BELL LABORATORIES RECORD

THE PANEL SYSTEM
A. F. Dixon

CRYSTAL OSCILLATOR
O. M. Hovgaard

SEQUENCE SWITCH
C. C. Barber

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Articles in this Issue

BELL LABORATORIES RECORD

Quartz crystals, from which plates are cut for frequency control, pictured by the Photographic Department against a background of small ("hypo") crystals

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An Introduction to the Panel System

By A. F. DIXON
Director of Systems Development

THE multifarious inventions, developments and adaptations that have gone into the making of the present telephone system may be divided into two classes. The first comprises those pertaining to the circuits and apparatus employed primarily for talking. Everything required for telephonic communication between stations connected to a single line would fall within this class. It was with problems of this nature that Alexander Graham Bell was primarily concerned, and various groups of engineers of the Bell System are constantly engaged in further perfecting the varied instrumentalities of this type.

That this communication apparatus may be effectively used by large groups of subscribers, however, a second class of developments must be carried on. The thousands of telephones within any one community must be organized into a system so that any one of them may be quickly connected to any other, either within the same community or in any other part of the country or of the world. This second class of developments, therefore, pertains primarily to switching and signaling methods. Over eighty million telephone calls are completed every day in this country alone. The prompt switching of these millions of calls daily requires an enormous amount of intricate equipment, and it is in connection with these means of uniting the twenty-odd million telephones of the country into an organic whole that the problems of telephone "systems" arise.

Man's most primitive tools are his hands, and it was natural, therefore, that in the early switching systems adopted all the operations required to signal and switch the telephone connection should be done manually. A subscriber by turning a crank would operate a magneto generator to signal an operator. She in turn would ring the called subscribed by a similar magneto, and then would establish the connection manually. At the end of the conversation the subscribers would signal the operator that they were through by again operating their magneto generators. Calls were few, telephones were few, and it was to be expected that all these various operations should be performed by hand.

With the growth of the system, however, conditions altered. Offices of a few hundred lines grew into those of thousands, and several offices became necessary in the same city. The evolutionary trend of the times was toward machine instead of hand work so that gradually more and more of the circuit operations came to be done automatically. Instead of having to ring the operator a subscriber would merely lift his receiver off the hook and a relay would operate to light a lamp in front of the operator. Ringing would be impressed automatically and would be automatically disconnected when the called subscriber answered. These and other features of a similar nature, although substituting automatic for manual operations, were still merely links in a system essentially manually operated and supervised. A completely automatic system such as the dial system of the panel type, now used by the Bell System for the larger metropolitan areas, is distinctly different and came into existence largely for other reasons.

Within the Bell System the initial demand for dial service arose in the larger areas. Its need was felt partly to give improved service to the subscriber, and partly to make it possible to meet the demands of the rapidly growing traffic. With more than a hundred central offices in a single city, as exist in New York today, and with many more offices in the outlying suburbs, the proper routing of calls is a problem of considerable complexity. Space on the switchboards does not permit running direct trunks from every office to every other office in the area. As a result tandem offices are largely employed and calls to many offices must be routed through them. Also adding to the complexity are calls to many offices which require toll charges, but which, because of the short distance involved, are handled by the regular local operators rather than by the long distance force.

These switching complications have necessitated intricate operating procedures, particularly in the manner of transmitting information from one operator to another, and in the variety of tone signals used to indicate various circuit conditions. All of this places greater mental demands on the operators and makes it more difficult to maintain the high grade service performance required. The need for mechanical substitutes which would perform switching operations with unvarying precision became steadily more evident. Then, too, there was the matter of space available at an operator's position. As the outgoing trunks became greater, it grew increasingly difficult to find space required at each position to locate them within reach of the operator.

The trend of these various factors was apparent about twenty years ago and development of the panel system was undertaken. There are many points of similarity in the evolutionary processes by which most developments are brought to their final status. For each, advantage is taken of the rapidly growing field of scientific knowledge, and in addition specific experimental work is carried on to discover the best way of applying basic knowledge to particular problems. Improved aeroplanes have followed cruder models. Smoother-running eight and six cylinder cars have succeeded the put-puttings of the early twos and ones. Usually each stage has been tried out on the public, and to a large extent the public has thus paid—in difficulties and losses during the earlier stages—for the development of the more nearly perfected apparatus.

With the panel system, however, the process has been distinctly different in some respects. No stages intermediate between first conception and culminating achievement were tried in actual service to distress and irritate the public because of shortcomings. Like Minerva from the brow of Jupiter, the panel system was born full grown from the brain of research. The first lot of panel equipment installed in Newark in 1914 and the complete panel office in Omaha of 1921 are both giving satisfactory service at the present time, and in most of their major essentials are like the latest offices of the present year. From the first the public had the advantage of a highly evolved and satisfactory system.

Such an achievement was made possible only by the availability of a large and adequately equipped research organization at headquarters: the General Engineering Staff of the American Telephone and Telegraph Company, and the Bell Telephone laboratories. Conceived in its broad outlines in successive conferences, the complete system was divided into natural divisions and each allotted to a group in the Laboratories for development. Certain groups developed the varied apparatus required, others devised the circuits and equipment arrangements, and continually conferences were being held to coordinate the various activities and to insure a design that would satisfactorily meet all the operating demands of a large telephone system.

Instead of putting untried designs in the field for public use, with the inevitable result of unsatisfactory service to the subscriber, set-ups were made in the Laboratories of all the component elements, and each was tried out under all possible conditions that might arise in actual practice. As these elements became perfected they were associatd with others to form more complete arrangements. Testing and redesigning went on continuously until a complete system was in satisfactory operation in the laboratory and ready for the field. Even then, however, Bell System engineers were not quite ready for a general field installation. It seemed best to install first a system complete so far as the mechanical completion of calls went but which maintained the operator's contact with the subscriber. Such an arrangement would give a complete field trial of the operation of the system, but so far as the subscribers were concerned would be a manual system since an operator would be available to answer all calls and to supervise all connections.

Such a system, known as semi-mechanical because of the retention of the operators, was installed in Newark in 1914. It was essentially a complete panel office except that the operators would answer subscribers' calls and then themselves do the necessary dialing (actually performed by key sets) to establish the connections. All the usual supervisory indications were provided at the operators' positions so that they would know of the progress of the call and be able to correct irregularities. So far as the establishment of a connection went, it was a panel dial system, but so far as contact with the subscribers went, it was the same manual system to which they had become accustomed.

The success obtained with this early office led to the installation of a complete dial office in Omaha in 1921. This was a panel office of the same type as that of Newark with the addition that calls were dialed by the subscribers themselves instead of being set up on keys by the operators. Since then panel equipment has rapidly been replacing manual switchboards in the larger areas.

Below is a list of articles that have appeared in Bell Laboratories Record in which are given simple and brief descriptions of the major elements and features of the panel system as it is today. Clarity, conducing to a broad understanding of the fundamental elements, rather than completeness, has been sought. Each was written as an independent article so that although a lack of close continuity may be noticeable, it should not detract greatly from the value of the assemblage as a whole. In a system that functions more or less as a unit there is no hard and fast order that should be followed in the description of its parts. The arrangement given in the list seemed natural and convenient, but since each story was written to be self-contained the actual order of arrangement is of minor importance.

Record Articles on the Panel System

Title	*Author*	*Published*
The Panel System	R. E. Collis	July, 1931, p. 523
Fundamental Circuit	R. E. Collis	June, 1929, p. 395
Line Finder and District	A. J. Busch	May, 1930, p. 412
Panel Senders	W. J. Scully	Dec., 1928, p. 143
All Relay Register Circuit	R. Raymond	June, 1929, p. 400
The Decoder	R. Raymond	May, 1928, p. 273
Panel Selectors	W. Whitney	Nov., 1930, p. 127
Hunting Features	E. L. Erwin	Sept., 1928, p. 5
The Panel Bank	C. W. McWilliams	Oct., 1931, p. 54
The Sequence Switch	C. C. Barber	Dec., 1931, p. 119
Panel System Clutches	P. E. Buch	Apr., 1930, p. 367
Routine Tests	L. M. Allen	May, 1929, p. 365
Automatic Prevention of Trouble by Decoders	R. K. McAlpine	July, 1930, p. 518
Trouble Indicator	R. Marino	May, 1929, p. 371
Human Errors and the Dial Telephone	A. O. Adam	Oct., 1928, p. 44
Dial "A" Board	R. C. Davis	Aug., 1931, p. 576
Dial "B" Board	R. E. Hersey	Dec., 1930, p. 162
Call Indicator	E. H. Clark	Dec., 1929, p. 171

A New Oscillator for Broadcast Frequencies

By O. M. HOVGAARD
Special Products Development

THE continued increase in the applications of radio has brought with it many engineering problems, not the least of which is that of efficiently utilizing a communication medium affording a limited number of channels. A fundamental difference between radio and wire circuits is that in general the path of a radio circuit cannot be controlled and therefore the effects of a radio transmitter cannot be localized at specified points. As a consequence of thus spreading power broadcast, it is necessary to use higher transmitter powers than would otherwise be needed, thereby increasing the mutual effects between adjacent channels in the common medium of transmission.

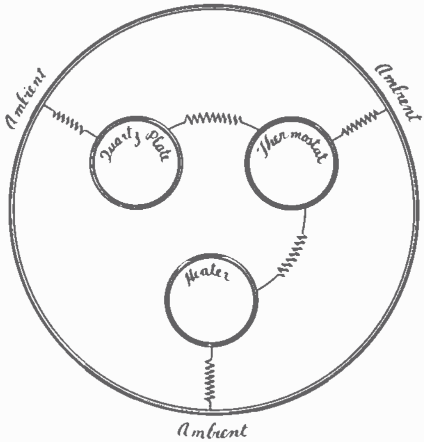


Fig. 1—The control of quartz plate temperatures by a thermostat can best be effected by a suitable choice of the impedances in this thermal circuit

To provide the greatest possible number of channels and at the same time to minimize the mutual effects, it is necessary first to limit the channel widths and then to stabilize the carrier frequencies of the transmitters so that their emissions will not encroach upon one another. The most effective means yet devised for stabilizing carrier frequencies is the quartz-controlled vacuum-tube oscillator. This consists essentially of a quartz plate, placed in a circuit between the grid and filament of a vacuum tube whose output circuit has the proper positive reactance. The general principles of its operation have been previously described in the RECORD.*

In the quartz-controlled oscillator, the responsibility for frequency stability has been largely shifted from the circuit to the quartz, and it is necessary to take all possible precautions to prevent the natural frequency of the quartz plate from varying. The main causes for variations in the natural period of a quartz plate are changes in the physical relations of the quartz plate and its electrodes, and changes in the temperature at which the plate is operated.

Until recently the quartz plates manufactured by the Laboratories were mounted between electrodes hav-

* BELL LABORATORIES RECORD, *Sept.*, 1928, *p.* 24, *and Oct.*, 1929, *p.* 54.

ing flat surfaces. With this type of mounting the small changes in electrode spacing, resulting from the presence of dust or lint on the contact surfaces, caused relatively large changes in the operating frequency. These changes have not proved serious with a permissible tolerance of ± 500 cycles in the stability of broadcasting frequencies, but a recent regulation reduces this tolerance to ± 50 cycles, which magnifies their importance.

To meet such a requirement, variations due to the plate holder must be eliminated, and in the recently designed 1-A quartz plate this is accomplished by clamping the quartz rigidly between electrodes having on their surfaces a number of small "lands," or raised portions. These lands constitute the physical contacts between the quartz plate and its electrodes and in addition introduce an air-gap between the quartz and the electrode surfaces. Changes in the relative positions of the quartz and electrodes have been eliminated by the clamping, and changes in spacing have been made insignificant by the air gaps.

While it is possible to produce quartz plates whose natural frequencies of vibration do not vary with temperature, the change of frequency with change of temperature in the ordinary plates is sufficiently low to make the control of temperature the more attractive method of obtaining stability at the present stage of the art. The temperature coefficient is high enough, on the other hand, to require that fluctuations in the temperature at which the plate is operated be held within quite narrow limits. The precise value of the coefficient varies with the orientation of the plate with respect to the crystallographic axes of the natural crystal from which the plate was cut, and may be either negative or positive. Moreover, for a given orientation, the value of the coefficient is an inverse function of the thickness of the plate, ranging from about five cycles per degree Centigrade for thicknesses of about seven millimeters to four hundred cycles for thicknesses of about a half millimeter.

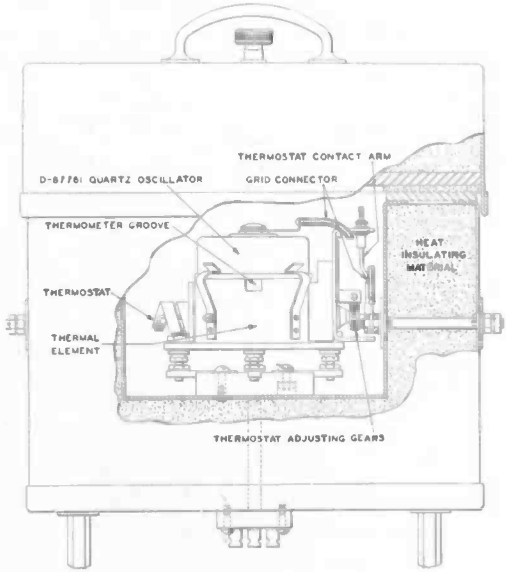


Fig. 2—The previous oscillator took this form

A temperature control system consists essentially of a heating element and a temperature-responsive device, enclosed together with the quartz plate in a thermally insulated chamber. A "thermal schematic circuit," indicating the paths of heat flow in a typical arrangement, is shown in Figure 1. When controlled by such a device, there are three major factors affecting the stability of the plate's temperature. In order of decreasing importance they are: varia-

Fig. 3—Mr. J. H. DeWitt testing the 700-A oscillator, for whose development he was largely responsible

tion in the temperature of the "ambient," or surrounding medium, operation of the thermostat, and generation of heat within the quartz by viscous dissipation of its vibrating energy.

In broadcast applications, the temperature of the ambient may range from 70 to 130 degrees Fahrenheit and to minimize the extent to which variations in ambient temperature affect the plate, the "thermal impedance" between it and the ambient must be made as high as possible. A good measure of the effectiveness of the thermal insulation is the ratio of the change in ambient temperature to the corresponding change in the temperature of the quartz plate. In modern broadcasting equipment this ratio is over 150, which means that the carrier frequency will change less than one-third of a cycle per second for each degree Fahrenheit of change in ambient temperature.

Periodic fluctuations in the temperature at which the quartz plate is maintained are caused by the operation of the thermostat, which inherently has an operating differential of temperature. To minimize its effect on the temperature of the quartz plate it is necessary to design the temperature control system so that the thermal impedance of all paths between the heater and the quartz plate are high with the exception of the path containing the thermostat. The two parts of this path must be so designed that the thermal impedance from the heater to the thermostat is reasonably low and the thermal impedance from the thermostat to the quartz plate has the characteristics of a low pass filter. Low impedance in the first part of this path is essential if the ratio of ambient to quartz plate temperature variation is to be high. The thermal filter in the second part of the path must practically be of the "brute force" type, since the frequency of the thermostat fluctuation is only about one-sixtieth of a cycle per second.

Because they permit a nearer approach to the desired thermal circuit, mercury-in-glass thermostats have replaced bimetallic strips as the responsive elements in temperature-control devices of recent design. Although strips have the advantage that their operating temperatures can be adjusted, mercury thermostats can be made more sensitive, and their construction permits closer thermal contact to be made with the body to be controlled through the use of such materials as fusible alloys or powdered graphite. The sensitivity of such a thermostat is inversely proportional to the cross section of the capillary and directly proportional to the size of the bulb containing the bulk of mercury. For high sensitivity the bulb is therefore made large and with a very thin glass wall, and the bulb and capillary are so proportioned that the expansion and contraction of mercury near the surface of the bulb causes flexing of the meniscus of the mercury column without motion of the column as a whole.

This design of the thermostat reduces to a minimum the time-lag which would be introduced if the expansion of the entire bulk of mercury had to be relied upon to obtain the required sensitivity and thus permits a rapid response to small temperature changes. If the time-lag is thus decreased the energy in the heat fluctuations at the input to the thermal filter is also small, and their effects on the quartz plate can be reduced to the order of one-thousandth of a degree Centigrade. The resulting frequency variations should not exceed plus or minus one-tenth of a cycle per million.

The heat generated within the quartz as a result of work expended in its physical displacements depends on the potential across the quartz plate and therefore on the supply voltage to the plate of the oscillator tube. Excepting when this voltage is first applied, the variation in the heating is small, and noticeable only over a long period. Its effect is minimized by the low thermal impedance obtaining between quartz plate and thermostat at low frequencies of temperature fluctuation.

Wherever considerations of space and weight are not paramount, the thermal requirements outlined above can be approximately realized, and this has been done in the recently developed 700-A Oscillator. Its application to Western Electric broadcast transmitters furnishes some interesting comparisons of stability. In previous oscillators (Figure 2) the temperature was controlled by an adjustable bimetallic thermostat and the quartz plate was mounted on the thermal element into which projected the thermostat and a thermometer. The assembly was enclosed in a heat-insulating container, and the adjusting control for the thermostat and the scale for the thermometer were brought out to the front panel so that proper compensation could be made for variations in the ambient temperature. Experience has shown this design to be adequate for meeting a

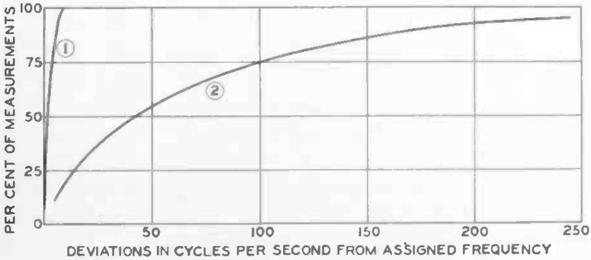


Fig. 4—These curves of actual measurements of the frequencies of radio stations show what proportions of the deviations from assignments were less than the indicated values. Curve 1 *is for the new oscillator, and curve* 2 *for the previous oscillator*

500-cycle stability requirement. The 700-A oscillator (Figure 3) was designed in anticipation of increased severity in the requirements for frequency stability proposed by the Federal Radio Commission. It embodies all the refinements of the thermal circuit described above and relieves the transmitter's operating staff from the responsibility of adjusting the thermostat to compensate for changes in ambient temperature. The 1-A quartz plate used with this oscillator is completely enclosed in a temperature-controlled metal compartment, which is in turn contained, with the oscillator tube and its associated circuits, in a single unit. The quartz plate is calibrated in the particular unit with which it is to be associated, in order to eliminate variations due to circuit differences.

TABLE I

Variable	*Variation in Cycles per Million* Old	New
Change of Ambient Temperature 70 F. to 130 F.	300.0	14.1
10% Change of Oscillator Plate Potential	3.5	2.6
10% Change of Oscillator Filament Potential	0.1	0.1
Thermostat Cycle	0.1	0.1
Charging Oscillator Tube	15.0	7.5
Deviation Capability	318.7	24.4

Table I—The "deviation capability" of an oscillator, which is the maximum departure from the oscillator's assigned frequency to be expected, can be obtained by summing the maximum contributions of the variables

A striking indication of the advance represented by the 700-A oscillator is a comparison of the possible effects which the variables, not under control of the manufacturer, may have upon the old and new units. A measure of these effects, the "deviation capability," can be obtained by considering that they all occur simultaneously and cumulatively. This total represents the maximum deviation that may reasonably be expected. For the 700-A oscillator and its predecessor, these data are shown in Table I in cycles per million. Recalculated for a typical broadcast carrier frequency of 1.5 million cycles, the figures indicate that the maximum anticipated deviation in frequency has been reduced from 476 cycles to 36½ cycles.

It is apparent that the deviation capability cannot be used to predict the actual performance of an oscillator. That a comparison of the deviation capabilities, however, constitutes a reasonable measure of the relative performance to be expected with two types of oscillators has been shown (Figure 4) by more than 700 measurements made over a period of two years on forty-seven transmitters using the old oscillator and about 50 measurements made over a period of nine months on two transmitters using the 700-A unit. It will be seen that in the new oscillator the deviations have become remarkably low.

Addressing Atlantic City Conventions

By J. E. CROWLEY
Special Products Development

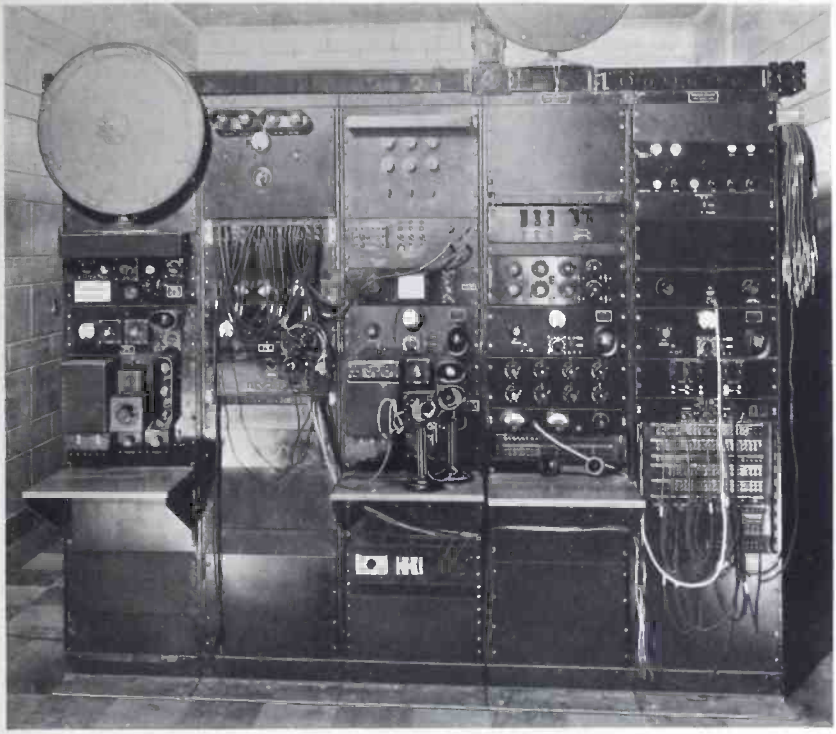
THE popularity of Atlantic City as a meeting place for organizations throughout the country led that municipality to construct one of the largest convention halls in the world for the use of its guests. Occupying an entire city block, the hall's facilities include an auditorium seating about 35,000 people, and a ballroom accommodating 6000 people.

The building is so large that Madison Square Garden could be placed in the auditorium, and a track meet and several large gatherings could be staged at the same time in the remaining area. The longest hit ever made by Babe Ruth or any other ball player would not carry a baseball from one end of the auditorium to the other. Its stage alone, the largest in the world, is 165 feet wide and 85 feet deep. Obviously the space available in such a hall could not be utilized to its fullest extent for any programs in which sound forms an important part unless facilities for the amplification of speech and music were provided. Furthermore, where such programs may take many different forms, the reinforcing system must be flexibly adaptable to all of them.

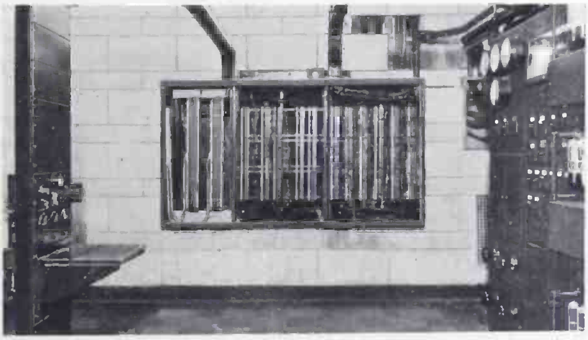
Since the hall can hold two conventions at once, one in the auditorium and the other in the ballroom,

In a gondola above and in front of the stage of the auditorium are located the projectors for stage performances

As occasion arises, loud speakers are temporarily placed on pavilions across the boardwalk to provide programs to people on the beach



The two bays at the right are the control racks for the public address input and output circuits. At the left are three bays of speech input equipment for the broadcasting station WPG



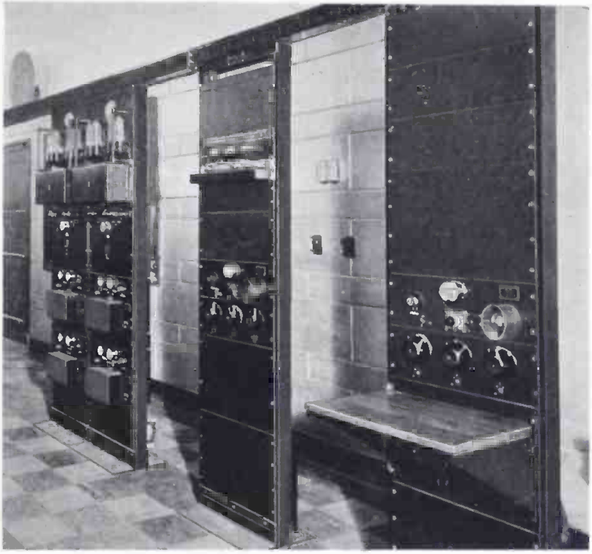
All wiring from outlying locations is led to a terminal box in the control room two complete public address systems are provided,* but so arranged that the same program can be transmitted over both when desirable. Each system can provide reinforcement of speech from a number of locations, or programs from a radio receiver or an electrical reproducer, or from the adjacent studios of the broadcasting station WPG. The systems can distribute not only to the main halls but to committee rooms, the program manager's office, the reception room, and positions outside the building such as the loggia and the arcade. When occasion arises, loud speakers can be arranged on two pavilions, providing programs to people on beach and boardwalk.

* *The design and installation of these systems were carried out under the supervision of Messrs. L. B. Cooke, D. G. Blattner, and J. E. Crowley. The equipment was manufactured by the Western Electric Company.*

In the control room are also the power amplifiers and their control racks

Since in the auditorium the stage is at one end and the musicians' balcony at the other, in either of which the events of interest may take place, permanent facilities for sound pick-up and distribution are located at both ends. No less than forty receptacles for microphone connections were installed in various locations on the stage alone. The projectors are housed in gondolas, roughly similar to the passenger-carrying gondolas of dirigible balloons. One of these housings is suspended from one of the ceiling trusses immediately in front of the stage, at about the level of the top of the proscenium arch, and the other similarly in front of the musicians' balcony. Each gondola contains four nineteen-foot horns with four receivers each, two fourteen-foot horns with two receivers each, and six six-foot horns with one receiver each. The projectors in each are arranged to give a uniform distribution of sound over the entire floor and balcony. The regions immediately beneath the gondolas are served by the six-foot horns, which are of the straight type and are pointed through openings in the floors of the gondolas.

The hall is also from time to time the scene of prize fights, staged in the center of the auditorium, at which the voice of the referee from the ring must be reinforced. For this purpose a special portable fixture was designed, combining the necessary lighting arrangement for the ring with a framework on which the projectors are mounted. These comprise twenty-four six-foot folded horns arranged in two circles, one above the other, again affording uniform sound distribution over floor and balcony. When in use the fixture is suspended from the ceiling so that it hangs above the prize ring about thirty feet from the floor. It is built, however, in several sections which can be disassembled and placed in a storeroom when it is not needed.

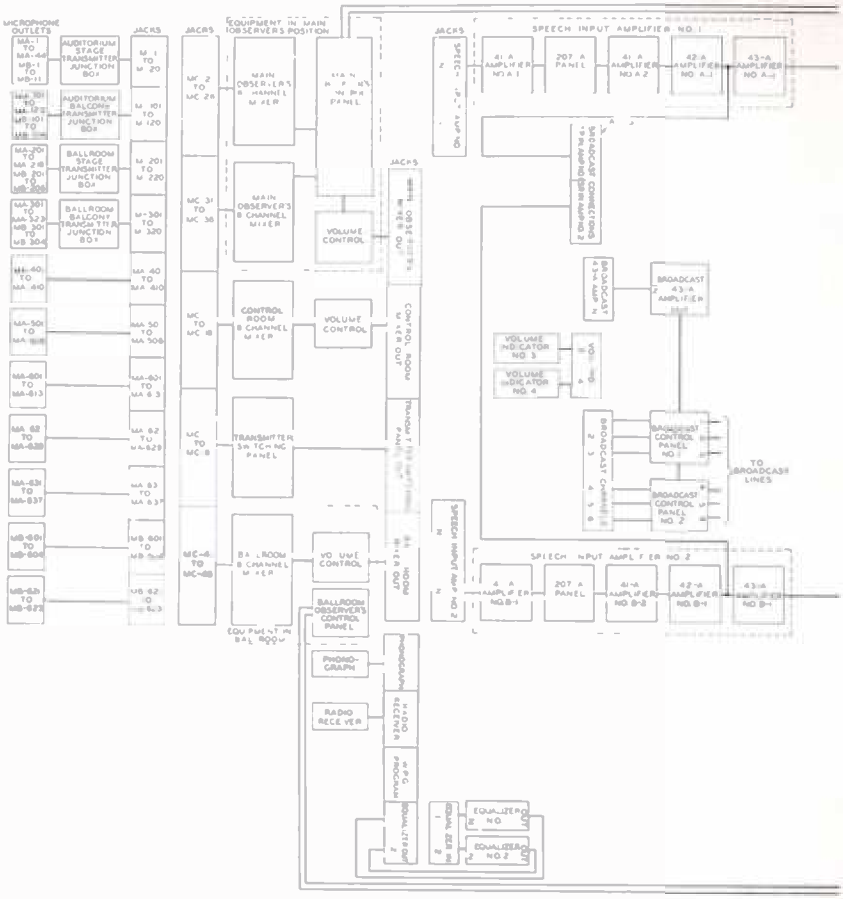


Programs transmitted to broadcasting stations are controlled from the two bays at the right. Adjacent to these bays are the two speech-input bays for the public address systems of auditorium and ballroom

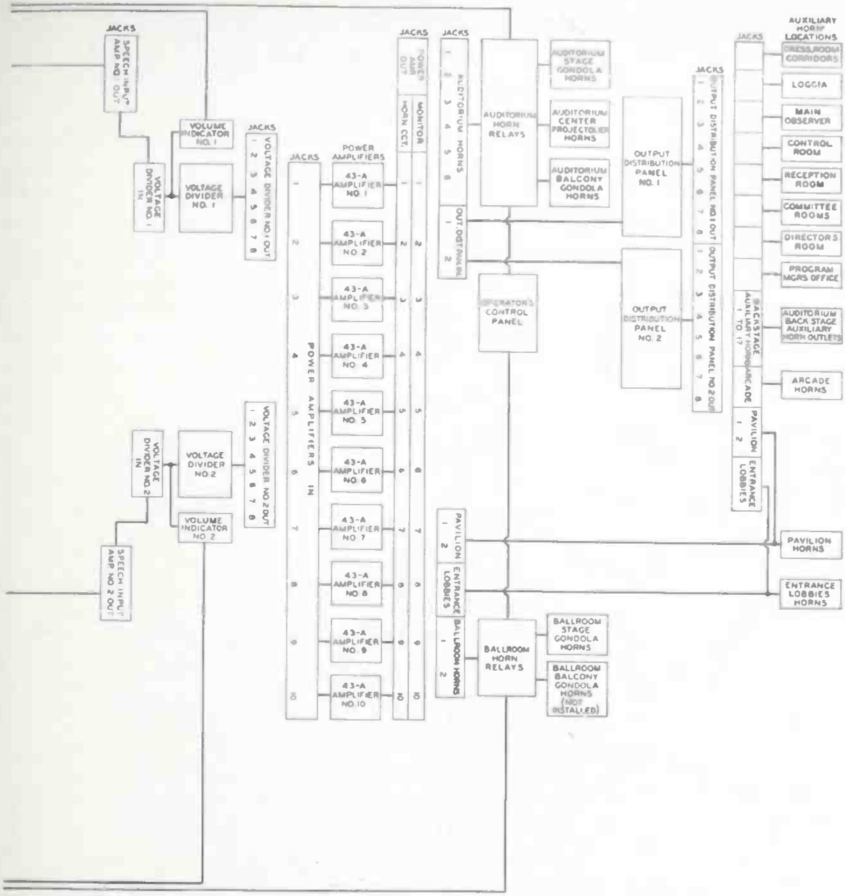
In the ballroom the projectors are also contained in a gondola, somewhat smaller than those used in the auditorium. Suspended from the ceiling, immediately in front of the ballroom stage, it houses four fourteen-foot horns.

The control room, located between WPG's two studios, is the electrical center for the associated systems. Here the wiring from all outlying locations is brought into a terminal box, whence it is connected to jacks on two control racks. At these racks input circuits from microphones, radio receivers, and the reproducer set, and output circuits to the various projectors, can be patched by cords into the amplifying equipment in whatever combination suits the event in progress. Here also are the master mixing panels and their controls for the microphone circuits. The input and output circuits of the power amplifiers are also terminated in jacks on another control rack, permitting interchange of amplifiers in case of trouble in any one. When events of national interest take place in the hall, six broadcasting stations can pick up the programs. For each station an individual channel gives means for controlling the programs sent over the telephone line to it.

The sound reinforcement for certain events, such as pageants and large spectacles, can be satisfactorily controlled by the mixer operator only if he can observe them directly. For such cases, the mixing equipment is duplicated in control booths located within sight of the performances. In the auditorium such a control room adjoins the motion picture projection room, suspended from the central ceiling truss. Here two eight-channel



Great flexibility, both electrical and mechanical, is afforded the Western Electric



public address system at Atlantic City by its extensive plug and jack equipment mixers, which can be operated as one sixteen-channel mixer, are mounted on a portable rack which can be wheeled to either side of the room. Observation windows in two sides of the room give the operator an unobstructed view of both the stage and the musicians' balcony, the two locations whose programs he can control. For programs from the ballroom stage, an eight-channel mixing panel and its associated controls are provided on the balcony at one side of the ballroom.

The Western Electric public address system of the Atlantic City Convention Hall well exemplifies the electrical and mechanical flexibility required today in large systems for reinforcing the sounds of programs. With the aid of such systems many persons, who could otherwise merely be spectators of these programs, become auditors as well.

Electric Clocks

Writing in "Nature" of October 17, Prof. C. V. Boys, F.R.S., says:

"An electric clock which vies in accuracy with the most perfect clock known—is the quartz crystal clock perfected by Mr. W. A. Marrison, of the Bell Telephone Company's research laboratory."

The "most perfect clock known," according to Prof. Boys, is that built by Shortt and installed in triplicate in the private laboratory of Mr. A. L. Loomis at Tuxedo Park; "their degree of perfection could never have been ascertained without the ceaseless record of each clock every half minute by the Loomis spark chronograph. Even so, the perfection of going could not be known without the use of the quartz clock in New York connected by private wire with Tuxedo, forty miles away. The quartz clock 'ticks' 100,000 times a second and 1,000 time signals a second are sent by it along the line. These are made to actuate the spark arm and the motor which feeds the paper.

"Now the degree of perfection to which I have been leading up is no less than the certain observation of a six-hourly fluctuation of rate of the pendulum clocks under the influence of the moon's gravity. It needed the unvarying rate of the quartz clock and the thousandth of a second accuracy of each record of each clock every half minute to bring this out. At the latitude of Tuxedo the calculated accumulated error of a pendulum clock at lunar six o'clock is −0.000153 sec. as compared with lunar noon and midnight, and this is certainly shown by the clocks.

"This is such a triumph that the four who have made it possible—Hope-Jones, Shortt, Loomis, and Marrison—might well believe that the limit has been reached, and rest; but it is certain that none of them will."

The Sequence Switch

By C. C. BARBER
Telephone Apparatus Development

DISTINCTLY different from all other schemes of telephone switching, the panel system required the development of a number of new pieces of apparatus. One of them, the panel bank, has already been described in the RECORD.* Another, of basic importance and extensively used in every panel office, is the sequence switch. This piece of apparatus makes it possible to perform a large number of switching operations in a predetermined and positive sequence, and it is from this function that the switch receives its name. As many as five thousand of them may be used in a single central office and at the present time some 150,000 are being produced each year by the Western Electric Company.

The sequence switch, shown in Figure 1, consists essentially of a group of contact cams each of which, except the first, makes or breaks contacts with four springs depending on how it is cut. All are rigidly mounted on a square shaft which may be rotated through a friction disk drive by the action of a magnetic clutch. Two sizes of switch are made: one will carry as many as 25 cams and the other 21, but as actually used only the number of cams required for the use to which the switch is put are mounted on the shaft. In all other details the switches are exactly alike.

The cams are lettered from left to right, running from A to Y on the large switches. Except for their cutting all are alike except the "A" cam, shown in Figure 2, which is used to control the action of the switch. The other cams, a typical specimen of which is shown in Figure 3, consist of an insulating disc 2-1/16 inch in diameter which serves as a support for a bronze contact disk on each face. These contact disks are electrically connected by four rivets which, running through the insulating disk, hold the three parts rigidly together.

The insulating disk of the "A" cam is smaller in diameter and carries, on one side only, a bronze disk which has a corrugated rim that projects over the edge of the insulation and completes the diameter to the

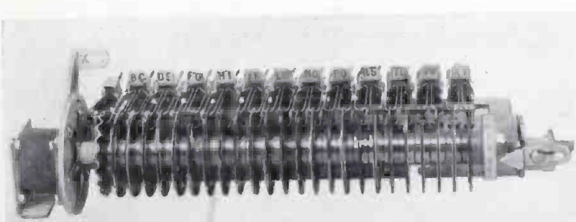


Fig. 1—At one end of the sequence switch the position numbers are marked on a metal collar and a pointer indicates the position under the springs at any moment

* BELL LABORATORIES RECORD, *Oct.*, 1931, *p.* 54.

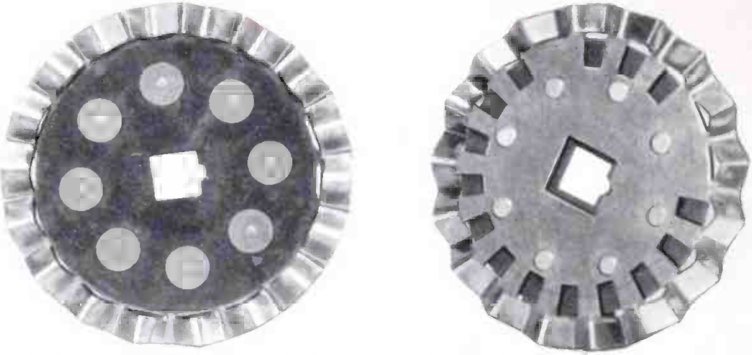


Fig. 2—The A cam provides contact with brushes on only one side

full 2-1/16 inch. There are eighteen corrugations in the rim and a spring-mounted roller riding along it acts as a centering device to insure that the switch stops at one of eighteen positions. Since there is metal on only one side of the "A" cam there are but two springs riding on it. The inner one makes contact continuously, but the metal around the track of the outer spring is cut out at each stopping position so that the outer spring makes contact only between stops.

On all the other disks there is metal on both sides of the insulation and two springs travel along an inner and outer track on each side. The metal along these two tracks is either cut away or allowed to remain depending on whether contact is to be broken or made. Since for the most commonly used switch there are eighteen positions, each is 20° wide and the contacting or insulating segments for each position are usually 10° wide although both narrower and wider cuttings are used when it is necessary for contacts or opens to hold from one position to another.

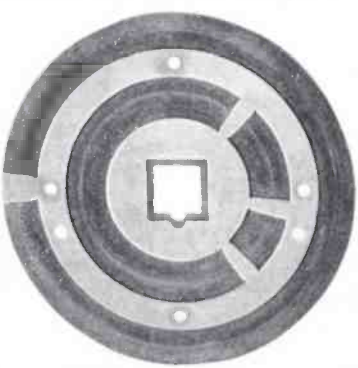


Fig. 3—All but the A cam are double sided and may be cut in any manner desired

Separating the cams on the shaft are brass spacers which may be used to connect adjacent cams electrically. When this is desired a circle of the metal is allowed to remain around the center of each of the adjacent cams where it will be in contact with the spacers. When no connection is desired the metal is all cut out from the center of the cams and a spacer in such a position is marked with a central groove cut around its circumference. Examples of a marked and an unmarked spacer are shown in Figure 1 between cams J and K, and K and L, respectively. All the insulating disks are cut with a square hole at the center to fit the shaft and when the cam metal is left at the center

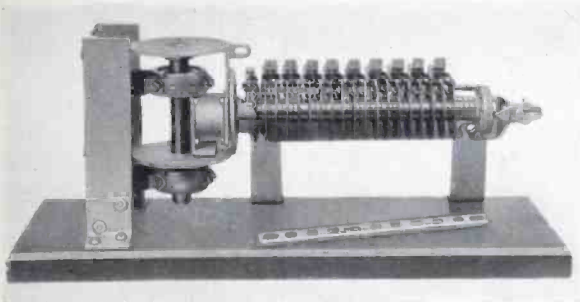


Fig. 4—The friction-disk clutch is simple but has proven effective over a long period of years

to make contact with the spacers, it also is cut with a square hole but slightly larger than that in the insulation so as not to make contact with the shaft.

At the end of the shaft adjacent to the "A" cam is an iron disk about three inches in diameter that serves as one of the friction elements of the clutch. The complete clutch drive is shown more clearly in Figure 4. The clutch disk of the switch is fastened to the shaft by a six-pronged bronze spider which allows it to be flexed by the pull of the magnet secured to the steel frame of the sequence switch. A driving shaft is mounted vertically along the outer end of the magnet for the full height of a frame, and carries similar but slightly larger iron disks, one of which is fastened opposite each sequence switch in line with the lower edge of the clutch disk on the cam shaft.

When the magnet is not energized there is a small gap between the two disks but when current flows in the magnet coil, the clutch disk on the sequence switch is pulled into contact with the driving disk and is driven by friction. The driving shaft rotates continuously at about 35 r.p.m. so that as long as the clutch is energized the cam shaft will turn. An adjustable yoke on the end of the clutch magnet nearest the vertical shaft forms part of the magnetic circuit. Flux flows through the magnet core, the adjustable yoke, the driving disk, the driven disk, and back to the core. Although about 90 per cent of the half million or more switches in service operate less than 75,000 revolutions a year, the remaining 10 per cent operate from 75,000 to a quarter of a million revolutions. The rotation per call may be only a fraction of a turn.

The contact springs are assembled in units of eight except the two springs for the "A" cam which are assembled by themselves. These spring assemblies are supported by punched steel brackets which are in turn fastened to a flange on the frame of the sequence switch as shown in Figure 5. One of the recent improve-

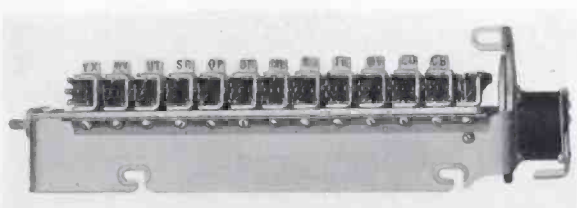


Fig. 5—A single strip washer for the spring assemblies and slotted mounting holes are two recent modifications of the switch

ments is a long strip which serves as a washer for all the screws holding the spring assemblies to the frame. This strip takes the place of individual cup washers used before, and simplifies the assembling procedure.

Since there are 24 cams with four springs and one with two there are in all 98 contacts for each position of the switch. This makes possible a very large number of combinations and since sequence switch connections enter into a large proportion of the circuits in the panel system, a standard method of indicating connections has been devised. A simple illustration involving a few positions on three cams is shown in Figure 6. Here, above, three cams and the clutch of a sequence switch are shown in perspective, and below, the method of indicating the connections on a circuit drawing.

The four springs on each cam are numbered 1 to 4. Number 1 represents the left inner spring, 2 the left outer, 3 the right inner, and 4 the right outer. The cams are represented by straight lines with a small circle at one end. When two adjacent cams are connected by the spacing sleeve the two corresponding circles are connected with a line. The springs are represented by arrows adjacent to the cam; the left springs are usually shown at the left of or below the cam. At the side of each arrow, numbers are written to indicate the positions at which contact is made with the cam. An open arrow head, touching the line which represents the cam, means that the path under that spring is continuous—that is, not cut in any position. Such a cam is sometimes used as a feed and is usually the inner track. A single number, as 4 at the top of the diagram, indicates that contact is made at that position only. A dash between two numbers indicates that contact is made at the two positions marked and open between them. A diagonal dash between two numbers indicates that constant contact is made between the two positions indicated.

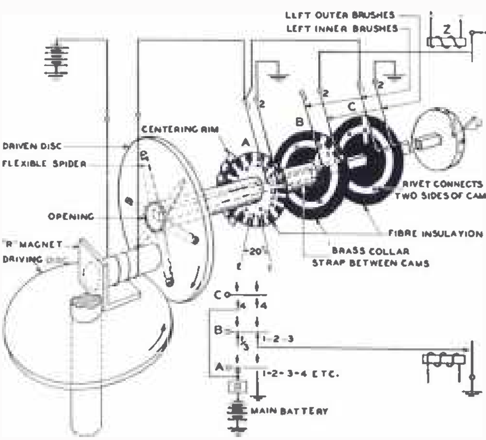


Fig. 6—Diagrammatic representation of part of a sequence switch and its method of operation

Battery is always connected to one side of the magnet winding, and the other side is connected to the inner spring of the A cam, and—in the circuit shown in Figure 6—to the left inner spring of the C cam as well. The outer spring of the A cam is grounded and since metal is left on the A cam between positions, the outer spring of the A cam insures that the rotation will always carry over from one position to another.

With the connections as shown in Figure 6 the switch will be at rest at position 1. When the relay Z operates, however, ground will be connected through the left outer spring of B to the B cam, along the spacer sleeve to the A cam, and will thus operate the clutch through the inner A spring. As the switch moves off position 1 the outer A spring will maintain the ground connection to position 2. If the relay Z remains operated the switch will continue to rotate, using alternately the outer springs of cams A and B, until position 4 is reached. At this position the ground connection will be established through the two left springs of the C cam but at position 5 the switch will stop. This is merely an illustration of the method of operation of the switch. Other cams on the switch may be making other contacts at various positions.

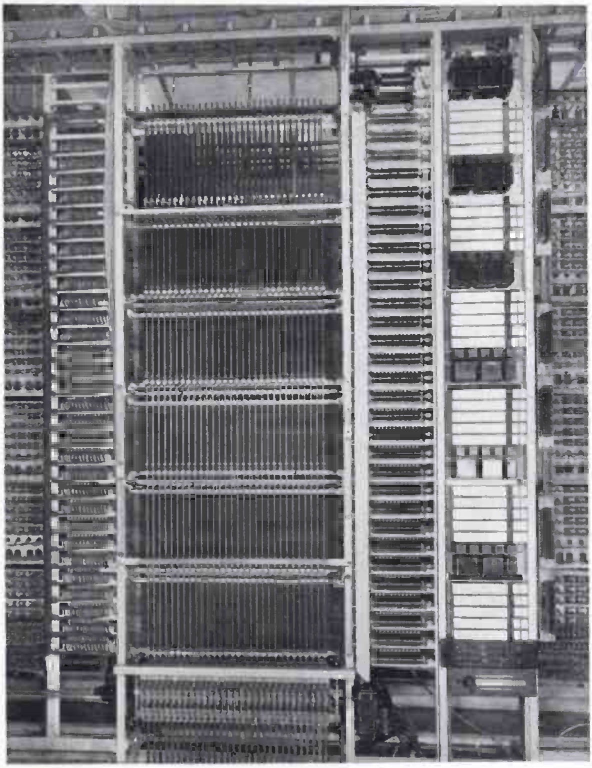


Fig. 7—One sequence switch is used with each elevator of a panel selector

The switches are usually wired and mounted on the frames at the Hawthorne factory. A typical bay associated with a panel selector is shown in Figure 7. The holes in the switch frame for the main mounting screws are slotted so that the screws may be put in the framework first. The sequence switches may then be slipped over them, lined up, and the screws tightened. The third mounting screw, running through the uppermost tab of the switch, is then put in place. Development work is constantly carried on to improve various details as increased use makes available more detailed knowledge of the action of the switch over long periods of service.

Reduction of Radio Interference from Telephone Power Plants

By J. M. DUGUID
Equipment Development

WITH the introduction of radio broadcasting and the widespread use of radio receiving sets by the public, it has become of great importance to suppress any electrical disturbances which interfere with the reception of programs. Considerable amounts are expended to provide radio equipment capable of transmitting programs without appreciable noise or distortion. The studios are soundproofed and every precaution is taken to insure accurate reproduction. All this is of little avail, however, if disturbing noises are introduced near the receiver and at power levels comparable to that of the program being received. Although telephone equipment has not offered serious interference to broadcast reception, the Bell System has joined with other public utilities in taking all reasonable precautions to eliminate such a possibility.

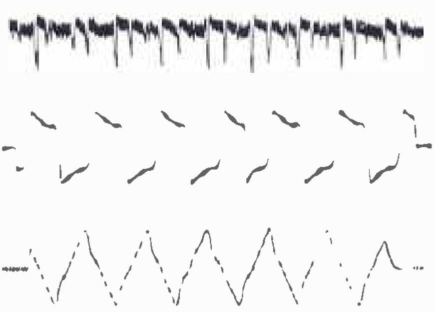


Fig. 1—Higher harmonics present in ringing current and the various tones are evident in these oscillograms: A—Voltage wave of a tone interrupter; B—Voltage wave of a ringing interrupter; C—Current wave of a ringing interrupter

As a result of these precautions relatively few complaints have been received by Telephone Companies and these have usually related to radio receiving sets in close proximity to central offices or other equipment. Generally, interference originating in the telephone plant is not prominent compared with that from atmospheric electricity and other sources. Ringing and signaling machines in telephone central offices constitute one source of possible interference but even this equipment does not usually cause trouble unless the receivers or antennas are very near these machines.

The ringing and signaling machines referred to above are either interrupters of the electromagnetic vibrator type, which produce ringing current by rapidly reversing the polarity of direct current from a battery, or motor-driven interrupters of the commutator type, which produce tones by interrupting battery current. The interference is caused by sudden electrical changes which generate transient currents with high frequency harmonics. The changes or interruptions take place at the point of contact between the interrupter drum and brush or at the contacts of the vibrating interrupters.

The wave forms of the current and voltage produced by both the vibrating and drum type interrupters are not smooth but rough and angular as shown by the accompanying oscillograms. The peaks in the tone interrupter wave, and the sharp angles of the ringing interrupter wave may clearly be seen. Some of the component frequencies are high enough to be in the radio frequency band. Unless counteractive measures are taken radiation of these currents may be great enough to interfere with receiving sets in the immediate neighborhood.

Action to eliminate this interference was taken by the Bell System as early as 1923 and since that time the problem has been extensively studied and considerable development work has been undertaken. In general, two methods are used to overcome this interference. The first provides low impedance circuits to by-pass the radio frequency currents, and the second adds sufficient impedance to reduce them to a negligible level.

The low impedance circuits used with the first method consist of small condensers of about 1 mf capacity or less. In series with a resistance they are bridged around contacts which may become sources of radio frequency currents.

With the second method, a high impedance in the form of radio frequency choke coils is placed in the leads close to the source of the disturbance. These coils are wound to have a relatively low resistance and a very high impedance to radio frequency currents in the broadcast range. The low resistance minimizes the reduction in the output voltage of

Fig. 2—Ringing interrupters of the vibrating type are mounted on the second panel from the bottom

the particular equipment to which the coil is connected. It has been found that unless the leads to these coils, or to the condensers of the first method, are kept very short—not more than a few inches—they act as antennas and materially reduce the effectiveness of the protection. The radio frequency choke coils housed in an aluminum finished box, and the short leads to the interrupter brushes may be seen in the accompanying photograph

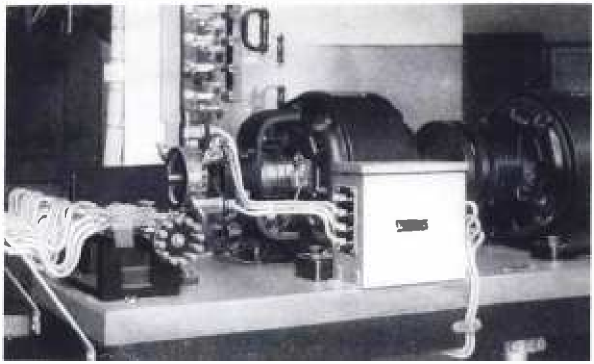


Fig. 3—Tone interrupter of the commutator type equipped with radio frequency choke coils showing short leads to interrupter

other source of disturbance. Measurements of the volume of interference with and without the corrective apparatus in use were a gauge of the effectiveness of the equipment.

It is standard practice to supply the protective equipment described above on all new installations which are at all likely to cause trouble with local receiving sets. The types of ringing machines and interrupters usually employed in the smaller central offices are more liable to cause interference than are the large machines used where the loads are heavy. The Western Electric Company, therefore, always equips the smaller offices with the suppression apparatus. The larger machines are equipped whenever local conditions, such as proximity of radio sets, make this seem desirable.

of a ringing machine (Figure 3).

In this connection, contacts which are subject to sparking are bridged with spark absorbing equipment consisting of condensers and series resistances. It has been found that this equipment reduces the sparking and brings about a marked reduction in radio interference. In making such tests, a radio set, tuned to bring in maximum interference, was set up adjacent to the ringing machine or

For Next Christmas

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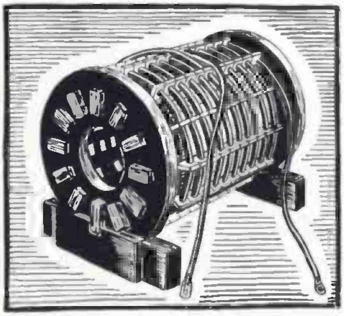
A 24,000 Watt Filter

By MANFRED BROTHERTON
Transmission Networks Development

THE term "electric filter" ordinarily brings to mind the picture of a network designed to handle about one-quarter of a watt and compactly assembled in a box which can be readily picked up and mounted on a relay rack. When a filter is built to transmit 24,000 watts, it weighs over a ton and its copper shield becomes large enough to house an automobile. Such a filter was developed for use in tests to determine whether two voice channels at different carrier frequencies could be transmitted from a single antenna without objectionable interference arising from modulation in the antenna. This question is of great importance in long-wave radio transmission at high power, since it determines whether two costly antennas must be used, or whether one will suffice.



Modulation occurs where an impedance varies with current and results in the production of frequencies not originally impressed. The problem was investigated by analyzing the currents appearing in an antenna on which were impressed 12 kw at 67 kilocycles and 12 kw at 69 kilocycles. This measurement required that the currents appearing in the antenna from modulation in the transmitter and other parts of the circuit should amount to less than one-millionth of the test currents or, expressed in terms of power, about 0.024 watt. The undesired currents were suppressed partly by certain selective circuits and partly by the band-pass filter which forms the subject of this article.

In the design of the filter a lattice-type structure was employed as requiring the least number of coils and condensers, and the most favorable values of inductance and capacity. A general picture of the manner in which the lattice network operates to give the transmission characteristic shown in Figure 4 may be obtained by reference to Figure 2, in which by a rearrangement in position of the elements the similarity to a bridge is made obvious. When the bridge is balanced, the current in the load is zero. For certain conditions of unbalance this current is equal to that flowing into the network and we have a condition for free transmission.

A requirement placed upon the filter was that the testing currents should be transmitted with high efficiency, while currents separated in frequency by less than three per cent should be strongly suppressed. Extremely low resistance in the coils, a

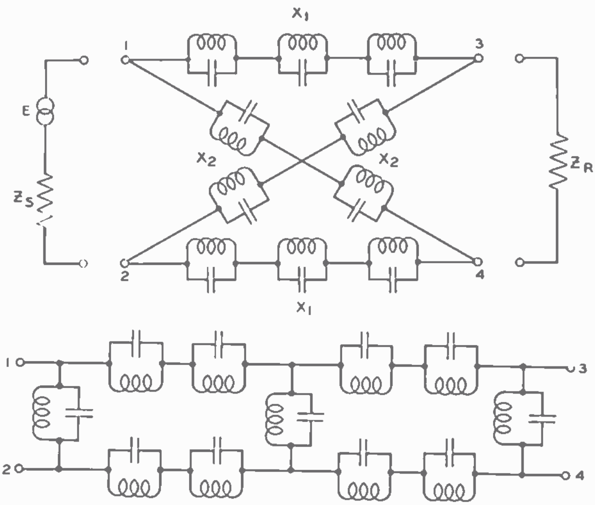


Fig. 1—(Above) Schematic diagram of the band-pass filter. X_1 and X_2 are generalized impedance values of the horizontal and diagonal arms respectively. (Below) Alternative ladder network

necessity for this sharpness of cut-off, had a further value in reducing the power losses attendant upon transmitting the large currents which flowed in the individual meshes of Figure 1. While the currents flowing into a mesh never exceeded five amperes, the parallel-resonance which obtained at a frequency close to that of the testing currents caused the locally-circulating current to attain values as large as 140 amperes.

The problem of securing low dissipation was attacked by the Coil Development engineers, who designed the coil shown in Figure 6. It consists essentially of widely spaced turns of highly-stranded conductor wound on "squirrel cage" frames of impregnated maple. The porcelain insulators on which the conductor is wound ensure a highly resistive path between turns and provide for mechanical adjustment. The conductor, which was of unusual design, consisted, in the case of the coils required to carry the heavier currents, of over 7,000 strands of enameled No. 36 wire wound on a ¾ inch rope core and covered by a serving of minimum weight to facilitate the escape of heat.

At certain frequencies where undesired components were to be strongly suppressed, the design provided peaks of attenuation. At these points the values of X_1 and X_2 (Figure 1) were required to differ by as little as one-third of one per cent. This accuracy was secured by employing condensers adjusted to within ¼ per cent of their theoretical values and by adjusting the coils to resonance with their associated condensers at the prescribed frequencies. Preliminary adjustment of the inductance was performed by sliding the porce-

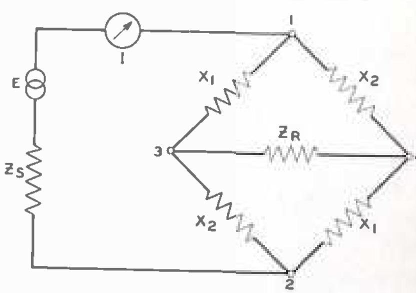


Fig. 2—The lattice network of Fig. 1 redrawn in the more familiar form of the Wheatstone bridge. Load currents in Z_R will depend on the ratio X_1/X_2. This current will be zero when $X_1=X_2$; and when X_1 is zero or X_2 is infinite the current will be equal to I

lain blocks along grooves in the longitudinal slats of the frame so as to vary the spacing between turns. The precision adjustment was effected by means of a circular copper disc mounted so that it could be set at any desired angle with respect to the field.

The realization of low resistance in the coils—too low, in fact, for direct measurement on available impedance bridges—involved certain refinements in construction which are not ordinarily necessary. It was found desirable to solder the heavy brass lugs instead of depending on the usual cleaned-and-bolted joints. Copper gauze as a shielding enclosure was replaced by sheet copper, with a considerable reduction in losses, due to the lower resistance paths for currents induced in the shield. Ventilation was then secured by an air blower.

Measurements made at the operating frequencies after the filter had been assembled in the shield indicated the effective resistance of the largest coil, consisting of 230 feet of special conductor, to be 1/1500 of its reactance or only 0.025 ohms. This is roughly equal to the effective resistance, at these frequencies, of four feet of one-half inch straight copper tubing, 1/32 inch in thickness. The ratio of reactance to resistance of this coil is over five times as high as the maximum value for coils ordinarily employed in low-power filter construction.

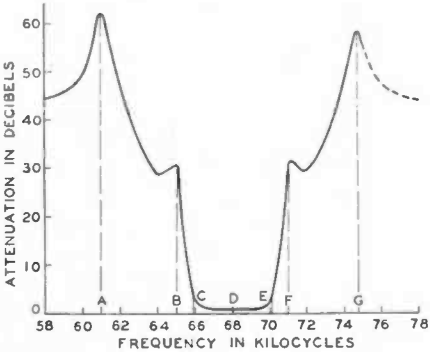


Fig. 4—Transmission characteristics of the filter

The total heat loss produced by the five coils and ten condensers of this filter amounted to less than 3 kw per test channel. About 16 per cent of this loss was attributable to the effects of the shield. Frequencies close to the test frequencies were suppressed in a voltage ratio of 30:1, while at more distant frequencies a suppression of 1000:1 was attained.

It was essential that the level of any products arising from modulation between the test currents in the coils and condensers of this filter should be negligibly small. Possible causes of

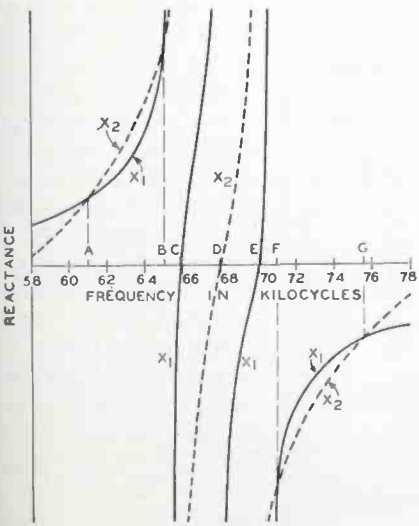


Fig. 3—Reactance characteristics of X_1 and X_2 of Fig. 2. $X_1 = X_2$ at frequencies A, B, F and G, corresponding to the peaks of loss in Fig. 4; at C, D and E, $X_1 = 0$ and $X_2 = \infty$ or vice versa, giving free transmission

modulation are the presence of magnetic materials in coil fields and the vibration of coil windings, tinfoil condenser plates and filter shield under the appreciable stresses to which they would be subject at this high power level. No magnetic materials were employed in the construction of this filter, all metal parts including screws and nails being of brass or copper. Vibration in the condensers was minimized by employing a specially stout form of construction while the coils were damped by the large mass of the conductor and frames. The copper shield was securely nailed to heavy wooden panels.

Undesirable vibration of the copper discs used in the coils for adjustment purposes was detected by setting up an ordinary carbon transmitter with its diaphragm mechanically connected to a disc. When the two channels were applied simultaneously to the filter the disc vibrated to the first order product of 67 kilocycles and 69 kilocycles, namely, 2000 cycles, which was audible in a pair of headphones connected to the transmitter. Subsequently, these discs were damped by nailing them to boards.

This filter was constructed so that it might be readily dismantled for shipment. It was later installed as part of the American Telephone and Telegraph Company experimental radio transmitter near Bradley, Maine.

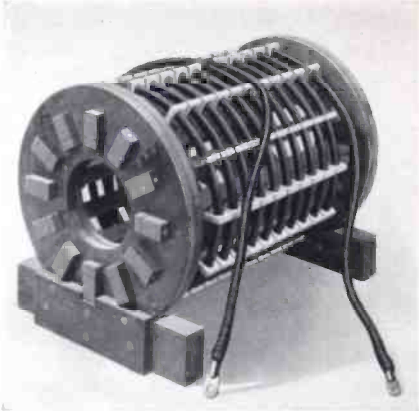


Fig. 6 — One of the smaller coils, 20 *inches in diameter,* 33 *inches long, has an inductance of* 28 *microhenries. It appears in the upper right-hand corner of Fig.* 5

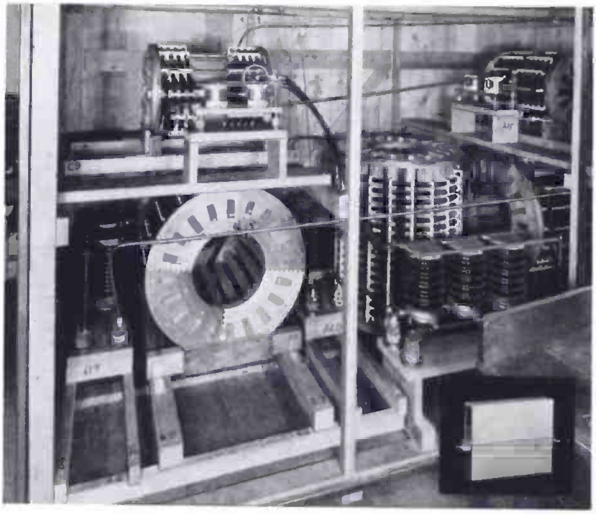


Fig. 5—The filter as set up at West Street. The three largest coils weigh about 300 *lbs. each, and have inductances in the neighborhood of* 100 *microhenries. (Insert) A carrier telephone filter photographed to the same scale*

The Toll Train

By E. D. BUTZ
Local Systems Development

TOLL calls, because of the greater length of line they traverse, require a higher grade circuit than do ordinary local calls. Losses and distortion, inevitably produced by the capacitance, inductance, resistance, and leakance of a circuit, must naturally be held to lower values for the longer lines. This is partly accomplished in the design of the long lines themselves but to secure the best effect the terminating circuits at each end of the line also require special treatment. For this reason, the apparatus and circuits used at the terminating offices for completing toll calls differ from those used for local calls. At the calling or outgoing end of a toll call these circuits, in the dial system, are obtained automatically when a subscriber dials a toll operator. At the receiving or incoming end, these higher grade circuits are selected by the completing operator.

In the dial system of the step-by-step type calls are completed through a train of step-by-step selectors and a connector. The method of operation has already been described in the RECORD.* For completing toll calls with this system a special group of switches is employed which is called the toll train. It consists of two or three selectors and a connector, all of which differ in function and arrangement from those of the corresponding local train.

In making a local step-by-step call the subscriber dials a number and various selectors and a connector follow the digits dialed and establish the connection. The subscriber hears ringing, or a busy signal, and if the called subscriber answers, the usual battery connection is supplied by the connector. On a call from a manual to a step-by-step subscriber the call proceeds in much the same manner only it is the operator at the calling subscriber's "A" board that does the dialing, and both ringing and busy signals are transmitted audibly.

With a toll call on the other hand an operator always completes the connection and to expedite her handling of the call, visual instead of audible busy signals are supplied, and the battery feed circuit is different from that for local step-by-step calls. For local calls the bridged impedance type of transmitter battery feed is provided in the local connector. With this method the battery supply for each subscriber is fed through separate retardation coils or relays bridged across the line. For toll calls the connector battery supply will not meet the Bell System standards and the 48-volt repeating coil type of feed is provided in the transmission selector. The connector, so far as the talking conductors are involved, consists of two leads run through the

* BELL LABORATORIES RECORD, *December*, 1929, *p.* 174.

apparatus. These and certain other operating features, it is the function of the toll train to provide. The necessity for these various special features may be better understood by following the completion of a toll call through the step-by-step toll train.

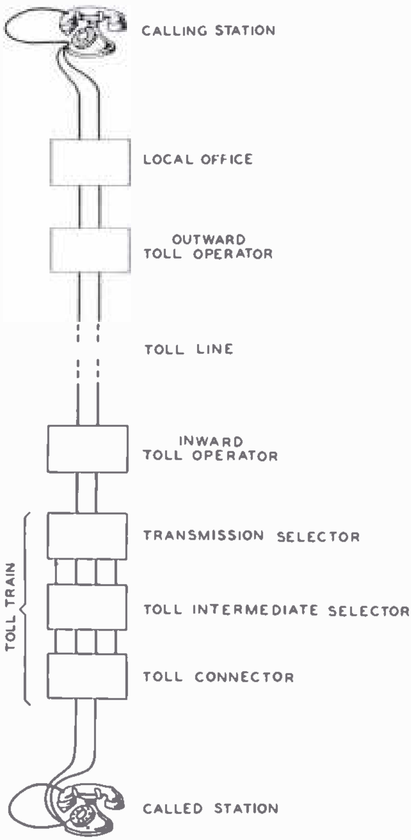


Fig. 1—The toll train is a link between the toll board and a subscriber

After the incoming toll operator has received the number wanted by the distant office, she plugs into an idle trunk that terminates in a transmission selector at the office wanted. This is the first switch of the toll train as indicated on Figure 1. With the dialing key thrown, the operator then starts to dial and the transmission selector, intermediate selector, and connector follow the dial pulses in the usual manner.

Should all the paths to which the transmission or intermediate selectors have access be busy, an interrupted signal is returned which flashes the operator's cord lamp. A similar sequence is performed should the subscriber's line be busy but in this case the flashing is at a different rate

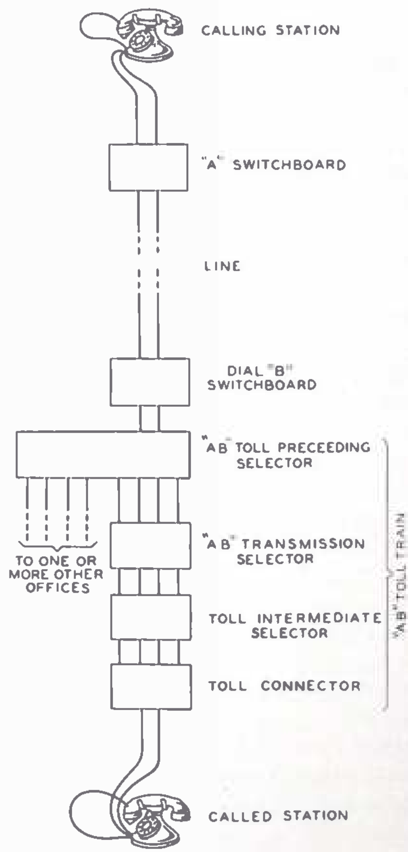


Fig. 2—The AB toll train is the link between a "B" operator and a subscriber when the toll call is completed by the "A-B" method

so that the operator may distinguish between the two situations. One set of interruptions is at the rate of 60 per minute and the other at the rate of 120.

An idle subscriber's line is indicated to the toll operator by a steadily lighted lamp. When the subscriber answers, this lamp is extinguished. The connection is under the joint control of both subscriber and operator. The subscriber may hang up, or if the subscriber's receiver is off the hook the operator may remove her plug, without tearing down the connection. This arrangement permits an operator to change her cord circuit while the calling subscriber remains on the line, or enables her to ring him back without re-establishing the connection should he hang up too soon.

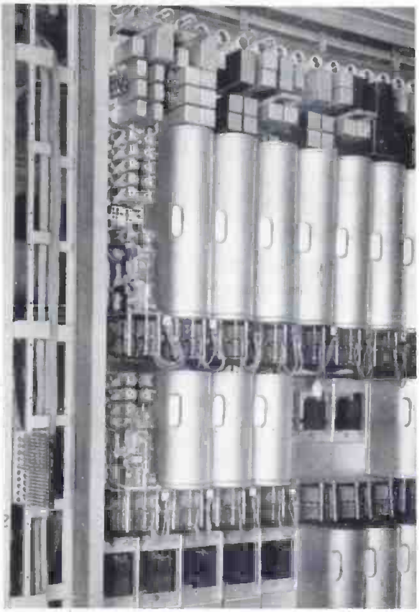


Fig. 3—Toll transmission selectors—upper row—occupy nearly twice as much vertical mounting space as local selectors, shown in the lower row

Under normal operation from the inward positions a spurt of ringing current is sent out automatically from the operator's position after the called line is seized. This spurt of ringing current starts machine-ringing from the connector, which is tripped in the usual manner when the subscriber answers. Should the subscriber have hung up before the conversation was completed, the inward operator may re-ring manually by operating her ringing key. Under these conditions, machine ringing is again sent over the line from the connector but if there were a bridge across the line when the operator threw her ringing key, which would exist if the called station were a PBX, uninterrupted ringing would be impressed on the line from the transmission selector and only while the ringing key was operated.

The toll train, in addition to being used for completing inward calls at the called office, may also be employed by the outward operator to call back the calling subscriber if necessary. If, for example, the outward operator was unable to complete a call immediately, due to the called subscriber being away from his telephone or to any other reason, the calling subscriber will be told to hang up and that he will be called when the person he wants can be reached. Under these circumstances the toll train at the calling office will be used by the operator at the outward toll board to ring back the calling subscriber.

The action of the toll train when controlled from an outward toll position, is exactly the same as when controlled from an inward position except that ringing is not started after the line is seized, until the ringing key is operated. This is to permit the toll operator to dial the subscriber's line and hold it until the called subscriber has been reached.

A modification of the toll train, known as the AB toll train, is employed for those calls which, usually because of the shorter distance, may be completed by an A and a B operator. For this class of calls, the A operator usually trunks to a B operator in the called area who completes the call over the AB toll train. The B operator reached with this class of calls may not be in the office called. She may be in an office central to a group of local offices and instead of providing separate trunks to each local office it is customary in such cases to employ a preceding selector which selects a trunk to the desired office. In such cases an extra digit is required, however. This arrangement is shown in Figure 2. As the AB toll train is used exclusively at the terminating end of the call, it has certain features which differ from those of the toll train. It is arranged, for instance, to ring immediately on reaching an idle line. In addition, the calling subscriber as well as the completing operator is given the busy signals. This is accomplished by superimposing a tone on the busy flashes, the tone reaching the calling subscriber and the flashes, the A operator. Switchhook supervision is given the A operator as in the case of toll calls.

The transmission selectors of these toll trains differ considerably from the local selectors, as may be seen in Figure 3. The actual selector mechanism is, of course, the same but the number of associated relays and the arrangement of the circuit are quite different. The apparatus for providing the battery supply, the battery and ground reversing relays, the battery removing relays, the ring start, and the re-ring apparatus are all in addition to the regular stepping relays located on the mounting plate. Because of this additional apparatus the mounting plate is much larger than that of the local selector—requiring about twice as much vertical space.

The connector, on the other hand, is simpler than the local connector because of the omission of the battery-supply apparatus.

The intermediate selector is practically the same as the local selectors except that a fourth lead, in addition to the tip, ring, and sleeve leads, is carried through it. This lead is used as a signaling path and runs between the transmission selector and the connector. In some areas it is the practice to run trunks from the incoming toll board to each thousand lines in an office instead of common trunks to the entire office. In such places the intermediate selector is omitted and only three digits need be dialed. Intermediate selectors and the connectors are common to both AB toll and regular toll trains when both are required in the same office.

Contributors to this Issue

Drafting in a plant manufacturing steam-boilers was A. F. Dixon's introduction as a high-school graduate to engineering work. In 1902 he joined Western Electric as a draftsman and was soon designing and inventing telephone equipment. Transferring in 1907 to the Laboratories he continued his output of invention and supervised groups engaged in designing printing-telegraph and, later, dial telephone systems. In 1919 he was made responsible as head of the Systems Development Department for all Laboratories work in the development of communication systems.

Following service with the British Army during the World War, Mr. Brotherton attended the University of London, King's College, and was graduated in 1921. Subsequently, under a grant from the Board of Scientific and Industrial Research, London, he assisted Professor O. W. Richardson in thermionic research and was awarded the degree of Ph.D. by London in 1924. Since joining the Apparatus Development Department in 1927, he has been engaged in the development of filters and equalizers.

A. F. Dixon

J. M. Duguid graduated from Stevens Institute of Technology in 1922, receiving the degree of Mechanical Engineer. Prior to graduation he worked during summer vacation with the Testing Laboratories of the Public Service Electric Corporation of New Jersey on electric power-plant testing. Upon graduation he had a few months training in the Installation Department of the Western Electric Company and then joined the technical staff of the Laboratories where he was assigned to the Equipment Development Department. Since then he has been with the group working on the development of telephone power plants where he has been mainly concerned with ringing equipment.

After graduation from a course in mechanical engineering at Pratt Institute in 1922, J. E. Crowley joined our specification group. Six years later he transferred to the Apparatus Development organization, where he has since been occupied with the mechanical design of public address and music reproducing systems. He had a large part in supervising the design and installation of the sound distribution systems at the Atlantic City Conven-

Manfred Brotherton

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O. M. Hovgaard

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tion Hall and the Hotel Waldorf-Astoria.

O. M. Hovgaard brought to the Laboratories a varied radio experience when he joined the Radio Apparatus Development group in 1928. After leaving Massachusetts Institute of Technology in 1919 after his freshman year, he had worked as a radio-telegraph operator for the Radio Corporation and the Tropical Radio Telegraph Company, first on ships plying the Gulf of Mexico and the Caribbean Sea and later at shore stations at New Orleans and Burrwood, Louisiana. Returning to the Institute, he received the B.S. degree in electrical engineering in 1926, then worked for various manufacturers on the design of transformers and chokes and on power-supply apparatus for radio receivers.

During his first year with the Laboratories, he worked on broadcasting antenna problems and the development of frequency controls for use in aircraft transmitters. Since 1929 he has been supervising the development and manufacture of frequency controls for radio apparatus and the design of antennas for broadcast stations, as well as conducting radio transmission studies.

E. D. Butz entered the employ of the Western Electric Company a few months after graduating from the Pennsylvania State College with the degree of B.S. in 1911. A year was spent in educational work with the Installation Department in Chicago, and in 1912 he was transferred to the Transmission Laboratory at 463 West Street, where he engaged in transmitter and loud-speaking receiver development for seven years. After the war he was transferred to the Systems Development Department, where he has been interested in the design and testing of step-by-step systems. For five years he has taught the step-by-step system in the out-of-hour classes and is at the present time engaged in designing circuits for use in dial system "A" boards.

After several years of experience elsewhere in the engineering field, C. C. Barber became associated with the Bell System in 1916 entering the Panel Apparatus Drafting Department at West Street. In April of 1918 he was made supervisor of this department.

In 1920 Mr. Barber transferred to the Panel Apparatus Design Group. Here a number of his ideas became the subject of patents, notably the method now in current use in attaching springs to centrifugal governors on the cork roll drive, and the oil circulating pump used on this drive. The use of cork compression discs to take up thermal expansion in the 153-type interrupter is also his idea. In February of 1924 he received a Professional Engineers license from New York State Regents. Since August of 1930, Mr. Barber has been engaged in the supervision of a group of engineers whose activities are identified with the design of panel dial apparatus.

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