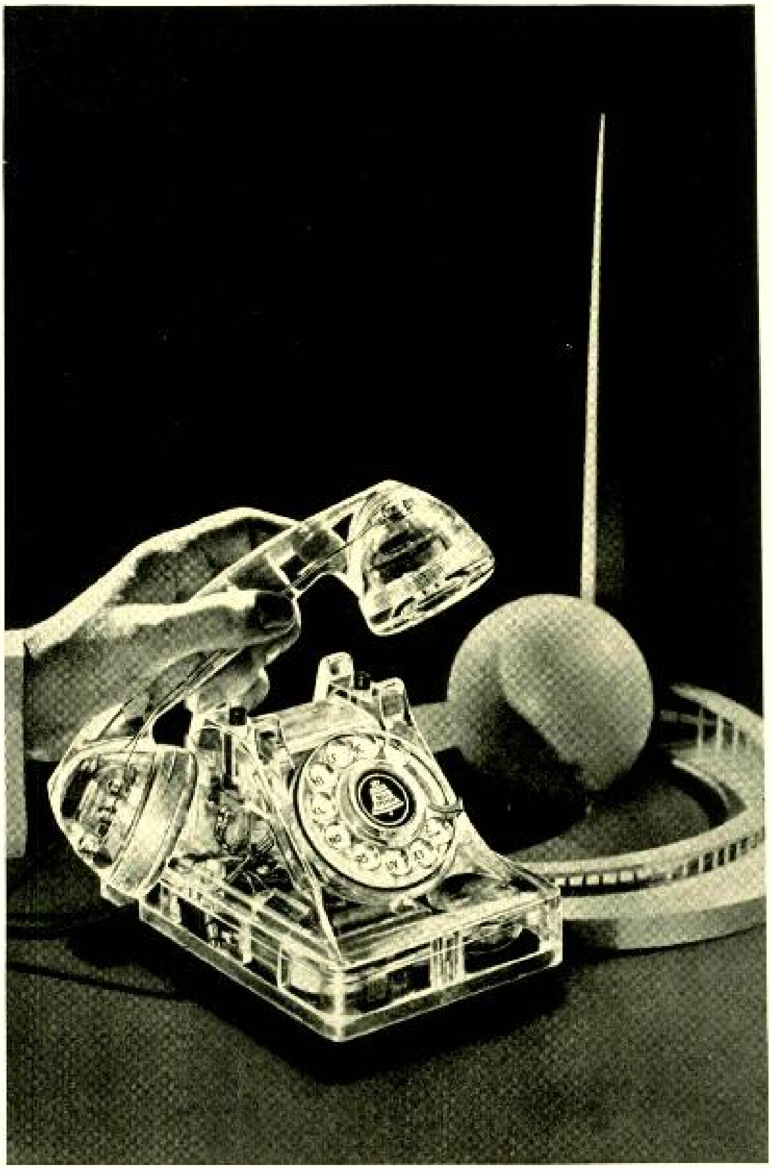
BELL LABORATORIES RECORD



DECEMBER
1939

VOLUME XVIII

NUMBER IV

Lucite model of combined handset, exhibited at the New York World's Fair

Analysis of World's Fairs' Hearing Tests

By H. C. MONTGOMERY
Acoustical Research

ONE of the popular Bell System attractions at the World's Fairs was the hearing test. A considerable percentage of the visitors to the Bell System exhibits at both the New York Fair and the Golden Gate Exposition at San Francisco have taken advantage of the opportunity to find out how well they hear and have thus made possible the widest survey of hearing that has ever been made. Information available heretofore in these Laboratories has been based on studies of a few thousand people at most, while the largest previous survey, that of the United States Public Health Service in 1936, covered only about 9,000. Some three-quarters of a million records are available from the World's Fairs data. The Bell System deals in hearing and if it is to provide the best service at the lowest possible cost, it is important that it have available reliable data on the hearing characteristics of the American people.

The tests are given in sound-proof rooms arranged to seat seven visitors, each partially screened from the others.* Both the tests and the instructions are given through telephone receivers; the visitor holds the receiver to his ear with one hand while he marks the results on a card with the other. Two types of tests are given, with separate booths for each. In one, the visitor hears spoken words, which are two numbers such as "eight-six." The numbers heard are written on the card, and each successive pair is at a lower volume. Twelve pairs of

*RECORD, *Aug.* 1939, *p.* 384.

numerals are spoken at successively lower volumes; and then the test is repeated with a different series.

In the other type of test, the two numbers are replaced by pure musical tones, each tone being sounded from one to three times, and the listeners write down the number of times they hear the tone. Five tests, each consisting of nine sets of tones at successively lower volumes, are given. The first is at a moderately low pitch, 440 cycles per second, which corresponds to A above middle C on the piano. Each following test is one octave higher in pitch, and thus the hearing is tested at 440, 880, 1760, 3520, and 7040 cycles.

At the San Francisco Exposition were three booths, one arranged for word tests, one for tone tests, and one that could be used for either. At New York eight booths were provided for each type of test. Only the tone tests were recorded. The word tests give only a check on one's ability to understand spoken words, while the tone test, by providing data at five frequencies over the most important part of the aural range, is more suitable for study and analysis.

Before a record is made on the test card, the attendant puts a check on it to indicate whether the visitor is male or female, colored or white, and to which of the five age groups—10-19, 20-29, 30-39, 40-49, or 50-59—she judges him to belong. The record is then photographed on sixteen-millimeter film with a Recordak machine.

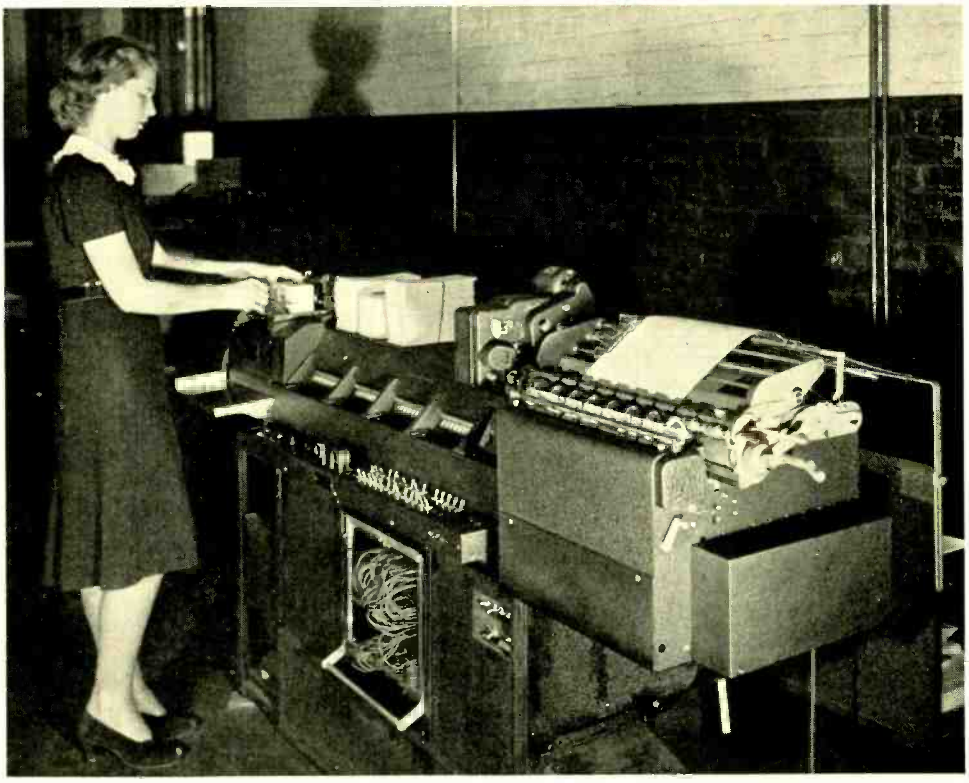


Fig. 1—After cards have been punched in accordance with the individual test results, they are run through this machine, which analyzes and sums up the information

At the Laboratories the data are transferred to "punch cards" by an operator who views the film in a Recordak projector as shown in the photograph at the head of this article.

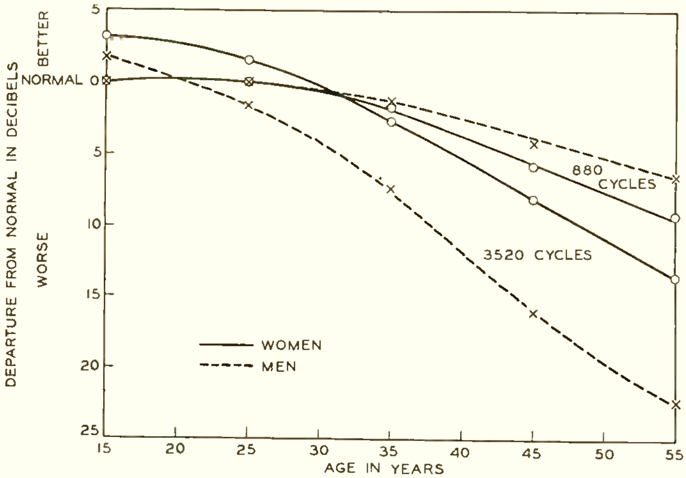


Fig. 2—Variation in hearing loss with age for men and women at 880 *and* 3520 *cycles*

The cards are punched to indicate not only the result at each frequency, but the age, sex, and color of the subject, and the date and hour of the test. These cards are then run through tabulating machines that analyze and sum up the data, as shown in Figure 1.

The results of this survey, in harmony with previous data, indicate a definite falling off in hearing acuity with age. This is particularly noticeable at the higher frequencies. A rather remarkable fact is that at the low frequencies, the falling off with age is less for men than for women, while at the higher frequencies it is less for women than for men.

These facts are indicated in Figure 2 on which average hearing loss is plotted against age for two frequencies. For a frequency of 880 cycles, which is next to the lowest frequency in the test, the loss for women in the oldest age group is about 3 db greater than for men, while at the higher frequency it is about 7 db less. For the youngest group the differential between men and women nearly disappears at the low frequencies, and is only about 2 or 3 db at the highest.

This difference between men and women is brought out better in Figure 3, on which the hearing loss is plotted against frequency for two age groups. In the lowest age group the difference between men and women is small, but even here the advantage is slightly with the men at low frequencies and with the women at high

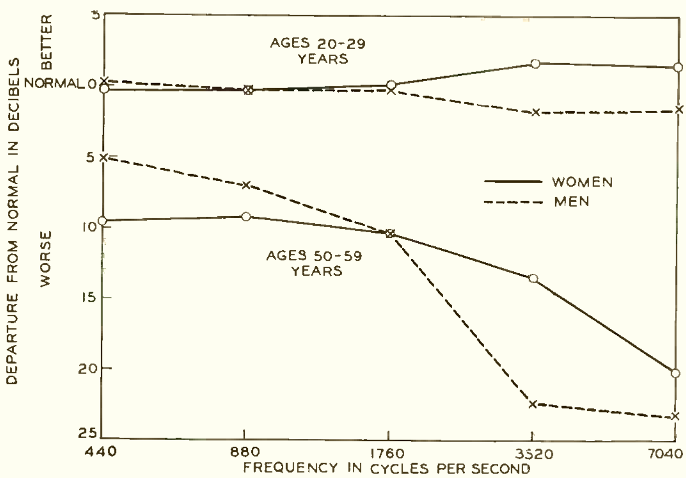


Fig. 3—Variation in hearing loss with frequency for men and women in the age groups 20-29 *and* 50-59

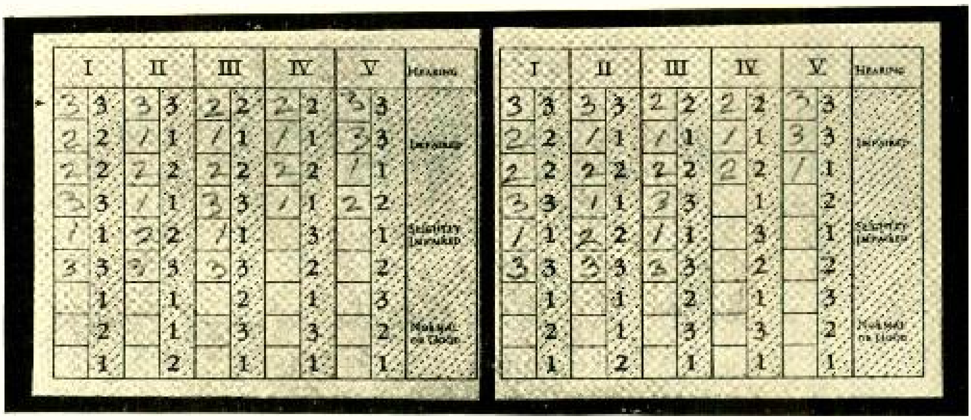


Fig. 4—Test cards as they would be filled out by average men and women in age group 50-59. The card for women is at the left, and for men, at the right

frequencies. In the age group from 50-59, the difference becomes much more pronounced. In both of these illustrations, zero on the ordinate scale of Figure 3 represents the average of both men and women in the 20-29 age group.

Average cards for men and women in the age group from fifty to fifty-nine are shown in Figure 4 as they would appear at the checking desk at the Fair. The numbers in the left half of each column are those written by the person taking the test, while the heavier ones in the right half of each column, which appear when the card is held against a bright background, are the correct ones.

The curves of Figures 2 and 3 give the averages only, while it is often important also to know the extent of the deviations from these averages, that is, whether the individuals range widely from the average or are closely grouped around it. The distributions of the deviations are indicated by the four curves of Figure 5. These are plotted from the data for men, but use of the data for women would not essentially change their characteristics. In each case, the area of the shaded sections represents the total number of tests, and the area under each step represents the number that failed at that step on the test. The abscissa scale represents hearing loss in db from the average for the age group from 20 to 29 years. A minus loss indicates a hearing better than the average. The small arrows along the abscissa scale indicate the average for that particular age group and frequency. The curves actually should extend farther on both sides, but since the range of the test was only 60 db, there is no distribution data available above the highest or below the lowest step, and thus the curves cannot be plotted. That they extend a considerable distance in some cases, however, is indicated by the positions of the arrow—particularly for the 50-59 age group at 7040 cycles. Since the arrow is so near the right-hand end of the curve there must be a large number of cases beyond the distribution shown. The light curves shown in Figure 5 have been drawn to indicate the general form of the distribution curve.

From these curves it will be noticed that for young ears and low frequencies, the tests are grouped fairly closely around the average—very few falling more than 15 db away. For older persons or higher frequencies, however, the distribution spreads. The number with average hearing becomes small; most differ from the average, in one direction or another and to one degree or another.

Not all the cards have been tabulated as yet, but as additional tests are examined, they are found to fall in line with those already tabulated; and there is little likelihood of any major change in trend being encountered as the tabulation proceeds. The interpretation of the losses at various frequencies is rather difficult except for specialists, since the evaluation of the effect on one's ability to hear in any particular band of frequencies is a function of many factors. It has been found, however, that one's ability to understand speech can be determined from the average of his hearing losses at 440, 880, and 1760 cycles as compared to good young ears. If this average is 25 db, there may be some difficulty in hearing in auditoriums and churches, while if it is 45 db, there may be difficulty in hearing in direct conversation. Only if the hearing loss is as much as 65 db will there ordinarily be much difficulty in hearing over the telephone.

By use of these figures, the tests indicate that about one out of twenty-

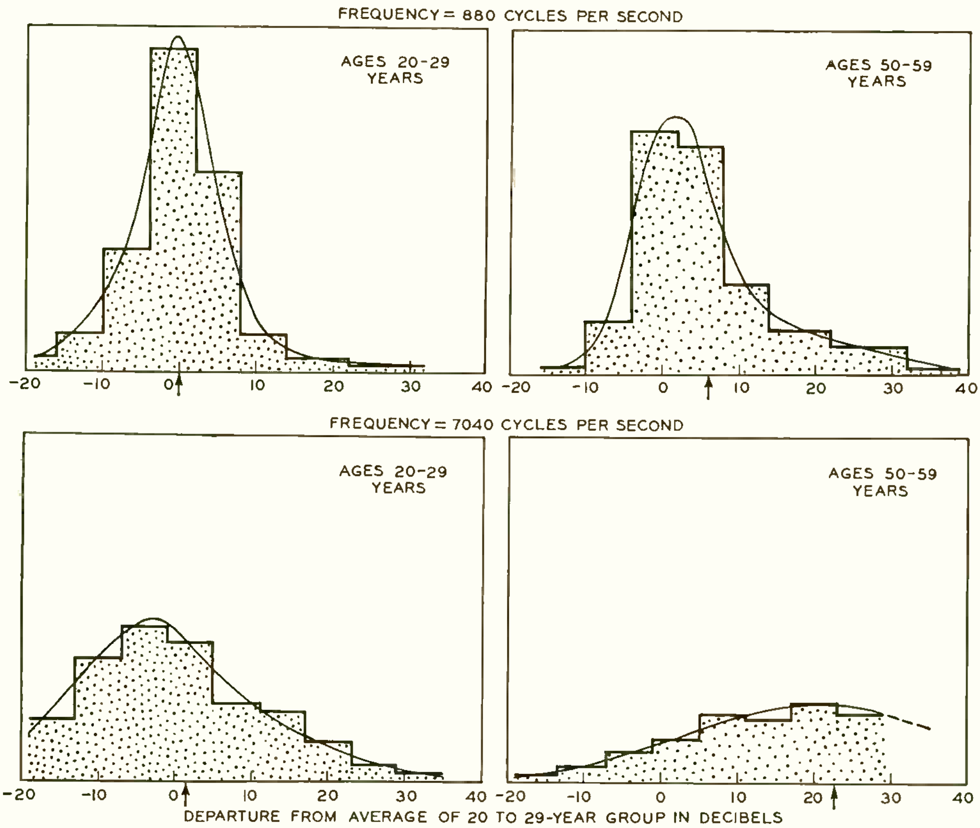


Fig. 5—Distribution curves for the hearing loss at frequencies of 880 and 7040 cycles and for men in the age groups from 20-29 and from 50-59

five persons have difficulty in hearing in auditoriums; one in 125 will have some difficulty in direct conversation; and one in 400 over the telephone. Two out of five men between fifty and fifty-nine will have a loss of at least 25 db at 3520 cycles, while only one in five women—half as many—will have as great a loss at this frequency. It was found, also, that about one in twenty-five of the group from ten to nineteen had a loss of at least 25 db at 7040 cycles. This figure assumes importance because it has been found that young people with a hearing loss of this amount will often tend to become progressively worse in later years, but that if remedial measures are taken immediately, the hearing impairment may be largely checked.

During part of the summer, visitors at each Fair were asked to indicate whether they lived in the vicinity or not, so that information would be available to determine sectional differences in hearing acuity. Studies of these answers, however, do not reveal any significant difference between New York and San Francisco. The time of day at which each test is taken is marked on the card by the attendant, thus permitting a comparison of the results for different periods of the day. No consistent difference has been found, however, even between early morning and late afternoon. There is thus no indication of any effect of fatigue on hearing.

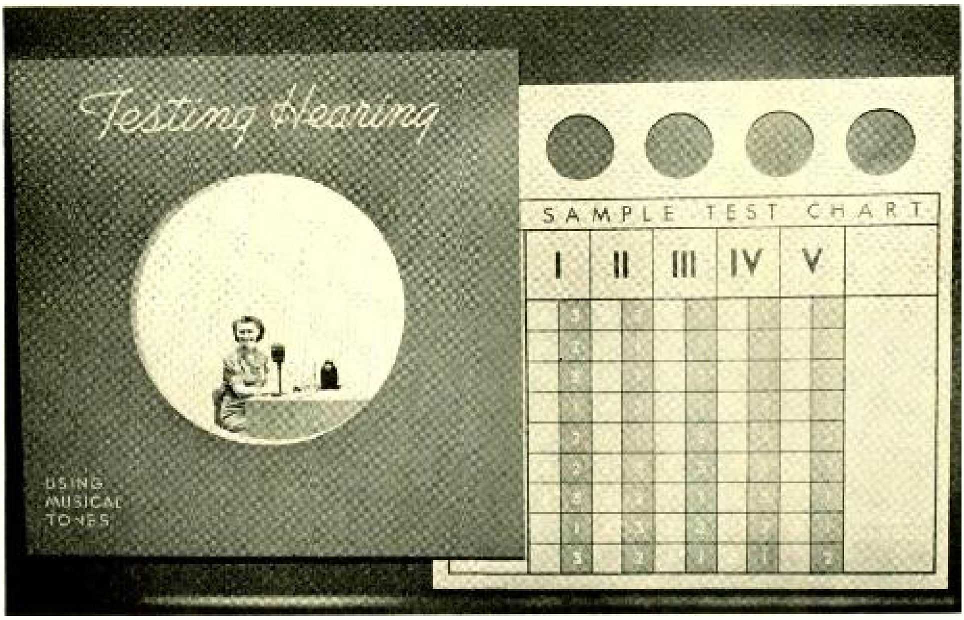
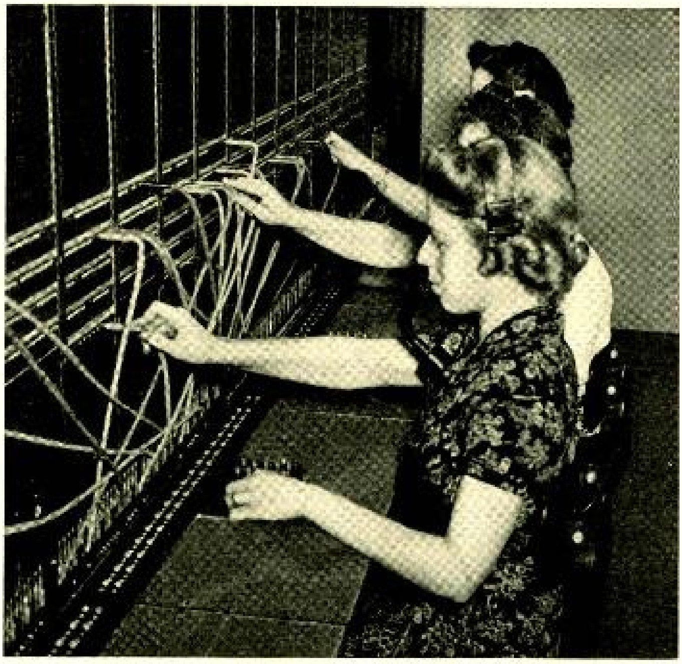


Fig. 6—To attract and assist visitors, the operator behind the round window explained the hearing test, using the large illuminated chart at the right



The 3B Toll Switchboard

By J. C. GREENE
Toll Facilities Department

AT TOLL switchboards in large centers it is often impossible to provide a multiple appearance of all outgoing intertoll trunks at outward positions because of insufficient space in the face of the switchboard, which must also contain incoming and outgoing local trunks. Toll tandem switchboards have been developed to provide the additional jack space required. Trunks are provided from the outward toll switchboard to the toll tandem board, where they terminate in single-ended cords in the key shelf. There has been a tendency in some toll centers to permit the "A" operators at local offices to handle certain toll calls directly, without the aid of outward toll operators. One method of accomplishing this has been to provide trunks to the toll tandem switchboard from "A" switchboards as well as from outward toll boards. When an outward toll or "A" operator wishes to reach an intertoll trunk group through tandem, she plugs into a trunk to the toll tandem board, and, upon receipt of order tone, passes the name of the group to the tandem operator. This operator in turn completes the connection to an idle trunk in the desired group.

Until recently, toll tandem switching in No. 3 type toll offices has been performed at the Toll Tandem Switchboard No. 3.* The 3B Toll Switchboard described in this article has been developed to provide improved toll tandem facilities for the same

*Record, *June* 1930, *p.* 473.

type of office. In general, the 3B board is more flexible in that it permits connections to be established not only to ringdown intertoll trunks, as with the No. 3 toll tandem board, but also to straightforward, key pulsing, or dialing intertoll trunks. It is also capable of establishing connections to straightforward, key pulsing, or dialing trunks to local central offices, thereby permitting the handling of short-haul tandem traffic as well as toll tandem traffic.

In the No. 3 toll tandem switchboard an outgoing trunk to which a connection has been established is held busy until the tandem cord has been removed from the trunk jack. In the 3B switchboard, however, the release of a tandem trunk by the originating operator causes the outgoing trunk to be released immediately, without waiting for the 3B operator to take down the cord. Since the tandem operator does not receive a disconnect signal at the conclusion of a call until after the originating operator has released the tandem trunk, and since she cannot always respond to this signal instantly, it is evident that the immediate release feature of the 3B board causes the valuable toll circuit time to be used in a more economical manner.

The 3B toll switchboard is equipped with a basic single-ended cord circuit, with which an auxiliary incoming trunk circuit is always associated. The type of incoming trunk circuit employed, however, varies with the type of switchboard at which the tandem trunk originates, and whether or not it is at a distance from the 3B board. When the tandem trunk originates at a No. 3 toll switchboard in the same building as the tandem board, the amount of equipment required in the cord and incoming trunk circuits is about the same for both the 3B and the No. 3 toll tandem switchboards. Under other conditions, however, the 3B board requires less equipment in these circuits than the No. 3.

Most of the fundamental circuit features of the toll switchboard No. 3 have been incorporated in the 3B board. It is therefore suitable for use as a tandem switchboard only in No. 3 type toll offices. To provide similar facilities for No. 1 toll offices, the 1B toll switchboard has been developed.

Depending on local conditions, it may be desirable to install the 3B positions in line with existing No. 3 toll positions or with positions of the 3C board, the most recently developed toll switchboard of the No. 3 type, or as a separate board by itself. It has been necessary, therefore, to arrange the 3B equipment so that it may be incorporated in three types of switchboard section. To match the No. 3 board, a two-position section with five 10¼-inch panels is used. When in line with the 3C board a one- or three-position section having three 8½-inch panels per position is employed. When the 3B board is to be installed as a separate line, a two-position section with seven 8½-inch panels is used, since this gives the most economical arrangement. All outgoing trunks appear as multiple jacks in the face of the board, and all incoming trunks terminate in cords in a single row in the keyshelf. Capacity for forty of these cords is provided at each position when the board is in line with No. 3 or 3C positions, and fifty when it is in a separate line.

As with the No. 3 toll tandem board, the 3B switchboard is arranged for automatic listening. The telephone set of an idle operator is connected automatically to any cord in her position on which a call has arrived. If a number of calls come in while the operator is busy, they are answered in order from left to right as each preceding one is disposed of. Associated with each cord, however, is a push-button type talking key through which the board can be operated on a key-listening basis should the automatic listening feature fail for any reason.

One of the features of the new board is the discriminating circuit, which recognizes the type of outgoing trunk to which a cord has been connected, and causes the position circuits to take appropriate action. If the outgoing trunk is of the ringdown type, for example, a two-second ringing signal is sent out automatically, while if it is a dialing trunk, the position dial or key-pulsing set is connected automatically, and the operator is notified that dialing or keying is required for completion of the call by the lighting of a pilot lamp.

In offices where the outward toll positions are provided with key sets, it is desirable for operating reasons to permit the operators at those positions to do the key pulsing on connections to dialing intertoll trunks, even though the trunks are secured through a tandem switchboard. The 3B discriminating circuit is accordingly arranged to recognize an incoming trunk from an outward board where this method of operation is used and to refrain from attaching the associated keyset, in spite of the fact that the outgoing trunk is one requiring key pulsing. The No. 3 toll tandem switchboard did not permit this through-keying operation.

Another feature of the 3B board is its ability to work with the new crossbar call-distributing system without modification. This system automatically directs incoming calls to idle cords in front of idle operators. When the distributing equipment is used, some or all of the incoming trunks may be connected to it instead of being permanently associated with cords at the various positions, and it provides a much more efficient use of both trunks and operators. Although this new distributing equipment can be used with the No. 3 toll tandem board, its application to that switchboard requires the modification of both the basic tandem trunk circuits and the associated incoming trunk auxiliary circuits.

Two lamps are associated with each cord on the keyshelf. The one nearer the operator, known as the "connect" lamp, lights when a call comes in to one of her cords. If she is busy on another call at the time, the lamp will burn steadily, but if she is idle, or as soon as her telephone set is connected automatically to the cord when she finishes the preceding call, the lamp starts flashing at a rate of 120 flashes per minute. At the same time a triple-zip order tone is sent back over the trunk to the originating operator. This tone is also heard by the 3B operator at reduced volume to warn her that a trunk request is about to be made. After plugging into the desired trunk, and dialing or key pulsing when required, the position "release" key is operated. When no dialing or key pulsing is required, the "release" key may be operated before the cord is plugged into the trunk jack. This puts out the connect lamp and makes the operator available for the next call.

As soon as the operator's telephone set is released, the cord is prepared to pass supervisory signals from the called point back to the originating operator. This is accomplished without bringing in any signal at the 3B board. Should an originating operator re-ring on an established connection, the signal is passed on to the trunk ahead. When the originating operator disconnects at the end of the conversation, the rear lamp associated with the cord lights as a disconnect signal.

Each position of the 3B board is equipped with a grouping key, which allows the position to be grouped with the next higher numbered one in the lineup, and by operation of keys at successive positions, any number of positions can be grouped together. When positions are grouped in this manner, an operator at one of them has access to the cords of all, and all position functions are performed by the circuits at the occupied position. When the 3B board is adjacent to No. 3 or 3C toll positions, a transfer key is provided by which the operator at the No. 3 or 3C position is given control of the adjacent 3B position and of any other positions grouped with it.

The 3B switchboard positions contain only the cord, key, and lamp equipment referred to above, the relay equipment for the operator's telephone circuit, and certain miscellaneous circuits, such as the busy back and re-order circuits. All other equipment is mounted on the relay rack, chiefly in the form of shop-wired units. The operator's control unit, which contains all equipment for the common position circuits not located in the switchboard, and the cord units, each of which contains the equipment for ten cord circuits, are of such a size that one of the former and four of the latter can be mounted on an 11-foot 6-inch relay rack bay. Since in most cases not more than forty cords per position will be equipped, a convenient grouping in one bay of all equipment associated with each position is usually possible.

The initial installation of the 3B toll switchboard is now in service in the Minneapolis toll office, with the positions in line with existing No. 3 toll positions. Here it is used as a toll tandem switchboard for handling traffic originating at outward toll positions in St. Paul and at manual "A" switchboards in Minneapolis. A second 3B switchboard has recently been installed in the Cleveland toll office. Here the new positions are in a separate line, and are used for handling calls originating at the outward toll board in the same office.

Measuring Lines for Program Transmission

I—The 19-Type Oscillator *by* S. J. Harazim

II—The 13A Transmission-Measuring Set *by* J. M. Hudack

THE operating telephone companies are frequently called upon to furnish circuits from broadcasting studios to their associated transmitters, to telephone offices on intercity program networks, or to remote pickup points such as hotels, theatres, baseball parks, or other such places for the transmission of occasional programs. The circuits usually available are not primarily designed for transmitting the wide frequency band required for broadcast programs, and require special treatment and equalization. In connection with the adjustment of the equalizers to secure the overall characteristics desirable, it is necessary to measure the transmission characteristics of the circuit that is involved.

Measurements of this type, which involve visits to the customers' premises at one or both ends of the circuit, require that a power of specified amount and adjustable in frequency be supplied to the circuit at one end, and that its magnitude, modified by the circuit, be measured at the other end. Such measurements are made at a number of frequencies over the band to be transmitted. The ratio between the sending and received testing power then gives the loss or gain of the circuit for each frequency. In order to expedite this work, small portable oscillators and transmission-measuring sets, designed to operate from commercial power supply as described in the accompanying articles, have recently been developed.

I—The 19-Type Oscillator

The provision of a portable oscillator to supply power of adjustable frequency for transmission measurements on telephone circuits was greatly simplified by the recent development of the 6A audiometer.* This is essentially a heterodyne oscillator covering the voice range and with a calibrated control for the out-

*Record, *June* 1937, *p.* 163.

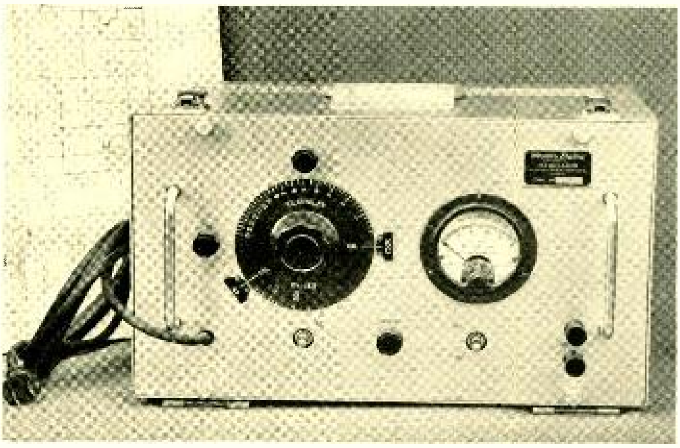


Fig. 1—*The* 19A *Oscillator*

put. By using the same basic circuit and a similar chassis construction, it was possible to use in the main the tools designed for the manufacture of the audiometer. A rugged metal case about nine inches square and fifteen inches long is provided as shown in Figure 1. All the apparatus is mounted on a welded steel chassis, insulated and suspended from a front panel. The controls project through this front panel, and are protected by a cover which protects also the terminals and the meter when the set is not in use. A handle is provided; and brackets are available as accessories to permit the oscillator to be mounted on a relay rack when desired.

The circuit comprises two oscillators each with a nominal frequency of about 110 kc. While the frequency of one of the oscillators is held fixed, that of the other may be varied over a range of about 15 kc by an adjustable condenser. The outputs of the two oscillators are combined in a copper-oxide rectifier, at the output of which appear the usual modulation products, including the sum and difference frequencies. To this output circuit is coupled a two-stage feedback amplifier. The input circuit of the amplifier is tuned to pass only the lower side-band, which will include frequencies up to 15,000 cycles. For any one setting of the adjustable condenser, therefore, only one frequency will be found; and this will be the difference frequency of the two oscillators. The amplifier is coupled to a 600-ohm output circuit, and an adjustment in the feedback circuit permits the output to be adjusted over a range from approximately 2 db below to 6 db above one milliwatt.

Frequency is controlled with a single dial, but an expanded scale is provided for the range below 200

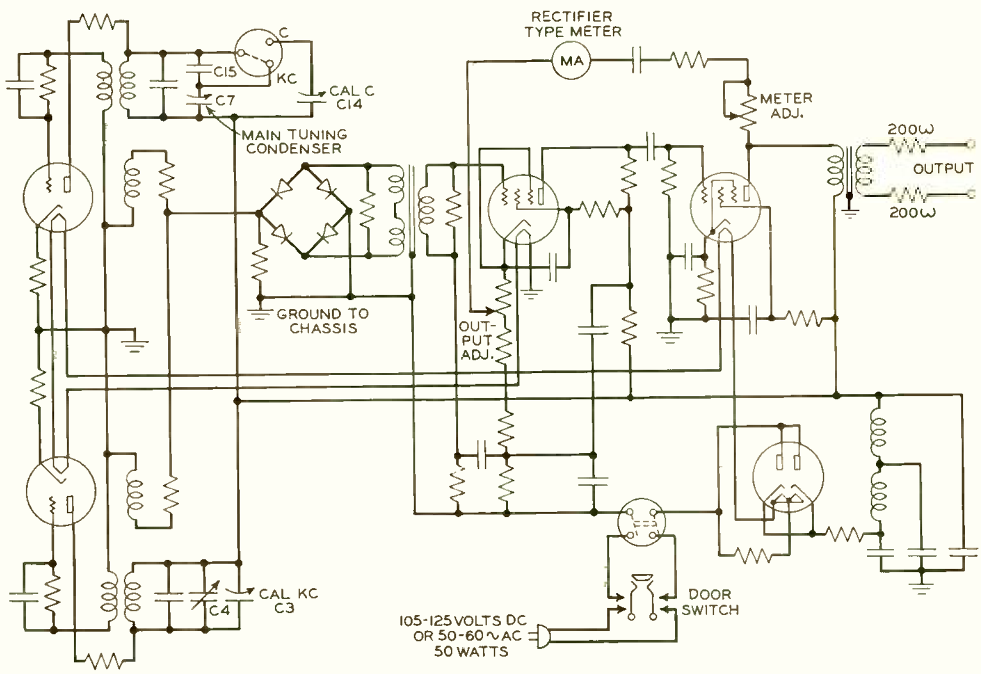


Fig. 2—Schematic circuit of the 19A *Oscillator. That for the* 19B *differs only in the addition of another condenser in parallel with* C7

cycles, and a toggle switch to transfer the control from one range to the other. This switch inserts two additional condensers when the low-frequency range is used. The circuit arrangement of the oscillator is shown in Figure 2. The main tuning condenser, C7, is controlled by the large dial on the face of the instrument. For frequencies above 200 cycles, the toggle switch is in the KC position and C7 alone controls the frequency. For low-frequency readings, the switch is moved to the C position, and both C15 and C14 are brought into the circuit, with C7 and C15 in series and C14 in parallel with them.

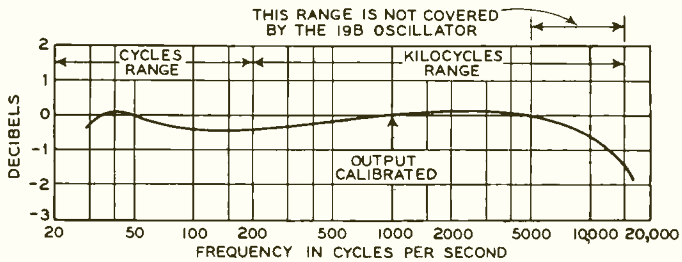


Fig. 3—The output of the 19A and 19B Oscillators is constant within 1 db over the range from 30 to 15,000 cycles

After the set has been calibrated, the only frequency controls employed are the toggle switch and the main dial. The output frequency is determined directly from the dial reading, and when the meter, which is in the feedback circuit, reads 0.3, the output will be one milliwatt, which is the level used for transmission measurements. Any variation in output can be adjusted by the output knob, which controls a rheostat in the feedback circuit.

To calibrate the set, the dial is turned to the calibrating position, shown in Figure 1, and with the toggle switch in the KC position, the

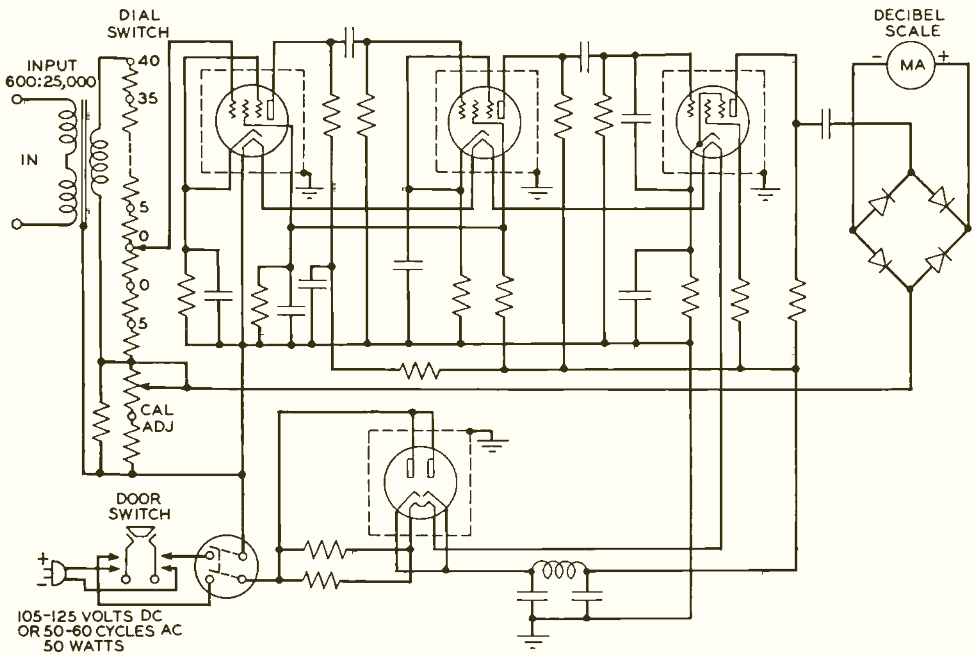


Fig. 4—Schematic diagram of the 13A Transmission-Measuring Set

KC knob at the left of the dial is turned until the meter pointer is at rest at zero. It will be oscillating around some position other than zero until the correct adjustment is reached. The toggle switch is then moved to the C position, and a second and similar adjustment is made with the C knob. The KC knob adjusts condenser C3; and the C knob, condenser C14; C4 is used only for adjustment at the factory. Since the adjustment of C3 may change the effect of C14, these adjustments may have to be repeated before the final adjustment is obtained.

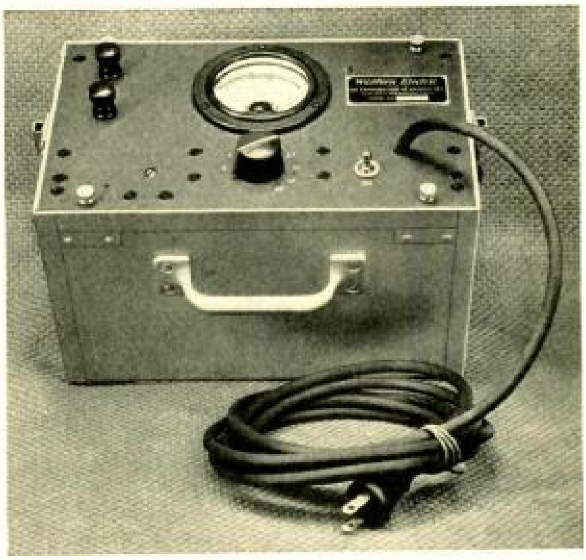


Fig. 5—The 13A Transmission-Measuring Set

The set is designed for operation from a commercial power source of 105 to 125 volts either d-c or 50 to 60 cycles a-c. In Figure 3, the output is constant to within approximately 0.5 db from 30 to 8000 cycles, and within 1.0 db over the complete range up to 15,000 cycles. The second and third harmonics and the hum from the 60-cycle power supply are down more than 27 db from the fundamental frequency. A toggle switch on the face of the instrument turns the power on or off; and a safety switch within the case interrupts the power when the oscillator is removed from the case.

Another oscillator of practically identical characteristics and construction, but with a frequency range up to only 5000 cycles, has been designed for use in maintenance of toll circuits and repeaters. This is called the 19B oscillator, and since it is intended for use only on relay racks, is furnished without the handle or cover, and instead of a cord and plug for the power supply, a receptacle—accessible from behind the rack—is mounted on the chassis. It is expected that the small size and convenient arrangement of these two oscillators will make them suitable for many applications besides those for which they were particularly designed.

II—The 13A Transmission-Measuring Set

The arrangement of this new transmission-measuring set is similar to that of the 19-type oscillator with which it will ordinarily be used. It is housed in a small metal case with handle and removable cover. Weighing only fourteen pounds, it occupies a space about eight inches square in cross-section and eleven inches long. A commercial power source of 105 to 125 volts, which may be either d-c or from 25 to 60 cycles a-c, is required and—as with the oscillator—a cord and plug is included as part of the equipment.

Except for the power switch, no controls are provided but the dial, which—in conjunction with the meter—provides a 600-ohm set capable of measuring received testing power from 0 to 45 db below and from 0 to 10 db above one milliwatt. The circuit employed, shown in Figure 4, is a three-stage resistance-coupled feedback amplifier terminating in an indicating circuit consisting of a copper-oxide rectifier and a meter calibrated in db. This meter has two scales arranged in 0.1-db steps from 0 to 5 db. One, marked in red and reading from left to right, is used for gain readings, and the other, marked in black and reading from right to left, is used for loss readings. This meter is used in conjunction with an attenuator controlled by a dial on the face of the set, as shown in Figure 5. The attenuator has red and white parts on its scale, the white for loss measurements from 0 to 40 db in 5 db steps, and the red part of the scale with only the zero and a 5-db position. The white numbers are used with the lower (black) meter scale, and the red with the upper (red) meter scale.

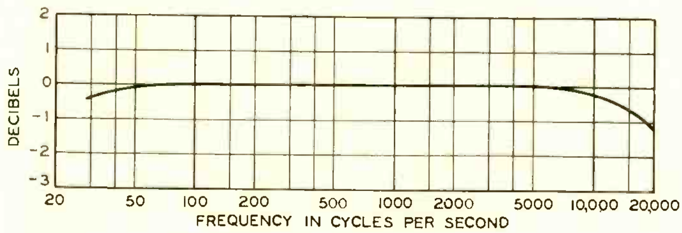
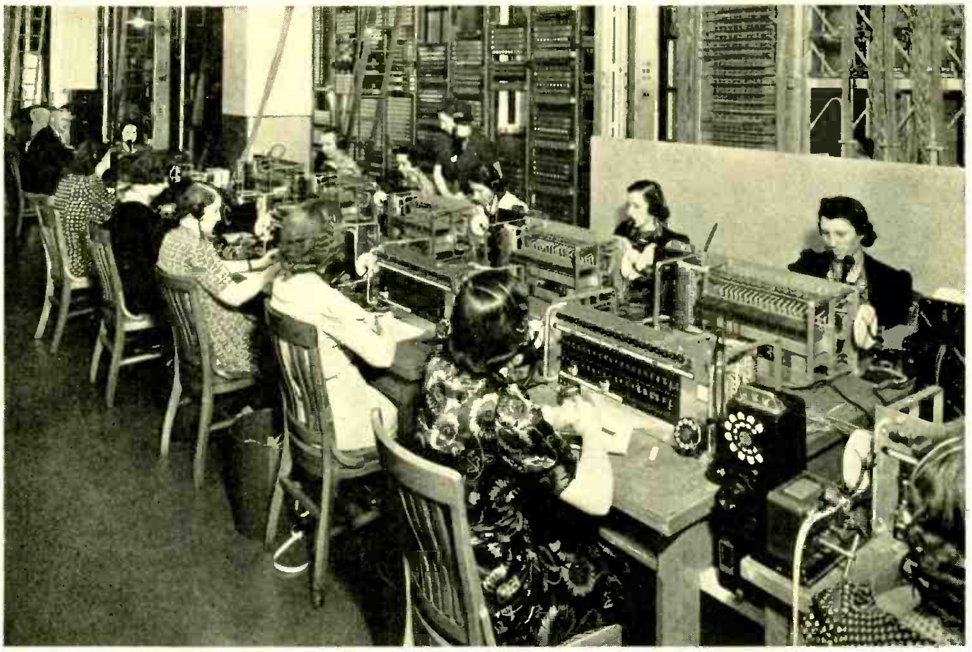


Fig. 6—Typical response characteristics of the 13A *Transmission-Measuring Set*

In operation the input of the set is connected to the circuit to be measured, and the power switch is turned on. The attenuator is then turned until a reading is obtained on the meter, and then the loss or gain in db, below or above the applied testing power, is equal to the sum of the attenuator and the meter readings. If a 600-ohm circuit is not involved, or if the testing power is not 1 mw into 600 ohms, suitable corrections are necessary.

The circuit is sufficiently stable so that only occasional calibration is required. This is accomplished by connecting the input to a one-milliwatt 600-ohm audio-frequency source, such as the 19-type oscillator, and, with the potentiometer on the white 0, adjusting a rheostat in the feedback circuit until the meter reads 0. Since this adjustment is required only occasionally, it is of the screwdriver type.

As shown by Figure 6, which is a typical characteristic, there is no appreciable deviation in the response from 80 to 5000 cycles. At 50 and 8000 cycles the response of the measuring set is down 0.1 db, and at 30 and 12,000 cycles, it is down 0.4 db.



Field Tests of the Crossbar System

By W. J. LACERTE
Field Development Department

ALL the varied apparatus and equipment of a dial central office has undergone extensive laboratory tests before the specifications are turned over to the Western Electric Company for manufacture; and during manufacture further inspections and tests are made to insure that the finished product satisfactorily meets all requirements. After a new office is installed, however, but before putting it into service, two additional procedures are carried through: first a physical inspection of apparatus characteristics and then a check by the Installation Department to see that the component elements act properly by themselves.

Under ordinary conditions an office is considered to be suitable for service if it satisfactorily passes the general Installation Department tests. For a new system, however, like the crossbar, it seemed desirable in the early installations to carry out a call-through test as well. This makes doubly sure that nothing has been overlooked, and that the various components function properly as parts of a complex system; and it gives the maintenance forces an opportunity to become familiar with the equipment before the cut-over. In such a test large numbers of calls are put through the office by a group of special operators trained for the work.

The first crossbar office to go into service was President-2 in Brooklyn, which is a relatively small office serving a residential area. The second was

Murray Hill-6, a full 10,000-line unit serving subscribers in the concentrated Grand Central area in Manhattan. The first of these offices was put in service in February, 1938, and the Murray Hill office in July of the same year. A summary of the equipment that is used in these two offices is given in Table 1.

The general installation tests required were conducted by the installation Department of the Western Electric Company following test methods written by their engineers based on requirements outlined by the Laboratories. These instructions were written with a view toward standardization for future jobs. The call-through tests were also conducted by the Installation Department. Their procedures were written and the tests directed by a Committee with representatives of the American Telephone and Telegraph Company, Western Electric Company, New York Telephone Company, and Bell Telephone Laboratories.

The general installation tests were started directly after the cabling period was completed and continued until the start of call-through tests. The tests consisted of what is generally termed supplementary and routine tests. The supplementary tests comprised those that were made only once and the routine tests those that were repeated at specific intervals.

Included in the supplementary group were such tests as verification of cabling connections and interframe wiring, electrical check of continuity of all crossbar-switch crosspoint contacts, check of contact protection units and non-inductive resistances, and verification that leads which loop to several places were free from false connection to ground or battery supply, and not crossed with other leads.

Routine tests were made at regular frequency on those circuits installed in quantities, such as senders, markers, district junctors, and incoming trunks. They followed methods based on performance requirements issued by the Laboratories which stated the frequency with which each test was to be made and the permissible number of failures.

The performance requirements covering routine tests of originating markers specify, for example, that no failure is allowable over the last two cycles of tests made before the acceptance date and that the acceptance cycle is to be made with a maximum frequency of once a working day and a minimum frequency of once every five working days. These requirements were met by the six originating markers at Murray Hill-6 office and the three originating markers at President-2 office. A similar procedure was followed with routine tests of other types of circuits. Since the circuits were of new design, the requirements were of a tentative nature, established to obtain a performance equal to and in some cases better than that of corresponding circuits of other systems. In practically all cases, regular testing circuits which were subsequently to be used for maintenance were used to apply the routine tests.

TABLE 1

	PRESIDENT-2	MURRAY HILL-6
Equipment Frames	65	289
Line Equipments	3230	9880
Crossbar Switches	538	2535
"U" & "Y" Type Relays	15816	70968
Multi-Contact Relays	1183	5686
Relays of Other Types	5357	22086

This thorough testing disclosed a

few irregularities due to design and to variations in the manufactured product which were not encountered in laboratory tests of a few samples. All such irregularities were investigated both in the central offices and in the Laboratories.

The call-through test program consisted in completing calls of various classes involving the crossbar equipment. Approximately 350,000 call-through test calls were made in President-2 office and 285,000 in Murray Hill-6 office. They were made at random by test operators, each provided with twenty-line sending and receiving test units. These units are in general like the call-through test set already described in the RECORD,* but were modified to meet the conditions of mass sending. The lines selected for test were distributed over all the line groups, and some connections were held so that several channels were busy periodically, thereby bringing into use a comprehensive number of paths through the office. Observations were made on some of the test calls, using standard service observing methods, to enable the Traffic Department to rate the service according to its usual standards. In so far as possible the proposed standard maintenance practices and procedures that have been developed were used in locating and clearing trouble encountered on these test calls.

During most of the testing, the test operators held all the connections on which trouble was encountered so as to enable the maintenance force to trace the call and locate the fault with least delay. To obtain a more representative picture of service conditions, however, the test procedure was varied for a period of time, and the test operators were allowed to simulate subscribers by not holding calls for tracing but depending on regular maintenance facilities for detection of troubles. During this later period a "subscriber's" complaint was originated only when a test operator could not complete the call on repeated attempts. Also, a special high calling-rate test was made to show the ability of the system to store calls in its senders and complete them as quickly as the equipment became available. This was done by allowing twelve to sixteen test operators to originate calls as rapidly as possible from and to certain line frames, and observing for proper completion.

The results of the call-through tests and service observations indicated that the crossbar office, although new and thus lacking some refinements that follow extensive service experience, would give a grade of service somewhat better than the older types of dial offices. Since cut-over, the service performances of both offices are being observed closely; and the maintenance results are being carefully examined and analyzed for irregularities arising from peak traffic loads and from other conditions that may be introduced by subscribers.

*RECORD, *Oct.* 1938, *p.* 38.

Beat Notes in High-Frequency Calibration

By F. R. STANSEL
Apparatus Development

FOR some time oscillators have been calibrated with a cathode-ray oscillograph by applying a standard frequency to one pair of plates and the frequency of the oscillator under calibration to the other. The oscillator's frequency is varied until one of the well-known Lissajou figures shows that its frequency is a multiple of the standard frequency. This multiple may be two to one, three to one, four to one, or even as high as 500 to one. It may also be a more complex ratio such as three to two, five to two, or four to three, but for each pattern the ratio is definitely known. By using these patterns and several standard frequencies such as 100, 1000, 10,000 and 100,000 cycles, oscillators may be calibrated from frequencies of a few cycles to over one megacycle. The method has in fact been used in making calibrations as high as thirty megacycles.

At the higher frequencies—above about one megacycle—this method encounters difficulties because the Lissajou patterns are stationary only when the frequencies are in exact ratio. If one frequency is higher or lower than the exact value the pattern moves. The number of cycles by which the frequencies may differ before the pattern becomes blurred is a fixed quantity of a few cycles regardless of the frequency of the oscillator under calibration. Thus the adjustment of a frequency of 5000 cycles to within five cycles involves adjusting to only one part in a thousand, but the same adjustment at five megacycles has to be within one part in a million. The frequency of the oscillator must also remain stable within these limits long enough for the operator to recognize the pattern. Unless the oscillator has an exceptionally fine scale and is quite stable, the operator will sweep through the standstill point of the Lissajou figure without recognizing it. When calibrating oscillators at high frequencies a wavemeter usually is used as auxiliary equipment to locate the patterns and insure that a pattern is not skipped.

Another method of comparing frequencies is to apply the standard and unknown frequencies to the input of a vacuum tube and listen to the beat note formed by their difference. Harmonics and other modulation products generated in the vacuum tube permit hearing these beats at the frequency ratios at which Lissajou figures occur. The higher the order of these modulation products the lower, in general, is their loudness.

As in the case of the Lissajou figures, the amount the unknown frequency may deviate from the exact value sought before the beat tones become unrecognizable is independent of frequency, but with beat tones the difference is increased to the audible range of the ear instead of being the few cycles permissible with Lissajou figures. That is, the frequency may differ by 5000 or more cycles. Thus the preliminary adjustment of an oscillator to be calibrated at five megacycles is changed from locating the frequency to within about five cycles, which is one part in a million, to that of locating the frequency to within about 5000 cycles, which is only one part in a thousand. When the approximate setting of the oscillator has been found, the oscillator's frequency is slowly varied in the direction which causes the frequency of the beat note to decrease. The exact calibration point is the "zero beat" point, that is the point at which the frequency of the beat note becomes inaudibly low.

This principle is used in equipment recently built by the Laboratories to calibrate oscillators from one to fifty megacycles. The standard frequency is obtained from a one-megacycle oscillator controlled by quartz plates with low temperature coefficients. This standard oscillator is equipped with a small vernier condenser capable of shifting its frequency a few cycles and a small cathode-ray oscillograph is permanently connected so its frequency can be monitored against the laboratory 100-kc standard.

The oscillator under calibration is connected to the grid of a modulator tube through an amplifier tube and a tuned circuit as illustrated in Figure 1. When Lissajou figures are used it is possible to tell exactly what the ratio is by counting the loops in the simpler figures. With the beat-note method this check is not available because the pitch of a beat note depends on the difference in frequency of the two inputs and is independent of the frequency of either of them. The approximate calibration of the tuned circuit, read directly from the dial, tells to which of the many harmonics of the standard the oscillator under calibration is tuned. The tuned circuit also suppresses noise.

An additional check is afforded by using a five-megacycle oscillator as a second standard. To determine whether the oscillator is adjusted to fourteen or fifteen megacycles, for example, the modulator tube may be switched to the five-megacycle standard. There will be a beat note against the third harmonic of the five-megacycle standard if it is at fifteen megacycles and none if it is at fourteen megacycles.

With this equipment, points one megacycle apart can be found up to well over thirty-five megacycles, but frequently it is necessary to calibrate oscillators at closer intervals. This is accomplished by passing the standard frequency through an auxiliary modulator tube before applying it to the main modulator. On a second grid of this auxiliary tube the laboratory

100-kc standard is impressed so that the output of the tube consists of one megacycle (or five megacycles) heavily modulated by 100 kc. When these frequencies are applied to the main modulator tube, beat notes may be found every 100 kc throughout the range of the oscillator. This 100-kc modulation may be shut off so that points every megacycle may be located first. The modulation is then applied and ten intermediate points filled in between each megacycle point. Under some circumstances, 50-kc points due to higher order modulation products may be found between each of the 100-kc points. These may be distinguished by lower intensity.

The equipment is mounted on a relay rack, illustrated in the headpiece. The large dial which controls the tuned circuit has seven scales corresponding to the seven coils used to cover the frequency range. Other switches control the input from the unknown, the selection of the one- or five-megacycle standard and the application of the 100-kc modulation.

The second panel from the top contains the two quartz oscillators and the oscillograph tube, which monitors the one-megacycle standard. Jacks on the panels allow these oscillators to be used for other purposes and switches in the plate circuits of the oscillators are provided for cutting them out.

The top unit is a commercial audio-frequency meter which may be connected to measure the frequency of the beat note. This meter is useful when studying the variation in an oscillator's frequency because of load, supply voltage or other reasons. The oscillator is tuned to a suitable beat note and the frequency of this note measured directly on the meter. Then the load or other variable is changed and any change in the beat note recorded. The change in frequency of the beat note is equal to the change in oscillator frequency.

The lower panel contains a power supply for the entire equipment.

This new apparatus while not superseding any of the older equipment offers a simpler and more rapid method of calibrating oscillators above one megacycle, and also provides a simple and effective method of studying oscillator stability in this range.

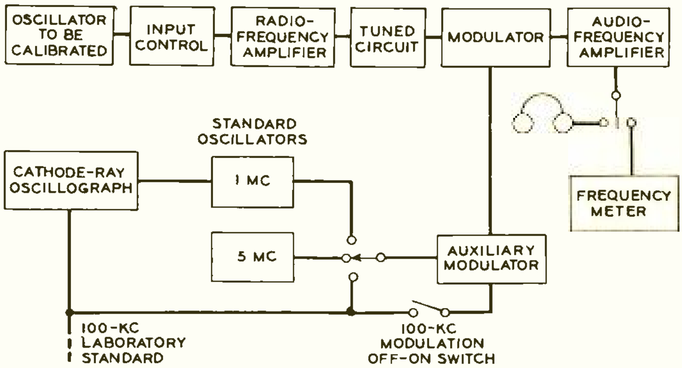
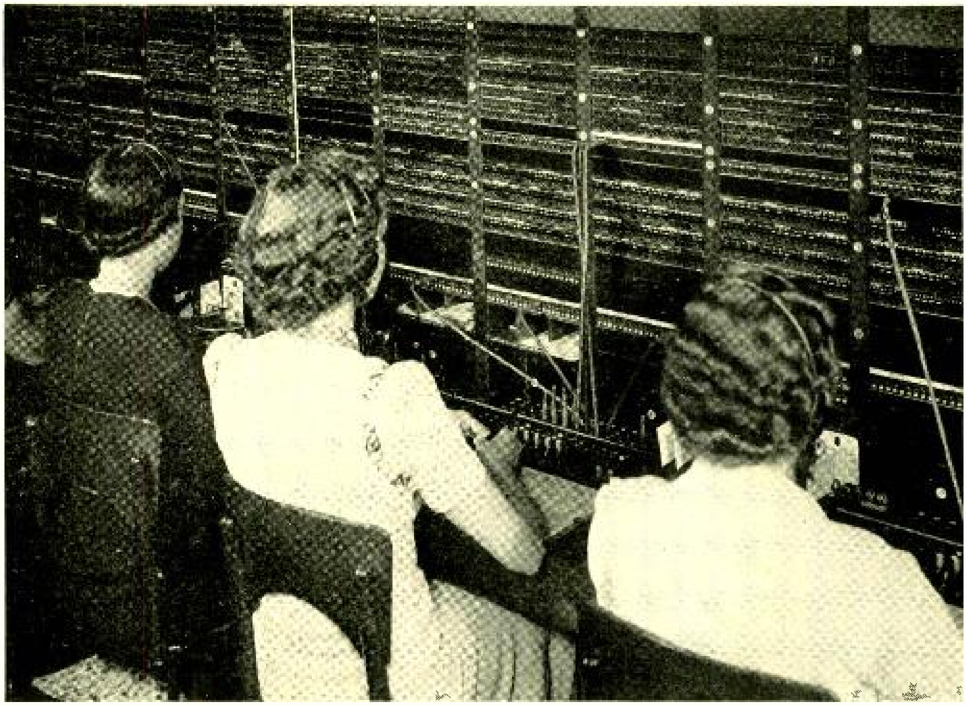


Fig. 1—The oscillator to be calibrated is connected through an amplifier and a tuned circuit to the grid of a modulator tube. Beat tones heard in the earphones determine the calibration. The standard frequencies are obtained from oscillators controlled by quartz crystals. The auxiliary modulator permits finding beat tones 100 kc apart up to over 35 megacycles



Operator-Training Facilities at Toll Switchboards

By A. M. ELLIOTT
Toll Facilities Department

EMPLOYEE training is carried on extensively by the Bell System and contributes substantially to giving day-to-day telephone service an outstanding quality that is recognized throughout the world. Telephone switchboard operators comprise one of the largest of these employee groups and the maintenance of this organization of operators requires the extensive training of some 25,000 new employees each year.

In the very early years of the telephone, training procedures were quite simple, but with rapid growth and increasing requirements for good service, training schools were established by the operating companies. In larger offices these schools became important organizations, with special classrooms, demonstration equipment, and staffs of full-time instructors. Students in groups of as many as fifteen or twenty were assigned to an instructor, and spent practically all their time in classroom work. Here the instructor described and demonstrated the work to be performed; and the students were supplied with textbooks from which they studied the standard methods of handling calls. Their opportunity to do actual operating at a switchboard was confined to training positions entirely separated from working switchboards, and each student's time at this work was very limited because cost and fluctuating demand did not justify the establishment of large training installations.

Many thousands of switchboard operators were successfully trained along these somewhat academic lines, but application of recent advances in vocational guidance to operator training has shown that the interest of new employees is raised and maintained in proportion to the promptness with which they are permitted to do actual operating at a working switchboard.

Both dexterity in handling cords and plugs and the understanding of their functions, for example, are gained more easily and in less time when description accompanies actual use of the apparatus. This applies also to other phases of the skill and knowledge required for operating. Consequently the new training facilities recently made available for Nos. 1, 3 and 3C toll switchboards provide for training operators at regular working positions at the toll board during light-load periods. The positions selected for this use have been modified somewhat to permit the students to handle practice traffic under a variety of conditions, without interfering in any way with normal use of these same positions for handling regular toll traffic when desired.

Preliminary discussions between students and instructors, and drills on certain basic operations, are conducted at unoccupied positions of the switchboard or, if none are available, in a corner of the operating room. The instructors are regular switchboard supervisors who take turns in this important activity. Operating is learned as it appears to an operator at work—by handling calls. The practice positions are in groups of two. A third switchboard position, called a control position, is associated with the two practice positions for the purpose of forming a training unit.

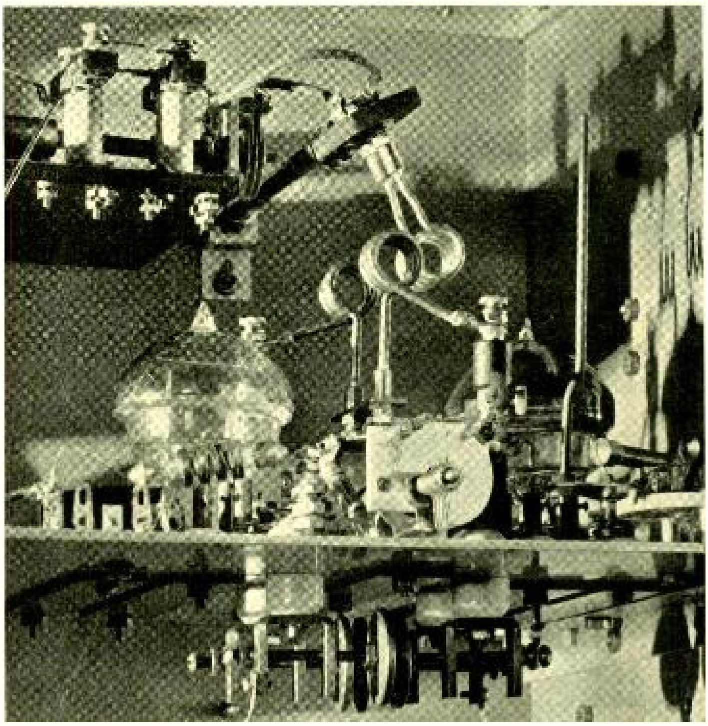
The control operator is an experienced assistant who handles practice traffic with the students as directed by the instructor. All three positions of the training unit are separated by at least two regular positions each so that students have experienced operators working on each side of them and no operator has more than one student adjacent to her.

Facing the operator at a typical toll position are jacks of the outgoing toll trunks. These are arranged in groups according to the toll points to which they connect. Below these are jacks for incoming calls from subscribers. At the student positions certain of these jacks are specially marked, and the student operators are instructed to complete calls only between these marked jacks. The trunks connected to these jacks extend to the control operator's position so that she is able to act either as a subscriber placing and receiving calls handled by students, or as another operator in the same or a distant office. She receives operating signals on these training trunks which indicate whether the students are handling the calls correctly, and she may give instructions directly over their telephone sets when desirable.

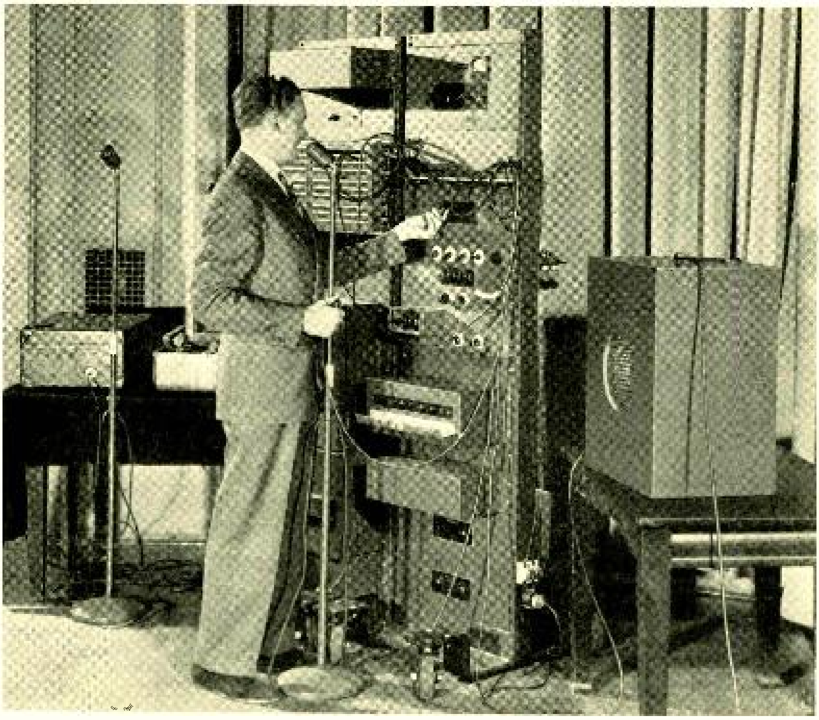
Delays are sometimes encountered and the calling subscriber is called to his telephone when the call can be completed. To provide training of this nature, provision is made for terminating at the control position a number of regular subscribers' lines from one or more local offices. The student operator reaches these lines by passing the call through the local office in the regular manner. The control operator can make busy the line which the student is calling, so that repeated attempts will be necessary to complete the call. A key mounted in the upper part of the control position is provided for inserting an additional loss of 8 db or 15 db in the transmission paths between the control operator and the students to train the students in understanding conversations under operating conditions.

Provision is also made for the students to listen in on the work of regular operators through one-way monitoring amplifiers that do not affect the circuit to which they are connected. In this way the students become familiar with the normal handling of calls. The control operator can talk to the students while they are monitoring and is thus able to make comments on the various steps.

With the new arrangements students find the work more interesting and learn more rapidly. Although the instructor cost per student per day is higher, this is more than offset by more rapid learning, and by the release of classrooms, equipment and space formerly required. A further advantage is that from the very beginning the students are in contact with those who will act as their supervisors later, and more quickly adapt themselves to normal operating conditions.



Section of an ultra-high-frequency oscillator for laboratory use



The Vocoder

By HOMER DUDLEY
Circuit Research Department

AT THE World's Fairs in New York and San Francisco great interest was shown in the speech synthesizer in the Bell System exhibits. Known as the Voder, this device creates spoken sounds and combines them into connected speech. Its raw materials are two complex tones, a hiss and a buzz; selection of one or the other and its intensity and tone quality are controlled by an operator through a keyboard.*

The Voder is an offshoot of a more extensive system, first demonstrated† in its experimental stage some three years ago. That system analyzed spoken sounds, and then used the information to control the synthesizing circuit. At the time World's Fair displays were under consideration, so it was naturally perceived that the synthesizer, manually controlled, could be made into a dramatic demonstration. Development was for a while concentrated in that field; as a successful Voder became assured, attention was shifted back to the broader and parent system. Shortly thereafter the system was given the name "Vocoder" because it operates on the principle of deriving voice codes to re-create the speech which it analyzes.

Figure 1 shows the over-all circuit for remaking speech; the analyzer is

*RECORD, *Feb.* 1939, *p.* 170.
†RECORD, *Dec.* 1938, *p.* 98.

at the left and the synthesizer at the right. Electrical speech waves from a microphone are analyzed for pitch by the top channel and for spectrum by a group of channels at the bottom.

In the pitch analysis the fundamental frequency, which for simplicity will be called the pitch, is measured by a circuit containing a frequency-discriminating network for obtaining this frequency in reasonably pure form; a frequency meter for counting, by more or less uniform pulses, the current reversals therein; and a filter for eliminating the actual speech frequencies but retaining a slowly changing current that is a direct measure of the pitch. (Unvoiced sounds, whether in whispering or the unvoiced sounds of normal speech, have insufficient power to operate the frequency meter.) The output current of the pitch channel is then a pitch-defining signal with its current approximately proportional to the pitch of the voiced sound and equal to zero for the unvoiced sounds.

There are ten spectrum-analyzing channels,* the first handling the frequency range 0-250 cycles and the other nine, the bands, 300 cycles wide, extending from 250 cycles to 2950 cycles, a top frequency which is representative of commercial telephone circuits. Each spectrum-analyzing channel contains the proper band filter followed by a rectifier for measuring the power therein and a 25-cycle low-pass filter for retaining the current indicative of this power but eliminating any of the original speech frequencies.

The operation of the analyzer is illustrated in Figure 2 by a group of oscillograms taken in analyzing the sentence "She saw Mary." To insure that the same speech was analyzed in obtaining the various oscillograms, the sentence was recorded on a high-quality magnetic-tape recorder and reproductions therefrom supplied current to the analyzer. The speech-

*A 30-channel vocoder covering the wide range of speech frequencies required for high quality has also been built and is being used as a tool in laboratory investigations.

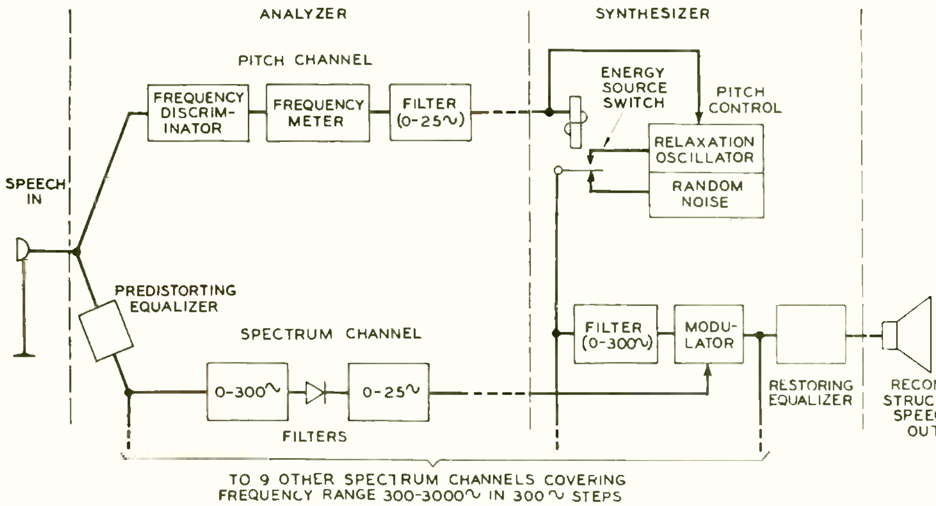


Fig. 1—Simplified schematic of the Vocoder

wave input to the analyzer is shown in the line next to the bottom while the output is shown in the other oscillogram traces; the pitch-defining signal is at the bottom in the figure and the ten spectrum-defining signals in numerical order at the top. For convenient reference the oscillograms are lined up together whereas in the actual circuit the speech-defining signals lag about 17 milliseconds behind the speech-input wave. The inaudible speech-defining output signals contain all the essential speech information as to the input wave, but it is to be noted that they are slow-changing and in this way correspond to lip or tongue motions, as contrasted with the higher audible vibration rates of the rapid-changing speech wave itself. The dropping of the pitch to zero for the unvoiced sounds "sh" and "s" is also readily seen.

Figure 2 gives an idea also as to the synthesizing process. In the analyzer the speech wave is the input and the eleven speech-defining signals are the output; in the synthesizer the eleven speech-defining signals are the input and the speech wave the output.

The steps in speech synthesis are indicated at the right of Figure 1. The relaxation oscillator is the source of the buzz; and the random noise circuit the source of the hiss. The hiss is connected in circuit for unvoiced sounds and for quiet intervals. (In the latter case no sound output from the synthesizer results because there are no currents in the spectrum channels.) When a voiced sound is analyzed a pitch current other than zero is received with the result that the buzz is set for the current pitch by the "pitch control" on the relaxation oscillator; also, the relay marked "energy source switch" operates, switching from the hiss source to the buzz source.

The outputs from the spectrum-analyzing channels are fed to the proper synthesizing spectrum controls with the band filters lined up to correspond. The power derived from the energy sources of the synthesizer in these various bands is then passed through modulators under the control of the spectrum-defining currents. The result is that the power output from the synthesizer is sensibly proportional in each filtered band to that measured by the analyzer in the original speech. From the loudspeaker comes, then, speech approximately the same in pitch and in spectrum as the original. This synthetic speech lags the original speech by about 17 milliseconds due to the inherent delay in electrical circuits of the types used.

In the present models of the Vocoder, control switches have been introduced which permit modifications in the operation of the synthesizer. Through the manipulation of these controls interesting effects are produced. Some of the possibilities of the Vocoder were recently demonstrated by the author and his associate, C. W. Vadersen, before the Acoustical Society of America and before the New York Electrical Society. In those presentations Mr. Vadersen supplied by his own voice the incoming speech which was picked up by a microphone as shown in the headpiece; and at the same time he manipulated the controls to produce desired effects. A remote-control switch was also provided through which, for purposes of comparison, the author could switch the microphone directly to the loudspeaker and so let the audience hear how the speech would sound if it had not been modified by the Vocoder.

In these demonstrations comparison is first made between direct speech and the best re-creation that the apparatus could make. Then by manipulation of dials and switches, speech is modified in various ways. Normal speech becomes a throaty whisper when the hiss is substituted for the buzz. Although the hiss is relatively faint, it is shown to be essential for discrimination as between "church" and "shirts."

Ordinarily the re-created pitch moves up and down with that of the original. If variation is prevented, the re-created speech is a monotone, like a chant. When the relative variation is cut in half, the voice seems flat and dragging; when the swings are twice normal, the voice seems more brilliant; when four times normal it sounds febrile, unnatural. The controls can be reversed so that high becomes low: the tune of a song is then unrecognizable, and speech has some of the lilting characteristics of Scandinavian tongues. Another control fixes the basic value of the re-created pitch; if this is "fluttered" by hand, the voice becomes that of an old person. By appropriate setting of the basic pitch, the voice may be anything from a low bass to a high soprano, and several amusing tricks can be performed. In one of these, the basic pitch is set to maintain a constant ratio of 5 to 4 to the original. This is a "major third" higher and harmonizes with the original. In two-part harmony, the demonstrator then sings a duet with himself. Connecting a spare synthesizer set for a 3 to 4 ratio he then sings one part in a trio, the others being taken by his electrical doubles. Finally, with the basic pitch-control of the apparatus, he becomes a father reprimanding his daughter; then the girl herself, and then becomes the grandfather interceding for the youngster.

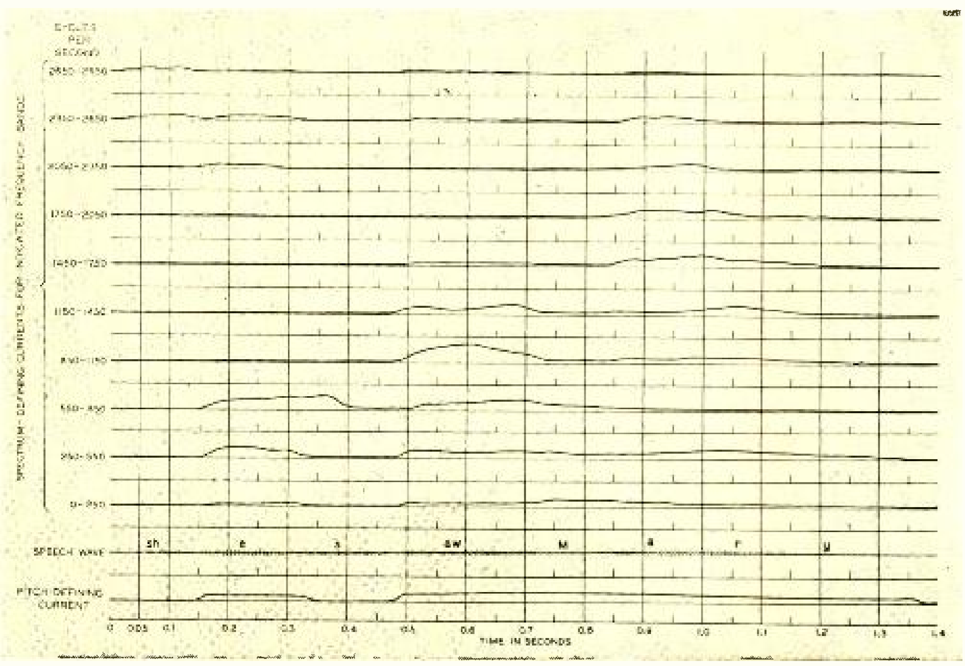


Fig. 2—The original speech wave and an analysis of its components, expressed as the variation of several direct currents

For the vocal-cord tones of the original, the Vocoder substitutes the output of a relaxation oscillator. But any sound rich in harmonics can be used: an automobile horn, an airplane roar, an organ. In some demonstrations, the sound, taken from a phonograph record, replaces the buzz input from the oscillator. Keeping careful time with the puffs of a locomotive, the demonstrator can make the locomotive puff intelligibly "We're - start - ing - slow - ly - faster, faster, faster" as the puffs come closer together. Or a church bell may say "Stop - stop - stop - don't - do - that." A particularly striking effect is that of singing with an organ to supply the tones. Although the words may be spoken, the demonstrator usually sings them to hold the rhythm. It makes no difference whether his voice is melodious or not; the tonal quality comes only from the musical source.

These tricks and others have suggested uses for the Vocoder in radio and sound pictures. It appears to have possibilities as a tool in the investigation of speech, since by its numerous controls important variables in speech can be isolated for study. The engineering possibilities which may grow out of the application of the principles employed in this device are hard to predict at the present time. The speech-defining currents, however, do have features of simplicity and inaudibility which may open the way to new types of privacy systems or to a reduction in the range required for the transmission of intelligible telephonic speech.

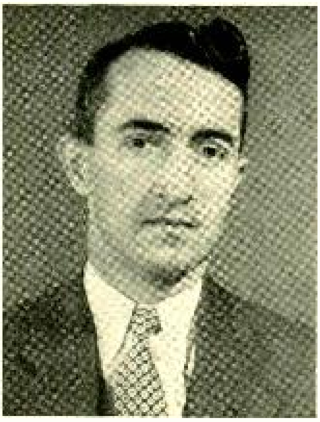
Contributors to this Issue

J. C. Greene received the A.B. degree from Harvard in 1921 and spent the following year at Trinity College, Cambridge University, England. He then took two years' graduate study at the Harvard Engineering School, and received the degree of S.B. in Mechanical Engineering in 1924. He at once joined the Technical Staff of the Laboratories, associating with the apparatus analysis group in the Physical Laboratory of the Apparatus Development Department. The following year he transferred to the Equipment Development Department, and for the next ten years was with the current development and toll switchboard equipment groups. In 1935 he transferred to the Toll Facilities Department, where he has since been concerned with development and maintenance problems associated with toll-switching systems.

A. M. Elliott joined the Western Electric Company at Hawthorne in 1923, where he designed equipment and methods for testing vacuum tubes, thermocouples and switchboard lamps, and later conducted inspection control surveys on carrier and repeater apparatus. In 1925 he transferred to the Installation Department of the Western Electric Company at New York with a group preparing the Handbooks used in testing toll equipment. Two years later he came to the Laboratories as Field Engineer in the Inspection Engineering Department and later was in charge of the Complaint Bureau. In 1938 he transferred to the Toll Facilities Department where he has been concerned with toll switchboards.

W. J. Lacerte joined the Laboratories immediately after receiving his B.S. degree in Electrical Engineering from Kansas University in 1923. For a few years he was engaged in laboratory testing of circuits for dial offices and private branch exchanges, and later conducted studies in the field on trial installations of circuits of these types. Since June of 1937

J. C. Greene



A. M. Elliott

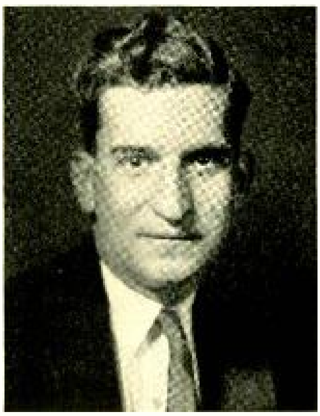
W. J. Lacerte

he has been concerned with field work associated with the first three installations of the crossbar system.

F. R. STANSEL received the B.S. in E.E. degree from Union College in 1926 and the M.E.E. degree from Brooklyn Polytechnic Institute in 1934. He joined the Laboratories in 1926 and until 1936 was assigned to the Whippany Laboratory where he was engaged in the design of high-power radio transmitters for broadcast and transatlantic service. Since 1936 he has been associated with the development of oscillators and detectors for testing purposes.

HOMER DUDLEY has been a member of the Research Department since his graduation from Penn State where he received the degree of B.S. in Electrical Engineering in 1921. His first work related to the transmission features of local telephone systems. Then for several years he supervised work on voice-operated circuits for transatlantic radio, long lines and submarine telephone cables. In 1930 his activities were diverted to research and development problems on coaxial-conductor systems. For the past five years he has been engaged in the design and construction of the speech-analyzing and synthesizing circuits which are described in this issue of the RECORD. He received the degree of M.A. in Physics from Columbia in 1924.

F. R. Stansel



Homer Dudley

H. C. MONTGOMERY received an A.B. at the University of Southern California in 1929 and an M.A. at Columbia in 1933. Since joining the Research Department of the Laboratories in 1929 he has been engaged largely in studies of hearing acuity and related problems in physiological acoustics. More recently his attention has been given to investigations in speech analysis.

J. M. HUDACK joined the Laboratories in 1916 as a member of the Transmission Research Department. Beginning at an early date he assisted in development

H. C. Montgomery *J. M. Hudack* *Stanley Harazim*

work on testing apparatus. From 1924, when he received a B.S. degree at Cooper Union, until 1928 he was with the Special Products Division of the Apparatus Development Department where he was engaged in work on power line carrier telephone, public address, and loudspeaker equipment. Since 1928 he has been engaged in the development of testing apparatus such as oscillators, detectors, harmonic analyzers, phase-measuring sets and similar apparatus.

Stanley Harazim joined the Engineering Department of the Western Electric Company in 1919 and immediately engaged in the drafting of electrical apparatus and in routine engineering, and later prepared manufacturing, testing, and conversion specifications on miscellaneous apparatus. In 1923 he graduated from the Technical Assistant Course, and in 1926 received the M.E. degree from Brooklyn Polytechnic Institute. Returning to the Laboratories in 1929 from a two and one-half years' leave of absence, he joined the apparatus analysis group where he was concerned with tests simulating service conditions of new designs of telephone apparatus. Since 1930 he has been engaged in the design of miscellaneous electrical apparatus; including a three years' period in the mechanical development of various units of transmitting equipment for broadcast and shipboard use, and several years in the design of testing apparatus, such as oscillators, amplifiers, analyzers, potentiometers, and specialized test sets.