Improving the Service Life of Storage Batteries

C. H. ACHENBACH
Power Development

That old proverb "you never miss the water 'till the well runs dry" never is more applicable than where storage batteries are concerned. Anyone who drives an automobile is quite likely, particularly if his car is two or more years old, to experience, sometime, that helpless feeling when his car won't start because the battery is "dead."

In the Bell System, the condition of central office storage batteries must *never* be permitted to reach a questionable stage. Storage batteries are a major item among the Bell System's many devices designed to provide continuity of service.

In the early days, these batteries were used for signaling purposes and to provide the power necessary for talking; at that time, two sets of batteries were used, one being discharged by the office load while the other was being charged. For the past twenty-five years or so, the practice has been to "float" the batteries—that is, a voltage from an external source is continuously applied to the battery. This voltage is closely held by regulating devices at 2.15 volts per cell under all load conditions.

Under these conditions power does not flow out of the battery but a small amount of charging current — just enough to offset the internal losses inherent in all batteries — flows into it. The energy needed for signaling and talking is obtained from the charging units—which may be motor-generator sets or any number of different types of rectifiers — and the battery is always fully charged. If commercial power should fail, the battery is always ready to take over the office load until the reserve engine-generator sets are started.

During the normal operation of a storage battery, the negative active material, sponge lead, and the positive material, finely divided lead dioxide, are both converted into lead sulfate during discharge, the process being reversed on charging. Even on open circuit, there is a slow discharge, about 25 per cent of total charge per month (on low gravity batteries), caused by the action of the sulfuric acid on the lead, resulting in the formation of lead sulfate and hydrogen.

To guard against this sulfation, it was recommended by the battery manufacturers

that the batteries be overcharged at a voltage higher than 2.15 volts per cell at about once a month intervals. This was to break up or drive off the sulfation from the negative plates before it is formed into hard crystals of lead sulfate that could not be removed by any amount of overcharging. The charging voltage is therefore raised about 7 to 15 per cent above the floating voltage and held there for a number of hours. Bell System practice has been to use a voltage of 2.3 volts per cell, holding the overcharge for about 16 hours.

During this period of overcharge, the higher voltage on the battery must be reduced to the proper limits required by the central office equipment. This is done by inserting "counter cells" into the circuit, cells with the polarity reversed. Because of the large amounts of current required in the larger central offices — thousands of amperes in some instances — the massive bus bars, circuit maintaining switches and control equipment needed to cut the counter cells in and out of the supply leads, are large and expensive.

Although there has been considerable controversy over the best method of maintaining batteries to obtain optimum life, battery engineers agree that if a battery were floated at a somewhat *lower* voltage than 2.15 volts per cell, the negative plates would sulfate, and if continued for some months, this would harm the battery beyond repair. On the other hand, if the battery is subjected to frequent overcharging, there is danger of loosening the lead dioxide in the positive plates and of weakening the lead grid of the positive plates by corrosive action. Was it possible that the insistence on frequent overcharge was merely a means of "playing it safe," since you could ruin a battery in a short space of time by underfloating (with consequent sulfation), whereas the overcharges would merely reduce the battery life by a few months, or a year or two at the most?

One might question the need for frequent overcharging, if the battery were properly floated so that sulfation could not take place. Guarantees of the battery manufacturers, however, were given on the basis that the batteries be fully floated and

Servicing storage batteries in one of the larger type power plants used to supply several central offices in the New York area.

periodically overcharged. The better batteries were guaranteed for 14 years.

In 1935, the first fully automatic power plant for central office use was ready for installation, and Roanoke, Virginia, was selected for the first trial. Not only is the central office voltage held very close in this equipment, but the charging units are automatically started and stopped as the office load grows and diminishes. Here was a chance to test the necessity of frequent overcharging under floating conditions that were favorable to such a trial. No provision for overcharging was made except that once a year the battery is floated at 2.2 volts per cell for one week. Three parallel strings of heavy duty, fourteen-year batteries were installed in the Roanoke office early in 1938, and have been well maintained since that time.

A capacity test of these batteries was made in 1946. Besides showing the capacity substantially unchanged, there was no sign of sulfation on the negative plates, and

no sediment in the bottom of the battery jars. (Sediment consists of particles of lead dioxide which are knocked off the positive plates when the batteries are overcharged.)

As a result of this test and examination, maintenance practices on all batteries were changed to reduce the number of overcharges per year, thus eliminating much of the voluminous record keeping — a substantial saving in itself.

Since the Roanoke batteries were in such excellent condition after 8 years of service, it was decided that future power plants should be engineered on the basis of omitting counter cells and their associated equipment. The first power plants developed without provision for overcharging the batteries were those needed for the TD-2* radio relay equipment. Omission of the counter cells made the power circuits less complex and considerably less expensive, especially since 12-volt, 130-volt, and 250-volt supplies are required for these installations. And the over-all annual savings due to omitting counter cells in all the various power plants will run into hundreds of thousands of dollars, with a further saving in maintenance expense.

The decision to omit overcharging of batteries was made after eight years of observation on fourteen-year batteries. Early in 1951, after thirteen years of service, further capacity tests were made on the Roanoke batteries, and again they were found to be in good condition and still have over 100

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per cent of rated capacity. Battery requirements for telephone plants have been calculated on the basis that only 75 per cent of the capacity will be available when the batteries are near the end of their expected life; since the Roanoke batteries had 120 per cent of their capacity after thirteen years of service, the question arose as to whether calculations had been overliberal or overcautious. Subsequent capacity tests in other central offices where the batteries were subject to the frequent overcharges showed these capacities to be slightly over 100 per cent — not quite as good as the Roanoke batteries. If additional data, now being obtained, confirm the initial findings, it should be possible to justify engineering on the basis of 100 per cent of battery capacity still remaining at the end of their "expected" life. With present demand for batteries for the Bell System in the neighborhood of 8 to 10 million dollars' worth per year, using 100 per cent instead of 75 per cent capacity will show additional large savings in battery cost.

Questioning the traditional practice as to the best method of maintaining batteries led to the trial installation at Roanoke that provided the knowledge upon which to base a "calculated risk." This knowledge is saving the Bell System hundreds of thousands of dollars. While this particular study represents only one small phase of the Laboratories' interest in battery development, its benefits are of value not only to the Bell System, but to other large users of storage batteries.

THE AUTHOR: C. H. ACHENBACH has been concerned with power supplies for all types of Bell System equipment for over twenty years. Prior to this assignment, he worked on equipment development of panel machine switching systems, analyzed telephone company orders, and did some engineering work on manual and toll switchboards. After being graduated from the University of Arkansas with a B. E.E. degree in 1913, Mr. Achenbach joined Western Electric Company at Hawthorne. His Bell System service was interrupted for a year by World War I, when he went to France with the 37th Engineers. In 1920 when he returned, he took a position with Western's Engineering Department which is now Bell Telephone Laboratories.

A. G. Jensen Awarded Gold Medal

The Royal Technical University of Denmark has awarded the G. A. Hagemann gold medal to Axel G. Jensen, director of television research at the Laboratories, in recognition of his contributions in the field of television research. The presentation climaxed an address given by Mr. Jensen in the conference room at the University, and came as a complete surprise to him. Although the award was originated in 1929, only six had been given to men prominent in technical fields prior to the awarding of the one to Mr. Jensen.

A national television convention in England in April, and an invitation to address the Institution of Electrical Engineers in

A composite of the obverse and reverse side of the medal awarded to A. G. Jensen by the Royal Technical University of Denmark.

London in May, were the reasons for Mr. Jensen's trip to Europe. He attended the convention in London, traveled through France, Belgium, Holland, and Germany studying television development in those countries, and then returned to London. His address to the Institution of Electrical Engineers in May dealt with the status of color television in the U. S. today, and the position of Bell Telephone Laboratories with regard to television. He pointed out that the Laboratories is not interested in the manufacture or sale of television equipment, but has a major interest in long-distance and point-to-point transmission of television signals.

A request to address the faculty of the Technical University then led him to Denmark. Mr. Jensen gave two addresses there, and it was at the second one that he was given the medal and a citation. The award was instituted in memory of the great Danish industrialist and former Rector of the University, G. A. Hagemann, and is granted for outstanding research in various technical fields.

Nossaman Describes Outside Plant Development

At the invitation of the Illinois Bell Telephone Company, R. J. Nossaman visited Chicago and Springfield, Ill., during June to give a series of talks on recent developments in Outside Plant. The talks were addressed to three groups of engineering and supervisory personnel and to Chicago Life Members of the Theodore N. Vail Chapter of the Telephone Pioneers. They outlined the facilities and manpower available at Bell Telephone Laboratories for Outside Plant development, and described a number of recent and current specific development projects.

Viewgraph transparencies and exhibits were used in illustrating various new developments. These developments include the various new kinds of insulated wire, aluminum-conductor cable, the new splice closure-terminal combination, the prelashing method of aerial cable placement, and the two-pair open wire line for use in rural areas. By coincidence, the first use of the prelashing method of aerial cable placement in Illinois was in progress at Springfield at the time of the visit, and the successful use of this new facility was observed.

Handset for the 500-Type Set

L. J. COBB
Station Apparatus Development

A primary objective of the new 500-type telephone set[*] — to increase the combined transmitting and receiving performance by about 10 db — is met by the use of a completely new handset with a more efficient transmitter and receiver. Also, in line with the over-all objective of making the new set pleasanter to use, the handset is lighter, easier to handle, and, for more natural reproduction of speech, is capable of transmitting and receiving a wider frequency range.

Like its predecessor, the new G-type handset is of molded phenol plastic but weighs only 12 ounces — 4 ounces less than the present F type. It is ½ inch shorter between the receiver cap and the transmitter mouthpiece, and thus better fits the dis-

Above, H. W. Bryant tests response of T1 transmitter of G1A handset with artificial mouth.

tribution of head dimensions and brings the transmitter closer to the mouth. As a result of improvements in the contour of the carbon chamber, the modulating efficiency of the new T1 transmitter (Figure 2) is higher than that of the larger F1 transmitter used in the present 302-type telephone set, and is less affected by the position in which the transmitter is used. Furthermore, this higher efficiency is maintained over longer periods through the use of an improved transmitter carbon. This granular carbon is now being manufactured by the Western Electric Company using a superior process recently developed at the Laboratories.

The transmitter is designed so that its response rises uniformly to a broad maximum in the region of 2500 cps as compared to an initial maximum at about 1800 cps for the F1 transmitter (Figure 1). This rising response characteristic not only compensates for the inverse characteristic of the loop but also increases the output at the higher frequencies. In this way the received speech is made to simulate more
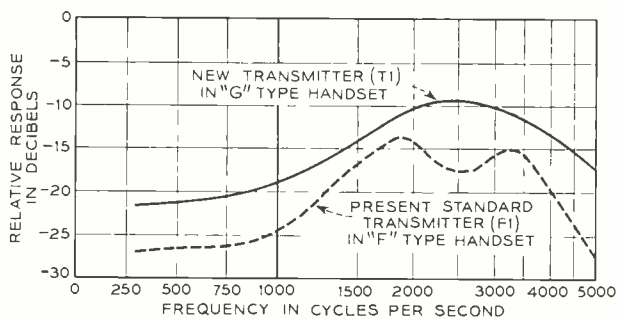
Fig. 1—Transmitter response characteristics.

nearly direct speech as heard by a listener a few feet from a talker.

The desired characteristic is achieved in the T1 transmitter by the introduction of a vibratory system substantially different from that employed in the F1 transmitter, and by the addition of an acoustical network. The new transmitter has a smaller diaphragm which is rigidly clamped at its periphery, whereas the diaphragm of its predecessor is floated between lightly compressed paper rings. The response-frequency characteristic of the new transmitter is controlled by an acoustic network obtained by coupling the chamber behind its diaphragm through a controlled acoustic resistance to the chamber formed by the plastic cup in the transmitter bowl of the handset. Specially woven rayon fabric is used for the acoustic resistance material. The plastic cup also serves as a barrier to prevent acoustic coupling between the transmitter and the receiver through the conduit in the handle.

Improved modulation accounts for about half of the 5 db volume gain obtained with the new transmitter. The other half comes from an increase in the effective acoustic pressure on the diaphragm obtained by locating the transmitter closer to the user's mouth. This reduced mouth-transmitter dis-
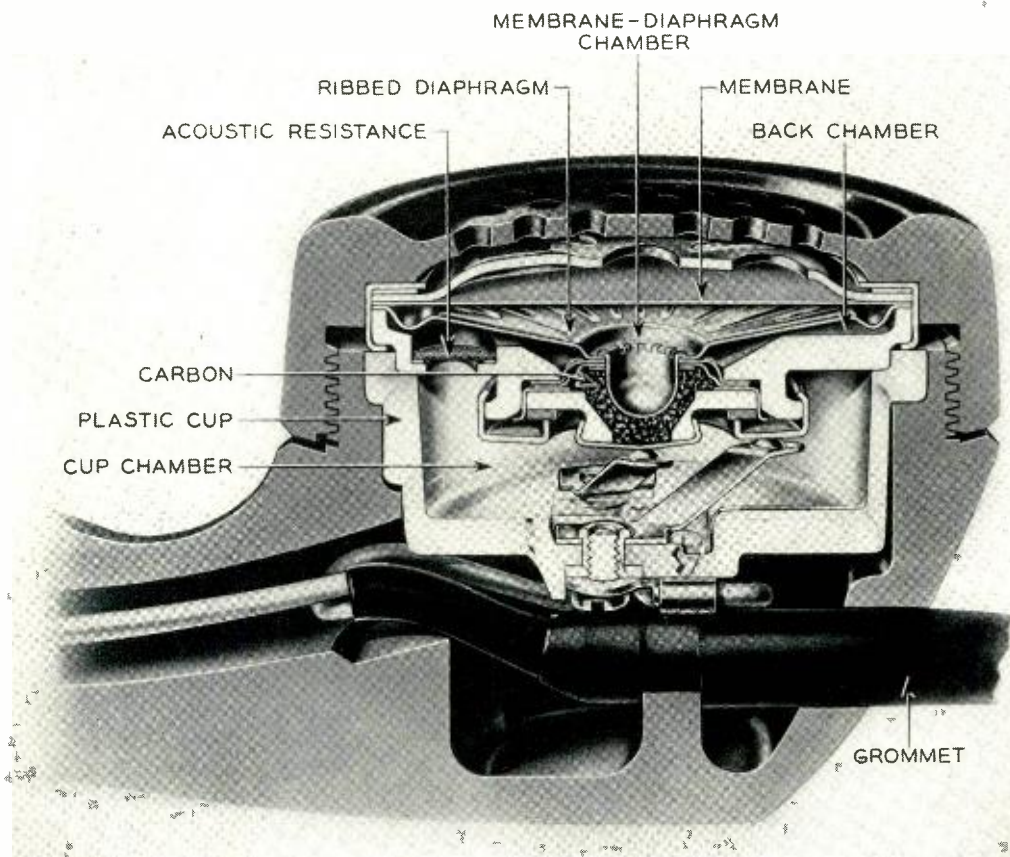

Fig. 2—T1 transmitter.

tance is of particular benefit to women whose head dimensions are smaller and whose voice level is lower than for men.

The improvements in efficiency and frequency response sought for the U1 receiver (Figure 4) are achieved by the use of a new design differing radically from any commercial predecessor. The simple magnetic disc of earlier receivers is replaced by a dome-shaped diaphragm of phenolic impregnated fabric cemented to a peripheral magnetic ring of vanadium permendur. This "ring armature" diaphragm calls for an entirely new type of magnetic system.

The outer edge of the ring armature rests on a circular seat of non-magnetic material. The inner edge is in close proximity to a circular permalloy pole-piece which conducts the flux from a ring-shaped remalloy type permanent magnet. Lighter than its predecessors and with its mass concentrated in the outer metal ring, the new diaphragm
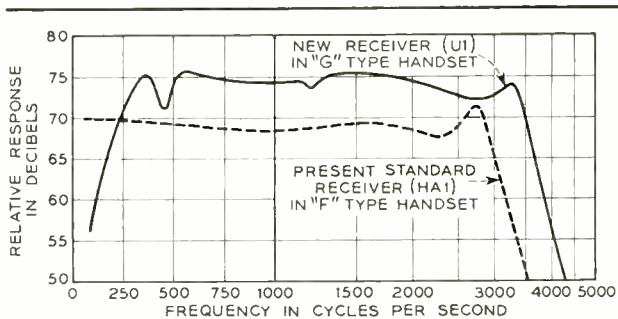

Fig. 3—Receiver response characteristics.

provides about a seven-to-one reduction in the mechanical impedance of the new receiver, and a correspondingly large increase in the ratio of effective area to effective mass. This accounts for an improvement in the receiving efficiency of about 5 db, along with an extension of the frequency range. Also, because of the lower mechanical impedance of the diaphragm system,
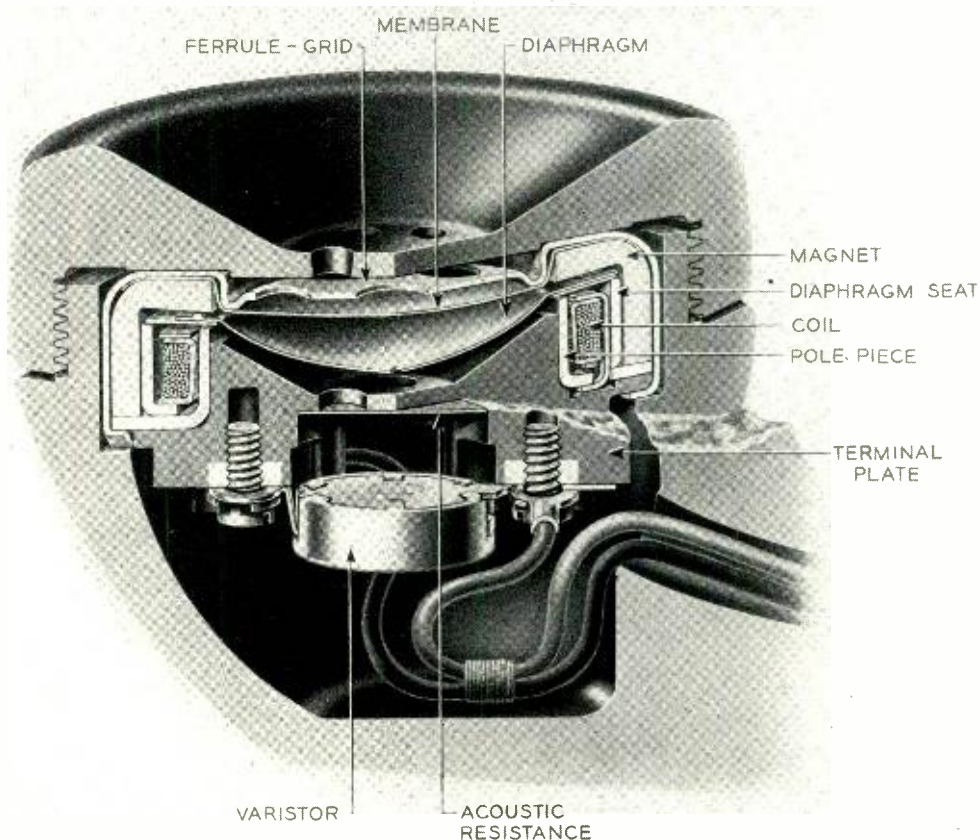

Fig. 4—U1 receiver.

it is a better acoustic radiator, with the result that when the receiver is held off the ear, the intelligibility is much better than that obtained from earlier receivers.

Acoustic controls on the response of the receiver are provided in the same manner as in the HA1 receiver of the F-type handset which forms a part of the present 302-type telephone set. Chambers on each side of the diaphragm connect to constricted passageways having the proper acoustic mass and resistance. The chamber under the diaphragm exhausts into the handset handle cavity through four holes covered with acoustic resistance fabric, while the chamber above the diaphragm exhausts into the listener's ear cavity through the acoustic mass and resistance of the holes in the receiver cap. The desired response-frequency characteristic of the new receiver in the G type handset is obtained by establishing the proper relationship between the acoustic and mechanical elements involved.

Because of the increased efficiency of the new receiver its diaphragm is pierced to introduce a low frequency cut-off to discriminate against disturbances due to the introduction of power frequency and its principal harmonics into telephone circuits. The diameter of the diaphragm hole is selected to obtain a response at 180 cps which is approximately 10 db below that obtained at 1000 cps. The receiver response-frequency characteristic is virtually flat from 400 up to 3500 cps as compared with the 3000 cps cut-off for the earlier receiver (Figure 3). The irregularities in the response characteristic of the new receiver at 450 and 1200 cps are not inherent in the receiver but are acoustical effects of the conduit in the handset handle. No adverse effects from these have been discerned.

To protect the user from uncomfortably high acoustic levels caused by transient electrical disturbances in the telephone circuit — a problem accentuated by the higher efficiency of the new receiver — a peak-limiting varistor is shunted across the new instrument. This copper oxide varistor also protects the receiver magnet from the demagnetizing hazards of such disturbances; consequently the magnet can be made less massive, thereby reducing the weight of the receiver, and economizing in the use of strategic magnet material.

Numerous simplifications make for economical manufacture. For example, there are no inserts in the molded handle as compared with six in the F type handle. Connections are made directly to screw terminals on the back of the receiver unit by running two of the four conductors in the cord through the cored handle. The other two conductors are attached to screw terminals on the back of the molded plastic cup at the transmitter end of the handset. The tinsel conductor cord is of lightweight neoprene-jacketed construction, and has a grommet molded on it at the handset end which serves to reduce destructively sharp bending at the point of entry and also seals the handset against room noises. A notch in this grommet engages projections molded inside the transmitter bowl of the handle, thereby eliminating the necessity for a conventional stay hook and attachment screw.

During the development, close cooperation with Western Electric engineers did much to insure a design suitable for large quantity and economical manufacture.

THE AUTHOR: LEONARD J. COBB is in charge of a group developing telephone instruments. When he joined the Laboratories in 1922 he was assigned the job of developing testing procedures for shop inspection of telephone transmitters and receivers. Later he designed and built specialized measuring facilities for laboratory use in this connection. In 1949 he took over his present responsibilities. Mr. Cobb was awarded an E.E. degree, cum laude, from Polytechnic Institute of Brooklyn in 1933.

The AMA Summarizer

GEORGE RIGGS
Switching Systems Development

Since local calls are billed to the customers monthly as a single item, instead of individually as are toll calls, they pass through a stage in the automatic message accounting system that is not required for toll calls. This stage is the summarizer, which is the fourth stage in handling local calls. In the three preceding stages,* the entries pertaining to each call are brought together as adjacent lines on the output tape of the assembler, the chargeable time for toll calls and the number of message units for local calls are calculated and placed on separate output tapes of the computer, and all the messages for each calling number are brought together on the output tapes of the sorter. The output tapes of the sorter serve as the input tapes for the summarizer, which adds the message units for the group of calls made by each subscriber and produces an output tape with a two-line entry for each calling number, giving the total number of message units chargeable to it.

The summarizer consists of a tape reader, relay control equipment, and a tape perforator as shown in Figure 1. Although adding is its major function, the summarizer must be able to discriminate between different calling subscriber numbers since only the message units for one number are added together. It thus includes two major circuits: one for comparing the calling numbers, and the other for adding the message units. The number comparison must be made first since whether the associated message units are added to the previous total or used as the start of a new total depends on whether or not the new calling number matches that of the previous entry. The calling number comparison circuit includes two sets of registers, and the calling numbers of successive entries are recorded alternately in them. Circuits are wired through the contacts of the register relays in such a way that if the
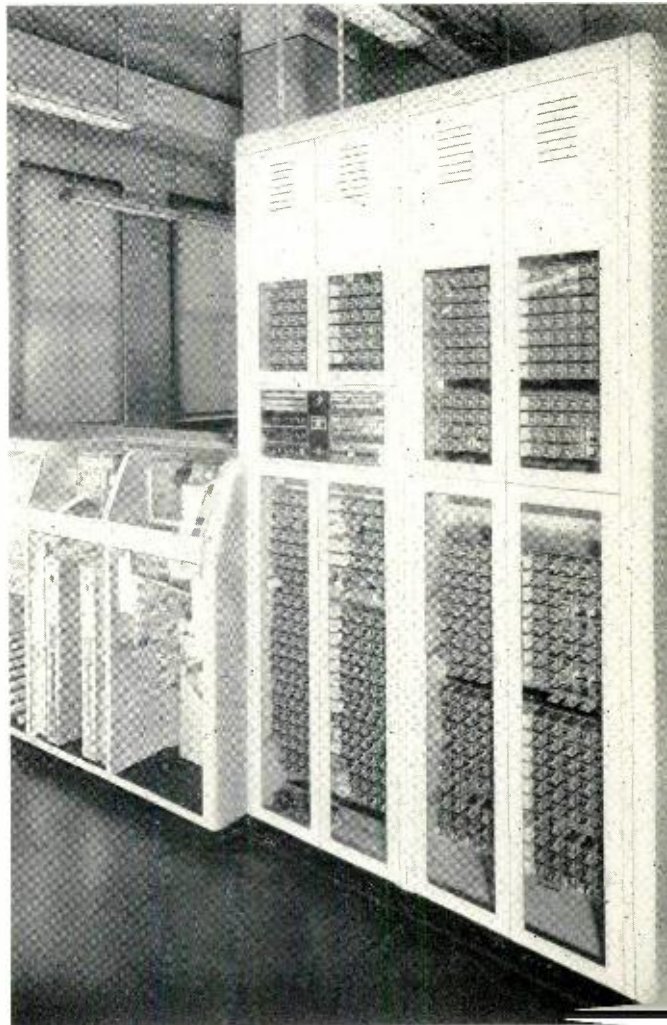
Fig. 1—A summarizer includes a tape reader, a tape perforator, and two cabinets of control equipment.

same number is recorded in both registers, the adding circuit will add to the previous sum the message units indicated in the last entry. If the calling numbers are not alike, the advance of the input tape is stopped momentarily, and the previous calling number and the total message units chargeable to it are perforated on t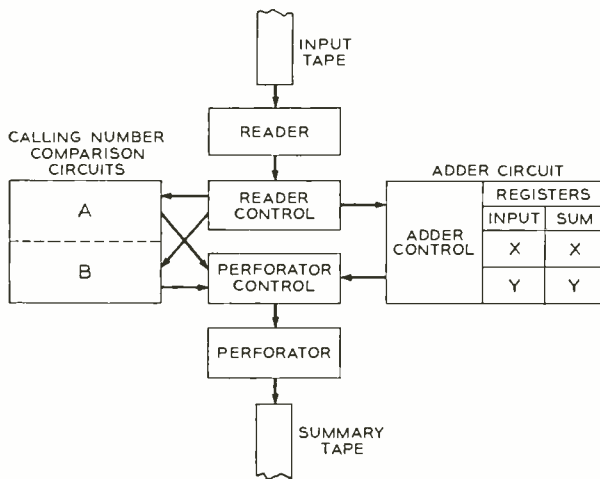he output tape. Immediately after this has been done, the input tape is allowed to advance and a new sum is started for the new calling number.

Fig. 2—*Block schematic of the summarizer circuit.*

put tape is allowed to advance and a new sum is started for the new calling number. Both the number comparison and the adding circuits carry out their operations so rapidly that the input tape is stepped along from line to line without interruption at the rate of sixteen lines per second as long as the calling number does not change.

The adding circuit includes two input registers and two sum registers, and the message units of successive entries on the input tape are recorded alternately in the two input registers. The message units of the first entry of the input tape will be recorded in the x input register, and immediately transferred to the x sum register, thus releasing the x input register. The message units of the second input entry will be recorded in the y input register, and – if the calling number is the same as for the first entry – will be added to the number in the x sum register and then the sum will be recorded in the y sum register, after which the y input and x sum registers are released. This recording in an input register,

adding to the total in the sum register of the opposite name, and recording in the sum register of the same name continues alternately back and forth as long as the calling numbers remain the same. When the calling number of an entry is found to differ from that of the preceding entry, the process is momentarily stopped after the message units for the new number have been recorded on the input register, and the previous calling number and the total of message units recorded in the sum register are used to control the perforation of an entry on the output tape. Immediately after this is done, a new summation is started for the new calling number.

A block schematic of the summarizer circuit is shown in Figure 2. As the entries are read, the calling numbers are recorded alternately in the A and B registers of the number comparison circuit, and the message units are recorded alternately in the x and y input registers of the adder circuit. If the number of a new entry recorded in the B register is the same as that already recorded in the A register, the A register will be released and the number of the next

Table I—Tabulated operation of the summarizer for four entries for line number w with associated charges of a, b, c, and d message units respectively, and one entry for line number z with e message units. Time flows across the table from left to right, and downward from top to bottom.

Entry	Calling Number Comparison Registers		Input Registers		Sum Registers	
	A	B	X	Y	X	Y
1	w	o	a	o	a	o
2	w	w	o	b	a	o
	o	w	o	o	o	a+b
3	w	w	c	o	o	a+b
	w	o	o	o	a+b+c	o
4	w	w	o	d	a+b+c	o
	o	w	o	o	o	a+b+c+d
5	z	w	e	o	o	a+b+c+d
	z	o	o	o	e	o

entry will be recorded in it. If this is the same as the number in the B register the latter will be released, and so on as long as the number remains the same. In step with these operations, the message units will be recorded alternately in the x and y regis-

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ters. A message unit figure recorded in the y input register will be added to the total in the x sum register, recorded in the y sum register, and the y input and x sum registers will be released. The next message unit figure will be recorded in the x input register, added to the total in the y sum register, recorded in the x sum register, and the x input and y sum registers will be released.

Only when a new calling number is encountered will this back and forth action be stopped long enough to perforate a total on the output tape.

This action is indicated in Table 1 for a series of input entries for calling line number w, and then for an entry for calling line number z. The number of message units for the various entries are indicated by the
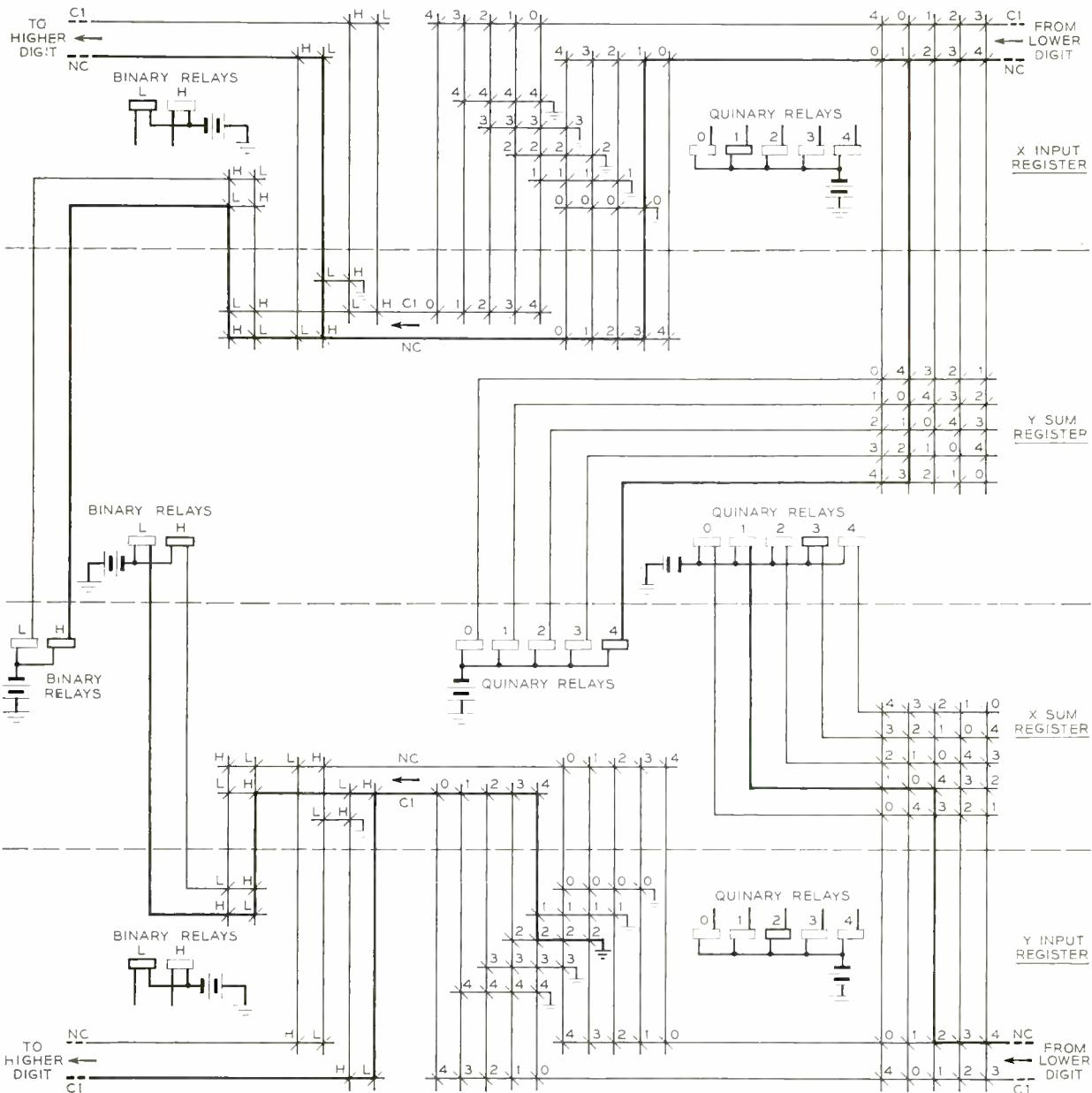

Fig. 3—*Simplified schematic of the adding circuit for the tens digit only.*

Decimal	2-out-of-5	Biquinary
0	4+7	L0
1	0+1	L1
2	0+2	L2
3	1+2	L3
4	0+4	L4
5	1+4	H0
6	2+4	H1
7	0+7	H2
8	1+7	H3
9	2+7	H4

letters a, b, c, etc. Time flows downward from the top of the diagram, the top line representing the first input entry. A small circle represents that the circuit is released.

Each of the four circuits of the adder – the x and y input and the x and y sum – is arranged to register and add three digits – units, tens, and hundreds – and thus the complete circuit will handle up to 999 message units. At the thousandth message unit, a carry-over signal from the hundreds circuit causes an entry for 1000 message units to be perforated on the output tape. Thereafter the circuits add as before until another 1000 message units have been added, when another 1000-message unit entry will be made. When a new calling number is encountered, the sum remaining on the adder will be perforated as an additional output entry for the preceding calling number. When there are more than 999 message units, therefore, there will be two or more output entries for the calling number that is involved.

A simplified circuit diagram for the tens digit of the adding circuit is shown in Figure 3. The circuit for the units digit is the same except that it will not have a "carry 1" (c1) lead coming in from the right. The circuit for the hundreds digit is the same as Figure 4 except that the "carry 1" lead extending out at the left, instead of being used to increase the next higher digit, will be used to initiate the perforation of a thousand-message-unit out-put entry.

The message unit digits recorded in "2-out-of-5" code on the input tape are translated to a biquinary code before they are transmitted to the input registers of the adder. In this latter code each digit is recorded by operating one of two binary relays and one of five quinary relays. The binary relays are designated L and H, to indicate "low" and "high," and the quinary relays are designated 0, 1, 2, 3, and 4. If L is understood to represent zero, and H, 5, the digit in the biquinary code is the sum of the operated relays in the two groups. The relationships between the decimal, "2-out-of-5", and biquinary codes are given in detail in Table II.

In Figure 3, the short slant lines at the intersections of the various leads represent contacts on the binary and quinary relays of the section of the circuit with which they are associated. With digit 1 recorded in the x input circuit, for example, register relays L and 1 will be operated, and thus all contacts marked L or 1 of that circuit will be closed. The y input and sum circuits are identical to the x input and sum circuits, but both are shown in Figure 3, so that their interaction may be followed.

Assume that when the digit L1 (1) is recorded in the x input register, a digit H3 (8) is already recorded in the y sum register. If there is no carry-over from the next lower digit, there will be ground on the xc lead at the upper right corner of the diagram. Since the NO. 1 relay of the x input register is operated, this ground is extended through the NO. 1 contact on the xc lead, down to the NO. 3 contact on the y sum register, which is also closed, and thence to the NO. 4 relay of the x sum register.

Ground on the NC lead will also be extended through the second NO. 1 contact on the NC lead down to the NO. 3 contact on the NC lead of the y sum register, and thence to the left to the two operated H contacts. Through the first of these, it passes up and then through the closed L contact of the x input register to appear on the NC lead running to the hundreds digit. Over the second H contact on the NC lead of the y sum register it passes up and through another closed L contact in the x input register and thence down to operate the H relay of the x sum register. These paths are indicated by heavy lines on the diagram. In this way number L1 in the x input register has been added to H3 in the y sum register to give H4 in the x

sum register. Expressed in decimal code, this is $1 + 8 = 9$, with no carry-over.

If the next entry is for the same calling number, the message units will be recorded in the Y input register. Assume that the tens digit is two with no carry-over from the units digit. Under this condition L2 will be recorded in the Y input register, and the heavy lines on the lower part of the diagram show how this would add to the 114 just placed in the X sum register to give L1 in the Y sum register (which had been released after 114 had been recorded in the X sum register) and the "carry 1" to the 100's digit. In decimal terms $2 + 9 = 11$, but the 1 in the tens place is carried to the next higher digit.
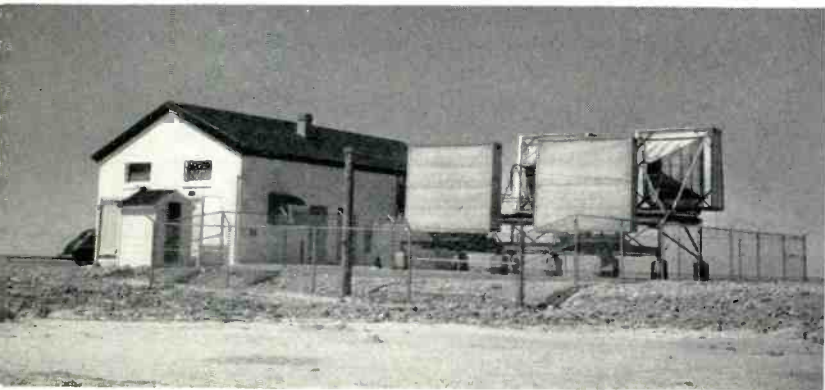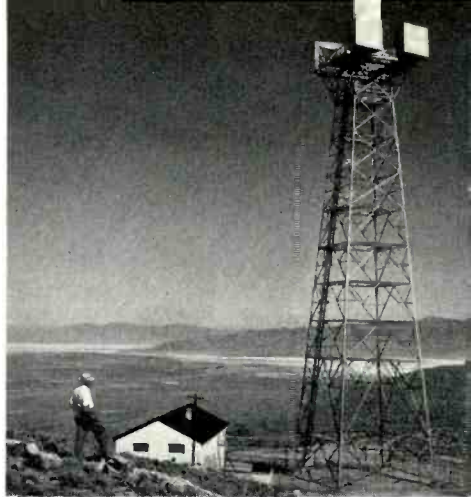
The two rectangles of contacts, five contacts square, at the right of the sum registers, together with the two parallel rows of contacts on the NC and CI leads in the input registers, perform the quinary part of the addition, while the rectangles, two contacts square, at the extreme left of the input and sum registers perform the binary part of the addition. The remaining part of the circuit is involved in the No-carry and "carry 1" operation — both from the quinary to the binary sections of the digit and forward to the next higher digit.

For billing purposes, the message unit summaries for an entire month are required. Each month, however, is broken up into a number of processing periods, and a summary tape is perforated for each. To obtain a cumulative summary, the summary tape for the first period is sorted with the message unit tapes for the second period. The summary tape for the second period then contains all of the message units for the first two periods. This summary tape is sorted with the message unit tapes for the next period, and so on until the end of the billing month. The summary tape for the last period will thus contain the message units for the entire month.

THE AUTHOR: GEORGE RIGGS is in charge of a group working on the design of circuits for AMA accounting centers. He joined Western Electric's Installation Department in 1921 and the following year transferred to the Engineering Department, which later became Bell Telephone Laboratories. Until World War II, when Mr. Riggs taught radar operation and maintenance in Bell Laboratories' War Training School, he designed test circuits for the local test desk and for dial central offices. Mr. Riggs was graduated from Sheffield Scientific School of Yale University in 1915.

Top, left, the TD-2 station at Hanna, Wyo.

Top, right, station at Cedar Mountain, Utah.

Above, left, at Barro, Utah, practically no elevation above the ground level is required for the antennas.

Above, right, the TD-2 station at Creston, Wyoming, is somewhat unusual in having the antennas for one direction at a different height from those for the other direction.

Left, at Arlington, Nebraska, the radio equipment is in a structure a little over half way up the tower.

Radio Relay Stations of the TD-2

W. L. TIERNEY
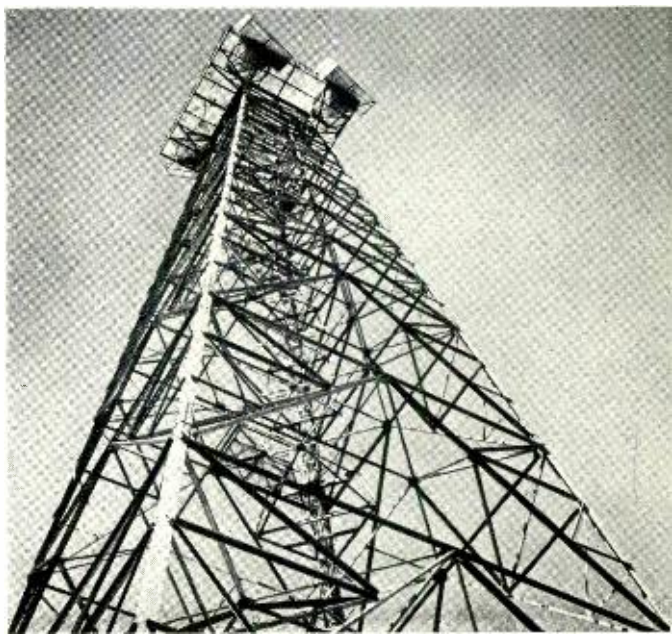*Transmission Systems Development*

Although the great circle distance between New York and San Francisco is 2570 miles, the distance over the transmission path of the TD-2 microwave radio relay circuit is 2992 miles. The use of sharply beamed antennas for transmitting and receiving the radio waves necessitates a zigzag course between stations to prevent interference caused by overshoot, because frequency assignments in the band between 3700 and 4200 megacycles are repeated at alternate stations. Several additional repeater stations are accordingly required to minimize the number of frequencies required.

Three functional types of stations are used on the transcontinental route: terminal stations at end points, where video signals are accepted or delivered; auxiliary stations to provide transmission gain; and main stations, which provide all the facilities of the auxiliary station together with added means for switching between channel frequencies or for accepting or delivering programs to local video or spur radio facilities. There are a total of 107 stations in the circuit from New York to San Francisco. The average distance between stations is 27.9 miles; the maximum being 50.1 miles and the minimum 9.3 miles. Profiles of the terrain spanned by the radio waves in crossing these maximum and minimum links are given in Figures 1 and 2.

The structural details of the repeater station buildings vary quite markedly. Between New York and the Wyndmoor station at Philadelphia, a reinforced concrete chimney type building is used, varying in height between 90 and 108 feet. West of Wyndmoor between Thomas Hill, Pa., and Des Moines, Ia., a square reinforced concrete type building is used varying in height between 67 and 197 feet. A structure of this type is shown in Figure 3. Both of these types of concrete buildings are used to support a maximum of four antennas on the roof area, and where spur circuits are required or when they may be added later, these structures have an added platform above the roof to mount additional antennas.

A view looking up the TD-2 antenna tower at Salt Lake City.

For the most part, one story buildings are used west of Des Moines with a steel tower ranging in height from 67 feet to 206 feet installed alongside to support the antennas. Stations of this type, with varying heights of tower, are shown on page 326. On the extreme western end of the route natural high elevation of the sites permit installing antennas on the roofs of single story buildings. Typical arrangements are shown in Figure 4. The station at Mt. Rose, Figure 5, just east of the California line in Nevada, with an elevation of 10,075 feet above sea level, is the highest point on the transcontinental route and has the minimum building height.

The steel tower installed beside the Northwestern Bell Telephone Company

Fig. 1—(Below) Profile of the longest link in the transcontinental TD-2 system—between Buckhorn Mountain and Broomfield, Colo.

Fig. 2—(Right) Profile of the shortest link in the transcontinental TD-2 system, between East Bench, Salt Lake City, and Pratts Pass, Utah.
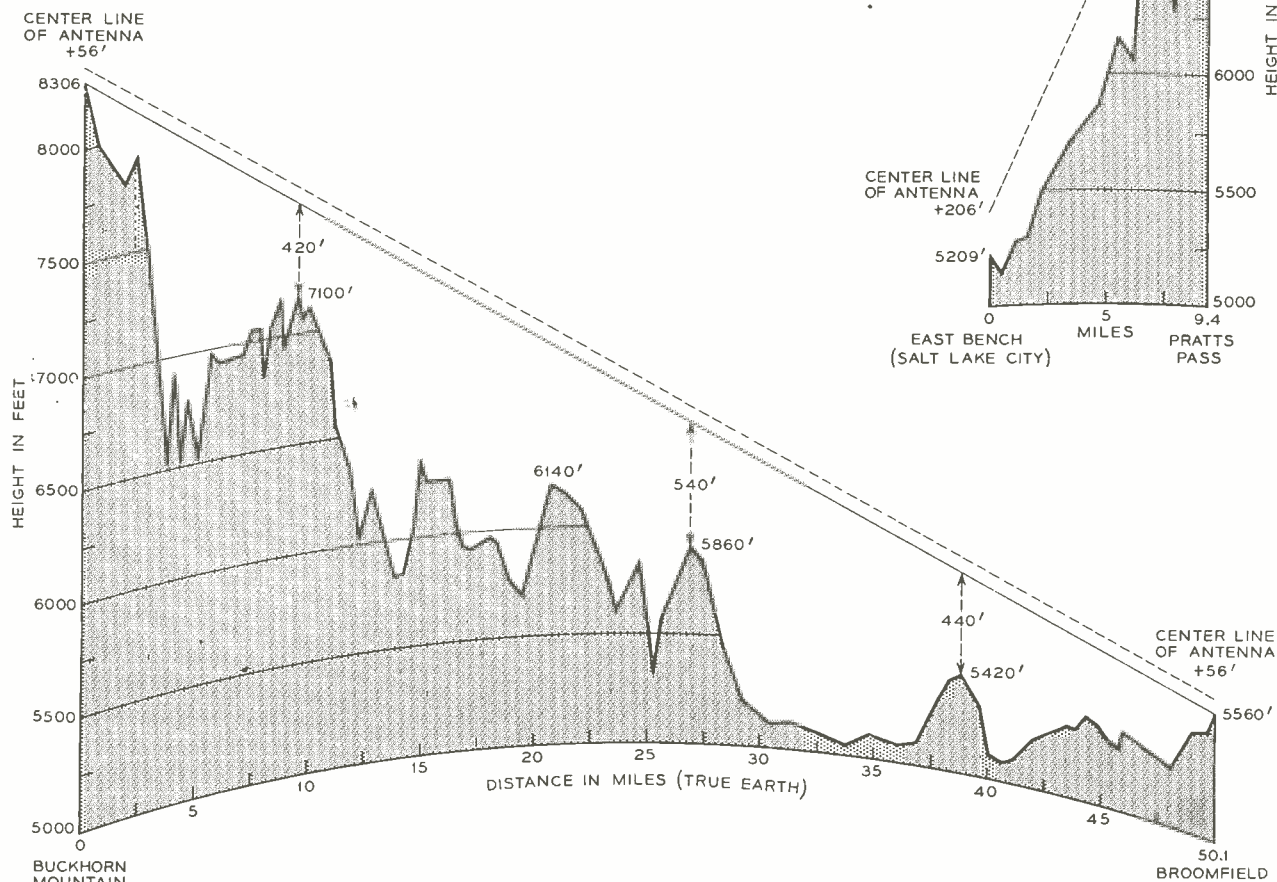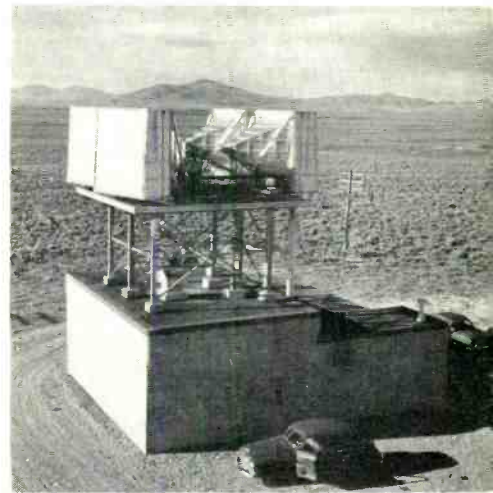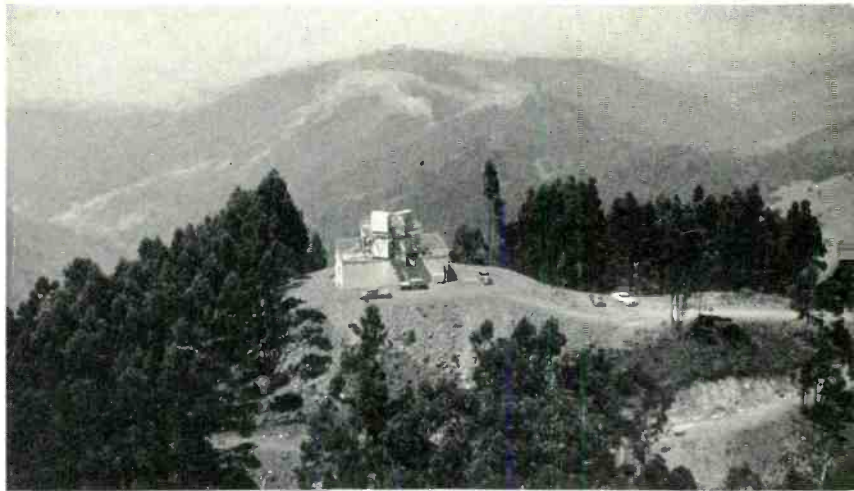
Fig. 4—Above, Radio relay station at East Bay Hills, Calif. Right, at Ruby, Nev., the antenna tower is on the roof of the building housing the equipment. Below, the TD-2 station at Wendover, Nev.
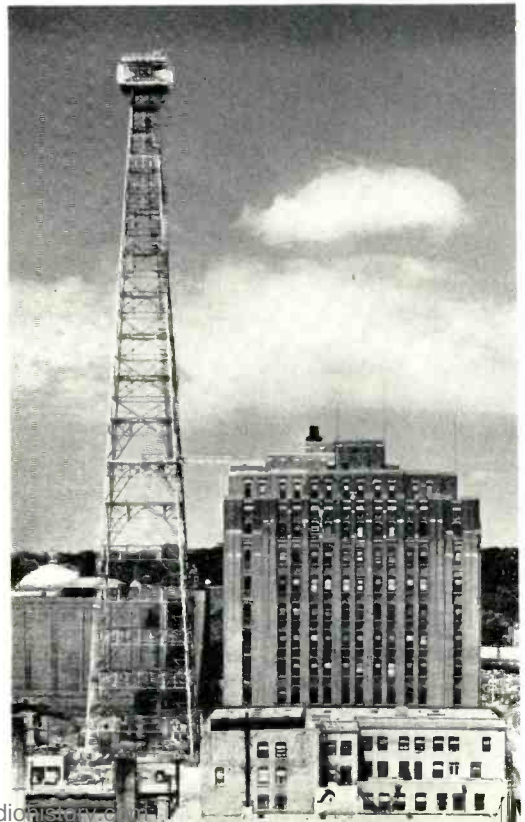

Fig. 3—TD-2 radio relay station at Richfield, Ohio.

Fig. 5—The highest antenna on the transcontinental TD-2 radio relay system is at Mt. Rose, Nev.

Fig. 6—At Des Moines, Iowa, the terminal apparatus is in the top floor of the telephone building while the antennas are on a 406-foot tower beside it.

building at Des Moines, Figure 6, is 406 feet high. The terminal apparatus is located on the uppermost floor of the building, and is connected to the antennas mounted atop the tower by waveguide which joins the tower at a point level with the roof of the building. In this case the building was not capable of carrying the additional structural load required to elevate the antennas to the required height.

The apparatus layout of all multi-floor buildings follows a general pattern, indicated in Figure 7, wherein the antennas are installed on top of the building with the radio transmitter-receiver bays placed in a room either directly below or at the uppermost level of occupancy. Storage battery and rectifier-charging equipment for 12 volts, 130 volts, and 250 volts is located on the two floors below the radio room. Emer-

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gency power plants are installed at the ground floor level.

In the single-floor or so-called ranch-type buildings, all of the power equipment is installed at ground level and the radio equipment may be installed either in the building or in a so-called "cabin in the sky", an enclosure constructed at an elevation within the tower structure in which the radio transmitter-receiver bays are installed to reduce the length of the waveguide connections to the antennas, and thus to secure a corresponding reduction in transmission loss.

Apparatus layout for a typical single floor installation for transmission in two directions is shown in Figure 8. Where spur circuits join the backbone system it may become necessary to facilitate transmission in three or four directions. Under such conditions added space is provided for additional transmitter-receiver bays and power supply equipment by expanding the long dimension of the building.

To meet the extreme range of temperature encountered over the transcontinental path, the buildings are equipped with either electric space heaters or oil-fired circulated warm air units for use during cold weather, and electric exhaust fans, either ceiling or wall mounted, for the summer. The radio equipment and storage batteries operate most efficiently in a range of ambient temperature between 40 and 105 degrees F. Thermostats for the heating system are set to maintain the equipment spaces at a minimum of 45 degrees. Manual adjustment
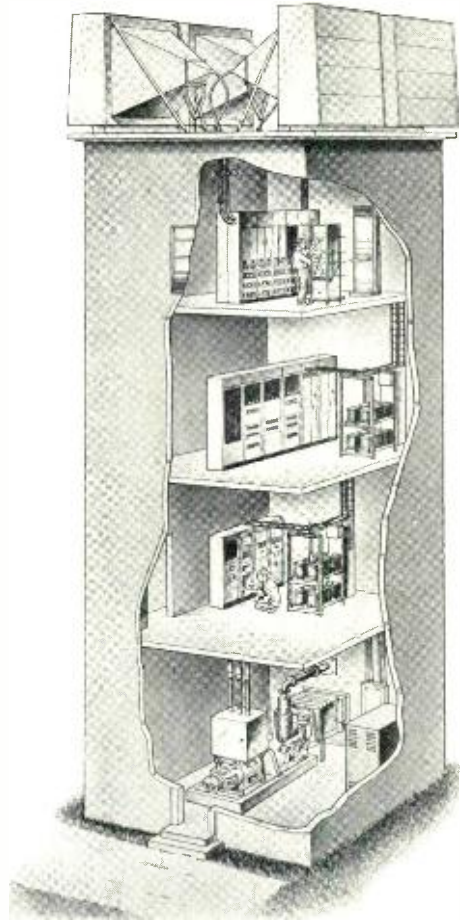

Fig. 7 — *Idealized cross section of an antenna tower showing the usual arrangement: emergency power supply on ground floor; 12-volt battery supply next above; then the 130- and 250-volt battery supply above it; and, at the top, the radio bays.*

THE AUTHOR: W. L. TIERNEY joined the Laboratories in 1925 and until 1940 was associated with the Specialty Products Department on field engineering of radio broadcasting and police radio systems. During World War II he worked on the Loran project at the Radiation Laboratory at Massachusetts Institute of Technology. Upon his return from war work he joined the Research Department, where he was concerned with field engineering problems on the New York-Boston microwave radio relay project. In the Transmission Systems Development Department since 1948, Mr. Tierney has worked on current development and field engineering problems of TD-2 microwave radio relay systems installed throughout the country.
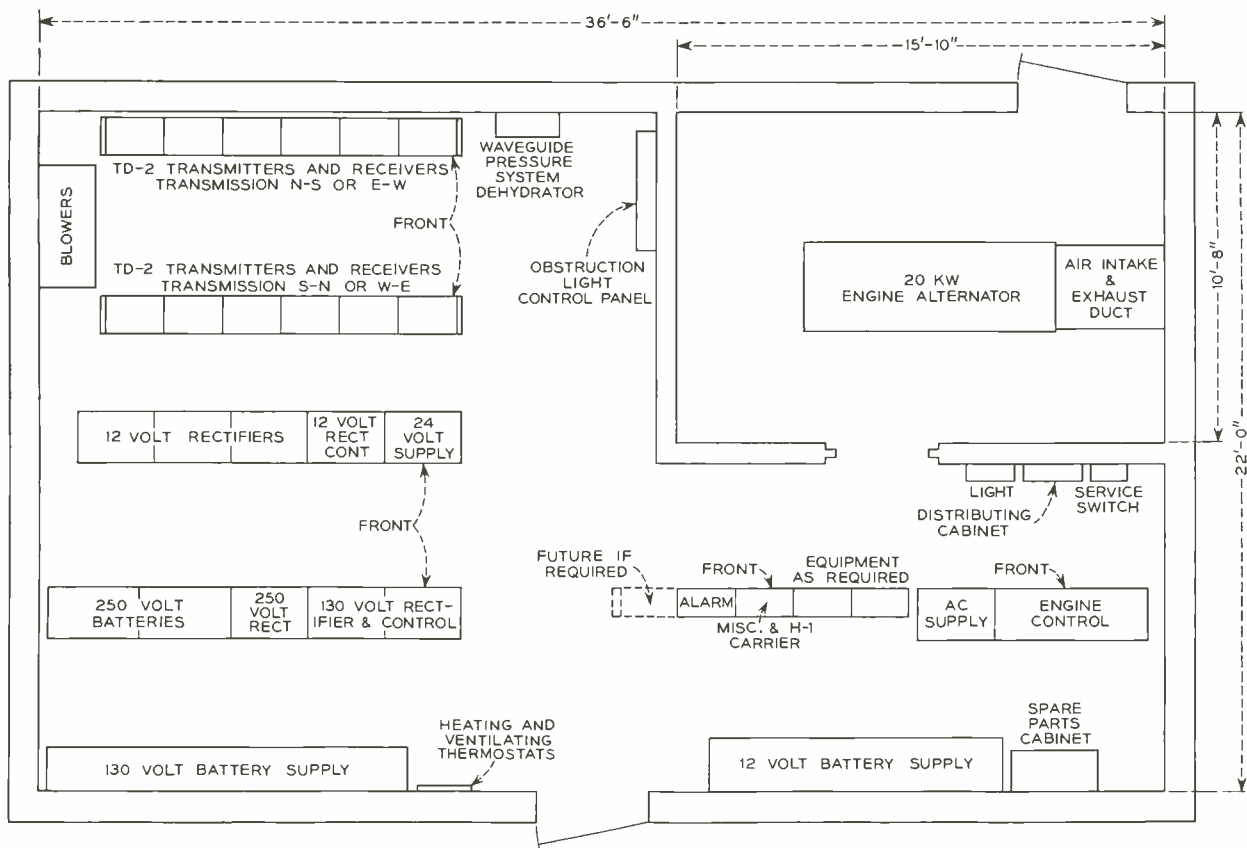
Fig. 8 — *Typical floor plan when all equipment is on one floor.*

permits an increase of temperature during maintenance periods. Thermostats for the exhaust fans are set to start these fans when the room temperature rises to 105 degrees. Automatically controlled motor-driven louvres are installed to exclude rain and snow at exhaust fan openings.

Fluorescent lighting is used throughout the areas where equipment is installed. For emergency lighting, direct current incandescent lamp outlets are installed at strategic points in the maintenance areas and in the stair wells.

Power supply with but few exceptions is obtained from central station sources. During periods of power interruption, gasoline or diesel engine alternators are automatically connected to the regulated vacuum tube rectifiers that charge the 12-, 120-,

and 250-volt storage batteries. All the radio equipment, the emergency motor for the filtered air supply for vacuum tubes and waveguides, and the emergency lighting system are designed for direct current operation. The change-over from central station to emergency power supply and restoration is made without any noticeable effect on the radio circuits.

Order wire and alarm circuits link the radio relay stations to alarm and maintenance centers, and permit diagnosis of troubles prior to the dispatch of maintenance people from these centers when faults occur. Emergency food supplies and bedding are provided in the stations high up on the Continental Divide and Pacific Coastal Range, which are difficult of access during the winter months.

Cable Transmission Characteristics for the N Carrier System

E. F. VAAGE
Transmission Engineering

One of the major problems that faced the design engineers during the development of the new type-N telephone system was that of obtaining the transmission characteristics of the great varieties of cables used in the Bell System Plant. To obtain measured values of these cables, in the needed frequency band and for various temperatures, by means of laboratory or field tests would have been a major undertaking. It was therefore decided to obtain these quantities from theoretical considerations supplemented by available data.

The most important transmission constants are the attenuation, or line loss, which varies with frequency and temperature, and the so-called primary transmission "constants." These constants, the resistance, inductance, capacitance and leakance, vary with conductor size, spacing between conductors, and type of insulation used in the cable; they are also affected by the presence of the adjacent wires.

Some of the factors affecting the line loss can be estimated with a fair degree of accuracy; others are more difficult to evaluate due to the complexity of the problem. However, with the aid of available measured values, extrapolations to higher frequencies, and interpolations between gauges and capacitances, the primary constants can be obtained with reasonable accuracy in the desired frequency range. The secondary transmission "constants," impedance, attenuation, speed of propagation, phase, delay, etc., can be obtained from standard formulas when the primary constants are known.

In the Bell System plant, wire sizes on which type-N carrier may be used vary from about number 16 to number 26 gauge. Several types of cable are manufactured for nearly all of these gauges, with capacitances varying from 0.062 to 0.084 microfarad per mile. Thus a large number of cable types had to be considered for N application.

The estimated line losses of some of the more frequently used cable types are shown in Figure 1. Other types, not plotted, are of similar shapes and would fall in-between, or above or below those shown, depending upon the gauge of the wires and capacitance of the pairs.

Separate pairs and a different frequency band for each direction of transmission are used in the N system. The "low" group operates from 44 kc to 140 kc and the "high" group from 164 to 260 kc. At each repeater point, the frequencies are reversed or "frogged," by making the output frequency different from the input frequency. Each repeater receives one of the groups, either low or high, and modulates this group into the other allocation.

This results in nearly a self-equalization of the system, as indicated in Figure 2. Curve (a) shows the line losses for 100 miles of low-frequency group transmission on 19-gauge toll cable. Similarly, Curve (b) shows the 100-mile line loss of the high
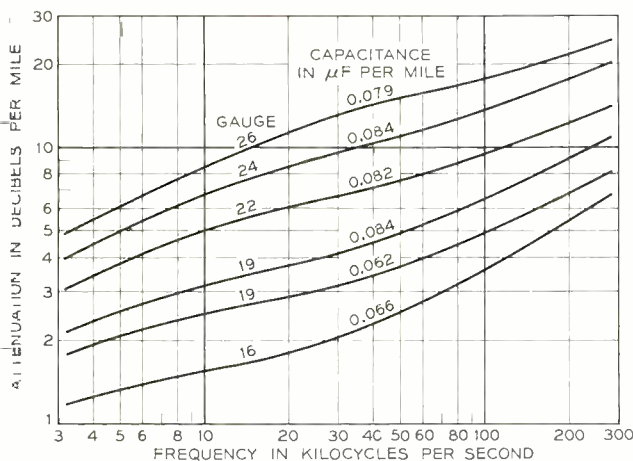

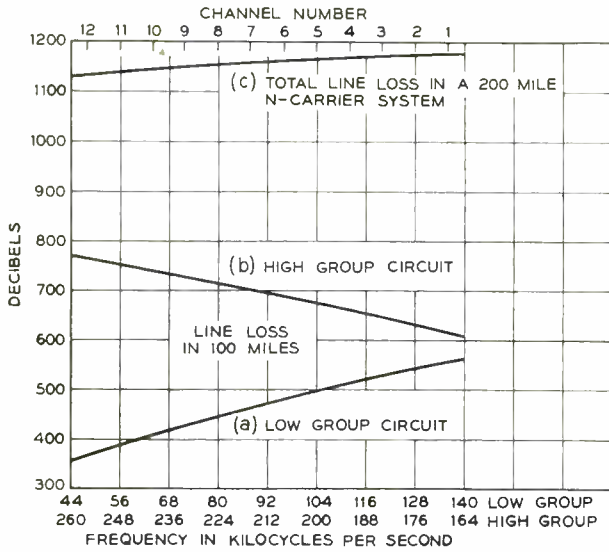*Fig. 1—Typical values of cable losses in db per mile at 55 degrees F.*

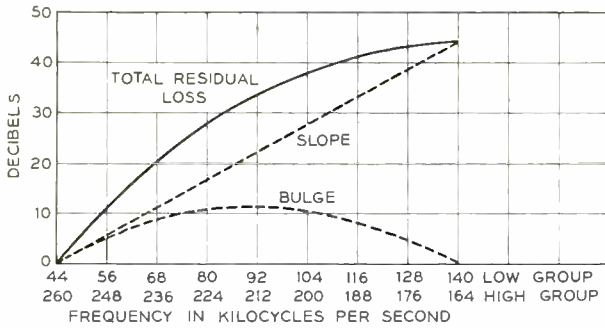Fig. 2—Equalization in frogged 200-mile N system, 19 gauge toll cable.

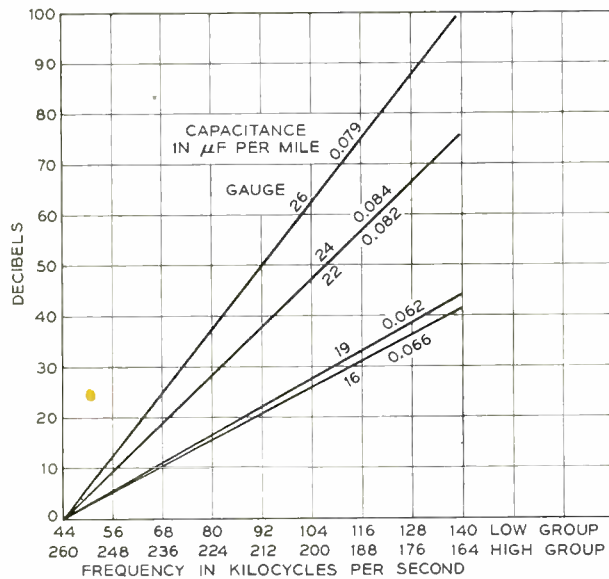Fig. 3—Residual loss in a 200-mile N system.
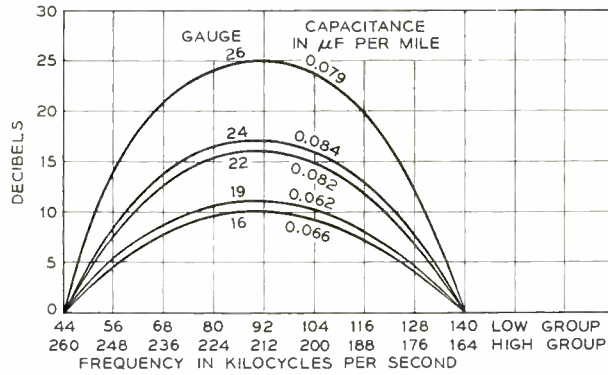

Fig. 4—Unequalized slope in a 200-mile N system.

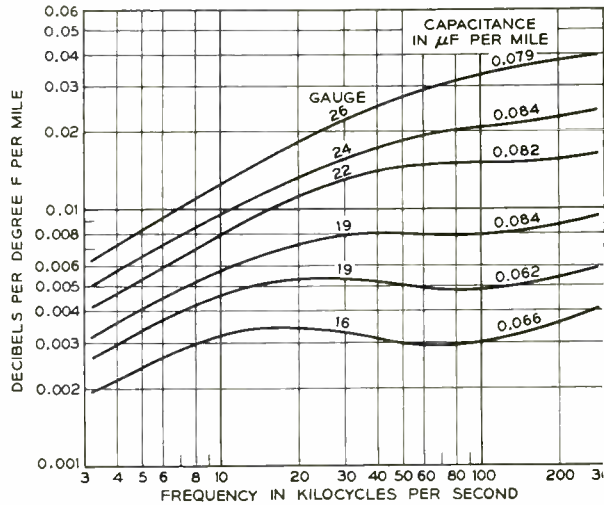Fig. 5—Unequalized bulge in a 200-mile N system.

Fig. 6—Average values of cable loss variation with temperature in db per degree fahrenheit per mile, over the range of 35 F to 75 degrees F.

TABLE I

Cable Type		Repeater Spacing*	Per Repeater Section		Ratio
Gauge	Capacitance	Miles	Slope db	Bulge db	Bulge/Slope
16	0.066	10.3	2.2	0.52	0.24
19	0.062	8.0	1.8	0.44	0.24
19	0.084	6.1	2.3	0.55	0.24
22	0.082	4.4	1.7	0.35	0.21
24	0.084	3.1	1.2	0.26	0.21
26	0.079	2.5	1.3	0.25	0.19

* Repeater spacings are based on a repeater gain of about 48 db at the midpoint of the frequency band (150 kilocycles).

group, which is reversed relative to the low group. The total line loss for the 200-mile system is given by Curve (c), which is rather flat over the whole frequency range from 44 to 260 kc.

Curve (c), however, is not entirely flat. Drawn on an expanded scale, Figure 3, the total unequalized line loss for the 200-mile system is indicated by the full curved line. This can be resolved into a slope and a bulge, as indicated respectively, by the dashed straight line and the dashed curved line. The equalizer networks that are built into the repeaters must be able to take care of this residual loss. For other types of cables, the total slope and bulge vary considerably, as shown in Figures 4 and 5. The range of slope in a 200-mile system is from 42 db for a 16-gauge cable, to about 100 db for a 26-gauge cable, and the bulge ranges from about 10 to 25 db.

There are two factors that contribute to simplification of the equalizers, in that correction for both slope and bulge can be accomplished with one type of adjustable equalizer at a repeater. First, the total slope in a 200-mile system is roughly proportional to the total line loss at about 150 kc, the midpoint of the frequency band, for the various gauges and capacitance of the cables. Furthermore, the ratio of the bulge to the slope is nearly constant, and independent of the gauge and capacitance as shown in Table I.

Another effect that had to be considered is the variation of attenuation with temperature. In underground or buried cables, the temperature may vary between 35 degrees F and 75 degrees F and in aerial cables from 0 degrees F and 110 degrees F, and even wider in extreme cases. Studies of this problem indicated that the variation in db per degree Fahrenheit per mile is not linear with temperature in the frequency band utilized by the N system. For example, if the cable temperature changed from 10 degrees F to 11 degrees F, the attenuation change would be different from the value obtained if the temperature changed from, say, 90 degrees F to 91 de-

THE AUTHOR: E. F. VAAGE is a member of a group engaged in systems studies, an outgrowth of his previous work of evaluating transmission systems. Mr. Vaage joined the D & R in 1927 and moved with that Department to the Laboratories in 1934. His first assignment was in a group concerned with inductive coordination studies, and since 1939 he has worked on the design requirements and transmission performances of communication systems.

Mr. Vaage was graduated with an E.E. degree from Technical University of Darmstadt in 1926, and in 1932 received an M.E.E. degree from Brooklyn Polytechnic Institute. Before coming to the United States in 1927, he was employed by Elektrisk Bureau in Oslo.

grees F. This non-linearity begins at 40 kc and increases with increasing frequency.

Figure 6 shows the approximate *average* values of temperature variations between 35 degrees F and 75 degrees F for the same types of cables shown in Figure 1. These changes, even though small in db per degree per mile, accumulate, and in longer systems amount to considerable change in line losses, with several db extra slope and bulge when the temperature varies from one extreme to another. The individual channel regulators (which will be described in a subsequent article) automatically compensate for this cumulative deviation.

Characteristic impedance of the various cable circuits is another item that received consideration. The estimated values, in the frequency band 44 kc to 260 kc, varied between 135 and 90 ohms for all the cables considered. Such variations are tolerable in the type-N system, since the line loss per repeater section is large enough to minimize the effects of these variations.

The speed of propagation of electric waves in free space is about 186,000 miles per second. In a cable circuit this velocity is reduced considerably due to the presence of dielectric insulation. N1 carrier transmission has a speed of about 125,000 to 145,000 miles per second, which corresponds to a phase delay of from 7 to 8 microseconds per mile. This is in the same order of magnitude as that experienced in the K system.

Actual measurements of transmission losses on a number of recently installed N systems have confirmed the calculated losses and variations predicted.

Oliver E. Buckley Solid State Physics Prize Established

An annual prize of one thousand dollars, to be awarded to a person adjudged to have made a major contribution in the field of solid state physics, has recently been announced. The contribution to the advancement of knowledge in this field must have been made in the five years immediately preceding the award, and the person to receive the prize will be chosen by a committee of five men selected by the American Physical Society. A 25-year trust fund of $50,000 has been provided for this purpose by Bell Telephone Laboratories. The award is named in honor of Oliver E. Buckley, former President and now Board Chairman of the Laboratories, who will retire at the end of this month after thirty-eight years in scientific and administrative work.

Physicists in recent years have slanted their research toward developing a better understanding of atomic nuclei, and one of the aims of the prize is to redirect attention to the importance of understanding more fully the relationships between the atoms of solid materials. It is fundamental research into these relationships that has led to the growing list of important theories, procedures, and materials that has come from the Laboratories during Dr. Buckley's regime. New magnetic materials such as supermalloy and new procedures for growing crystalline materials have been developed; the basic aspects of polymeric compounds are better understood and have led to new plastics; the theories of magnetic behavior and of superconductivity have been significantly advanced; and the theory of electrical conduction in semi-conductors has resulted in the invention of the potentially revolutionary transistor by Bell Laboratories physicists.

Administration of the prize is wholly the responsibility of the American Physical Society which has selected a judging committee consisting of Harvey Brooks, J. B. Fisk, J. C. Slater, Cyril S. Smith, and J. H. Van Vleck. This committee will determine the winner of the first award. Trustee for the funds is the Bankers Trust Company of New York. A prize will be awarded for each of the twenty-five years that the trust is operative, but the Society may delay an award to a subsequent year. At the termination of the trust, in 1978, the remaining funds revert to the American Physical Society.

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Improvements in Subscriber
Line Testing

D. RITCHIE, Jr.
Switching Systems Development

Since the first central offices began to connect one subscriber's line to another, some means for testing the line conductors has been necessary. At first, and until well into the present century, the lines of each office would be tested by the local wire chief using a circuit of the form shown in Figure 1. The voltmeter and the necessary keys and jacks were located in a turret at the test desk. Trunks from the test desk would run to the switchboard or to the main frame, where they could be connected to the lines to be tested. The basic tests were for ground on one or the other wire of the pair or for a short circuit between them. The two positions of the reverse key, REV, permitted voltage, through the meter, to be applied first to one wire and then to the other, while the ground key G gave a test for short circuit by leaving the meter connected to one wire of the line and

Above, the test center in the Humboldt central office in Newark in which the No. 14 test desk positions are equipped with the electronic voltmeter and multifrequency key pulsing

grounding the other. A test for continuity was also possible by operating and then restoring the reverse key. If the line was continuous to the subscriber's station, the charge and discharge of the subset condenser would cause a momentary deflection of the meter. The circuit was also used to obtain an approximate measurement of the resistance of a fault. The shunt key SH provided a low meter range for measuring faults of low resistance.

A typical early test circuit provided resistance ranges of 200 and 10,000 ohms with a meter scale of thirty volts. Satisfactory resistance measurements could be made up to about 90,000 ohms (ten per cent of full scale deflection) using the 10,000 ohm range.

As central offices have grown in size and number, there has been a corresponding growth in the test desk. Desk line-ups of several positions, with multiple appearances of the test trunks, have been provided and new test features have been added in the test circuit. These various changes and modifications appeared in successive coded
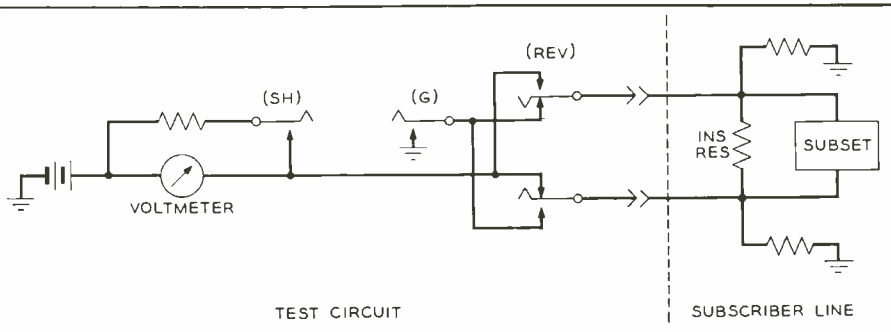
Fig. 1—Line testing circuit used for testing subscriber lines from the early test desk.

test desks, and finally resulted, about 1930, in the No. 14 local test desk, which was designed to provide centralized testing, thus permitting the lines for a number of offices to be tested from a central location. Special test trunks would run directly from the test desk to each of these offices, and connection to the line to be tested would be established through the central office equipment. The resistance of the test trunks would, of course, add to the resistance of the line tested, and because of this, and because the switching at the distant office was controlled by a number of relays, some of them marginal, it was necessary to restrict the length of the trunk. The maximum permissible resistance for the trunk loop was established as 750 ohms.

The meter circuit now used with the No. 14 test desk, indicated in Figure 2, provides four ranges for resistance measurement. The 100,000-ohm range, which is the maximum, indicates a resistance of 900,000 ohms at 10 per cent of full scale deflection as compared with 90,000 ohms for the earlier circuit, Figure 1. For higher resistances the meter deflections are too small to provide desirable accuracy.

These improved facilities and more ef-

fective techniques have aided in the constant effort to improve the service given the subscriber. To secure appreciable further improvement, it became evident that greater emphasis would have to be placed on preventive maintenance, that is on the detection and repair of line faults before service is affected. Slightly defective insulation, particularly in the open portion of the subscriber line (drop wire), may interfere with service during wet weather although providing adequate service when dry. To detect this type of fault, circuits have been in use for some time for making insulation tests on the subscriber lines in an office. The test circuit indicates all lines which do not come within the insulation resistance limits. To investigate the faults on the sub-standard lines, the test desk must be able to measure much higher resistances than are necessary for ordinary trouble reports.

To make this more effective testing possible, several new test features have recently been made available for the No. 14 test desk. One of these is an electronic-voltmeter circuit, shown in block diagram form in Figure 3, to permit measurement of very high resistance faults with the existing
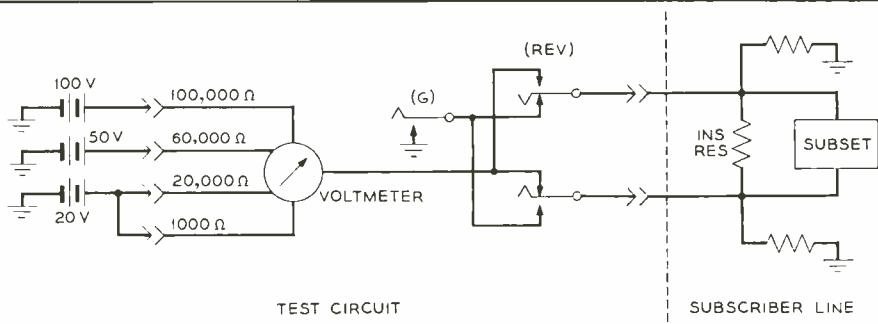

Fig. 2 — Voltmeter line testing circuit used with the No. 14 test desk.

test-desk meter. With this arrangement a resistance of twenty megohms is indicated at ten per cent of full scale deflection.

In the new circuit, the potential across a part of the test resistance is interrupted at the rate of forty pulses per second by a "chopper," then passed through a step-up transformer and connected to a cathode-follower vacuum-tube arrangement whose low impedance output is rectified and connected to the test meter. The capacitor across the input of the chopper provides a by-pass for practically all induced ac frequencies apt to be present on the line, and thus, by eliminating this possible

from high adverse line capacitance charges which may be present.

Because of the limitation of the test trunk loop to 750 ohms already referred to, a central No. 14 test desk has been able to serve only offices within about a 4 mile radius with a 22-gauge cable pair. Another of the recent improvements is the doubling of this testing range. The maximum test-trunk loop resistance has been increased from 750 to 1500 ohms. To make this possible, studies were made of the circuits of the test desk and the connecting circuits in all types of central offices so as to determine the maximum range over which
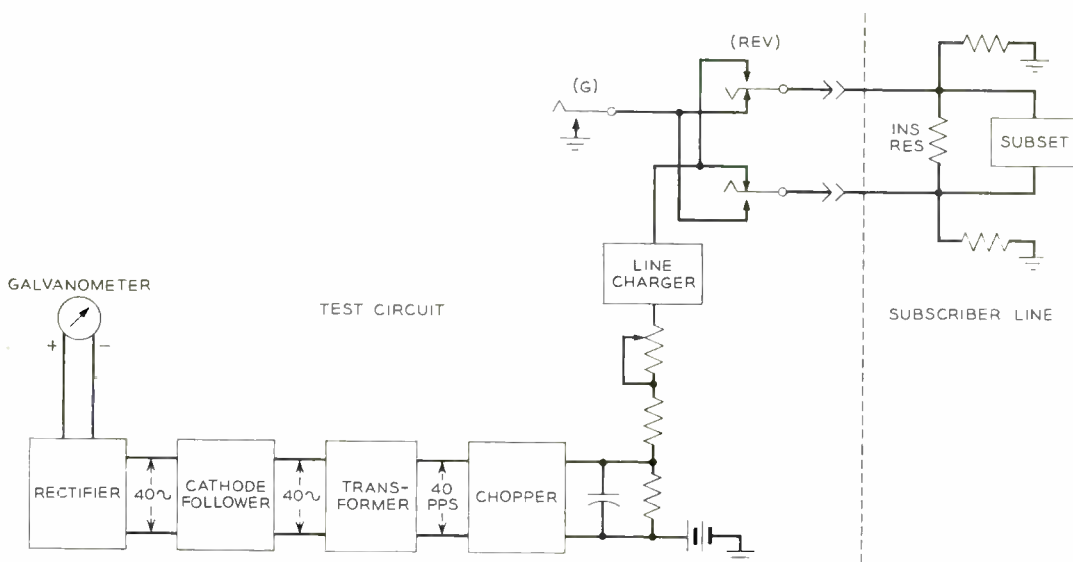

Fig. 3—Block diagram of the new electronic voltmeter test circuit now available for the No. 14 test desk. This arrangement permits the measurement of very high resistance faults with the existing test-desk meter. A resistance of 20 megohms is indicated at 10 per cent of full scale.

source of disturbance, increases the accuracy of the measurements in the presence of induced voltage. A problem encountered in the measurement of high resistance is the slow response of the meter caused by the charge or discharge of the line capacitance through high resistance. To improve meter response, a line charging feature is employed in the test lead whereby the line is first discharged by grounding both conductors and then charged rapidly before the test circuit is connected to the line. This line conditioning feature also guards the sensitive galvanometer section of the meter

existing circuit arrangements could be made to function. Then by readjusting the present relays to closer limits, by making minor wiring changes, and in a few cases by replacing apparatus, the trunk range of the No. 14 desk was doubled.

The third of the major improvements has been the provision of circuits and equipment at the No. 14 desk to permit multifrequency key pulsing over the test trunks. In many central offices multifrequency pulsing equipment is used for completing regular inter-office traffic connections to subscriber lines. If the No. 14 test desk

were capable of sending out only dial pulses, dial pulse incoming registers or senders would have to be provided in the associated offices solely for completing test connections. By the provision of a multi-frequency key pulsing set and the associated equipment at the test desk, this is avoided, and the over-all cost is decreased.

These three major improvements, and a number of others that experience has suggested, are available for inclusion in No. 14 test desks singly or in combination wherever and whenever local conditions justify them. The electronic voltmeter circuit will probably find widest application, since its use in preventive maintenance contributes materially to the improvement of subscriber service.

To meet the increasing needs of the system, further additions and modifications are under development for the No. 14 local test desk.

Fig. 4—Close-up of one No. 14 test desk position equipped with an electronic voltmeter and multi-frequency key pulsing. The multifrequency key pulsing set is evident just to the right of the dial.

THE AUTHOR: DAVID RITCHIE, JR., has been engaged in the circuit design of the No. 14 local test desk, used for testing subscriber lines in common systems. He has had over thirty years' service with the Bell System. From 1921-49, Mr. Ritchie was a member of the central office installation group at Western Electric Company. Until 1927 he tested installations and from then until 1949, when he joined the Laboratories, he served as a supervisor in that group. During World War 1, Mr. Ritchie served in the United States Navy.

Deal-Holmdel Colloquium

F. M. Ryan, radio engineer with the O & E Department of the A T & T, was the speaker at the last meeting of the 1951-52 season, held at Holmdel on May 16. In discussing his topic, *Radio in the Bell System*, Mr. Ryan presented a general picture of the radio services provided by the Bell System. These facilities are divided into four types: overseas, ship, land mobile, and domestic point-to-point. Of a total investment of roughly one hundred million dollars in all four branches, over 60 per cent is represented by domestic point-to-point service, chiefly microwave. Land mobile, overseas, and ship services follow in that order.

Traffic in overseas communication, now in its twenty-fifth year, amounted to 900,-000 messages in 1951 alone. Since service interruptions due to atmospheric disturbances are higher in this branch than in any of the others, consideration is being given to the use of distribution or relay points in southern Europe. It is hoped that such relay points would help alleviate transmission difficulties frequently encountered over the North Atlantic path.

Three classes of ship communication — high seas, coastal harbor, and VHF maritime mobile — serve about 19,000 vessels while land mobile for highway and urban telephoning is expanding rapidly, with about 11,500 telephones in operation at the present time. Mr. Ryan concluded his talk with a discussion of the recently inaugurated domestic microwave system for communication and television network service. These microwave facilities now span the continent with over 650,000 miles of toll telephones circuits, and expansion of the system to cover more of the country is expected to boost this figure to nearly one million miles of circuits by the end of the year.

Before adjournment of the meeting, officers were chosen for the 1952-53 season. R. S. Ohl was elected president, L. E. Hunt, program chairman and A. F. Dietrich, secretary. Following the tradition of past seasons, a dinner party was held for the speaker, members, and invited guests.

Patents Issued to Members of Bell Telephone Laboratories During the Month of May

2,595,232 Telephone Switching System Employing a Transistor, T. L. Dimond.

2,595,646 Television Test Signal Generator, S. Doba, Jr. and J. J. Jansen.

2,595,652 Coupled Cavity Resonator, J. B. Fisk.

2,595,662 Automatic Volume Control for Oscillators, E. W. Houghton.

2,595,667 Sweep Circuit, W. L. Gaines.

2,595,670 Reflecting Surface Bonded to a Film, W. R. Goehner.

2,595,680 Constant Resistance Pseudohybrid Channel Branching Microwave Filters, W. D. Lewis.

2,595,691 Signal Responsive Circuit, J. A. Morton.

2,595,701 Recording System, R. K. Potter.

2,595,944 Reverting Call Circuits, R. E. Hersey.

2,596,199 Error Correction in Sequential Code Pulse Transmission, W. R. Bennett.

2,596,251 Wave Guide Lens System, W. E. Kock.

2,596,288 High-Frequency Phase Measuring System, S. D. Robertson.

2,596,584 Pulse Conversion System, H. J. Michael and W. Whitney.

2,596,617 Increasing Number of Holes in Apertured Metal Screens, G. K. Teal.

2,597,028 Semiconductor Signal Translating Device, W. G. Pfann.

2,597,071 Signal Monitoring, S. L. Cory.

2,597,428 Checking Means for Pulse Counting Circuit, A. E. Bachelet.

2,597,570 Variable Impulse Transmitter, H. L. Coyne.

2,597,589 Electro-optical Device, B. T. Matthias.

2,597,898 Automatic Impulse Sender, D. B. Parkinson.

2,598,221 Power Amplifier Circuit, E. T. Burton.

2,598,317 Preparation of Two-sided Mosaic Screens, G. K. Teal.

2,598,318 Method of Thickening Relatively Thin Apertured Metallic Screens, G. K. Teal.

Teachers Taught About Transistors

"Students" attending a school on transistor physics at Murray Hill during the week of June 9-13 were members of the staffs of electrical engineering and physics departments at a number of universities, colleges, and institutions of technology A total of 63 students, representing 33 schools, included several department heads and one Dean of Engineering. About 60 per cent of the members of the technical staff of Bell Telephone Laboratories have, during the course of their education, attended one or more of the schools represented by the group.

The course was designed to facilitate the introduction of transistor physics into university courses, and emphasis was placed on experiments that might be carried out in universities. Ten lectures on the basic theory of semi-conductors and the principles of transistor action were presented by Prof. John Bardeen, of the University of Illinois. Prof. Bardeen, during his period of employ-

ment at the Laboratories, and in collaboration with W. H. Brattain, invented the point contact transistor.

Several discussion sessions were held, and a group of six experiments were included in the laboratory portion of the course. Such items as transistor action, point contact transistors, the properties of p-n junctions and junction transistors, and the behavior of injected holes and electrons in the presence of electric and magnetic fields, were demonstrated. One evening session was held at the request of the students, in which some of the techniques of preparing specimens for scientific purposes were demonstrated. A group of six students remained for several additional days to gain experience and to prepare specimens for use in their own laboratories.

On Wednesday evening the participants in the course were guests of the Laboratories at an informal dinner attended by the men who conducted the course and other

A group of the students of the Transistor Teachers Summer School are engaged in the fabrication of specimens for use in their courses, with instruction being given by members of the Laboratories' staff. At extreme left are Prof. D. G. Burkhard, U. of Colo., and R. M. Showers, U. of Penn. Seated at right are E. J. Scheibner, Ill. Inst. of Tech., D. W. Gade, Iowa State, and Dr. B. Lax, M. I. T. Standing, Prof. B. R. Russell, U. of Penn., P. W. Foy, K. Metzgar and W. Westphal, BTL.

W. H. Brattain (right) is giving instructions on the point contact transistor as produced by a micromanipulator. Capt. H. E. Curtis of West Point is at the micromanipulator and Dean E. C. Easton, Rutgers, and Prof. F. C. Walz, U. of Colo., in the background.

members of the Laboratories staff. This was followed by a talk by J. W. McRae who described the aims and objectives of the Laboratories in its post-graduate educational activity for new employees. Guests at the dinner then joined in a lively discussion of educational problems of mutual interest to the educational institutions and to the Laboratories.

Information and material presented in this course will be introduced into courses at several of the schools represented. Present indications are that over eighteen different courses will contain transistor physics experiments as presented at the Laboratories, and some of the schools plan to extend their teaching in transistor physics and electronics to a full year. To assist in this activity, Bell Telephone Laboratories plans to furnish a number of specimens of germanium and transistors to the schools. Some of these specimens were prepared by the students themselves who stayed on after the course.

W. E. Grants Transistor Licenses

Military and civilian demand for the transistor invented and developed by Bell Telephone Laboratories is so heavy that many manufacturing companies have applied for licenses to produce and sell them under Western Electric patents. In line with the Bell System's long established policy of making its inventions available to others at reasonable royalty rates, Western Electric has now licensed twenty-six domestic and nine foreign firms.

The transistor is a revolutionary electronic device which supplements and may replace vacuum tubes in many applications. They can demodulate radio carrier waves to extract audio signals suitable for activating telephone receivers or loudspeakers, rectify alternating currents, generate sustained oscillations, respond to light, and amplify weak signals. Contrasted to vacuum tubes, transistors are tiny, physically simple, long lived and require very little power. Therefore, they make possible substantial savings in space, material, power and maintenance.

Telephone Traffic Studies During Political Conventions

R. C. Pfarrer and C. L. Beckham visited Chicago during the Republican and Democratic National Conventions to make traffic studies of the performance of the No. 4 toll crossbar switching system under heavy load conditions. They were particularly interested in evaluating several improvements developed by the Laboratories as a result of previous traffic studies. Some $10,000 worth of special registers and recorders were installed to measure the loads carried, the delays encountered, and the general traffic efficiency exhibited by the common control circuits, such as sender link controllers, senders, and markers.

During heavy traffic loads, delays tend to cut down the rate at which the common control circuits handle calls. This means that the traffic capacity for the system may be reduced at the very time when the submitted load is greatest. Careful analysis of the circuit action under these conditions

may point the way to improvements in design that will speed up the system's handling of heavy traffic.

Such analyses cannot be made on the spot — the circuit interactions are far too complex and too fast. Instead, pens connected at strategic points follow circuit operations automatically, tracing a detailed record on paper. Traffic volumes are recorded on special traffic registers, which are either read directly or photographed at intervals. All these data are sent back to the Laboratories for analysis.

Traffic overloads most frequently result from unpredictable circumstances — disasters, storms, and transportation breakdowns. It is rare that engineers can observe an overload with a complete set of recording apparatus connected and working. The political conventions, however, offered heavy loads that could be definitely anticipated with full preparation.

Collegiate Degrees

In June the following members of Bell Telephone Laboratories were granted degress: C. B. Brown, Bachelor of Electrical Engineering from Brooklyn Polytechnic Institute; C. H. Dagnall, R. L. Dougherty, F. J. Herr, C. E. Jakielski, and J. C. Rile, Master of Science from Stevens Institute; Stella Lawrence, Master of Electrical Engineering from Brooklyn Polytechnic Institute; J. W. Shaw, Master of Science in Electrical Engineering from Newark College of Engineering; and H. A. Wells, Master of Science in Mechanical Engineering from Newark College of Engineering.

Special TV Channels for Convention Coverage

Viewers in ten cities added to the Bell System's television network increased "live" coverage of the political conventions in Chicago to 99 per cent of the TV receivers in the country, according to the Long Lines Department of A T & T. Some of the cities that were added to the network had existing coaxial cables for voice service, and some of the spare circuits were utilized temporarily for TV. Others were part of the long-range planning by the A T & T for future television expansion, and were expedited for the conventions. Thus both coaxial cables and radio relays were brought into play for the occasion.

The TV services were made available to twelve stations in Miami, New Orleans, Houston, San Antonio, Dallas, Ft. Worth, Oklahoma City, Tulsa, Phoenix and Seattle. Residents of Denver, Fresno, and Portland, Oregon, were also able to view the proceedings of the conventions although there are no stations in these cities. TV signals were piped into theaters and hotels where TV receivers were provided on a "closed-circuit" basis. The Republican convention in Philadelphia in 1940 was the first to be televised. In 1948 the Republicans were again covered, and this year saw coverage of both major conventions for the first time.

Future Microwave Route

Plans to construct a $4 million microwave radio-relay system between Chicago and St. Louis were disclosed in an application filed with the Federal Communications Commission on July 11 by the Long Lines Department of the American Telephone and Telegraph Company. Planned for completion in mid-1953, the new Midwest route will initially provide 300 telephone message circuits. When fully developed, it will be able to carry over one thousand telephone conversations plus a number of television programs.

Nine intermediate radio-relay stations will be required to transmit the signals. The antenna towers will vary in height from 137 to 275 feet at different stations. Part of an over-all plant expansion program to provide better and faster long distance telephone service to the residents of the Midwest, the 283-mile route will augment wire as well as coaxial and other cable facilities now furnishing telephone service to this area. Future plans call for four television channels, two in each direction between Chicago and St. Louis, to provide added flexibility in routing TV programs over the Bell System's nationwide network facilities.