February 1961

Bell Laboratories RECORD

TH Tower at Rawlins, Wyoming

THE BELL LABORATORIES RECORD is published monthly by Bell Telephone Laboratories, Incorporated, 463 West Street, New York 14, N. Y., J. B. Fisk, President; K. Prince, Secretary; and T. J. Montigel, Treasurer. Subscription: $2.00 per year; Foreign, $2.95 per year. Checks should be made payable to Bell Laboratories Record and addressed to the Circulation Manager. Printed in U. S. A.

Bell Laboratories **RECORD**

Volume 39 • Number 2 • February 1961

Contents

COVER

This radio relay station is one link in first section of a new coast-to-coast-transmission system. Designated TH, this new system can handle three times as many circuits as any previous system. *(See page 48.)*

Over-all view of the ESSEX *(Experimental Solid-State EXchange) research model set up at Bell Laboratories. Units shown behind the control console comprise only half the total equipment.*

By harnessing one of man's most precious possessions—time—researchers at Bell Laboratories have demonstrated an entirely new approach to telephone communication. This experimental system uses time-divided switching and transmission to integrate for the first time, both major operations involved in communication between two telephones.

W. A. Malthaner

ESSEX: *A New Concept in Telephone Communications*

In the modern telephone system, each customer must be permitted to talk with any other customer within a reasonable time after his request (usually by dialing) to do so. The system must, of course be arranged to carry out many such requests simultaneously. For all telephone calls, the two essential operations are transmission and switching. That is, *transmission* paths must exist to handle the information, in this case the voice conversation, and these paths must be combined properly, or *switched,* to establish a connection between the calling and called telephones. These same operations are basic to many other types of communication services—for example, data and telegraph transmission, and radio and television broadcasting.

In theory, both transmission and switching may be space-, frequency-, or time-separated. These three methods are explained and described in the diagram on page 44. In practice, all three of these methods have been used for transmission systems. For switching, however, most systems presently in operation are space-divided, including the electronic central office (ECO) now being field tested in Morris, Illinois (RECORD, *December,* 1960). Frequency-separated switching has been explored, but is not economically attractive at the present time. Time-division switching, on the other hand, is being studied extensively, both in this country and abroad (RECORD, *July,* 1959).

There is no need here to give a detailed account of the various advantages and disadvantages of these three techniques. It will be sufficient merely to point out that time-division communication has become increasingly interesting in recent years because of the availability of high-speed, solid-state devices, such as transistors and semiconductor diodes. Older devices, although their use is possible, are generally unsuitable for the economical design of a time-division system. The advent of solid-state devices therefore led to an intensive research study of time-division techniques at Bell Laboratories and to the development of an experimental model of a time-division communicating system, called ESSEX.

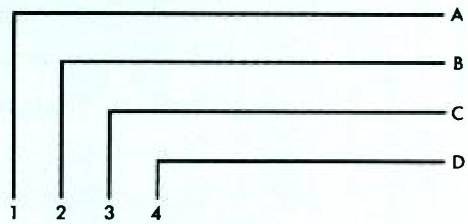
ESSEX—an acronym for Experimental Solid-State EXchange—demonstrates an entirely new approach to telephone switching and transmission. The experimental system applies new design precepts that integrate and solve simultaneously these two fundamental problems in telephone communication.

Time, Frequency, Space Separation in Transmission and Switching

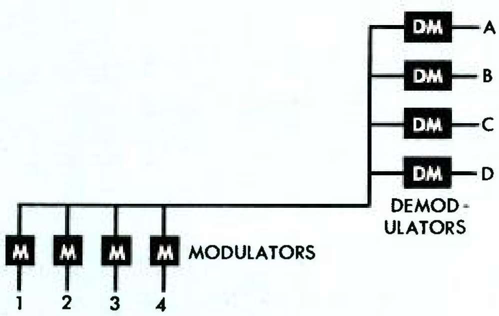
TRANSMISSION

Each path between input and output terminals is permanent, whether in use or not.

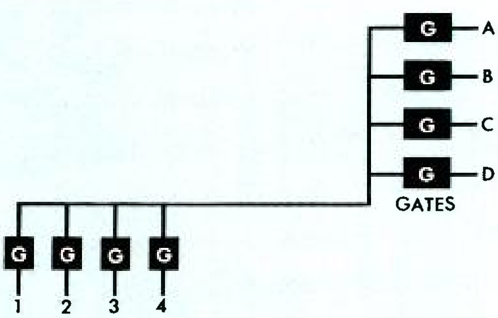
Number of output terminals equals number of input terminals.



An individual "space" path is provided between each input terminal and its associated output terminal.



Signals at an input are converted to a band of permanently assigned frequencies not shared by any other input terminal. Frequencies of the whole input group are sent over a common path. At each output terminal, signals in the specific frequency band of the common path are reconverted to original form.



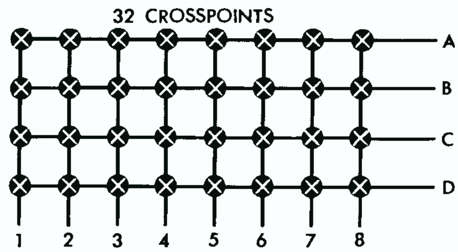
Gates with permanently assigned time slots connect one input and one output terminal at a time to a common path. Each input-output pair is connected momentarily in fixed sequence. These operations are repeated at high speed to give the effect of continuous connections.

SWITCHING

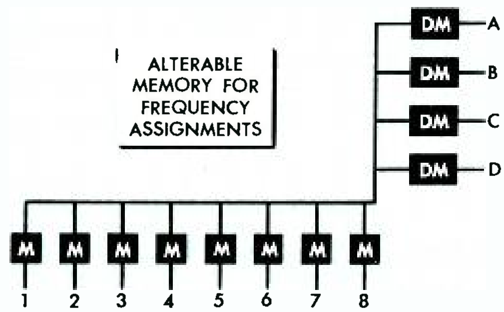
Path between an input and output terminal is completed only when needed.

An input can connect to any output.

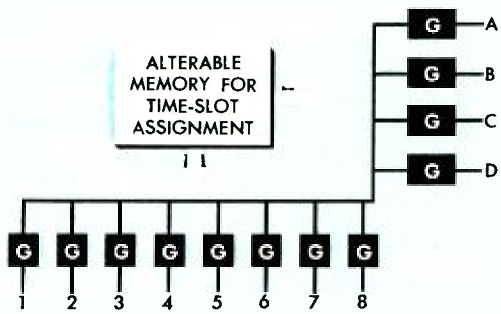
Number of output terminals may be greater or less than number of input terminals.



Spacially separate paths between desired input-output combinations are completed by switches operated for the duration of the use of the path.



A separate frequency subband on the common path is assigned by the memory to each desired input-output connection for the duration of each use.



A separate connecting time in the gating sequence to the common path is assigned by the memory to each desired input-output connection for the duration of each use.

There are four important, inter-related points involved in the ESSEX concept. The first is that line concentrators are used near the customers' premises. Instead of having a pair of wires between each telephone and the central office, the traffic is "concentrated" locally, and only a few, efficiently used wires connect to the central office.

Second, switching at a concentrator—between the many customer lines and the fewer pairs to the central office—is time-divided. During a conversation, customers share in rapid succession a single transmission path, and each customer uses the path repetitively at a rate high enough that the interruptions for other customers are unnoticed.

Third. the high speed of the switching elements permits the use of coded, digital transmission between the concentrator and the central office. Voice-frequency signals are sampled, and each "amplitude" sample is coded into a group of binary pulses identifying the amplitude. This is called pulse-code modulation (PCM). The coded group of pulses is then sent over the transmission medium. Control pulses in the same form are transmitted from the central office to the concentrator. These determine in which intervals the customers are connected to the common speech path. These ideas are all depicted in the illustration on page 47.

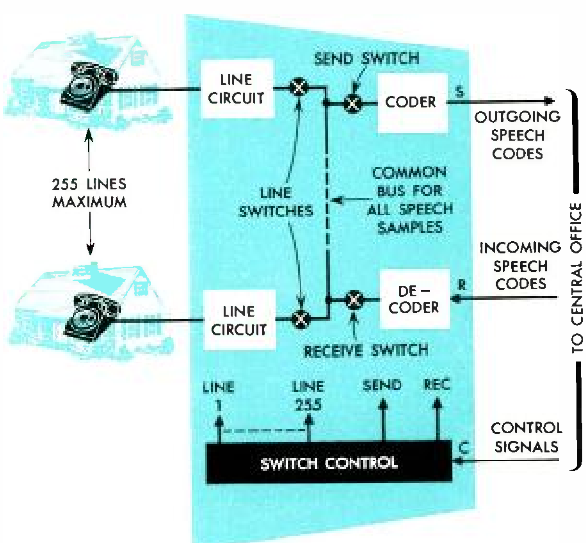
The fourth point in ESSEX plan is that the PCM signals are connected *directly through* the central office by time-division switches. A customer's conversation in this system exists in voice-frequency form only from his telephone to his concentrator, perhaps a few hundred yards. At the concentrator, his voice is sampled many times per second and each sample is switched to a coder shared by all the customers at his concentrator. His voice then stays in coded form to the office, through the office, and to the concentrator near the called customer. There, it is reconverted to a standard voice-frequency signal for delivery to the called telephone.

As shown in the illustration on the next page, a voice-frequency signal appearing on a customer's line at remote concentrator A is switched within the concentrator to coding equipment, and appears as coded pulses on the cable pair designated S. Speech is transmitted in this form to the central office. At the central office, the signal (still in digital form) passes through concentrator controller A to the central-stage switch. Here, it may be switched to the path leading to concentrator B. The coded pulses now pass along the cable pair designated R to concentrator B. Here, they are decoded and then switched to the proper customer line, appearing there in the original voice-frequency form. Voice signals in the other direction pass in the same manner from the S lead at concentrator B to the R lead at concentrator A. Signals in the two directions pass each other during a momentary operation of the central-stage switch.

Numbers identify which customers are to be connected to the R and S leads and the path they are to use in the central-stage switch. These numbers are stored in memory units at the concentrator controller and are read from the memory again and again at specified times. The customer numbers are transmitted in pulse-code form to the concentrator and connect the corresponding customers to the S and R leads each time they arrive. Similar numbers in the memory identify the central-office paths and control the central-stage switch directly.

A switching plan of this kind has several important attractions. Savings should result from the use of only a few pairs of wires from the concentrator to the office. Only a single switch per line, with a couple of additional switches used in common by all lines, is required for the interconnection of transmission paths at a concentrator. Also, the switching network at the central office is greatly reduced in size: first, because it interconnects concentrators rather than individual telephones; and second, because the interconnections are time-divided.

For transmission, the problem of maintaining



Simplified schematic of ESSEX concentrator, showing essential elements and pairs to central office.

at a low level the voice-frequency crosstalk between customer lines is made easier because it occurs directly only within the group of lines at a centrator. PCM has the advantage that so long as the system can distinguish between a "pulse" and "no pulse," a code can be kept error-free, and to that extent the information-bearing signal is free from noise. Thus, in the PCM transmission medium, the crosstalk limits are more liberal. With pulse-recognition and -repeating circuits properly spaced along the cable, signals do not suffer from the gradual accumulation of noise that is characteristic of other methods of transmission. This is also true of loss of volume because a given speech code is equivalent to a given "loudness" in the speech sample. Thus, the variation in loudness between calls from nearby and far-away points is also reduced.

These are the direct advantages. But what is the price, in terms of system complexity, that must be paid to obtain them? Circuits such as coders, decoders, and regenerative repeaters must be included in the system, and must be engineered to keep a new kind of "noise" at low level. Between the "loudest" sound and "deep silence," there are an infinite number of intermediate possibilities. In PCM transmission, however, loudness codes must be provided, and these can specify only a fixed number of levels (128 in ESSEX. In the transmission process a code for the level nearest to the exact level is transmitted,

High-speed solid-state devices make possible time-division switching. Printed-circuit boards, shown here being tested, make up most of ESSEX *units.*

and it is this level that the listening customer hears. The small difference between actual loudness level and the coded level, as it appears in the system, is called "quantizing noise."

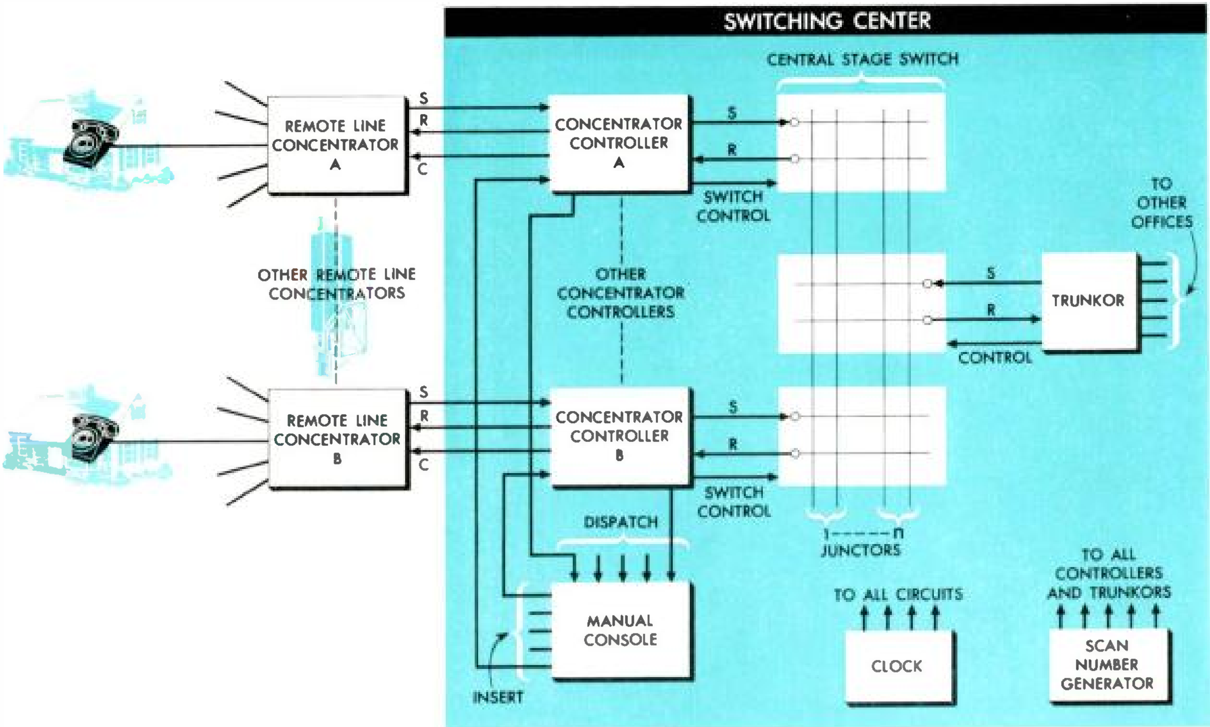
In addition to its direct advantages, the ESSEX plan has other attractive possibilities. The transmission path between a concentrator and its central office carries 1.536 million pulses per second, representing, in terms of PCM, the speech of a whole group of customers. However, these pulses may be multiplexed in many ways. For example, by doubling the sampling rate for some customers their voice-frequency band could be doubled for the transmission of music. Or, an entire channel could be used for slow-speed-PCM television.

Because such potentialities, and indeed the entire ESSEX concept, are based on electronic actions that take place in very minute time segments, let us consider in a little more detail the numbers associated with the research model of ESSEX constructed at Bell Laboratories. Each concentrator is capable of identifying up to 255 voice-frequency lines. But because of traffic considerations, it would probably actually handle only half this number. From the concentrator to the exchange, 24 PCM channels are provided on a time-division basis. Twenty-three of these are for voice conversations, and the 24th is reserved for scanning the lines to detect new requests for service. Each conversation is sampled, and the samples are put into a seven-bit code, with an eighth bit reserved for control signals to the exchange. Each coded sample is sent, bit-by-bit, at its assigned time, over the pairs to the exchange.

In the research model, each customer would receive the nominal telephone-channel bandwidth. By a well-known theorem, the sampling rate must, therefore, be at least twice the maximum frequency of this band, so each conversation is sampled 8000 times per second. Thus, successive samples from one conversation are spaced 1/8000 of a second, or 125 microseconds, apart.

For 24 channels, this 125 microseconds, divided by 24, is allotted for the operations on each sample. Each of these sample periods—5.2 microseconds—is further divided into eight parts to be used for pulse-coding. The individual code elements are called "bits," the period allotted to a sample is called a "time-slot," and the 125-microsecond period for 24 samples is called a "frame." This means that the required pulse rate on the pairs to the central office is 8 pulses per sample times 24 samples per frame times 8000 frames per second, or 1.536 million pulses per second.

With the 1.536-megacycle pulse rate being sent over standard cables with 22-gauge conductor



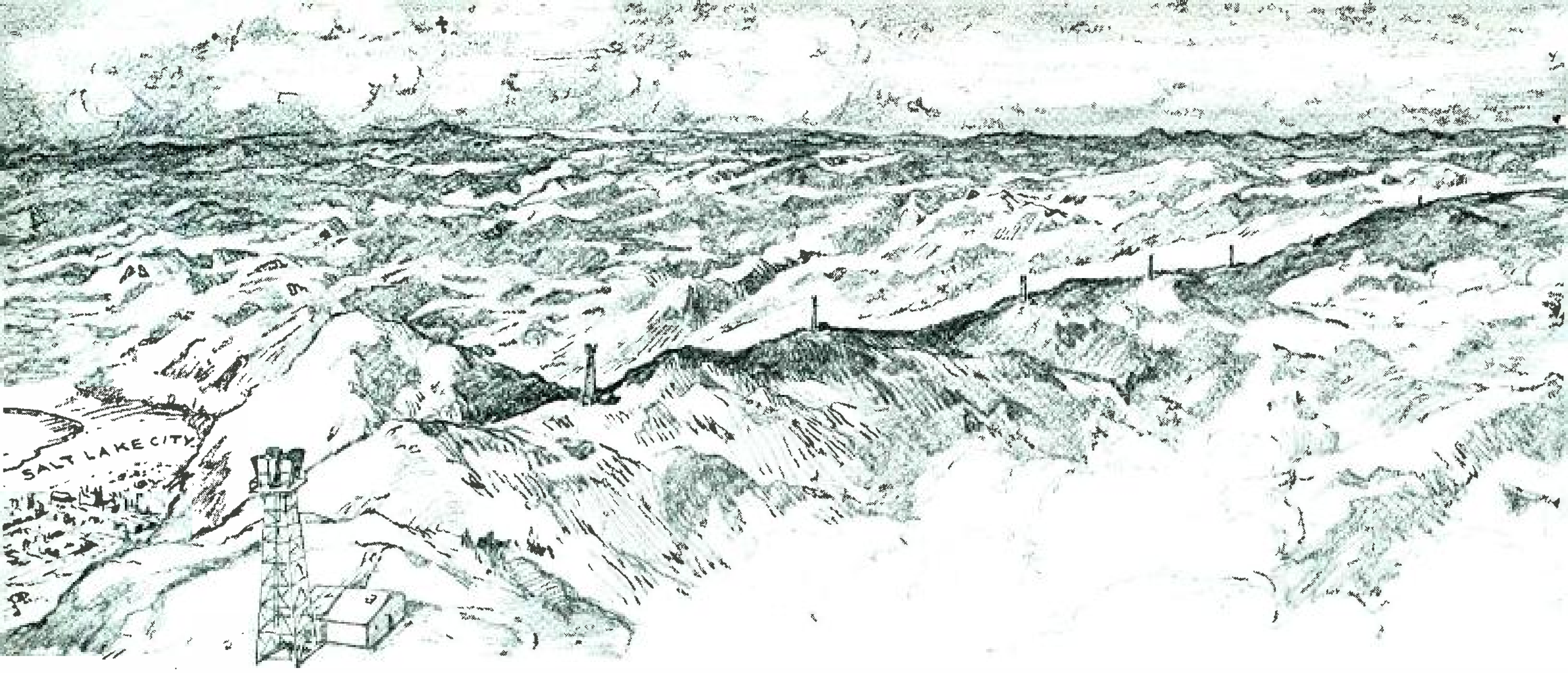
System diagram of ESSEX. *The manual console shown here performs the memory and control functions that would be done by a high-speed electronic control section in working* ESSEX *system.*

pairs, regenerative repeaters will be required about every 6000 feet, under normal noise conditions. ESSEX uses four-wire transmission—one pair for each direction. A third repeatered pair is used for synchronization and control.

The research ESSEX model built at Bell Laboratories is shown in the photograph on page 42. Two concentrators have been built, each capable of handling up to 255 voice-frequency telephone lines. The model also has a trunkor—a unit that connects to the voice-frequency trunks of existing exchanges. A 4000-line office might require a total of 30 such units. ESSEX is skeletonized, however, and uses only three centrally-located controller units, one for each remote concentrator and one for the trunkor. A central switching network and a master source of timing pulses complete the transmission and switching parts of the model. Each concentrator controller includes a memory section. It contains information for operating, at the proper times, the switches in the remote concentrator and in the central network. By use of this memory and associated logic circuits, a controller also performs for its own remote lines simple supervisory functions, such as the recognition of a request for service, the answer of a called party, and the hang-up at the end of a conversation.

That section of the central-office equipment that governs its over-all operation—storing and operating upon orders received from customers, and internal instructions for setting-up and taking down connections—is simulated in the model by the actions of an operator at a control console. Considerable work already has been directed toward modern systems of high-speed electronic control, particularly in the development of the experimental ECO, so that it was unnecessary to explore this area in the ESSEX experiment.

The system arrangements described here imply potential savings. But to get a realistic picture of their future value, we would have to include the many complex considerations of manufacturing and installation costs for new solid-state devices and circuits, many of them not yet in large-scale production nor yet reduced to a corresponding cost. We would also have to be accurately prophetic of the economic climate and service requirements a decade or more in the future. In the early phases, research studies at the Laboratories are concerned primarily with what can be done technologically. Nevertheless, it seems certain that high-speed electronic systems are inevitable, and that communication needs are expanding so rapidly that presently used methods of switching and transmission cannot be expected to keep up with them much longer.



A superhighway for telephones crosses the Rocky Mountains and connects Salt Lake City with Prospect Valley, Colorado. This telephone highway is the first section of the TH System.

H. E. Curtis

TH Radio Relay System

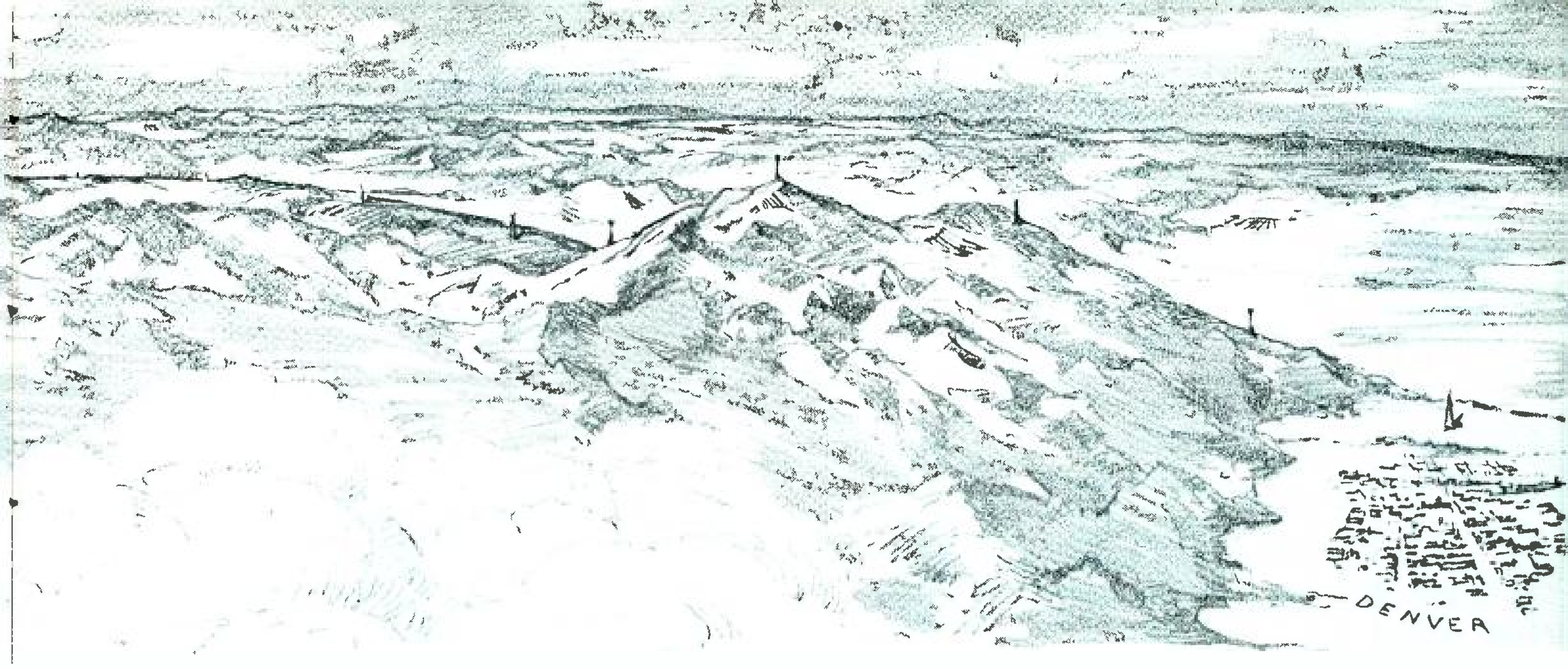
Today, the United States is criss-crossed with a microwave network stretching from the Atlantic seaboard across the Rocky Mountains to the Pacific coast. This system—known as the TD-2—has six two-way broadband channels. Each channel normally carries up to 600 telephone circuits, or one 4.3-mc television circuit. Despite this capability, many of these routes often have all six channels in service at the same time. Construction of new routes is expensive and, in some cases, impractical.

Although Laboratories engineers have devised a way to double the number of TD-2 channels from six to 12, even this would provide only temporary relief for the increasing demand for telephone, television, and data circuits. A new microwave system was needed—one that would act as a communications superhighway. Such a highway had to be capable of carrying nearly 11,000 two-way telephone circuits across the nation using existing radio relay towers, antennas and buildings.

Here we examine how Bell Laboratories engineers overcame the fundamental problem in creating this new transmission system. Briefly, this problem was: how to formulate an economical system that has a greatly increased circuit capacity and at the same time maintains the high standards required for telephone, television, and data transmission.

The radio spectrum is a valuable national resource, and any radio system must use it efficiently. For this reason it is more than desirable—it is absolutely necessary—to derive as much communication capacity as possible from a system by maximizing the use of frequency space and the re-use of frequencies. Efficient use of the radio spectrum depends on three factors: (1) the bandwidth of each radio channel, (2) the spacing between these channels, and (3) the number of times each frequency can be re-used in each link of repeater stations.

A key feature of the TH system is its frequency scheme. Three common-carrier bands suitable for radio transmission are available at 4, 6, and 11 kmc. The TD-2 system uses the



4-kmc band, and the band at 11-kmc (which is not suitable for a long-haul system such as TH because of rain attenuation) is occupied by the TJ system. This leaves the 6-kmc band, which is completely satisfactory for TH.

Ideally, the 6-kmc common-carrier band could be divided in half, and each half used by a single very broad channel. It is not yet feasible, however, to amplify such a single wide band. Consequently, the designers had to divide the common-carrier band into a number of channels. In so doing, they achieved a great flexibility of use and a relatively simple integration into the Bell System growth pattern.

To illustrate this point, let's take a simple example. A system connecting Boston, New York, and Philadelphia includes circuits between Boston and New York, New York and Philadelphia, and Boston and Philadelphia. If all these circuits were carried by a single wide-band channel, the Boston-Philadelphia circuits would have to pass through New York. This means the channel would have to be modulated at that point (since it is not possible to modulate part of an FM signal). If, however, the Boston-Philadelphia circuits are carried by a direct channel, unnecessary modulation at New York is avoided; furthermore, less equipment is required, and the transmission is better.

Of course, there is a point of diminishing returns. If this concept of direct routes were carried to the extreme, providing separate channels between all intermediate points (such as, say, Hartford and Trenton), the complexity of the system would overbalance the savings. So there is a kind of "golden mean"—a point that depends on the facilities that already exist.

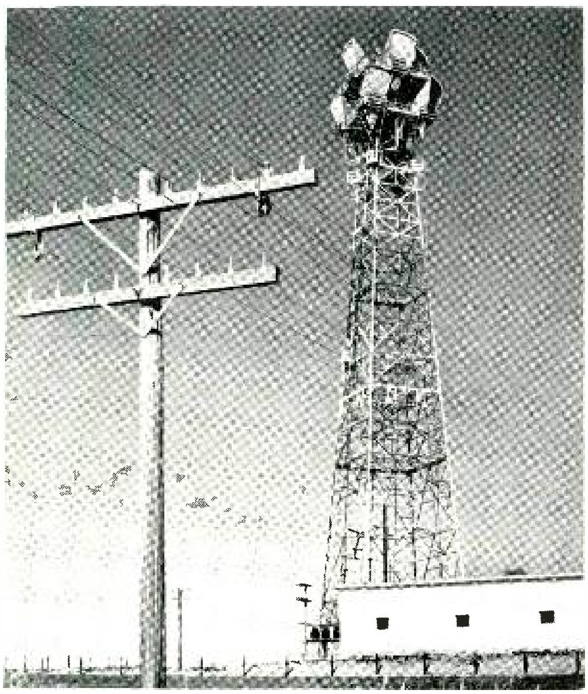
When a common-carrier band is divided into several narrow bands, it is essential to have some guard frequency space between adjacent bands. In this way, the filters that separate the channels can build-up the required suppression. Unfortunately, the guard frequency space does not decrease appreciably as the channels are made narrower, so that the fewer the radio channels, the greater the frequency utilization. Also, more equipment is required as the number of channels increases and the bandwidth decreases.

These were some of the factors considered before it was decided to divide the frequency band into eight two-way radio channels, each approximately 29.7-mc wide. This band made each channel wide enough to accommodate a low-index frequency-modulated wave with a baseband signal extending from just above zero frequency to 10-mc. At the same time, each channel can handle 1860 telephone circuits—more circuits than have ever been put on a radio channel before.

The frequency band for such a system must not only be divided into radio channels, but also into two directions of transmission. There are two ways to do this: In the TD-2 system, the transmitting and receiving channels are interspersed throughout the band. The TH system divides the 5925- to 6425-mc band into two equal portions. At a repeater station, transmitters operating in both directions use one portion of the band and receivers operating in both directions use the other. At the next repeater station, the frequency assignments are reversed.

Both schemes have advantages and disadvantages. The TD-2 arrangement is more flexible and more adaptable to a complex network of stations. The filtering problems, however, are more severe because transmitters and receivers are on adjacent frequencies and there may be some interference from crosstalk. The TH arrangement uses frequency space more intensively, but it is less flexible in application, particularly in complex networks. Thus, the two systems are complementary. TH may be regarded as a limited access highway, to be added to a complex network of secondary roads of TD-2 when the traffic requires it. Like the superhighway, TH has large capacity, but it is not so adaptable to local service as the TD-2 secondary highway.

The second major factor that determines the efficiency of a radio transmission system is the spacing between channels. The TH system uses the radio spectrum efficiently by spacing the carriers as closely as possible consistent with the maximum baseband frequency to be transmitted and requirements on interference between adjacent channels. Carriers are spaced at intervals of 29.65-mc; and in this system each channel has this bandwidth. Since the system was designed to transmit baseband signals up to 10-mc, first-order sidebands occupy 20-mc of the allotted band, and second-order sidebands extend slightly more than 5-mc into adjacent channels. The interference resulting from this overlap is negligible.



TH repeater station at Prospect Valley, Colorado. The TH equipment at this station can handle almost 11,000 two-way telephone circuits simultaneously.

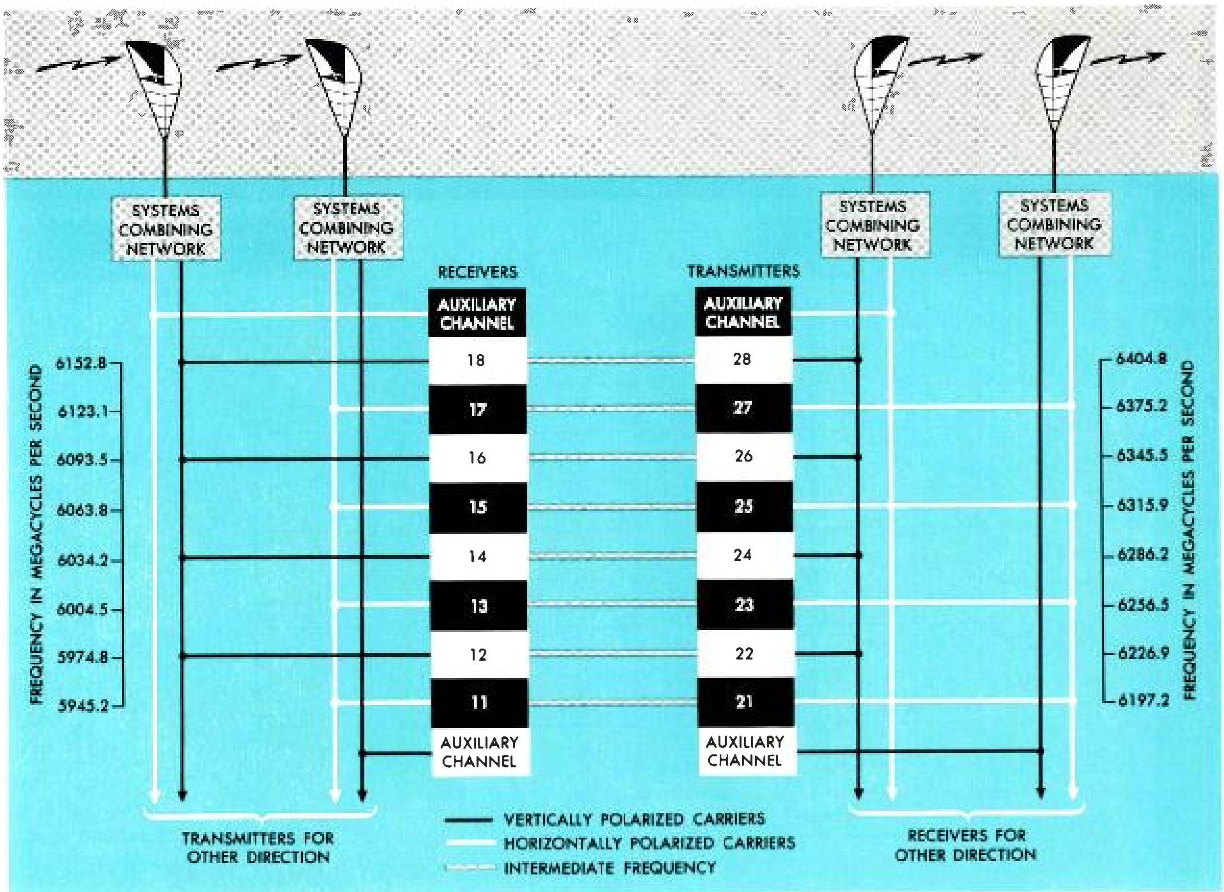
Just as in FM broadcasting, the TH system transmits information by shifting the frequency of a carrier wave back and forth. This deviation is about ±4 mc, some 50 times that used in FM broadcasting. Even at that, the index of modulation of the FM carrier (that is, the ratio of peak frequency deviation to highest baseband frequency) is relatively low. Therefore, the second-order sidebands in any particular radio channel extending out to ±20 mc from the carrier are very much weaker than the first-order sidebands which extend out only half this distance.

Polarization Process

Also, vertically polarized channels are placed beside horizontally polarized channels. The two polarizations are separated in the waveguide system connecting the antenna with the radio equipment. This separation process is so precise that the interfering signals from adjacent channels are attenuated more than 25 db relative to the wanted signal. Consequently, the resulting power for the second-order sideband spectrum that falls into adjacent channels is very low. The filtering action of the intermediate-frequency amplifiers in each channel reduces still further the interfering effects between adjacent channels. The designers expect little distortion or interference from this intensive use of the radio spectrum.

The third factor involved in the efficient use of the radio spectrum is the use and re-use of frequencies. The mutual coupling, or interaction of signals between receiving and transmitting antennas, is important in determining the number of times assigned frequencies can be re-used. If the antennas are not well shielded, a frequency used between one pair of repeater stations cannot be re-used in the adjacent stations because of crosstalk. Thus, each two-way radio channel usually requires four frequency assignments—one for transmitting and one for receiving in both directions. However, because the TH and TD-2 systems use well-shielded horn reflector antennas, a frequency may be re-used in successive sections, and only two frequency assignments are required for each two-way channel.

To illustrate this use of frequency space, let's look at what happens when a signal is transmitted. At every TH repeater station, there is a block of ten channels, eight for normal use and two narrow auxiliary channels for order wires, alarms and controls. When an antenna receives a signal from one direction in the lower block of frequencies, the signal appears in one of the eight broadband channels and is modulated to an intermediate frequency of 74.1 mc; here it is amplified



TH frequency plan. A signal coming in on receiver 18 at 6512.8 mc is modulated to an IF of 74.1 mc and sent out on transmitter 28 at 604.8 mc. A frequency shift of 252 mc is common to all channels.

and then shifted by 252 mc to the upper block of frequencies, and transmitted. Similarly, signals from the opposite direction are also received in the lower block, modulated to the intermediate frequency, amplified, shifted to the upper block of frequencies, and transmitted. There is a certain amount of unavoidable coupling between antennas pointing in the same direction. The frequency shift minimizes the effect of such coupling.

Notwithstanding the benefits derived from all the modulating and shifting processes that take place at a repeater station, some interference may fall into the intermediate-frequency band of the various channels. To decrease this effect, the designers chose a frequency plan that minimized the number and amplitude of such interference signals.

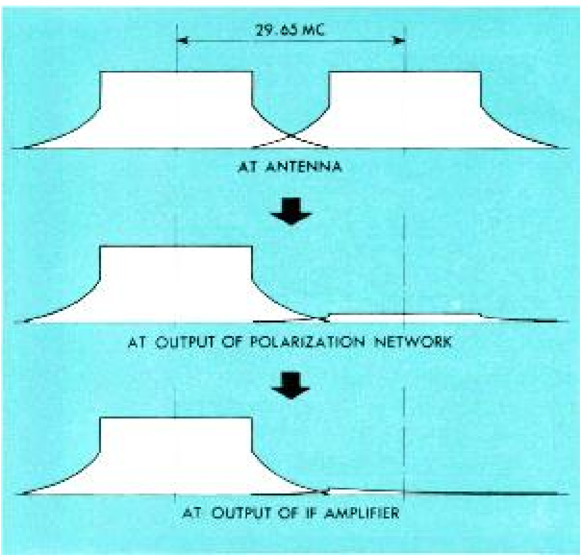
Over-all system performance is determined by fluctuation noise, intermodulation, and interference. The amount of fluctuation noise depends on the frequency deviation, the ratio of the microwave carrier power to the noise power at the converters, and the number of telephone conversations the system handles. The IF bandwidth available for each broadband channel and the possibility of interference into adjacent channels limit the maximum frequency deviation to about ± 4 mc, which is the same as in the TD-2 system.

The designers wanted to obtain the same transmission performance as they had with the TD-2 but with three times as many telephone channels. To do this, they had to increase the average carrier-to-noise ratio at the converter by approximately 14 db.

By using a traveling-wave tube, they increased the output power and therefore the carrier-to-noise ratio by 10 db over that in the TD-2 system. An additional 2 db was gained by improving the noise figure of the converter. With the same antennas and repeater spacing as the TD-2, the net loss from transmitter to receiver is about 3.5 db less at 6 kmc than at 4 kmc. Although slightly offset by higher filter losses, these factors provide the increased carrier-to-noise ratio required for handling 1800 telephone channels.

Just as the carrier-to-noise ratio had to be improved, so the amplitude intermodulation had to be improved approximately 9 db to obtain performance equal to that of the TD-2 system. Because of the careful circuit design of the TH repeaters, the phase and amplitude characteristic is so smooth and stable with time that the intermodulation requirements can be met with relatively simple equalizers. Even though there are limiters in each repeater, the over-all gain of the system will not be uniform with frequency unless the gains of the inner parts of the system—such as IF and RF—are uniform with frequency. As a signal passes through a repeater, it undergoes a certain characteristic distortion in its phase and amplitude. Equalizers in each repeater correct this basic distortion. After the signal passes through several repeaters, more complex adjustable equalizers counteract the minor differences between the repeater and the basic equalizer.

Echoes caused by very slight differences in matching the impedance of a waveguide to the impedance of an antenna constitute another major source of intermodulation between telephone channels. These echoes are so random in nature that they cannot be equalized and hence must be controlled. There are nearly 210 waveguide runs in a coast-to-coast TH system, and the echo power introduced by each must be roughly one millionth of that of the carrier power. To satisfy such a severe requirement calls for careful attention to (1) uniformity in the waveguide structure, (2) the impedance match of the antenna terminating one end of the waveguide, and (3) the impedance match of the radio equipment at the other end.



This diagram shows two adjacent channels at various points in a repeater station. By the time a signal has passed through its intermediate frequency amplifier, the adjacent channel is so weak that interference from it is negligible.

As pointed out above, a pair of radio frequencies is used for each of the eight radio channels. At a repeater station, one radio frequency is used to transmit in both east and west directions and a second frequency is used to receive in both directions. Now, if the antenna that receives signals from the east picks up an appreciable amount of the signals from the west, crosstalk occurs at baseband frequencies. There also are many other coupling paths that must be considered in the over-all system planning.

Protection Channels

Like all transmission systems, the TH system is subject to occasional interruptions caused by fading and equipment failures. To anticipate such contingencies, the designers set aside a certain amount of frequency space for two protection channels. If any of the regular channels fail, these protection channels stand ready to take over. In line with present Bell System practice, all other active equipment carrying 600 channels or more, as well as the TH carrier supply equipment and the power supply, has standby equipment that automatically takes over in case of failure.

Over-all system reliability depends on the length of the switching sections, the number of protection channels relative to the number of working channels, and the time of day that maintenance is done. Fading of the signal is expected to be the greatest single cause of out-of-service-time, and therefore "outage" may be expected to be a maximum during the early morning hours of the summer months. Thus, there is a substantial improvement in reliability by doing maintenance in the daytime rather than at night.

It is estimated that with six working channels and two protection channels, six repeater sections per switching section, and daytime maintenance, the outage for a coast-to-coast system during the worst month will be of the order of 0.03 per cent. The annual outage time is expected to be slightly less than .01 per cent.

The TH Radio System will provide a tremendous increase in the number of long-haul circuits in the United States. This system is another example of how the Bell System meets the growing demands for telephone, television, and data-type circuits.

The efficient use of central-office switching equipment means wise use of invested capital. To improve this efficiency, traffic specialists at Bell Laboratories and A.T.&T. have devised a scientific method of balancing telephone traffic in dial offices. This new method reduces complex statistical theory to simple clerical practice.

Valerie Miké

Quality-Control Techniques Applied To Dial-Office Load Balancing

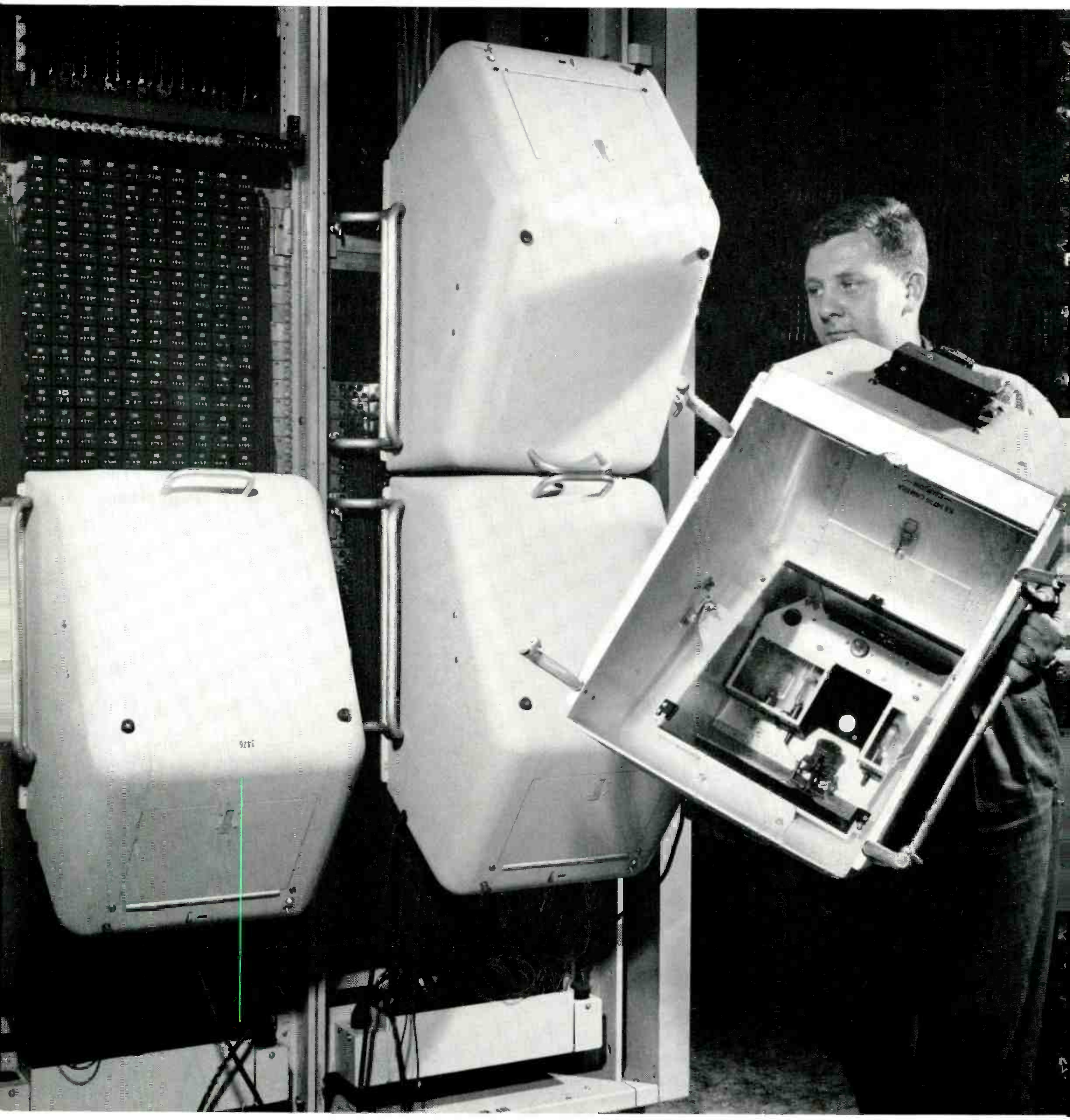
It's a known and registered fact that some of us talk more than others. Some people just like to talk. Some don't. Other people have to talk more or less than usual because their business or some other situation demands it. These differences in talking habits are generally reflected in our telephone usage.

Variations in customer usage is a very important factor in meeting the Bell System's basic objective of offering the best possible service at the least possible cost. To do this, it is essential that telephones used a lot and those used less frequently be "balanced" among the available paths through a telephone exchange. This important telephone art is called "dial-office load balancing."

In a dial office each customer is connected to a particular group of switching circuits. If all of the lines connected to a particular group of circuits belonged to high-usage customers, they would get deficient service. And if all the lines assigned to another group of circuits belonged to low-usage customers, these circuits would operate far below their capacity. Merely assigning the same number of customer lines to each circuit group is not a satisfactory solution, because even a few very busy lines in the same group may mean poor service for all customers sharing the equipment.

The problem of load balancing is analogous in many ways to that of controlling the quality of a manufactured product. Here, the manufacturer wants to keep the quality of his products within certain limits of an ideal value. Similarly, the traffic engineer wants to keep the usage level of a group of switching circuits close to an ideal value; in this case, the average usage level of the whole office.

The manufacturer's quality-control problem is now being solved by modern statistical techniques. These statistical quality-control techniques were originally developed at Bell Laboratories in the 1920's by W. A. Shewhart and were initially used by the Western Electric Company in the manu-



W. Edgar of N. Y. Telephone Co. positions Traffic Usage Recorder camera on bank of traffic registers.

facture of communications equipment for the Bell System. Shewhart's methods resulted in important reductions in the cost and substantial improvements in the quality of telephone equipment, and are today employed by industry all over the world.

In statistical quality control, one establishes limits within which the results of a manufacturing process must lie if the products are to be usable and economical. If the measured results stay within the assigned limits, the process is said to be "under control."

Although the characteristics of telephone traffic differ in many ways from the manufacturing process, some of the basic techniques of quality control can be applied by the dial administrator. One of the great advantages of quality-control methods is that, although they are based on complex statistical theory, they can be used effectively by people not trained in mathematics. Thus, modern scientific concepts can be applied to dial administration by clerical personnel.

With these facts in mind, the Laboratories and the American Telephone and Telegraph Company have developed a statistical quality-control method applicable to dial-office administration. The method has recently been introduced in the Bell System and can be used in either manual or mechanized form.

How an Office Is "Balanced"

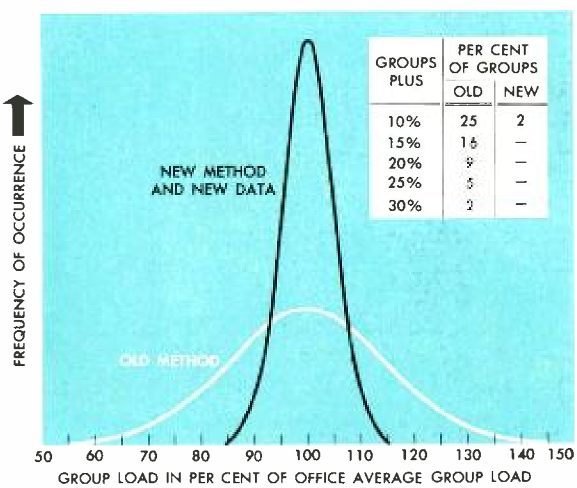
To be able to "balance" an office, it is first necessary to obtain an estimate of the traffic handled by the different groups of switching equipment. In general the most accurate indication of traffic conditions is not the number of calls served, but the total amount of time these calls hold the switching paths busy—that is, the "usage" of each group of switching equipment. This usage is commonly expressed in terms of CCS, or 100 Call Seconds (RECORD, *October*, 1957).

Realizing the importance of accurate and regular usage measurements for traffic engineering and administration, the Laboratories developed several years ago the Traffic Usage Recorder, or TUR (RECORD, *September,* 1954), and its companion recording device, the Traffic Usage Camera (RECORD, *July*, 1956). One problem presented by the TUR is the considerable clerical expense of analyzing the large amount of data it produces. However, modern methods of processing data on high-speed electronic computers will effectively minimize this difficulty. Such data-processing machines are now available to most of the Operating Telephone Companies.

In each office, those subgroups of the switching equipment to which the customer is immediately connected are the ones that are balanced. It is here that unbalance is most likely to occur. Examples of these equipment groups are the line finders and connectors in step-by-step offices and the line-link frames and horizontal groups of crossbar systems. Each set of such equipment, partitioned into independent subgroups of the same type and capacity and designed to be loaded in a similar manner, is called a "loading division." The data derived from the TUR consist of successive weekly busy-hour (one or more) load readings, in CCS, for the equipment groups within the loading division.

Each week the average load carried by the equipment groups in the loading division is calculated. This load is usually referred to as the "office average." The traffic people can then determine the relative standing of individual equipment groups in the office by the so-called "score" method. In this method, the CCS obtained for each group is assigned a number, or score, depending on the degree of its deviation from the office average, or mean.

The score is assigned from readings within a given "zone" above or below the mean. These zones are defined by two sets of "control limits," a statistical concept that will be explained later. Group loads within the inner limits are assigned a score of plus one (above the mean) or minus one (below the mean). Groups outside these, but within the wider set of limits score plus or minus two, and those falling beyond these limits plus or minus four. The use of four rather than three in the outer load ranges tends to emphasize groups



White curve shows present methods of line assignment—equal distribution of all line classes over all groups. Black curve shows expected improvement in the load balance with the new method.

whose loads are considerably out of balance.

By keeping a five-week cumulative score of each group in a loading division, the dial-office administrator can get a good guide to the assignment procedures or to corrective action that will bring about a balance of the load on the individual equipment groups. New lines are assigned to groups with the lowest scores, and possibly transfers made from groups with extremely high scores. It is expected that line transfers will be necessary only rarely and that balance can be established by proper assignment procedures, allowing disconnects to accumulate on high groups. To aid administrators in the Operating Companies in interpreting the scores, the Laboratories and the American Telephone and Telegraph Company have prepared an "Assignment and Corrective Action Guide." A more detailed description of how the new balancing procedure works will be outlined later.

One of the most important factors in this entire load-balancing procedure is the setting of control limits. These limits determine the zones for the various scores. And it is the cumulative scores of the individual groups that serve to indicate the load conditions in the office. Thus, the limits are important for obtaining an adequate picture of the office. Limits that are too wide will not give the best possible results, while limits that are too narrow lead to wasteful over-correction. Mathematical statistics provides the method of obtaining the proper control limits. Quality control limits, originally developed to designate the allowed variability of quality of a manufactured product, in this case express allowed variability in the traffic load.

Mrs. N. K. Powell of the Laboratories records traffic data onto business-machine cards with the help of Bell System Traffic-Register Film Reader.

In measuring the variation in a set of data, the most significant values are the average and the standard deviation, called "sigma." The average is the familiar arithmetic mean of all the values in the sample, while sigma (or sigma squared, the variance) gives a measure of the spread of the individual values about the mean. The observed spread is determined by the variability of a number of different contributing factors.

Analyzing Load Variance

To analyze these factors, statisticians employ the "analysis of variance," a technique used to partition over-all variability into amounts due to different factors. If a set of observations can be classified according to different criteria, then the total variation among the members of the set can be broken up into "components." These components can in turn be attributed to one of the various criteria of classification. Thus, in any study the statistician is able to select and examine the particular component of variation in which he may be interested.

The traffic data used in load balancing consist of weekly load readings for the equipment groups of a loading division. Examining any such set of data, we see that the readings fluctuate about the over-all office average from week to week and from one group to another. The load on any given group is affected by: (1) the characteristics of the group itself, (2) by the week during which traffic was measured, and by (3) any number of random causes, generally classified as "chance." For example, a particular load reading may be very high because: (1) the group in general carries a heavy load; (2) it was a very busy week for the entire office; or (3) chance. A mathematical model of the analysis-of-variance type expresses this situation and provides formulas for computing the variation due to: differences among groups; differences among weeks; and chance. These three components comprise the total variance.

Balancing is aimed at eliminating the variation due to differences in groups and thus at narrowing down the distribution of group loads about the office average. This is illustrated on page 55 for the line-link horizontal groups of a crossbar system. To accomplish this, the formula for the chance variance is used for the control limits, to allow for chance variation only. (Week-to-week variation does not have to be included, since each week the group loads are related to their own weekly average.)

The outer limits represent plus and minus three times the square root of the chance variance.

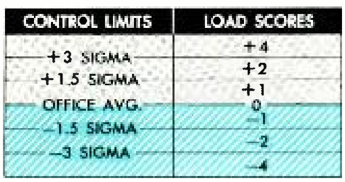
GROUP OR FRAME LOAD BALANCE CHART

LOADING DIVISION: Line Finders ENTITY: Bridgeport Ed 6F07-8

GRP. OR FR.	WEEK	11/13	11/20	11/27	12/4	12/11	12/18	12/24
	RECORD NO.	1	2	3	4	5	6	7
181	CCS	352	304	393	313	311	295	345
	WKLY SCORE	+2	−1	−1	+1	−1	−1	+2
	CUM. SCORE					0		0
182	CCS	254	290	334	266	292	310	312
	WKLY SCORE	−2	−1	−1	−2	−1	+1	+1
	CUM. SCORE							
183	CCS	343	337	377	297	324	306	296
	WKLY SCORE	+2	+1	+2	−1	+1	+1	−1
	CUM. SCORE					+5	+4	+2
184	CCS	375	387	398	356	349	307	279
	WKLY SCORE	+4	+4	+2	+2	+1	+1	−1
	CUM. SCORE					+13	+10	+5
	CCS							

SCORE EVALUATION RECORD

WEEK		11/13	11/20	11/27	12/4	12/11	12/18	12/24
RECORD NO.		1	2	3	4	5	6	7
+2	120 %	372	376	402	368	380	366	371
+1	110 %	341	344	369	338	349	336	340
0	AVG.	310	313	335	307	317	305	309
−1	90 %	279	282	302	276	285	275	278
−2	80 %	248	250	268	246	254	244	247



Portion of score sheet used to record traffic volume and score for line-finder groups in a step-by-step office. Scores were determined using zones as shown in "Score Evaluation Record." Bottom chart relates control limits to load scores. Limits computed for above office were: ±3 sigma = ±20%.

"Three-sigma limits" are standard for quality control applications in the United States. They mean that we can be practically certain that a group measuring "beyond limits" is in fact running higher (or lower) than office average. In other words, the chances are very small—about three out of 1000—that a group running at office level exceeds it (or falls below it) by more than 3-sigma during any given week. However, as a group mean moves away from office average, the chances of a weekly load falling outside the 3-sigma limits increase.

This process of detecting group deviation from the office average can be made more sensitive by establishing an additional set of control limits, at plus and minus 1.5 sigma. Relatively small deviations from the office average, which might take a long time to show up with only 3-sigma limits, show up considerably faster if we also note load-reading occurrences outside 1.5-sigma limits. The relationship of the 3-sigma and 1.5-sigma limits to the score zones mentioned earlier is shown on the left. The cumulative score of a group can then be used to estimate its long-term average and the resulting correction needed to bring it to office-average level.

The control limits computed at the Laboratories for use in establishing the new load-balancing technique were based on data from panel, step-by-step and crossbar offices. The results of these studies formed the basis of tables of suggested control limits for the three different types of offices. In setting up the tables, Laboratories statisticians allowed for varying load levels and several possible time intervals (numbers of hours) that might be used in computing the weekly averages. These tables, together with a description of the balancing procedure, have been published by the A.T.&T. Company in the *Central-Office Management Circular*. A program for computing control limits on an electronic computer (IBM 650) is also available from A.T.&T.

How the New Method Is Used

To this point, we have been concerned primarily with the basic tools of dial-office administration developed by the Laboratories and A.T.&T. Let us look now at the practical application of the new method in the Bell System. Dial administration is generally handled in an Operating Telephone Company on the district level, and is the responsibility of the Dial Administrator, who reports to the District Traffic Superintendent. Three groups do the actual work: line assignment, load and service, and customer instruction. Each group is usually headed by an assistant dial administrator and staffed by clerical personnel.

The load-and-service group collects traffic data from the central offices in the district. For this, traffic usage registers on the individual line groups are photographed by the TUR cameras at predetermined time intervals. To obtain the usage of an equipment group during a given time, the register reading at the beginning of the period must be subtracted from the corresponding reading at the end of the period. This must be done for all equipment groups and for all time periods required for analysis. One camera photographs 150 registers, and the information can be easily retrieved by projecting each set of readings on a microfilm reader. A special traffic-register film reader is now being produced for Bell System use.

In the next step, the load-and-service clerks compute the weekly averages and cumulative scores from the new data, using special forms such as the one on page 57. An up-to-date set of scores gives the dial administrator a clear picture of load conditions and serves as a simple, ready guide to the line-assignment group, which makes the actual initial line assignments or line changes in the office. The customer-instruction group is responsible for the customer-relations aspects of dial administration.

In conjunction with plans for the complete mechanization of line assignment, service orders and loading of equipment, traffic specialists are currently studying methods and programs for mechanizing the balancing procedure. These studies are incorporating automation of many manual operations. In the recording of traffic data, for example, register readings are key-punched directly into business-machine cards from the microfilm reader (*see photograph on page 56*). From these cards, a computer then automatically performs the necessary subtractions, and computes the weekly averages and the control limits. In such a mechanized procedure, the score method, chosen because of its relative simplicity from the clerical viewpoint, will be replaced by the more accurate approach of keeping a cumulative record of load readings in terms of a "moving average" for each line group of a loading division.

Further Automation of Traffic Data

One bottleneck that remains in this otherwise automated procedure is the electromechanical recording of traffic data on registers, which requires the use of cameras and manual key-punching. To eliminate this bottleneck, the Laboratories is developing a Traffic Data-Processing (TDP) system that will record traffic data directly on magnetic tape, sort and summarize it, and produce an output compatible with the general-purpose electronic computers being used by the Operating Telephone Companies.

The application of quality-control methods to line-load balancing will result in better service for telephone customers and savings in equipment for the Bell System. In addition, the solution to this problem of traffic administration illustrates that it is possible to make available to the clerical personnel handling traffic data the advantages of relatively complex statistical analysis. At the same time, this approach is an important step in plans leading to the total mechanization of all traffic measurements.

An Improvec

One of the services performed by the Bell System is the transmission of program material—music and speech—for music distribution systems and radio broadcasting. In the local telephone plant, this service is required for transmission from pickup points, such as concert halls or studios, to central offices, and from central offices to final destinations, such as broadcasting stations. In the toll telephone plant, the transmission service is needed to distribute program material to the radio networks.

Program amplifiers in the local plant are used as "line" amplifiers to compensate for signal losses in the line and to maintain adequate signal-to-noise ratios. They are also used as "distribution" amplifiers to transmit the same program material to a number of circuits. These amplifiers, of course, should have characteristics that will not impair the quality of a transmitted signal.

For a number of years, the Bell System has used the Western Electric 106A Amplifier as a program line amplifier in the local plant, particularly in locations where power for battery operated amplifiers is not available. The Western Electric 124B Amplifier has been used as the distribution amplifier for central offices in music distribution systems and for monitoring. Designed in 1937 as part of Western Electric's line of radio broadcasting equipment, the 106A was primarily intended for sale to broadcasters as a line

One of the responsibilities of Bell Laboratories is to establish the performance requirements for commercial equipment used in the Bell System. A recent example is a new program amplifier produced commercially for use in music distribution systems and radio broadcasting.

E. L. Owens

Amplifier for Program Circuits

amplifier in speech input equipment. The Operating Companies have also used it extensively on program circuits requiring an ac-operated amplifier with a self-contained power supply.

The 124-Type Amplifiers were designed in 1939, primarily for various commercial applications such as public address systems. But the Bell System has also found use in its telephone plant for a large number of these amplifiers, particularly the 124B's. Thus, when Western Electric discontinued its commercial products business, the 106A and 124-Type Amplifiers were retained because of their continuing demand in the Bell System.

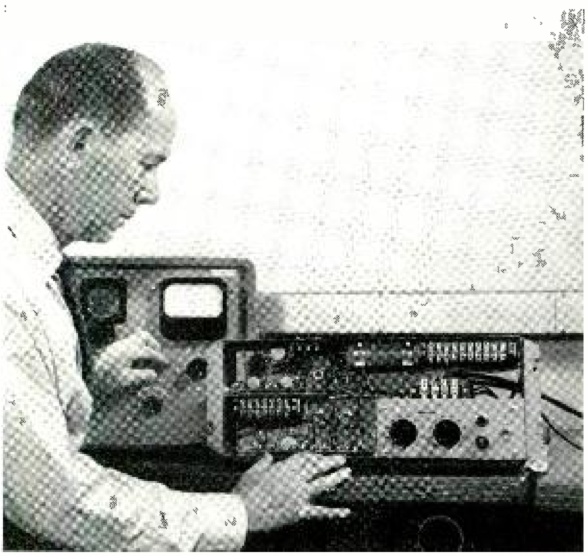
In metropolitan areas, program circuits are currently being established over longer distances than before, and through offices that do not have the power equipment for battery-operated amplifiers. This requires amplifiers with self-contained power supplies, and when several 106A Amplifiers operate in tandem on such circuits, signal-to-noise ratios are often marginal and sometimes inadequate. Many transmission channels, designed to serve large numbers of customers over great areas, frequently require four, and in some networks as many as seven, amplifiers in tandem. This places severe requirements upon frequency response, harmonic distortion and electrical noise in individual amplifiers. Both the 106A and 124B Amplifiers are satisfactory as individual amplifiers. But when it is necessary to operate a number of them in tandem in the larger networks, they are not adequate for the service. Thus they must be replaced with new types of amplifiers with improved transmission characteristics.

In the past several years, to meet the demand of the high-fidelity market, manufacturers of commercial amplifiers have made vast strides in the development of audio-frequency amplifiers with good transmission characteristics. A number of companies now manufacture amplifiers with transmission characteristics and component reliability which, with some modification, would meet the requirements of the Bell System's program plant. In view of this, Bell Laboratories decided to investigate the possibility of having a new program amplifier designed. This would have to meet Bell System requirements as set down in specifications prepared by the Laboratories, but also be suitable for manufacture in conjunction with the production of commercial amplifiers. Such a unit would require special features, making it different in some respects from the standard commercial line. However, manufacturers could use a surprisingly large number of common components and of standard production line facilities, thus realizing most of the cost savings of large-quantity production.

To increase the demand for the new amplifier, thereby lowering the cost, Laboratories engineers combined the requirements for the 106A and 124B replacements, and decided to have developed one amplifier to suit both applications, with only a change in terminal connections differentiating the two. Accordingly, a new, improved program amplifier has been developed in cooperation with a commercial supplier which is manufacturing it. This new amplifier, coded KS-16575, List 1, meets the Bell System requirements for program service applications.

The new program amplifier, shown in the accompanying photograph, is mechanically interchangeable with both the 106A and 124B Amplifiers. The components are assembled on a recessed chassis which is arranged for mounting on a 19-inch relay rack or in a cabinet. The amplifier requires 7 inches of vertical rack space, is 8½ inches deep, and projects 7 inches to the rear of the mounting surface. Gain controls, a power switch, a pilot light and a fuse holder are easily accessible on the front. The amplifier operates from a commercial source of ac power, requiring approximately 100 watts at 110 to 130 volts, 50/60 cycles. The front panel of the amplifier has a light gray finish, and all the exterior surfaces of the chassis are hammertone gray.

The new program amplifier has input impedances of 150 and 600 ohms for operation with program lines, and 10,000 ohms for "bridging" a line. The output circuit can operate into load impedances of 2, 8, 16, and 600 ohms with internal output impedances of approximately 1/10 of the



Components of new program amplifier are assembled on recessed chassis, arranged for mounting on 19-inch relay rack or cabinet. Amplifier takes up 7 inches of vertical rack space, is 8½ inches deep, projects 7 inches behind mounting surface.

nominal load impedance. In addition, the amplifier has one output circuit with an internal impedance of 600 ohms for operation with program lines. Both the input and output circuits are sufficiently well balanced so that there is normally no need for supplemental repeating coils to suppress longitudinal currents. The amplifier has a gain control by which the gain can be reduced 44.5 db in steps of 0.5 db. The frequency response is uniform within plus or minus 0.5 db over the range of 20 to 20,000 cps and within plus or minus 0.25 db over the range of 30 to 15,000 cps.

When used as a line amplifier to replace the 106A, the KS-16575 Amplifier operates with either the 150 or 600-ohm input, and the matched 600-ohm output. In this case, the amplifier has a maximum gain or approximately 58 db and is rated for continuous operation at an output power of 3.2 watts, with both harmonic and intermodulation distortion of approximately 0.25 per cent over the range of 20 to 20,000 cps. At full signal output, the "unweighted" signal-to-noise ratio is 90 db or greater. The output noise level is —55 dbm, and is independent of the setting of the gain control. When the amplifier is operated at low output levels the signal-to-noise ratio may be increased if desired, by using a fixed attenuator between the amplifier and the load.

As a replacement for the 124B, the new program amplifier uses one of the outputs with low internal impedance, depending upon the application. In this connection, the amplifier has a maximum gain of approximately 63 db. It is rated for continuous operation at an output power of 10 watts, with harmonic distortion of 0.5 per cent or less, over the range of 20 to 20,000 cps. At frequencies above 100 cycles the amplifier will deliver approximately 15 watts, with distortion approximately 0.5 per cent. While it is not rated for continuous single-frequency operation at this level, the generous margin in design permits it to handle peak audio powers of this magnitude without noticeable distortion.

The improved transmission characteristics of the new program amplifier make is suitable for the highest grade of program service. Its flat frequency response, low harmonic and intermodulation distortion, and high signal-to-noise ratio make its performance satisfactory even in large systems requiring the maximum number of tandemed amplifiers. In addition, this amplifier possibly will find considerable application in systems for data and facsimile transmission. The KS-16575, List 1 Amplifier, while providing superior performance for this type of transmission, affords a substantial saving to the Bell System.

While communications designers continue to study applications of semiconductor devices, manufacturers are concerned with how to make those devices reliably. This problem can be partially solved by periodic checks on the cleanliness of the fabricating environment. At Bell Laboratories, this is done with a specially designed atmospheric analyzer.

M. J. Elkind

Analysis of Atmospheres in Manufacture of Electronic Devices

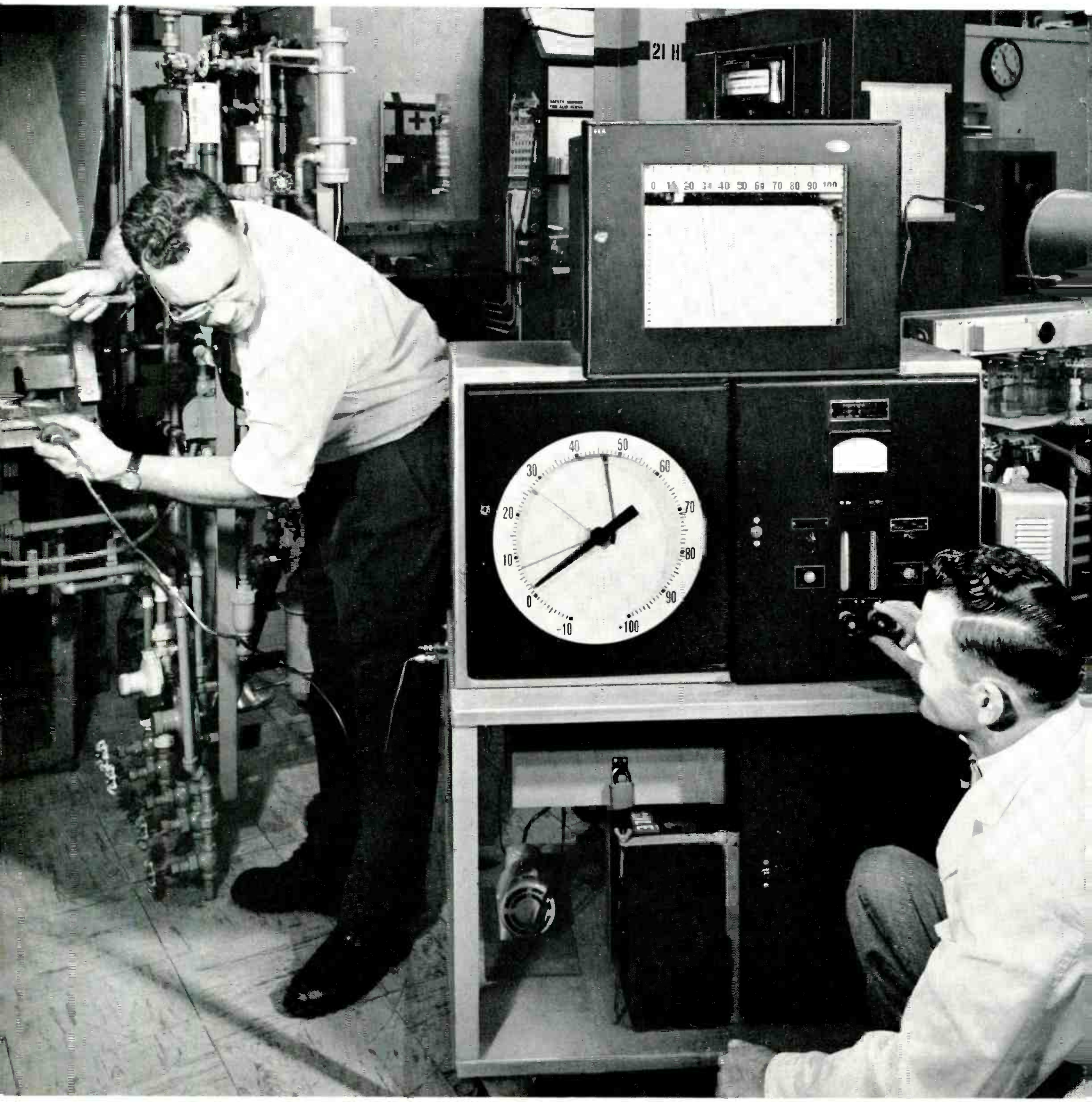
The electronics industry has developed and refined electronic devices to an extreme measure. Today, these devices may be virtually tailored in electrical characteristics and reliability to the specified requirements of an engineering system. In achieving this refinement, we have come upon an important concept. The performance and reliability of the devices are strongly influenced by the impurities they may encounter during fabrication (RECORD, *August*, 1958).

Techniques for fabricating electronic components have progressed rapidly in the last decade, especially in solid-state devices. In part, this advance can be attributed to highly specialized techniques evolved during the development of electron tubes. Also, additional refinements required to make semiconductors are contributing to a better understanding of the processing common to both types of devices. There is much yet to learn, however, about environmental conditions during such fabrication. Our most sensitive evaluation of processing parameters comes from studies of the electrical properties of the final device. Therefore, we must strive to understand and carefully control all possible processing variables during fabrication.

The metallurgical and chemical operations of making electron tubes and semiconductors require various kinds of gaseous ambients, or surrounding atmospheres. These operations include: heat treating metal parts; soldering and brazing; growing single crystals of semiconductor materials; diffusing; gaseous "doping"; and assembling and storing components or devices in dry boxes. Each of these processes must be carried out in a gas that is either inert—such as argon, helium, and nitrogen—or reducing—such as hydrogen or mixtures of nitrogen with hydrogen. These gases provide a protective atmosphere for a wide variety of metals; almost all are easily oxidized.

For such sensitivity to oxidization, we must take particular care to minimize contamination by oxygen and water vapor. For example, purifiers are used to reduce these contaminants in gases supplied to various treatment and storage facilities. In some circumstances purity requirements are less than two parts per million (by volume) of moisture and two parts per million of oxygen. But these purified gases have to be introduced into an operating unit, such as a furnace or dry box. It is here that the status of their contamination, under variable operating conditions, is not readily apparent.

In a furnace, the composition of the ambient gas may vary significantly because of contamination from external sources. It can thereby critically affect the performance and stability of the device by allowing uncontrolled oxidation to occur.



M. J. Elkind, left, inserts probe in muffle of heat-treating furnace while D. R. Benn readies portable analyzer for readings. This equipment helps ensure the reliability of semiconductor devices.

For example, in many transistors and diodes gold plating is used to uniformly bond a semiconductor "wafer" to a metal support. Oxidized surfaces or plating, improperly heat-treated in an oxygen- or moisture-contaminated atmosphere, prevent intimate contact between the pure metals.

Contamination problems also arise in the alloying of indium, gallium, or lead-arsenic into germanium to form transistors with p-n-p or n-p-n junctions. Alloying can only be done properly with oxide-free materials that flow uniformly at the alloying temperature. If an oxide forms in a contaminated atmosphere, the temperature has to be raised or the contact force increased, to achieve alloying. But then, control of the regrowth region may be lost, to the detriment of electrical characteristics.

We can use diffusion techniques, involving gases and the evaporation of relatively low-melting metals or volatile oxides, to "dope" germanium and silicon to alter their electrical conductivity. For example, one application of the diffusion process uses the volatile metal antimony, carried in a stream of carefully purified hydrogen gas. This process makes high-frequency germanium amplifiers and switches which depend on extremely thin base regions. In this application, the amount of antimony available in the carrier gas critically controls the distribution of the impurity in the germanium. Unfortunately, the antimony surface reacts to traces of oxygen, and the oxide can impede uniform evaporation of the metal.

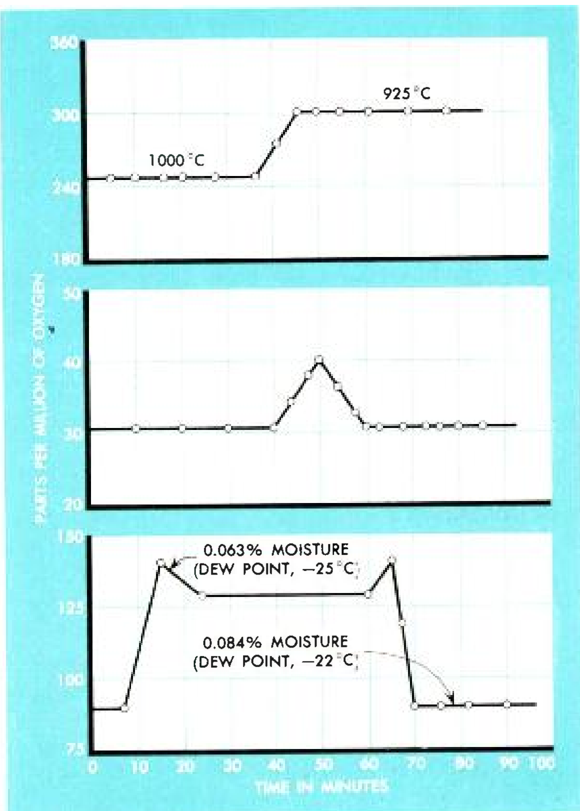
In a converse problem, fabrication of certain electronic devices involves processes that depend on the *presence* of moist or oxidizing atmospheres. Particularly important is the operation of sealing metals to glass in nitrogen atmospheres containing small amounts of oxygen and moisture. Here, fluctuations in the amount of oxygen and water vapor in the ambient nitrogen of the furnace can result in the formation of random metal oxides. This condition can result in nonuniform and leaky seals. The exact composition of the ambient atmosphere in such a furnace is generally known only within approximate limits. Therefore, the gas concentrations are "inferred" from the final properties of the treated parts, rather than by a direct evaluation of the furnace atmosphere.

Evidently these processes need either an atmosphere completely free of oxygen and moisture or one with critical amounts of them. Consequently, we must evaluate both the purity of the incoming gases and the composition of the ambient atmosphere within a treatment area. Furthermore, to insure uniformity and reliability of the product, we must monitor this condition.

To make this type of measurements, engineers at the Allentown location of Bell Laboratories have assembled a system that can continuously analyze for the principle contaminants of oxygen and moisture. The equipment is ideally suited to follow minute changes in the composition of the ambient atmosphere in device-treating facilities.

The instruments in this analyzer are rugged and portable. Mounted on a double-deck cart, they are arranged to readily analyze gases in tanks and plant supply lines at elevated pressures, or gases in such facilities as furnace muffles or dry boxes at atmospheric pressure. A one-quarter inch probe, made of nickel or quartz, is generally used to withdraw a continuous sample of the ambient from the treatment zones of furnaces.

With this gas analyzer system, we can readily determine concentrations as low as one part per million, by volume, of water vapor and two parts per million of oxygen with a precision of plus or minus one ppm moisture and plus or minus two



Top—rise in oxygen content of hydrogen ambient in defective muffle. Middle—chain of events in opening and closing furnace doors, protected by nitrogen curtain. Bottom—change in ambient when furnace doors are opened to insert and remove parts; returns to original "purity" after flushing.

ppm oxygen in a range below 10 ppm. To understand how "pure" such a gas would be, one must realize that in an average living room, at 70 degrees F and 50 per cent relative humidity, the amount of water vapor is approximately 12,300 parts per million.

This surveillance of ambient gases and supplies of hydrogen, nitrogen, oxygen, and inert gases is supplemented by mass spectrometric analyses for such contaminants as organic vapors, ammonia, carbon monoxide, carbon dioxide and hydrogen. If present, these impurities may be detected in the gas supply or the ambient by "batch sampling" techniques.

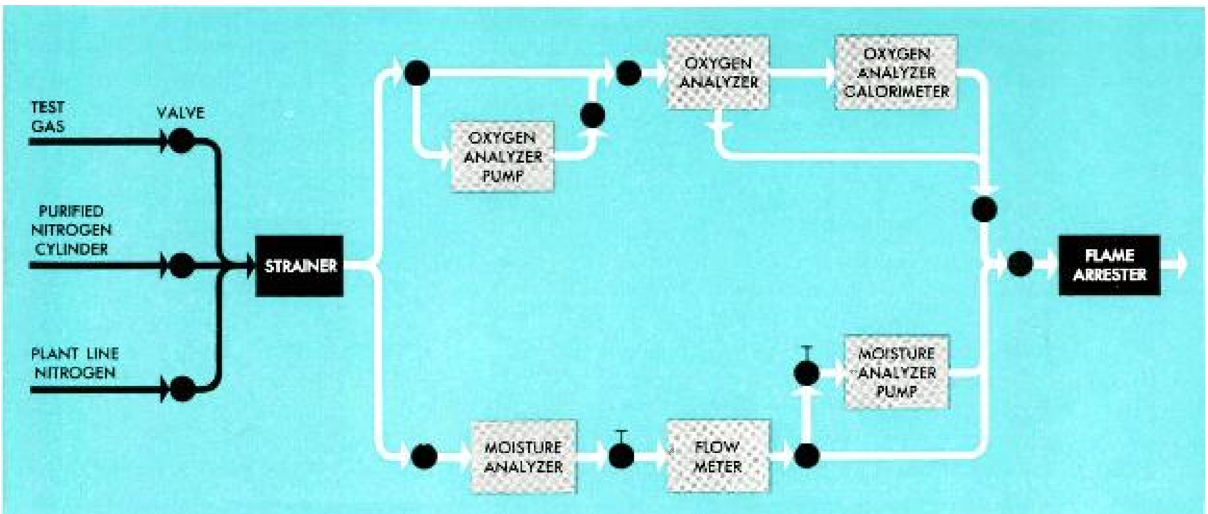
Device manufacturers are particularly interested in gas-atmosphere furnaces having quartz open tubes and single or double open-end muffles. Since these furnaces perform varied operations, their ambient atmosphere is subject to contamination by oxygen and moisture from many sources. Ideally, the atmosphere in these furnaces is in equilibrium with the muffle walls under constant conditions of temperature, gas flow, and composition of input gas. A furnace with such stable parameters is an "equilibrium" furnace.

One example is a diffusion furnace using a quartz open tube supplied with nitrogen or hydrogen atmosphere of high purity. It is used for the diffusion doping of semiconductor materials. To evaluate this entire furnace, we first examine the supply of input gas by measuring it before it enters the purifiers at the control panel, and again after it leaves the purifiers at the entrance to the furnace tube. This procedure affords a check on the general tightness of all piping, regulator and selector valves, and on the effectiveness of the purifier system. Since our equipment operates on a continuous sampling basis, we can readily locate any sporadic leaks in a valve by manipulating it during the test. Defective valves are often a cause of contamination, and without such systematic analyses they can easily remain undetected.

After examining the furnace gas supply, we proceed to analyze the ambient gas in the furnace tube. To do this, we vary the input flow of purified gas and move the probe to different distances from the mouth of the tube, establishing equilibrium measurements for each position *(see photograph on page 62)*. This permits a selection of conditions to minimize the "back" diffusion of moisture and oxygen from the room into the open tube. The ambient atmosphere of an open-tube furnace can show contamination of less than two ppm of oxygen and two ppm of moisture.

Sources of contamination in these tube furnaces can be evaluated quite readily because the system is relatively simple. For large and more intricate equilibrium furnaces, however, additional sources of contamination may be present and must be carefully considered. For example, double- and single-end furnaces may be equipped with ceramic muffles, water-cooled chambers, and atmospheric "curtains" of hydrogen or nitrogen to protect the furnace doors.

In this type of furnace, the muffle can develop small cracks as a result of the cycle of raising and lowering the temperature. This results in atmospheric contamination in the muffle from diffusion



Major instruments in portable analyzer and sampling system. Arrangement permits ready analysis of gases in tanks and supply lines at high pressures, or gases in such facilities as furnace muffles or dry boxes at atmospheric pressure. Analyzer can follow minute changes in composition.

through insulating linear sections. In addition, small leaks from improperly welded joints in a water-cooled chamber could contribute high concentrations of moisture. This can diffuse directly into the hot zone, or more subtly, through the brickwork and into the insulated section surrounding the muffle.

In the presence of such defects, the composition of the atmosphere in the furnace varies with pronounced changes in temperature. Thus, in a typical case, we find the concentration of water vapor in a nitrogen atmosphere varies from 150 to 700 ppm as the temperature of the muffle increases from 25 degrees C to 1200 degrees C. The oxygen content also increases at the same time. When a hydrogen atmosphere replaces one with nitrogen however, the oxygen concentration decreases with increasing temperature because of the chemical formation of water.

Quite frequently we find a variation in ambient composition within and just outside the muffle, resulting from atmospheric contamination entering through improperly fitted doors. We can minimize this effect by increasing the flow of input gas until the continuous analysis indicates a uniform composition. For example, a thirty per cent increase in the amount of a gas supplied to a muffle lowers the oxygen and water-vapor composition by fifteen per cent.

Further studies on equilibrium furnaces have demonstrated that moisture and oxygen contamination can increase as a result of inserting parts and opening furnace doors, and is proportional to the degree of protection afforded by gas curtains at the doors. Analysis has shown how long it takes to sweep out contamination. Accordingly, we can adjust the heat-treatment schedules so that parts will be subjected to a minimum of contamination in any section of the furnace.

In practice, the operating temperatures, the input gases, and the rates of flow may be changed at any time to accommodate the different parts being treated. Under such variable conditions, a state of equilibrium is not established in the ambient atmosphere of the muffle. Measurements in these furnaces will indicate only approximate maxima and minima of oxygen and moisture contamination during processing of devices. However, data of this kind is valuable because it determines the general degree of contamination of the furnace atmosphere. With proper precautions, we can expect contamination levels of 50 ppm water and 30 ppm oxygen in a manufacturing furnace of this type.

Another group of furnaces requiring extreme control of their ambients are those used for the growth of single crystals of germanium and silicon. We have made continuous measurements of moisture and oxygen to determine the type, number, and regeneration schedules of purifier equipment in the gas-supply system. We have also made them, to observe the influence of the mechanical moving parts and seals on the contamination level. Information gained by such analyses has led to modification of furnaces to lower contamination levels to less than five parts per million each of oxygen and water.

Contamination levels have also been measured in "dry boxes" used to store electronic piece parts, processed semiconductor materials, and devices awaiting encapsulation. These boxes are supplied with a flow of dry air or nitrogen. Facilities in which parts are stored undisturbed for long periods of time generally contain low levels of moisture if the input gas flows at a sufficiently high rate. However, in dry boxes used for short storage periods, moisture levels may vary from three to ten times that of the input gas because of "carry-in". Dry-boxes used on assembly lines show much the same effects.

Box Flushing

In some cases, this contamination problem has been minimized by introducing an appropriate "flushing" procedure between the time the box is loaded with parts contaminated from the room air and some later operation such as welding. Usually five to ten minutes of flushing is required to lower the amount of water vapor in the box's atmosphere to its original value.

Another source of contamination is that of moisture carried in by personal protective equipment such as rubber gloves. Moisture content may increase four or five times when rubber gloves are used to withdraw parts. This less obvious source of contamination is not readily avoided. Moreover, if the manipulation is done frequently, a high level of moisture may build up in the box. Therefore, continuous measurements of moisture or oxygen are extremely useful to determine if the air in the box circulates rapidly enough to sweep out the accumulation of contaminant during an operating cycle.

The problem of evaluating and controlling gas atmospheres is quite extensive and complex. But although purified gases become readily contaminated with oxygen and moisture, the contamination can be detected by systematic continuous analyses. Apparently then, the judicious application of such analytical data can result in better control of gaseous treatment processes used for the manufacture of semiconductors.

As communications technology grows, so may the size of its equipment. Thus, to keep space requirements reasonable, designers often consider "packaging" as one of their engineering problems. A noteworthy example of this practice at Bell Laboratories is the effort expended in housing the circuitry for the 82B1 Teletypewriter Switching System.

E. T. Ball and G. A. Waters

Equipment Features of the 82B1 Teletypewriter Switching System

Seldom has the circuit designer been concerned with the problem of suitable housing for his circuitry. Yet recently this has become a very important matter, sometimes constituting a real challenge in the design of a system. For example, in the 82B1 Teletypewriter Switching System (RECORD, *May*, 1960), Bell Laboratories engineers incorporated several design features as a result of certain physical problems in the equipment.

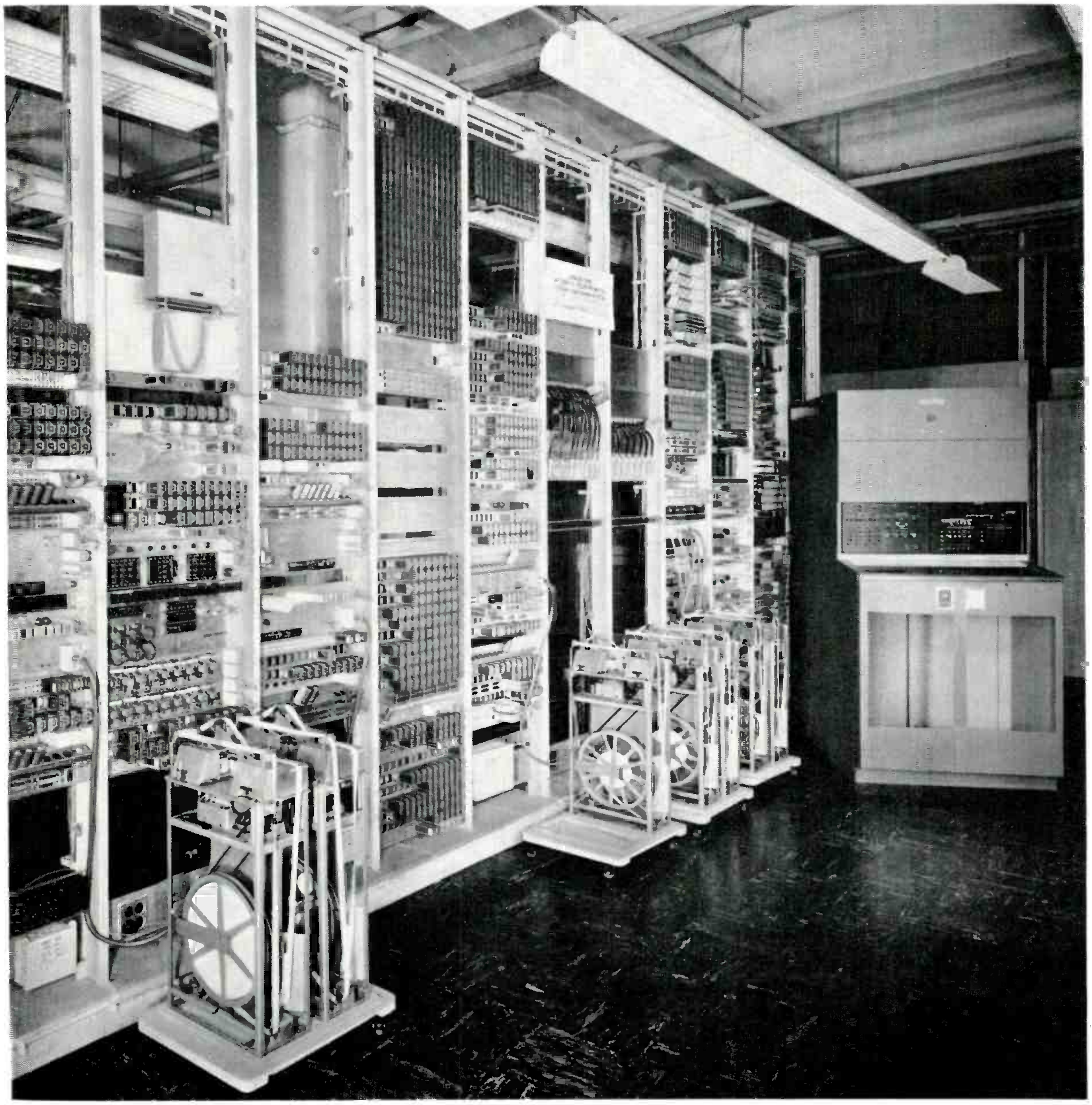
In the 82B1 system, messages are first, prepared on sending teletypewriters at originating stations; second, sent to a switching center where they are stored and then transmitted; and finally, received and typed out on receiving teletypewriters at destination stations. Laboratories engineers designed the switching center with two things in mind: (1) the possibility of complete failure was to be eliminated, and (2) the customer was to be able to change the size of his center in a very short time.

The "building block" principle satisfied both these requirements in one stroke. Thus Laboratories engineers divided the components into two major "packages"—the incoming and the outgoing cabinets. These two units give the 82B1 system both flexibility and autonomy.

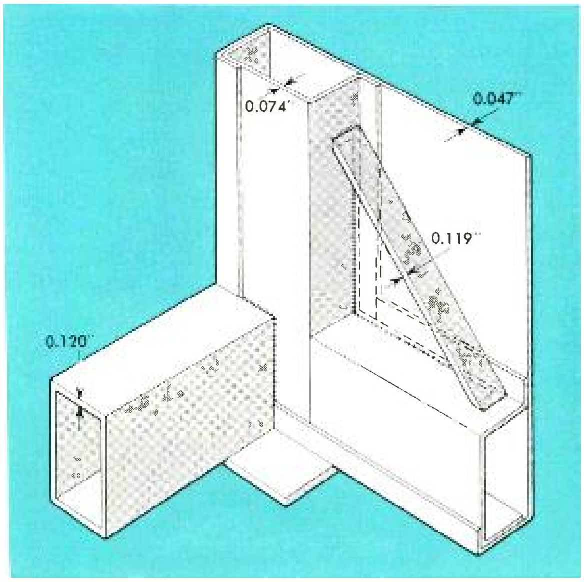
As a result, the principal engineering effort centered around packaging all the apparatus so that it could be accommodated properly in two cabinets of which one is shown at the right of the photograph on page 67. In addition, each cabinet was to house four "reperforator-transmitters" and a power plant. The basic need was for an adequate cabinet structure. Because of extreme compactness the design of this structure involved, besides economy of manufacture, a satisfactory strength-weight ratio, proper access for maintenance, an involved wiring pattern, and adequate ventilation. These problems will be described later, but first, we should note some of the needs and desires of the customer and their effect on the equipment's design.

Making the switching-system structure transportable required that it be divided in some way. Several methods looked attractive. Engineers based their final choice on methods that would keep interconnection to a minimum and at the same time make individual packages small enough to pass through restricted openings on a customer's premises. Preferences of the customer also were influential here in that all connections between packaged units were made on a plug-in basis. This permits rapid installation, and the easy removal and replacement of any unit in the line-up.

Each cabinet may house either of two types of equipment—"incoming" or "outgoing." These may be either in separate line-ups or intermingled in any order in the same line-up. Consequently, intercabinet cables must be interchangeable. This was done with 29 plug-ended cables mounted in the roof panel of each cabinet. Only those leads needed for the particular lines or trunks the cabinet serves can be cross-connected into the cabinet.



Large amount of equipment on this frame comprising part of a teletypewriter switching system was designed to fit into cabinet, rear. Compactness and accessibility were key requirements in design.



Lower left front corner of cabinet framework. Tubular construction for load-bearing members reduces over-all weight of system equipment.

A roof panel is mounted at the top of each alternate rear-cabinet unit and is covered by a coping whose sides are left open to permit passage of cables to an adjoining cabinet or to a duct leading to another line-up. The coping also has a hinged top so that maintenance personnel can install or rearrange cross connections.

Laboratories engineers furnished a similar plug-in arrangement for connections between a pair of rear-cabinet units. These connectors are accessible to maintenance personnel who may have to remove a unit from the line-up. Furthermore, openings in the side frames are eliminated so that the frames become effective fire walls, as well as restrict the volume served by each cooling fan. Power supply and distribution panels mount on the face of the rear cabinet units below the control panel. The space below this is left open for the blower housing. This makes full use of all the available space on the top and at the front of these units.

All equipment in the interior of the cabinet is mounted on sliding racks. Each rack accommodates thirty-six mounting plates, each measuring 2 inches by 23 inches. The area of these racks, plus the areas available on the front and top faces, yield a total mounting space of nearly 5600 square inches. Yet a unit occupies a floor space of 20 inches by 36 inches and is only seven and one-half feet high.

A further increase in volumetric efficiency comes from eliminating the pile-up of cables on the rear of the uprights of the sliding rack and apparatus terminals. The installer lays cables in the hollow channel uprights and feeds their branches through openings in the webs to the apparatus terminals. These openings form a convenient grid for the unformed cable ends which are then "dressed" back on top of the surface wiring of the system.

Since both uprights are used, very little wire piles up on the ends of the mounting plates. The upright nearer the front accommodates entrance cables; a maximum of 34 of these is used on one of the racks. The cables are clamped to the inside top corner of the rack, "draped" into a V shape, and at their other end again clamped to a tubular cross member on the front of the stationary part of the cabinet. They then lead to terminal strips in the front and roof.

Equipment on the racks themselves comprises mainly relays divided into units. Wiring between these units runs in the rearmost upright which also holds lamps for the fuse alarms. This cover extends laterally beyond the opening in the cabinet wall to conceal cracks, but the cover is spaced about one-eighth inch toward the rear to permit egress of ventilating air.

Despite the effort made to secure maximum mounting space in the volume available, reserve for future expansion on some racks was small and engineers felt further compacting to be desirable where maintenance would not be impeded. Some of the measures taken illustrate this need. For instance, the crossbar switches in the bid receivers were designed originally for a narrower rack than that eventually used. To bridge this gap, the engineers devised "adapters" as part of the chassis of the mounting panels. The space the adapters made available permitted mounting the apparatus in three accessible planes.

Some of the structural features of the teletypewriter equipment are perhaps of interest. For example, immediately below the lowest mounting plate of a cabinet are three transverse bars fastened with bolts to the wide channel below them. When a maintenance man removes these bolts, together with their opposites and the three at the top above the wiring, he can lift the rack out of the cabinet. Efficient production demands, in addition to easy removal, the ability to return a rack to either its original position or to a similar position in any other cabinet without adversely affecting the adjustment of the slide mechanism.

Laboratories engineers introduced this interchangeability in the following way. The bottom of each rack moves through the medium of a pair of ball-bearing slides. The outer stationary slide members are, in effect, wide channels that are bolted to the base separately through brackets between the slide pair. Inside the stationary member is a similarly shaped sliding member and inside of that a sliding bar. Ball races are formed in the adjacent horizontal faces of all three members. The wide channels, on which the rack rests, are fastened to the center bars.

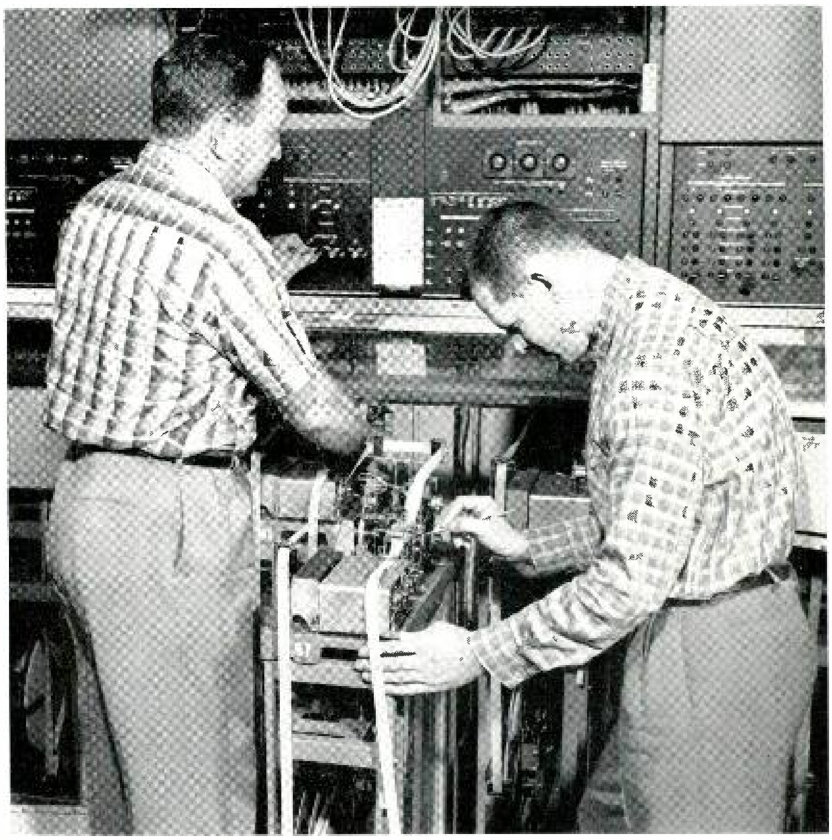
For a pair of slides to operate with minimum friction, they must be made to move in the identical horizontal plane and in exactly parallel vertical planes. This is done through the use of "spacer bars." These are machined to proper length in matching pairs, and the base on which the slides mount is ground flat. Together, these members form a "cradle" which is first assembled and then placed within the cabinet and bolted to the base. In this manner, tedious and repetitious aligning operations are avoided and racks can be interchanged at will.

Another slide-member is mounted flat at the top of each rack. This distance between upper and lower slides makes it impractical to align them very accurately. Therefore a limited biplanar "runout" is introduced by using shock mounts to attach the upper slide to the rack. Excessive movement, such as might occur during shipment, could rupture these shock mounts. This is avoided by arranging the upper horizontal member of the rack to "bottom" on the stationary framework.

A rear cabinet framework unit alone weighs 580 pounds; with full equipment it weighs 1200 pounds. To reduce weight, engineers employed tubular construction for the load-bearing members either through fabrication, as around the edges of the end panels, or by commercial rectangular tubing, as in transverse base members.

Such a construction permits the end panel "skin" to be reduced to 0.05 inch—about the minimum that can be handled in the shop without incurring the danger of accidental denting or perforation. One problem in the design of an open-ended box structure is to build in adequate resistance to diagonal strain in the plane of the opening. In the conventional way builders employ large corner gusset plates which in the case of the 82B1 would have involved an increase in frame height to clear the sliding racks. Since increased height was not permissible, Laboratories engineers took advantage of the tubular skeleton to weld internal reinforcements into the top corners. They further reduced diagonal strain by interleaving connecting parts to create an opposing couple.

Other equipment in the front unit includes two blowers for ventilation. Here, air is drawn



P. E. Carroll, left, and R. J. Bialota, both of the New Jersey Bell Telephone Company conduct tests on trunks and teletypewriter machines in office.

through grills in the toe plates and passed through replaceable filters in the base on its way to the blowers; at the blowers it is projected in two streams—one goes upwards through the active elements and the other backwards into the relay equipment.

Another interesting feature of these cabinets is a torsion spring device with an "over center" linkage attached to the covers of the patch panels. It is so arranged to hold the covers in one of two positions by coming to rest either when they are open or when they are closed.

Visible and audible major-alarm signals complete the equipment of the front unit. Located in the crown moulding these plug into one of the associated rear units.

An installation of the size and complexity of an 82B1 Switching System must have test facilities which are extensive and permanent. These facilities must be readily accessible to all the cabinets and also be located at a convenient center for the testing and maintenance of portable units such as the teletypewriter machines themselves. For this reason, the customer must have an area adjacent to, or near, the operating room to house the test equipment.

One unit of 82B1 test equipment comprises two standard open-faced cabinets with hinged backs and removable sides. These cabinets are located next to one another with their adjacent side panels removed for an unrestricted passage between them. This is needed for power cables and other wiring.

One of the pair of cabinets houses common equipment, including power rectifiers, while the second contains relay and electronic equipment used principally for testing the line cabinets. Circuitry in the second unit duplicates certain portions of both incoming and outgoing line equipment. This is selected so that either type of line cabinet will work into its "opposite portion" while being tested.

In addition to the cabinets, a set of test facilities includes two benches installed back-to-back for checking the adjustment of the reperforator-transmitters. On top of each bench are "turrets" with key and jack equipment in their front faces, and transmitter-distributors and a teletypewriter test set on their roofs. The transmitter may transmit tapes as needed for testing either a machine, or on occasion, the entire switching office.

Engineering both the system and its package at the same time has proved very practical for the 82B1 Teletypewriter Switching System. The result is equipment in which every bit of space has been put to use, and yet any component can be easily reached for maintenance or replacement.

First Computer-Designed Computer Developed by Bell Laboratories

News of Military Development

The first computer ever built from complete information furnished by another computer was recently installed on Ascension Island in the South Atlantic, near the target area of the Atlantic Missile Range. Developed by Bell Laboratories at the Whippany, N. J., location, the computer is being used in the Nike-Zeus system for special tracking tests of ballistic missiles launched from Cape Canaveral. The computer collects and processes data concerning the radar characteristics of incoming missiles—a vital requirement in the development of the Army's Nike-Zeus anti-missile defense system.

The Bell Laboratories Automatic Design (BLADE) system can save thouands of man-weeks in the design of missile defense equipment and large sums in defense funds. While computers have been used before as an aid in designing new computers, the BLADE system marks the first time that a computer has been built from complete assembly information, wiring information and parts lists furnished by another computer.

The BLADE system converts basic design data, originated by Laboratories engineers, into manufacturing information, which can. in turn, control automatic machinery for producing subassemblies of data-processing equipment. With the BLADE system. manufacturing information for each unit can now be automatically produced in 20 to 25 minutes. Conventional methods of drafting formerly required four weeks. The self-checking capability of the BLADE system also eliminates costly human errors, inevitable in the use of manual methods on complex equipment.

The BLADE process starts with engineers determining a "logic network" that will perform the necessary data-processing operations. The network is then converted into a set of equations; the computer takes the equations (in the form of punched cards or tape), determines the placement of components, and specifies the wiring connections that must be made. The computer automatically seeks the shortest distance between wiring points. This is important in high-speed digital computers where excessively long wires tend to slow down the circuits. The final output provides the parts list. assembly information and wiring information for Western Electric, which built the computer-designed computer.

W. A. Wadsworth of the Military Systems Development Department and G. L. Taylor of Western Electric at Burlington, N. C. make final checks on the first computer designed by another computer.

A Bell Laboratories scientist has recently clarified the phenomenon of tropospheric scatter—how microwave signals are transmitted beyond the curvature of the earth.

New Look at Over-the-Horizon Transmission

At a joint meeting of the Institute of Radio Engineers and the International Scientific Radio Union, recently held in Boulder, Colorado, Kenneth Bullington of the Systems Engineering Department presented a new and more complete explanation of over-the-horizon radio communication.

News of Transmission Systems

Until a few years ago, it was widely believed that radio frequencies in the present television band and higher could be transmitted only slightly beyond the optical horizon. Experimental work in the past decade, however, pointed the way to the successful use of these higher frequencies at distances many times the distance to the horizon.

Many such "over-the-horizon" systems are in operation, especially with the military services in the Arctic and in Europe. Commerical systems are presently handling telephone traffic between Florida and the Bahamas and between Florida and Cuba, the latter handling both telephone and television services.

Engineering plans for such systems had to be based on experimental data because the basic mechanism of this type of transmission was not clearly understood. During the past ten years, many theories were advanced to explain the experimental data, but none was completely successful. Most explanations assumed that the transmission is caused by scattering from the irregularities in the atmosphere and that the effect of the gradual decrease in atmospheric pressure with height can be neglected.

The present concept postulates that long-range transmission is a result of the decrease in the index of refraction of the atmosphere with height. In effect, Mr. Bullington bases his theory on calculations of the total energy reflected coherently from a dielectric gradient. The irregularities in the atmosphere cause fading but do not add significantly to the average signal.

This concept was considered several years ago, but it was neglected at that time because the mathematical approximations then available indicated that the effect of a smooth atmosphere is too small. Mr. Bullington's theory contains a new mathematical approach that is easier to interpret in physical terms. The result indicates that the earlier approximations discarded the most important effect, and that this concept not only offers a good quantitative explanation but also ties together more diverse experimental data than had been attempted in previous theories.

Over-the-horizon antennas located at Florida City, Florida, link the United States with Cuba.

news in brief

H. K. Onstott

Howard K. Onstott Elected Vice President and General Manager of Laboratories

At a meeting of the Board of Directors of Bell Laboratories Howard K. Onstott, assistant vice president of American Telephone and Telegraph Company, was elected vice president and general manager of the Laboratories and a member of the Board of Directors. Mr. Onstott will succeed Ralph L. Helmreich, who has resigned to accept a position as assistant vice president of the A.T.&T. Co. in the Personnel Relations Department. The move became effective January 16.

R. L. Helmreich

Mr. Onstott, a native of Saltsburg, Pa. received his A.B. degree from Cornell University in 1924 and started his Bell System career with the Western Electric Company the same year. He served in various capacities with that company and in 1947 he was appointed personnel relations manager at Western Electric. In 1952, Mr. Onstott was named assistant vice president for general-staff activities of Bell Laboratories. He became an assistant vice president at A.T.&T. in 1956.

Mr. Helmreich was born in Kansas City, Kansas, and graduated from Kansas State College with a degree in Mechanical Engineering in 1928. He joined Southwestern Bell the same year, and rose to become general manager of Kansas in 1950. The following year, he was named vice president in charge of personnel for the Mountain States Telephone Co. In 1953, he came to New York as director of operations at Long Lines. In 1956, he was appointed vice president and general manager and a director of the Laboratories.

Allen G. Barry Elected A.T.&T. Vice President

Allen G. Barry, vice president and general manager of Michigan Bell, was elected a vice president of A.T.&T. effective January 1. He is handling special assignments in the Executive Department until April 1 when he will succeed S. Whitney Landon as vice president and secretary. Mr. Landon is retiring at that time.

Mr. Barry started his Bell System career in 1928 as a traffic student with the New York Telephone Company following his graduation from Harvard University. Rising through a series of assignments in the traffic department he became general traffic manager for the upstate New York Area in 1945. Later that year he became general commercial manager for the same area.

Mr. Barry came to Michigan from the Wisconsin Telephone Company where he had been vice president-operations since 1948.

A. G. Barry

For several months before going to Wisconsin he was on loan with the Office of Civil Defense Planning in Washington where he was in charge of the Organization Planning Division.

Hardy G. Ross Named Western Electric Company Vice President

Western Electric's Board of Directors recently named Hardy G. Ross vice president of the Purchasing and Traffic Division.

H. G. Ross

Mr. Ross succeeds Gus F. Raymond, who retired in November at his own request.

Mr. Ross was previously General Purchasing Agent for Western Electric and had served as manager of the Indianapolis Works since May, 1957.

M. R. Schroeder Honored

M. R. Schroeder of the Visual and Acoustics Research Department was recently named a Fellow of the Acoustical Society of America (ASA) and elected a governor of the Audio Engineering Society.

He was cited by the ASA "For originating a novel theory of sound transmission in rooms, for improving feedback stability of public-address systems, for new methods of measuring reverberation time and sound diffusion, and for numerous advances in the analysis and synthesis of speech."

Editors Named for RECORD and B.S.T.J.

Effective with this issue, H. W. Mattson, formerly Technical Information Supervisor, is appointed Editor of the RECORD. He succeeds W. W. Mines, who has transferred to the position of Information Supervisor—Whippany. A. G. Tressler, formerly an Assistant Editor on the RECORD has been named Associate Editor.

Mr. Mattson graduated from the University of Michigan in 1949 with a BSCh degree. Prior to joining Bell Laboratories, he did polymer research at the LOF Glass Company, and later was associated with the Bristol Company in Public Relations and Advertising. He joined the Laboratories in 1958 in the Technical Information group and in 1960 was promoted to Technical Information Supervisor.

Mr. Mattson is a member of the American Chemical Society, the Instrument Society of America and the National Association of Science Writers.

G. E. Schindler, Jr., recently returned to Bell Laboratories to become Editor of the BELL SYSTEM TECHNICAL JOURNAL. He joined the Laboratories in 1953 on the Bell Laboratories RECORD and served as Editor of that magazine from 1957 to 1959 when he accepted a position with A.T.&T.

Mr. Schindler studied chemical engineering at the Carnegie Institute of Technology, graduated from the University of Chicago, and received a master's degree from the University of Pittsburgh. He taught technical writing at both the University of Pittsburgh and Carnegie, and did additional graduate work at Chicago before joining the Laboratories.

G. Feher Receives Physics Award

George Feher of the Semiconductor Research Department, presently on leave of absence at the University of California, received the American Physical Society Prize at a recent meeting of the Physical Society in Chicago.

The prize, awarded for outstanding work published before a physicist reaches the age of 33, cited Mr. Feher for "originating and developing the electron nuclear double resonance technique and for applying it to solid state and nuclear research."

This is the second time this prize had been awarded. Last year it was given to Donald A. Glaser for the invention of the bubble chamber.

Born in Czechoslovakia, Mr. Feher received the B.S., M.S., and Ph.D. degrees from the University of California. He came to the Laboratories as a research physicist in 1954 and has done pioneering research on many aspects of electron-spin resonance in solids. Mr. Feher has devised new techniques for getting precise information about energy bands in crystals, for measuring the electronic wave functions of impurities and lattice defects, and for studying fundamental mechanisms of electron spin relaxation processes. He has also used these techniques to study atomic nuclei and has discovered new methods for polarizing nuclei. In collaboration with physicists at Columbia's Nevis Laboratory he has recently studied the properties of "muonium"—a hydrogen-like atom whose nucleus is a positive mu-meson. With co-workers at the Laboratories, Mr. Feher achieved the first successful operation of the three-level solid-state maser and also of the two-level solid-state maser.

The World's Telephones

According to the latest A.T.&T. survey, the number of telephones in the world increased by more than 8,800,000 during 1959. This brings the number of telephones throughout the world to 133,600,000. The count of telephones practically doubled during the past decade, and even trebled for the continent of Asia.

The United States, which accounted for nearly half of all the telephones added, continues to account for more than half of the world in total service, and has 17 times as many telephones in proportion to population as the rest of the world.

Beverly Hills, California with a population 96,000 has 87,911 telephones, or 92.1 phones for every 100 residents—more phones per capita than any other city on earth.

Canada led the world in the use of its telephones. The average Canadian held 530 conversations during the year. This was followed by Iceland with 509 calls, and the U.S. with 496. Nigeria was low with less than one per person.

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

Anderson, E. W., see Douglass, D. C.

Ballik, E. A., see Bennett, W. R., Jr.

Benes, V. E., *Weakly Markov Queues*, Trans. Sec. Prague Conf. on Inf. Theory, Statistical Decision Functions, and Random Processes, pp. 9-25, 1960.

Bennett, W. R., Jr., Javan, A., and Ballik, E. A., *Measurement of Radiative Lifetimes*, Bull. Am. Phys. Soc., 5, p. 496, Dec. 29, 1960.

Bond, W. L., *Precision Lattice Constant Determination*, Acta Crys. 13, pp. 814-818, Oct., 1960.

Brown, W. L., see Miller, G. L.

Buck, T. M., *Damaged Surface Layers—Semiconductors*, Electrochem. Soc. Monograph, The Surface Chem. of Metals & Semiconductors, pp. 107-135, Fall, 1960.

Burrus, C. A., *Millimeter Wave Esaki Diode Oscillators*, Proc. I.R.E., 48, pp. 2024-2025, Dec., 1960.

Burrus, C. A., see Trambarulo, R.

David, E. E., Jr., and Schodder, G. R., *Pitch Discrimination of Two Frequency Complexes*, J. Acous. Soc. Am., 32, pp. 1426-1435, Nov., 1960.

Dillon, J. F., Jr., and Nielsen, J. W., *Ferrimagnetic Resonance in Rare Earth Doped Yttrium Iron Garnet I Field for Resonance*, Phys. Rev., 120, pp. 105-113, Oct. 1, 1960.

Donovan, P. F., see Miller, G. L.

Douglass, D. C., Frisch, H. L., and Anderson, E. W., *Self-Diffusion of Water in Tobacco Mosaic Virus Solutions*, Biochimica et Biophysica Acta, 44, pp. 401-403, 1960.

Drenick, R. F., *Random Processes in Control and Communications*, Science, 132, pp. 865-870, Sept. 30, 1960.

Early, J. M., *PNP Variable Capacitance Diode Theory*, Proc. I.R.E., 48, pp. 1905-1906, Nov., 1960.

Feder, C. O., see Koontz, D. E.

Feher, G., Prepost, R., and Sachs, A. M., *On Muonium Formation in Semiconductors*, Phys. Rev. Letters, 5, pp. 515-517, Dec. 1, 1960.

Fisher, E. S., see McSkimin, H. J.

Fox, A. G., and Li, T., *Resonant Modes in an Optical Maser*, Proc. I.R.E., 48, pp. 1904-1905, Nov., 1960.

Frisch, H. L., and Lloyd, S. P., *Electron Levels in a One-Dimensional Random Lattice*, Phys. Rev., 120, pp. 1175-1189, Nov. 15, 1960.

Frisch, H. L., and Wasserman, E., *Topological Chemistry of Closed Ring Systems: Catenanes and Rings*, A.C.S. Div. of Polymer Chem., pp. 93-97, Sept., 1960.

Frisch, H. L., see Douglass, D. C.

Frisch, H. L., see Helfand, E.

Frisch, H. L., see Rice, S. A.

Garrett, C. G. B., *Organic Semiconductors*, Radiation Res. Suppl., 2, p. 340, 1960.

Geballe, T. H., *Measurements of Surface Transport Phenomena*, The Phys. & Chem. of Solids, 14, pp. 72-74, 1960.

Geller, S., *Magnetic Interactions and Distribution of Ions in the Garnets*, J. Appl. Phys., 31, pp. 30S-37S, May, 1960.

Geyling, F. T., *Fundamental Satellite Perturbations*, J. Am. Rocket Soc., 30, pp. 1009-1012, Nov., 1960.

Glarum, S. H., *Dielectric Relaxation of Polar Liquids*, J. Chem. Phys., 33, pp. 1371-1375, Nov., 1960.

Gupta, S. S., *Selecting a Subset Containing the Best of Several Binomial Populations*, Contr. to Probability & Statistics, pp. 224-248, June, 1960.

Gyorgy, E. M., and Hagedorn, F. B., *Interaction Between High Power Microwave Losses and Magnetic Flux Reversal*, J. Appl. Phys., 31, pp. 1775-1778, Oct., 1960.

Hagedorn, F. B., see Gyorgy, E. M.

Helfand, E., Reiss, H., Frisch, H. L., and Lebowitz, J. L., *Scaled Particle Theory of Fluids*, J. Chem. Phys., 33, pp. 1379-1385, Nov., 1960.

Herring, C., *Effect of Random Inhomogeneities on Electrical and Galvanomagnetic Measurements*, J. Appl. Phys., 31, pp. 1939-1953, Nov., 1960.

Hogg, D. C., and Semplak, R. A., *The Effect of Rain on the Noise Level of a Microwave Receiving System*, Proc. I.R.E., 48, pp. 2024-2025, Dec., 1960.

Hopfield, J. J., *Fine Structure in the Optical Absorption Edge of Anisotropic Crystals*, The Phys. & Chem. of Solids, 15, pp. 97-107, Aug., 1960.

Hopfield, J. J., see Thomas, D. G.

Javan, A., see Bennett, W. R., Jr.

Ketchledge, R. W., *Electronic Switching*, Bell Tel. Mag., XXXIX, pp. 2-7, Autumn, 1960.

Kinariwala, B. K., *Theoretical Limitations on the Esaki Diode as a Network Element*, NEREM Record, II, pp. 86-87, Nov., 1960.

Kirkwood, J. G., see Stillinger, F. H., Jr.

Koontz, D. E., Feder, C. O., and Thomas, C. O., *Cleaning in the Electronics Industry*, Tech. Proc. of Am. Electroplaters Soc., pp. 188-198, 1960.

Lander, J. J., *Reactions of Li as a Donor and as an Acceptor in Zinc Oxide*, The Phys. & Chem. of Solids, 15, pp. 324-334, Oct., 1960.

Lax, M., and Mengert, P., *Influence of Trapping, Diffusion and Recombination on Carrier Concentration Fluctuations*, The Phys. & Chem. of Solids, 14, pp. 248-267, 1960.

Lebowitz, J. L., see Helfand, E.

PAPERS (CONTINUED)

Lloyd, S. P., see Frisch, H. L.

Li, T., see Fox, A. G.

Looney, D. H., *New Magnetic Devices for Digital Computers*, 1960 Proc. of Electronic Components Conf., pp. 96-104, 1960.

Lowry, W. K., *Some Functions, Interactions and Problems of Communication*, Special Libraries, 51, pp. 479-482, Nov., 1960.

Mackintosh, I. M., see Miller, G. L.

Matthias, B. T., see Peter, M.

McSkimin, H. J., and Fisher, E. S., *Temperature Dependence of the Adiabatic Elastic Moduli of Single-Crystal Alpha Uranium*, J. Appl. Phys., 31, pp. 1627-1639, Sept., 1960.

Mengert, P., see Lax, M.

Miller, G. L., Brown, W. L., Donovan, P. F., and Mackintosh, I. M., *Silicon p-n Junction Radiation Detectors*, Trans. I.R.E. on Nuclear Science, 7, pp. 185-189, June-Sept., 1960.

Nielsen, J. W., see Dillon, J. F., Jr.

Peter, M., and Matthias, B. T., *Paramagnetic Resonance in Metallic Europium and Intermetallic Compounds*, Phys. Rev. Letters, 4, pp. 449-450, 1960.

Porbansky, E. M., see Trumbore, F. A.

Prepost, R., see Feher, G.

Reiss, H., see Helfand, E.

Rice, S. A., and Frisch, H. L., *Some Aspects of the Statistical Theory of Transport*, Annual Revs. Phys. Chem., 11, pp. 187-272, 1960.

Rothkopf, E. Z., *A "Do-It-Yourself Kit" for Programmed Instructions*, Teachers College Record, 62, pp. 195-201, Dec., 1960.

Sachs, A. M., see Feher, G.

Schodder, G. R., see David, E. E., Jr.

Semplak, R. A., see Hogg, D. C.

Shive, J. N., *Characteristics of Electrons in Solids*, Trans. I.R.E. on Ed., 3, pp. 106-110, Dec., 1960.

Slichter, W. P., *Defects in Polyethylene Crystals*, J. Appl. Phys., 31, pp. 1865-1868, Nov., 1960.

Smith, W. L., see Warner, A. W.

Stillinger, F. H., Jr., and Kirkwood, J. G., *Theory of the Diffuse Double Layer*, J. Chem. Phys., 33, pp. 1282-1290, Nov., 1960.

Thomas, C. O., see Koontz, D. E.

Thomas, D. G., *The Exciton Spectrum of Zinc Oxide*, The Phys. & Chem. of Solids, 15, pp. 86-96, Aug., 1960.

Thomas, D. G., and Hopfield, J. J., *A Direct Observation of Exciton Motion in CdS*, Phys. Rev. Letters, 5, pp. 505-507, Dec., 1960.

Trambarulo, R., and Burrus, C. A., *Esaki Diode Oscillators from 3 to 40 KMC*, Proc. I.R.E., 48, pp. 1776-1777, Oct., 1960.

Trumbore, F. A., and Porbansky, E. M., *Solvent Evaporation Technique for the Growth of Arsenic-Doped Germanium Single Crystals for Esaki Diodes*, J. Appl. Phys., 31, p. 2068, Nov., 1960.

Warner, A. W., and Smith, W. L., *Quartz Crystal Units and Precision Oscillators for Operation in Severe Mechanical Environments*. Proc. Fourteenth Annual Symposium on Frequency Control, pp. 200-216, 1960.

Wasserman, E., *Preparation of Interlocking Rings: A Catenane*, J. Am. Chem. Soc., 82, pp. 4433-4434, Aug. 20, 1960.

Wasserman, E., see Frisch, H. L.

Weber, J. H., *Traffic Efficiencies in Congested Band Radio Systems*, Proc. I.R.E., 48, pp. 1910-1911, Nov., 1960.

PATENTS

Following is a list of the inventors, titles and patent numbers of patents recently issued to members of the Laboratories.

Abbott, G. F., Jr.—*Electronic Selector Circuit*—2,964,735.

Avery, R. C.—*Translator Circuit*—2,965,718.

Barney, H. L. and Burns, F. P.—*Hall Effect Memory Device*—2,964,738.

Bissell, H. M. and Zarouni, A.—*Transistorized Bipolar Amplifier*—2,964,656.

Buck, T. M.—*Surface Treatment of Silicon*—2,966,432.

Burbank, R. D., Heidenreich, R. D. and Nesbitt, E. A.—*Magnetic Annealing*—2,965,525.

Burns, F. P., see Barney, H. L.

Buschert, R. C. and Miller, S. L.—*Switching Transistors*—2,964,689.

Cagle, W. B. and Chen, W. H.—*Diode-Transistor Switching Circuits*—2,964,653.

Chen, W. H., see Cagle, W. B.

Christensen, H.—*Method of Making Improved Contacts to Semiconductors*—2,965,519.

Courtney-Pratt, J. S. and Mason, W. P.—*Piezoresistive Accelerometer*—2,963,911.

Crowley, T. H. and Gianola, U. F.—*Magnetic Control Circuits*—2,963,591.

Dahlbom, C. A. and Weaver, A.—*Signaling System*—2,966,659.

DeGraaf, D. A.—*Transistor Switching Circuit*—2,963,592.

DeMonte, R. W.—*Simulation Network*—2,965,859.

Doucette, E. I. and Spector, C. J.

—*Semiconductor Capacitor*—2,964,648.

Fay, C. E.—*Magnetic Tuned Cavity Resonator*—2,965,863.

Garn, P. D. and Sharpe, L. H.—*Etching Bath for Copper and Regeneration Thereof*—2,964,453.

Gianola, U. F., see Crowley, T. H.

Goodall, W. M.—*Stabilized Directly-Coupled Amplifier* — 2,963,657.

Heidenreich, R. D., see Burbank, R. D.

Hershey, H. J.—*Call Transmitter*—2,963,554.

Hewitt, W. H., Jr.—*Adjustment of Isolation Ratio of Field Displacement Isolators*—2,963,667.

Hofmann, H. R.—*Dial Tone Gating Circuit*—2,966,556.

Irvin, H. D.—*Gas Diode Flip-Flop or Register Circuit*—2,964,680.

Jansen, J. J.—*Polarizing Circuit for Television Signals or the Like*—2,964,682.

Jordan, H. G.—*Slide Switch*—2,966,570.

Ketchledge, R. W.—*Electrical Circuit*—2,965,855.

Ketchledge, R. W.—*Signal Comparison System*—2,965,298.

Ketchledge, R. W.—*Steering Systems Utilizing Thermal-Energy Radiations*—2,964,265.

Kohman, G. T., Miller, S. E., Rose, C. F. P. and Young, J. A., Jr.—*Electromagnetic Wave Guide Structure*—2,966,643.

Mann, H. — *Transistor Trigger Circuit Stabilization*—2,964,655.

Marcatili, E. A. J.—*Waveguide Transducer*—2,963,663.

Mason, W. P., see Courtney-Pratt, J. S.

May, J. E., Jr.—*Tapped Ultrasonic Delay Line*—2,965,851.

McSkimin, H. J.—*Measurement of Dynamic Properties of Materials*—2,966,058.

Miller, S. E., see Kohman, G. T.

Miller, S. L., see Buschert, R. C.

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

Ohm, E. A.—*Broad-Band Electromagnetic Wave Transmission Means*—2,963,668.

Rose, C. F. P., see Kohman, G. T.

Seidel, H.—*Wave Guide Filter*—2,963,661.

Sharpe, L. H., see Garn, P. D.

Spector, C. J., see Doucette, E. I.

Sweeney, J. F.—*Altitude Control System*—2,965,894.

Thomas, L. C.—*Electrical Circuit Employing Transistor*—2,964,651.

Wadsworth, P. W.—*Multiparty Telephone System*—2,966,553.

Weaver, A., see Dahlbom, C. A.

Yostpille, J. J.—*Multiple Input Diode Scanner*—2,965,887.

Young, J. A., Jr., see Kohman, G. T.

Zarouni, A., see Bissell, H. M.

TALKS

Following is a list of speakers, titles and places of presentation for recent talks presented by members of Bell Laboratories.

AMERICAN PHYSICAL SOCIETY MEETING, Chicago, Ill.

Alff, C., and Wertheim, G. K., *Hyperfine Structure of Fe^{57} in Yttrium-Iron Garnet from the Mossbauer Effect.*

Blumberg, W. E., and Eisinger, J., *Band Structure of Gray Tin from Knight Shift Measurements.*

Bommel, H. E., see Dransfeld, K.

Clogston, A. M., and Jaccarino, V., *Susceptibilities and Negative Knight Shifts in Certain Intermetallic Compounds.*

Dietz, R. E., and Pappalardo, R., *Optical Absorption Spectra of the First Transition Series in CdS.*

Dransfeld, K., and Bommel, H. E., *Proposed Mechanism for Far Infrared Absorption in Ionic Crystals.*

Eisinger, J., see Blumberg, W. E.

Jaccarino, V., see Clogston, A. M.

Knox, K., Shulman, R. G., and Sugano, S., *Crystal Field Splitting in $KNiF_3$.*

Linares, R. C., see Pappalardo, R.

Pappalardo, R., Wood, D. L., and Linares, R. C., *Optical Absorption of Ni^{2+} and Co^{2+} in Cubic Symmetry.*

Pappalardo, R., see Dietz, R. E.

Peter, M., see Sugano, S.

Piksis, A., Sugano, S., and Schawlow, A. L., *Strain-induced Splitting of a Chromium Fluorescence Line.*

Schawlow, A. L., see Piksis, A.

Sherwood, R. C., see Williams, H. J.

Shulman, R. G., see Knox, K.

Sugano, S., and Peter, M., *The Effect of Configuration Mixing and Covalency on the Energy Spectrum of Ruby.*

Sugano, S., see Knox, K.

Sugano, S., see Piksis, A.

Walker, L. R., *The Ferrimagnetic Resonance Field of Terbium Doped Yttrium Iron Garnet.*

Wertheim, G. K., *Mossbauer Effect in Magnetic Materials.*

Wertheim, G. K., see Alff, C.

Williams, H. J., and Sherwood, R. C., *Correlations Between Superconductivity and Susceptibility.*

Wood, D. L., see Pappalardo, R.

CONFERENCE ON MAGNETISM AND MAGNETIC MATERIALS, N. Y. C.

Barrett, W. A., *Demagnetization of Twistor Bits.*

Denton, R. T., *Theoretical and Experimental Characteristics of a Ferromagnetic Amplifier Using Longitudinal Pumping.*

Dillon, J. F., Jr., *A New Characteristic in the Temperature Dependence of Ferrimagnetic Resonance Line Width in Some Rare Earth Doped Yttrium Iron Garnet.*

Dymanus, A., and Kaminow, I. P., Reported by Rado, G. T. *Ferromagnetic Resonance in Piezoelectric $Ga_{2-x}Fe_xO_3$.*

Geschwind, S., *Anisotropy of YIG Calculated from Crystal Field Parameters of Fe^{3+} in Yttrium Gallium Garnet.*

M. J. Elkind

the Bell system. Mr. Owens is a member of the Audio Engineering Society and the author of the article "An Improved Amplifier for Program Circuits."

Michael J. Elkind received the B.S. degree in chemistry at the University of Detroit in 1943. After serving in the U. S. Army, he returned to the University to obtain his M.S. in 1948 and then his Ph.D. in inorganic chemistry from Wayne State University in 1951. Following five years in the chemical industry, he joined the Allentown branch of the Bell Laboratories in 1956, residing in Easton, Pennsylvania. A member of the Applied Chemistry group at Allentown, Mr. Elkind has been engaged in the development of chemical processes as applied to the design and reliability of electron devices. He is a member of the American Chemical Society, American Electroplaters Society, and the American Physical Society. He is author of "Analysis of Atmospheres in Manufacture of Electronic Devices" in this issue.

E. T. Ball, co-author of the teletypewriter equipment article in this issue, was born near Cambridge, England, and received his engineering education at the City of Lincoln Technical College. He joined the Western Electric Company equipment engineering department at Hawthorne, Ill., in 1922 and transferred to the Laboratories in 1937 when he entered the general standards group. Immediately after World War II, he engaged in the early development of the No. 5 Crossbar System

E. T. Ball

where he designed the tubular frameworks used in that system and later participated in changing over the system to wire spring relay operation. In 1954 he joined the telegraph group at the inception of the 82B1 Switching System. While in that group, he also did the equipment design of the SAC primary alerting system and on its subsequent extension to foreign bases. At the time of his recent retirement, he was engaged in data-set development.

G. A. Waters

George A. Waters of East Orange, N. J., recently retired from the data systems development department of Bell Laboratories. A native of Wayne County, Illinois, Mr. Waters started his Bell System career in 1920 at the Western Electric Co. Hawthorne Plant in Chicago, and later transferred to the company's Kearny Plant in New Jersey. At Western Electric he specialized in engineering telephone central-office equipment. In 1931 he joined the Laboratories where he has been concerned with the development of teletypewriter switching systems and teletypewriter equipment for use at customers' offices. Most recently he was engaged in work on automatic teletypewriter switching systems and associated station equipment. He is co-author of "Equipment Features of the 82B1 Teletypewriter Switching System" in this issue.