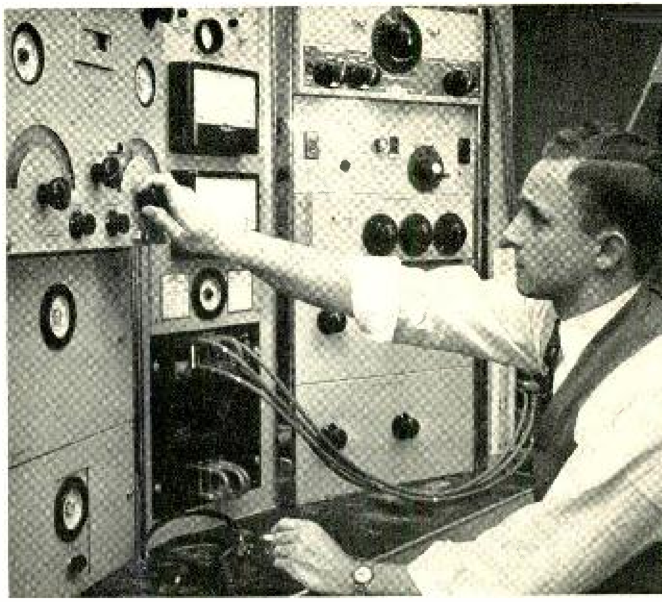
Stilwell, G. R., see F. W. Reynolds.

Varney, R. N., Drift Velocities of Ions in Krypton and Xenon. Phys. Rev., 88, pp.362-364, Oct. 15, 1952.

Weiss, M. T. and Fox, A. G., Magnetic Double Refraction at Microwave Frequencies. Phys. Rev., 88, pp.146-147, Oct. 1, 1952.

Wiener, F. M., see W. A. Munson.

New L3 Carrier System Placed on Field Trial



O. L. Williams of the Laboratories tests transmission characteristics of the new coaxial cable system, known as "L3" carrier.

A new coaxial cable system, known as the L3 carrier, has been developed by Bell Telephone Laboratories and is now undergoing field trials prior to its installation for use in the Bell System. It is expected to go into actual service on circuits between New York and Philadelphia early in 1953. The new system, which can handle three times as many telephone conversations as any now in use, will enable one pair of coaxial "pipes" to handle simultaneously more than 1,800 telephone conversations or 600 telephone conversations plus one television program in each direction. It is the first carrier system on which both television signals and regular telephone conversations can be sent over the same pair of coaxial pipes at the same time.

The field trials are being conducted in cooperation with A T & T Long Lines and associated companies of the Bell System. Western Electric is manufacturing the equipment.

In designing L3, Laboratories engineers have brought numerous advances into the new system. For example, new amplifiers were designed having characteristics exceeding earlier types. New terminal equipment was also necessary to make it possible to furnish 1,800 telephone circuits and to permit the addition and subtraction of smaller groups of circuits at intermediate points. Means for putting television signals on the line and distributing them at intermediate points without introducing distortion, were developed. Sending both television and telephone signals over the same circuits created a problem of preventing interference between the two signals.

Kansas City—St. Louis Radio Relay System

As a joint project between the Southwestern Bell Telephone Company and A T & T Long Lines, a radio relay system will be installed between Kansas City and St. Louis, Missouri. This new radio relay route, which is scheduled for completion by the end of next year, will carry both long distance telephone circuits and television channels. This nine section system will be 260 miles long and will employ towers ranging from 100 to 300 feet in height.

The proposed link will augment the existing cable and wire lines now furnishing communications in that area. It will interconnect at Kansas City with coaxial cable to Omaha and to the radio relay route stretching south into Texas. At St. Louis, it will tie into coaxial cables extending east and south and with the planned radio relay system to Chicago.

Patents Issued to Members of Bell Telephone Laboratories During October

Barney, H. L.—*Control of Impedance of Semiconductor Amplifier Circuits.*—Re 23,563 (Reissue of Patent No. 2,585,077).

Clarke, W. J.—*Polyethylene-Polyisobutylene Composition*—2,615,857.

Clos, C.—*Apparatus for Recording Numerals in Code*—2,614,632.

Dimond, T. L.—*Translating and Selecting System*—2,614,175.

Dimond, T. L.—*Electronic Induction Number Group Translator*—2,614,176.

Edson, J. O.—*Trigger Circuit*—2,614,142.

Edson, J. O., and Kreer, J. G., Jr.—*Counting Circuit*—2,614,141.

Goodall, W. M.—*Frequency Controlled Radio Relaying System*—2,614,211.

Goodall, W. M.—*Cathode Ray Coding Tube*—2,616,060.

Gooderham, J. W.—*Calling Line Identification System*—2,615,987.

Hague, A. E.—*Automatic Accounting Device*—2,615,628.

Herborn, L. E.—*Dielectric Test Circuit*—2,614,152.

Kreer, J. G., Jr.—*Trigger Circuit*—2,614,140.

Kreer, J. G., Jr., see J. O. Edson.

Malthaner, W. A., Newby, N. D., and Vaughan, H. E. *Pulse Position Dial Receiver. Employing Pulse Superposition for Identifying Digits*—2,615,971.

McLean, D. A.—*Impregnated Electrical Condenser*—2,615,955.

Means, W. J.—*Magnetic Testing System*—2,615,961.

Newby, N. D., see W. A. Malthaner.

Skellett, A. M.—*Wave Generating Circuits*—2,614,222.

Vaughan, H. E., see W. A. Malthaner.

Vroom, E.—*Signal Transmitter*—2,614,168.

J. R. Townsend on Leave to Sandia

Effective December 1, 1952, J. R. Townsend, who has been Director of Materials Applications Engineering, became Director of Materials and Standards Engineering of the Sandia Corporation. Mr. Townsend will be on leave of absence from the Laboratories while fulfilling his new duties at Albuquerque, New Mexico.

Deal-Holmdel Colloquium

K. S. Dunlap of the Switching Research Department spoke before the Deal-Holmdel Colloquium, November 6. The subject of his talk was *Rural and Suburban Telephone Switching*. Mr. Dunlap discussed methods of increasing the capacity of suburban lines by using new types of switching devices called concentrators, external to the central office.

A. I. E. E. Winter General Meeting

The A. I. E. E. Winter General Meeting, to be held at the Hotel Statler in New York on January 19-23, will include a number of technical papers by members of the Laboratories. At the *Magnetic Materials Session,* H. J. Williams will present a paper on *Stressed Ferrites with Rectangular Hysteresis Loops;* J. N. Shive will give his paper *Germanium Phototransistors* at an all-day session on *Semiconductors,* at which time B. Sawyer will give a paper entitled *Zener Breakdown as a Function of Material Resistivity.* The *Metallic Rectifiers Session* will include J. Gramels' paper *Problems to Consider in Applying Selenium Rectifiers,* and the *Magnetic Materials Session* will have a paper *The Ferromagnetic Faraday Effect at Microwave Frequencies and Its Application* by C. L. Hogan.

The entire *Communication Switching Systems Session* will consist of four papers by members of the Laboratories. These are *Communication Switching Systems as Complex Automata* by W. Keister; *The Maze-Solving Mouse* by C. E. Shannon; *Automatic Error Detecting and Correcting* by R. W. Hamming; and *Mechanized Intelligence in Nationwide Dial Telephone Switching* by J. B. Newsom. In the *Session on The Safety Aspects of Grounding Versus Insulating,* L. S. Inskip will give a paper *Fundamentals and Principles Involved.* H. M. Pruden will give his paper *The C-1 Alarm and Control System for Use with Microwave Radio Relay* at the *Session on Instruments and Measurements. The Communication Switching Systems Session* will include W. B. Groth's paper *Principles of Tape-to-Card Conversion in the AMA System. Polyethylene Terepthalate—Its Use as a Capacitor Dielectric* by M. C. Wooley, G. T. Kohman and W. McMahon, will be presented by title for discussion at the *Session on Dielectrics.* At another session, D. Edelson, C. A. Beiling and G. T. Kohman will give the paper *The Electrical Decomposition of Sulfur Hexafluoride.*

E. P. Felch will present a paper by Dr. M. Abdel-Halim Ahmed, Foad I University, entitled *Cathode-Ray Synchroscope and Automatic Synchroniser* at the *Session on Instruments and Measurements in Medicine and Biology. The Session on Wire Communication Systems* will also consist of four papers, all on the new L3 Coaxial *System,* by Laboratories people: *System Design,* by C. H. Elmendorf, A. J. Grossman and R. D. Ehrbar; *Amplifiers,* by L. H. Morris, G. H. Lovell and F. R. Dickinson; *Equalization and Regulation,* by R. W. Ketchledge and T. R. Finch; and *Television Terminals,* by J. W. Rieke and R. S. Graham.

In the *Session on Complexity of Electronic Systems,* E. L. Nelson (retired), will give a paper entitled *This Problem in the Signal Corps* and H. T. Budenbom one on *A Manufacturer's Viewpoint.*

Talks by Members of the Laboratories

During the month of November, a number of Laboratories people gave talks before professional and educational groups. Following is a list of the speakers, titles, and place of presentation.

Anderson, J. R., *Ferroelectric Materials as Storage Elements for Digital Computers and Switching Systems,* A.I.E.E. Section, Chicago, Ill.

Dinkes, P., *Talk and Demonstration of Relays in Switching Systems,* Electrical Society of the University of the State of N. Y., New York, N. Y.

Edelson, D., *The Electrical Decomposition of Sulfur Hexafluoride,* Rutgers University Seminar, New Brunswick, N. J.

Felch, E. P., *Preliminary Development of a Magnettos Current Standard,* A.I.E.E. Conference, Philadelphia, Pa.

Ferrell, E. B., *Double Sampling Inspection Applied to Pilot Production of Relays,* American Society for Quality Control, Long Island.

Fisk, J. B., *Adaptation of the Graduate to the Industrial Environment,* Rutgers University Seminar, New Brunswick, N. J.

Foster, F. G., *Optical Aids for Better Seeing,* Rutgers University, New Brunswick, N. J.

Hamming, R. W., *Error Correcting Codes,* I. B. M. Corp., Endicott, N. Y.

Harris, C. M., (formerly BTL), *A Speech Module Synthesizer,* Acoustical Society of America, San Diego, Calif., and *Pulse Techniques—Astable and Monostable Circuits,* A.I.E.E.-I.R.E. Fall Course, New York, N. Y.

Herring, C., *Creep of Wires at High Temperature,* Johns Hopkins University, Baltimore, Md., University of Virginia, Charlottesville, Va.

Hogan, C. L., *The Ferromagnetic Faraday Effect at Microwave Frequencies,* Columbia University, New York, N. Y. A.I.E.E. Section, Washington, D. C.

Hussey, L. W., *Transistor Circuitry,* I.R.E.-A.I.E.E., Fall Course, New York, N. Y.

Kircher, R. J., *Transistors,* A.I.E.E.-I.R.E. Student Chapter, New York University, New York, N. Y.

Linvill, J. G., *Transistors,* University of Conn., Storrs, Conn., and *Linear Negative Impedance Circuits,* A.I.E.E.-I.R.E. Fall Course, New York, N. Y.

Mason, W. P., *Use of Barium Titanate in Capacitors, Transducers, Dielectric Amplifiers and Storage Devices,* I.R.E., Connecticut Valley, Middleton, Conn.

Miller, S. E., *Some Complete Wave Theory and Application to Waveguides,* I.R.E. Fall Symposium on Microwaves, New York, N. Y.

Peterson, G. E., *New Trends in Experimental Phonetics,* N. Y. Society for Speech and Voice Therapy, New York, N. Y.

Scaff, J. H., *Segregation in Semiconductors,* A.I.E.E., Section, Philadelphia, Pa.

Schimpf, L. G., *A New Junction Transistor for High Frequency Use,* I.R.E., Section, New York, N. Y.

Sparks, M., *Some Aspects of Transistor Science,* Seminar at M. I. T., Cambridge, Mass.

Subrizi, V., *Speech Volume Distributions and Their Effects,* Operations Research Society of America, Washington, D. C.

Tuckey, J. W., *Statistics and The Design of Experiments,* American Institute of Chemical Engineers, North Jersey Section, Murray Hill, N. J.

Wallace, R. L., *Transistors,* Harvard English Club, New York, N. Y.

Washburn, S. H., *The Design of Switching Circuits,* I. B. M. Corp., Poughkeepsie, N. Y., and Endicott, N. Y.

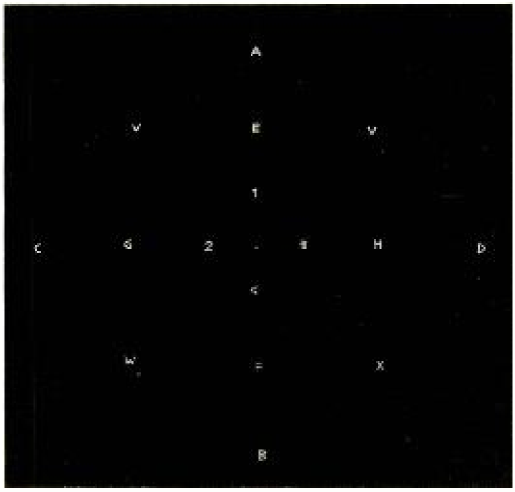


Fig. 1—A typical display of sixteen characters formed by the symbol generator on the screen of a CRO tube.

vertical line that is properly positioned.

Many letters and numerals consist entirely of straight lines and can be formed perfectly in this way. Other characters are composed entirely or partially of curved lines, which may also be generated. If a sine wave, for example, is applied to the horizontal plates, and a similar wave, shifted 90 degrees in phase, applied simultaneously to the vertical plates, the resultant trace will produce a circle, as shown in Figure 2(a). In this diagram, the two wave forms are represented with the zero axis of each divided into eight equal time-intervals. The lines extending from the axes to the waves at the indicated intervals represent the amplitudes of the waves at these selected instants. Another set of lines, parallel to the axes, is plotted from the extremities of the corresponding pairs of amplitude lines, and their points of intersection mark the positions of the resultant trace at those instants. The path of this trace describes the indicated circle on the screen during each cycle of the impressed signals. When the voltage applied to the horizontal plates is made smaller than that applied to the vertical plates, the circle becomes an ellipse and a well-proportioned "O" is produced.

If the horizontal signal, in the combination used to produce the "O", is replaced by a full-wave rectified voltage, the result on the screen will be a well-formed "C". Figure 2(b) uses the method employed in Figure 2(a) to illustrate the way these two wave forms combine to form a "C". If these signals are interchanged and the amplitudes suitably adjusted to elongate

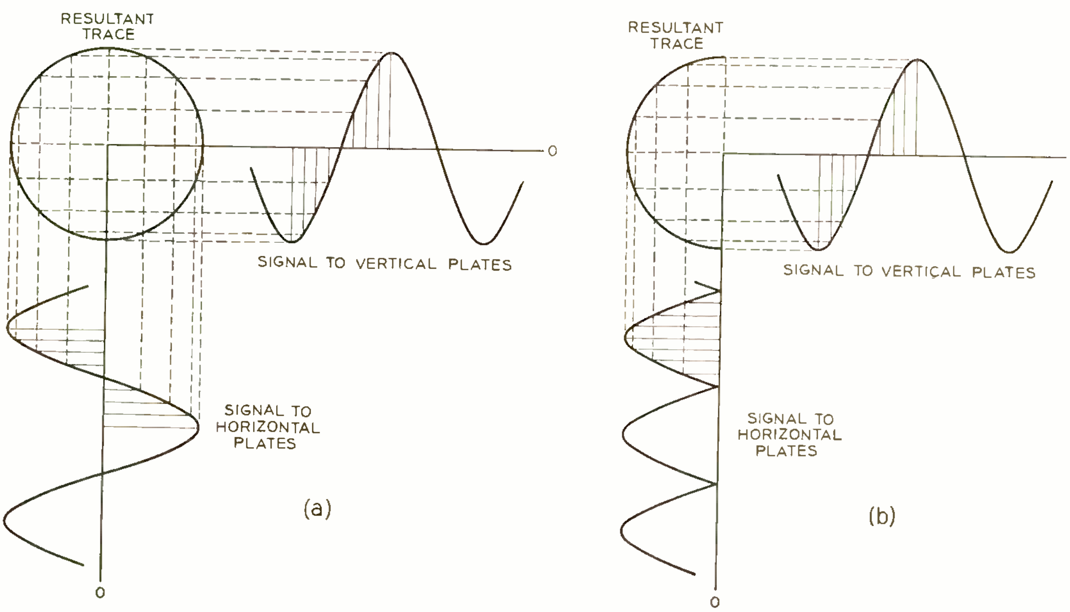


Fig. 2—A diagram of the way in which wave forms applied to the horizontal and vertical plates of a CRO tube combine to form a circle and a "C" on the screen.