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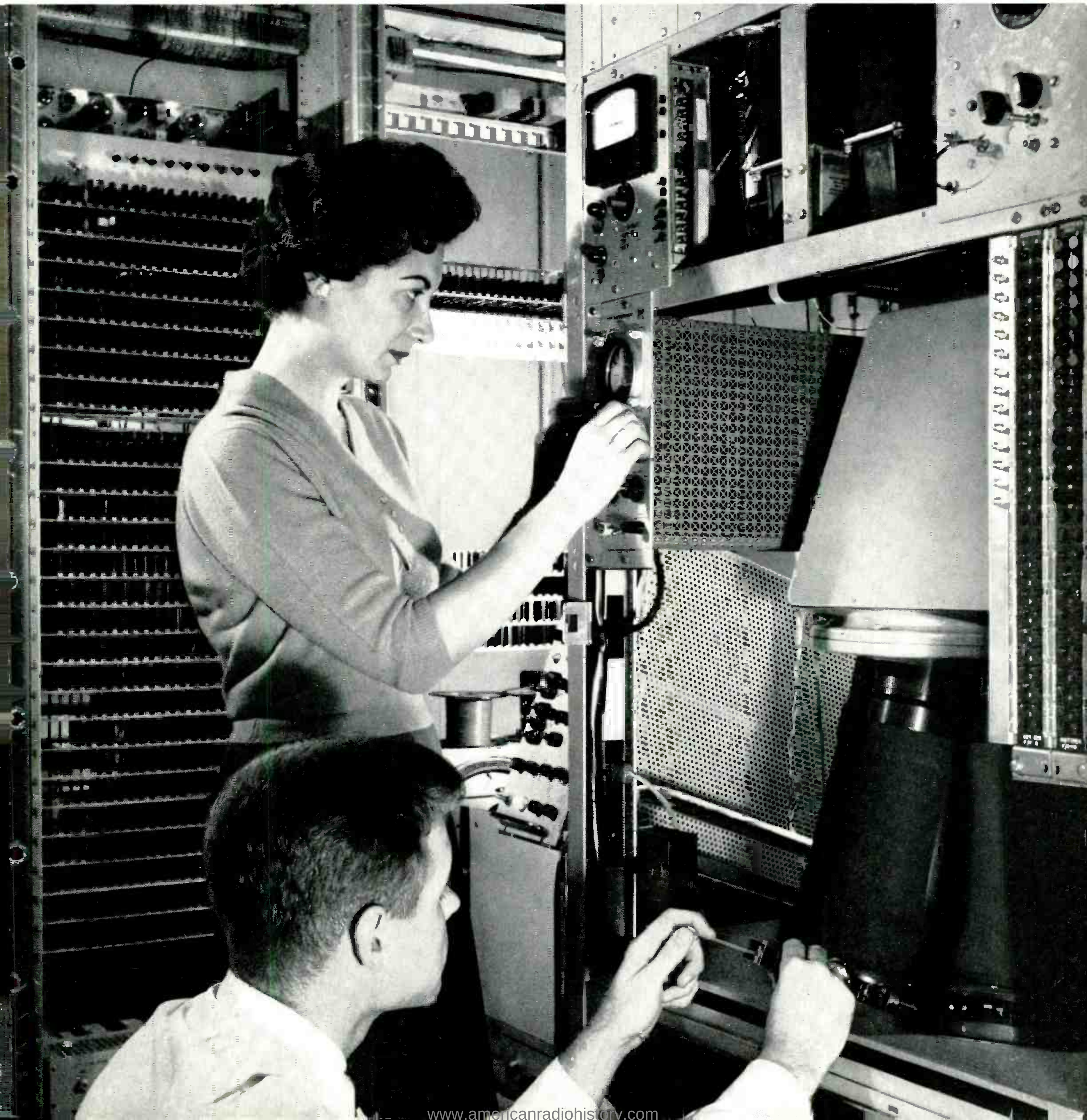
Bell Laboratories RECORD



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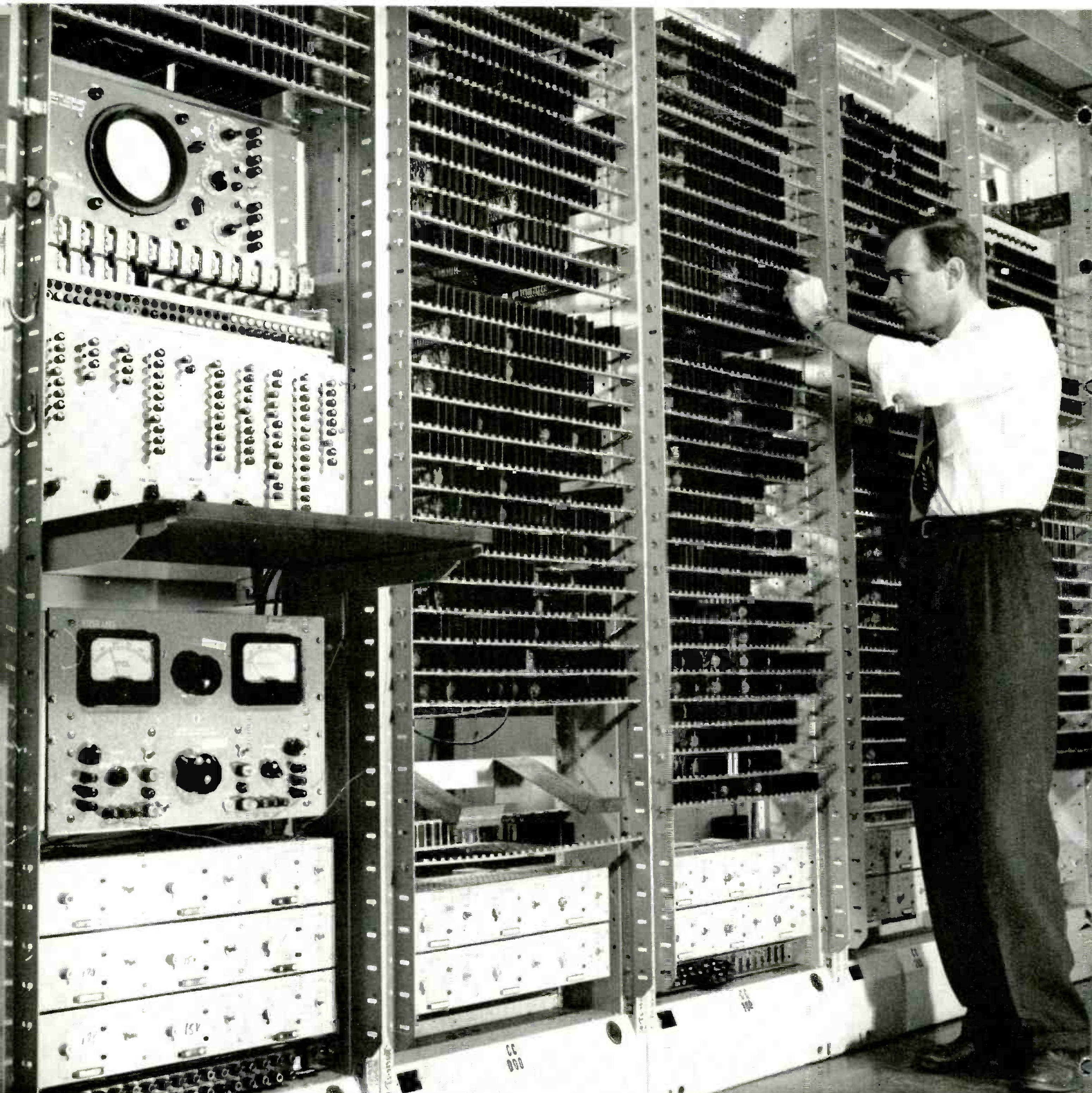
Cover

Flying-spot store equipment for an experimental electronic telephone switching system (see story starting on page 359). Mrs. R. K. Dudek makes an adjustment as E. J. Blythe inserts a photographic plate into one of the optical channels.



E. J. Miller examines a circuit package from central-control section of the experimental system. The left-hand bay contains equipment for tests.

The telephone switching system of the future may be entirely electronic — actions performed by the controlled flow of electrons rather than by the mechanical motions of relay armatures. As the first step in an extensive development program, Bell Laboratories has built an experimental system that illustrates many of the new principles of electronic switching.

A. E. Joel, Jr.

An Experimental Electronic Switching System

Over the years, Bell Laboratories has carried out a number of engineering studies and experimental programs in the field of electronic switching — studies that have built up a wealth of information important to all new systems designs (*for example, see* RECORD, *September*, 1954). Thus, in recent years it has become apparent that electronic switching must be seriously considered as a possibility for providing telephone service. Transistors and related semiconductor devices, plus the new insight into communications resulting from information theory, have added greatly to the significance of this work.

It was also apparent, however, that a comprehensive development program would be necessary before electronic switching could become a reality to the telephone customer. Electronic switching is so entirely new — both in broad concept and in detail — that a system meeting Bell System standards involves considerable development effort to achieve the desired objectives of service, economy and reliability.

The development effort is far from complete, but some of the questions related to connecting telephones electronically have now been answered. Specifically, a switching development department at Bell Laboratories has built an experimental electronic system incorporating features that may someday be commonplace in the telephone industry. With this experimental equipment, a talking and signaling path is established through the system with no use of electromagnetic relays, metallic contacting elements, or mechanical motion.

Because electronic switching is so new, the intention here is to give a broad picture of the experimental system. The first part of this discussion concerns its basic organization, and later a call is traced to illustrate its operation. The accompanying block diagram will be helpful in identifying the functional location of the various equipment units.

Perhaps the most noticeable parts of the new system are its two "memories" — the "barrier-grid store" and the "flying-spot store," referred to in this article by the abbreviations BGS and FSS. These are functionally concentrated units; that is, they represent an attempt to group into one compact physical unit all functions of a closely related type. Such concentration, as distinct from physically distributing related actions at many locations, is characteristic of the system.

The barrier-grid store or BGS is the temporary memory of the system, and is a type of electrostatic storage tube. Its "screen" or target area is considered to be divided into discreet areas or "spots," each of which either does or does not have an electrical charge. Thus, each spot records one bit of information. Rows of spots record information on the status of each call as it progresses through the system.

These rows of spots are known as "registers," since they perform functions very similar to those of relay registers in electromechanical systems. In other words, this is the unit that, among other functions, remembers the number dialed by the telephone user. In the electronic system, register "spots" also take the place of certain relays in the trunk circuits of existing systems, and for this reason the trunks are relatively free of complex circuitry.

The Flying-Spot Store

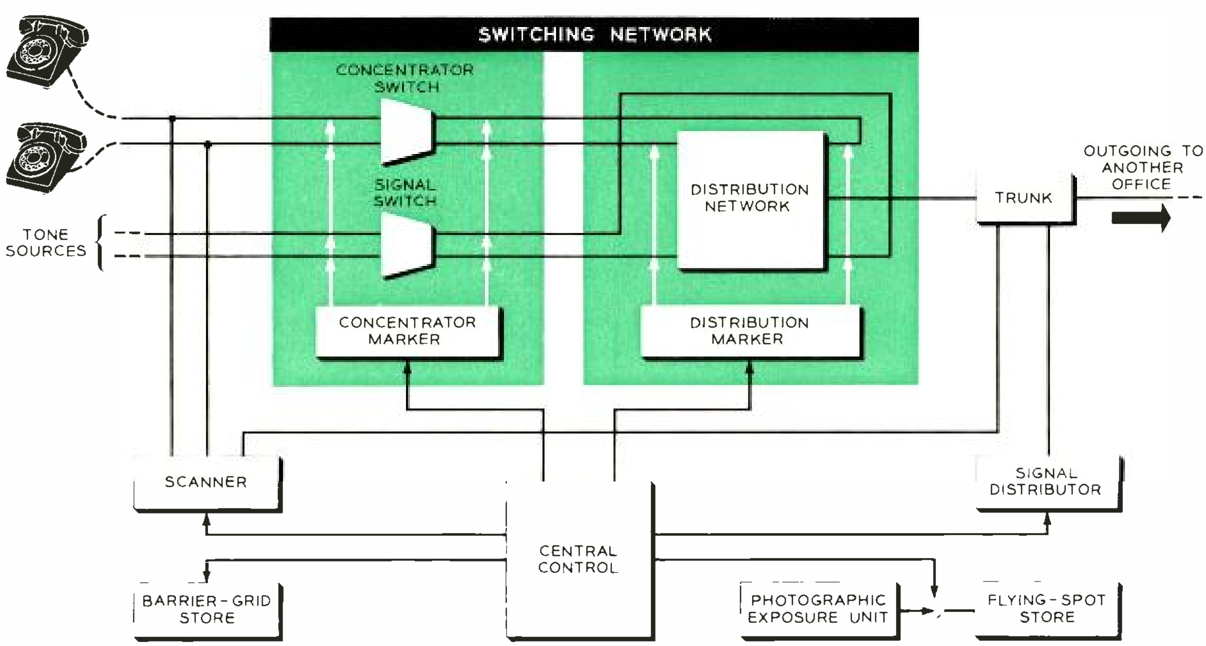
The second memory unit — the flying-spot store or FSS — can also be compared to equipment in electromechanical systems. In existing dial telephone offices, it is necessary to relate the customer's number (as it appears in the directory) to an equipment number (arbitrary numerals for use by the office). In existing systems, the characteristic feature of the arrangements designed for this and similar functions is a field of wires that crossconnects frames of relays. Such wiring, installed semipermanently in the office, comprises a type of built-in "intelligence" that decides how the system will act under each possible circumstance that may be encountered as a telephone call is processed.

In place of this "wired-in" memory, the memory media of the FSS are photographic plates, and the coded information placed on the plates is called the "stored program." It appears as an array of transparent and opaque areas on the photographic film. From the analogy with electromechanical switching, an important difference in the new system is evident: presently, wiring must be altered to make changes, but with the electronic system, new photographic plates are prepared and inserted into the FSS.

In the FSS, a beam of light from the face of a cathode-ray tube is focused on the plates through a system of lenses. The beam from one location on the phosphor of the cathode-ray tube may be imaged simultaneously on several photographic plates, and thence on a corresponding number of photomultipliers. Consequently, a parallel (simultaneous) set of bits may be read out of the plates for each location on the face of the cathode-ray tube.

In the experimental system there are nine photographic plates and optical channels, and two successive locations on the tube are read to derive a "program word" of 18 bits. This "word" is a statement describing what the system must do under an existing group of circumstances. For example, it might be expressed verbally as an instruction that the system must "Take certain equipment location numbers and establish telephone connections between these points."

It is apparent that the BGS and the FSS perform two of the vital jobs required of any



Block diagram of experimental electronic telephone switching system built at Bell Laboratories. Semiconductor diodes and transistors are used extensively in the central control and scanner.

modern automatic telephone system. But we have not yet described the network through which the actual telephone connection is established. For the experimental system, a simple network is used. As indicated in the block diagram, it consists of a distribution section, concentrators, and a switch for ringing tone. The one distribution section is an array of 3-by-3 switches, and there are two concentrators, each with two lines for two telephones. So that only audio signals will be transmitted through the electronic network, the system makes use of tone ringing (RECORD, *February*, 1957).

Role of the Scanner

In this system, all information from the telephone lines is received through a matrix of semiconductor diodes known as the "scanner." Periodically and at high speed, the scanner "looks" at each telephone line to detect whether a user has begun to originate a telephone call since the last look, or, if a call was already in progress, whether the call has been disconnected. For each line, there are two BGS spots that indicate its status: (1) idle, (2) busy and being handled by the register spots in the BGS store, or (3) busy with the connection in the talking state.

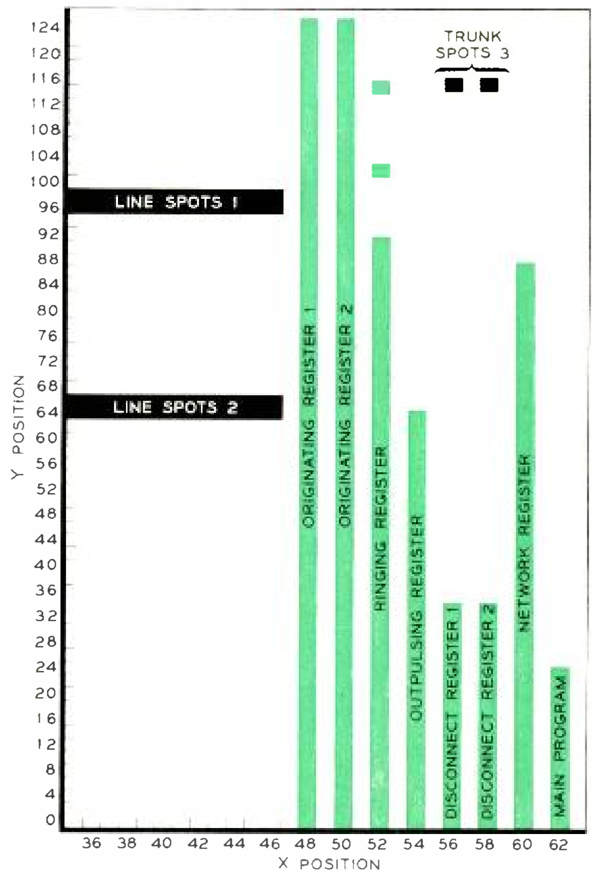
Other spots in the BGS are used to record the equipment number (physical location) of the calling telephone line while the call is being processed. These spots are read out every 10 milliseconds, so that the scanner can detect the shortest open which might occur in dialing at the rate of twenty pulses per second. In other words, the scanner is able to detect pulses at this rate without confusion.

Obviously, considerable information is being handled in the system, and a central "director" or "coordinator" is therefore required. This is the "central control" indicated in the block diagram — a circuit consisting of some 15,000 semiconductor diodes and 1,500 transistors. The central control is the section which directs the scanner in inspecting the condition of a line and which notes what this condition is. As a result, the system knows whether or not a change has occurred since the previous "look" at the line, and is able to decide what to do next. On the basis of such decisions, different "program addresses" are sent to the FSS, where different instructions are received so that appropriate changes are made in the BGS.

Decision-Making Circuit

If the chief characteristics of a "brain" are logic and memory, the central control could be considered the logic portion of the brain of the experimental system. It brings together the information gathered from the two memories, the scanner and the switching network, and with this information decides the actions to be taken. It might be well to mention at this point that, as in most descriptions of switching systems, the actions take place very much faster than the telling. For one call, everything we have described to this point would probably take place in a fraction of a second.

The decisions just referred to are usually binary in nature — that is, at a given instant the system ordinarily decides between only two alternatives. And it makes only one such decision at a time. It therefore has what can be considered a very rudimentary type of "brain," but one that works very rapidly. At a given moment, the system control may be looking at a telephone line and deciding that a user wants service. It will then take the necessary steps for placing the equipment number of this line in an idle originating register (blank column of spots in the BGS). At the next moment, the same control might be serving another telephone line whose



Portion of drawing showing how various areas of the "target" in the barrier-grid store are assigned for different purposes. This temporary "memory" characteristically includes the registering functions of an automatic telephone switching system.

equipment number has already been recorded; or it could be adding a dial pulse in another originating register.

This one-at-a-time type of operation is possible because of the high speed at which the electronic elements of the system are capable of operating. It is often referred to as "time-division control."

Another major element apparent in the block diagram is the signal distributor. With this unit, the system selects one of a number of circuits — for example, trunk circuits — to send signals from the high-speed central control to slower-speed signaling circuits. In the experimental system, for instance, the signal distributor is used to actuate a relay on one network terminal so that a trunk terminal could return dial tone or busy tone to a telephone line. It is also used to generate dial pulses on a trunk for transmission to other switching systems.

In generating these pulses, the signal distributor receives an instruction from the central control about every 50 milliseconds — an instruction to open or close the trunk loop to start or end a particular pulse. The pulses are counted in another column of BGS spots called an outpulsing register.

The Main Program

To this point, although some of the interrelationships of the major elements have been stated, we have been mainly concerned with the actions of the separate units in handling a telephone call. These actions are tied together by a series of instructions known as the "main program." The time-division control is started by addressing the FSS to the first of these instructions. Then, the main program guides the system through various steps that are repeated at different time intervals. Some intervals are very short — 10, 50, or 100 milliseconds, for example — while others, such as "timing out" signals, may be as long as 10 to 20 seconds. In the BGS, certain spots are used as a "main-program register" to aid the counting of time.

Let us now trace a call through the system and notice how the main program divides the steps into time actions and how the central control makes decisions. The next few paragraphs will describe what happens in the very short space of time from the point when the user picks up his handset to the point when he hears dial tone. We assume here that the user is attempting to place an inter-office call — that is, a call to a customer in another office.

As long as the user leaves his handset on the switchhook, his line is scanned every tenth of a second (100 milliseconds), and the system, of course takes no action when the telephone line is in this idle condition. Now imagine that the user lifts the handset off-hook. During the next one-tenth second scan, once the request for service is recognized, the main program is devoted to that part of the FSS that deals with the search for an idle originating register in the BGS. In each register, one spot indicates whether or not the register is in use, and for this reason it is known as the "availability spot."

When an idle register is found, the equipment number of the line desiring service is stored in a set of spots. Twelve spots are used for this purpose in the experimental system. The equipment number of the line is known because during the one-tenth second scan, it has a correspondence

Actual photographic trace of the "flying-spot" or beam of light in the semipermanent memory of the experimental switching system. Movement of beam indicates progress of a cycle of the main program; spots are places where beam dwelt on transparent or opaque areas of the ESS plates.

to the address of the scanner. After the equipment number is stored in the BGS, the central control is directed by the FSS back to a one-tenth second scan for the next line.

The system now has the equipment number in the BGS, and it must prepare itself to detect dial pulses. For this purpose, every 10 milliseconds the main program causes the BGS to "read out" the equipment number, which is formed into an address for the scanner. During scanning, most lines will show no change in condition, but when a change is detected, the central control directs the FSS to the section of the main program dealing with the counting of dial pulses.

Meanwhile, at the point when the equipment number of the calling line was first placed in the originating register, the central control began preparing for an essential element of the connection — a dial-tone trunk. It consulted the appropriate instructions in the main program of the FSS and thus initiated a search of certain spots in the BGS. These spots indicate trunk terminations connected to the source of dial tone, and they are read in succession until an idle trunk is indicated.

Gas-Tube "Crosspoints"

The system now knows which line wants service and has determined that a particular dial-tone trunk is available. The central control therefore sends the numbers identifying the line and the trunk to network "markers": separate sets of controls that are part of the network. A concentrator marker and a distribution marker are indicated in the block diagram. These place an electrical signal (a "mark") on each of the two points to be connected, and the busy-idle status of the various paths through the distribution network determines an idle path for the new connection. The two marks cause a gas tube to fire in the concentrator, and then six more gas tubes fire in series in the distribution network. Through these seven fired gas tubes (or "crosspoints" of the switching section) dial tone is sent to the person placing the call.

The preparations previously made for receiving the dialed number are now put into effect. In accordance with the instructions from the main program, the pulses for one digit are recorded in binary form as a combination of four "pulse-counting" spots in the BGS.

With spots in the main-program register of the BGS, the main program counts time to detect any passage of at least 100 milliseconds without the recording of a dial pulse. This lapse of time indicates that the pulses for one digit are complete and that the pulses for the next digit will begin. As a result of such an interdigital period, steps are taken to transfer the recorded digit to the register and thus leave pulse-counting spots free for the next digit.

At the time the calling party received dial tone, a type of "follow-up" procedure was undertaken. The distribution marker reported back to the central control that the desired connection through the crosspoints had been established. Similarly, when the beginning of the first dial pulse was detected, the markers applied a "release potential" to drop this connection so that the user will not hear dial tone while he dials the number. Later, when dialing is completed, network actions are again started. A "network register" in the BGS is used to provide the information needed for starting new programs if a delay is encountered in setting up the connection.

The connection for the inter-office call is now complete. The only remaining actions are to transmit the required called-number digits to the receiving office, which will either ring the called party or return busy tone.

On an intra-office call (call to another telephone served by the same system) a somewhat different procedure is followed. Briefly, the system translates the dialed number by using a "table" stored in the FSS, and then looks at spots in the BGS to determine whether the *called* line is busy or idle. If it is idle, it sets up a ringing connection. This connection is established from a source of ringing tone in one concentrator and thence through the distribution network to the *called* line. Then a similar connection is established from the *calling* line to another source of ringing tone to indicate, to the *calling* party, that the *called* telephone is being rung.

A record of this call is transferred from the originating register to a "ringing register" in the BGS, and the *called* line is scanned every 80 milliseconds for answer. If the called party has picked up his handset to answer the call, the scanner detects this at this time. Similarly, the *calling* line is scanned every 100 milliseconds to determine whether the calling party abandons his call before completion.

When the *called* party answers, the ringing register indicates that a network action is required. If the network is available, the central control transmits information to the network to release the two ringing connections and to establish a single connection from the called to the calling line. The two lines are now connected through eight fired gas tubes, and the call is no longer recorded in a BGS register. "Line spots" for both lines are set to indicate that talking path has been established.

Now that the conversation is in progress, both lines are scanned to determine when either party hangs up. When the first disconnect signal is detected, an idle "disconnect register" in the BGS is seized, but to guard against a spurious open (false disconnect), no action is taken for 300 milliseconds. Then, however, an order to the network releases the connection by marking the terminal of the line on which the disconnect timing has been completed. Finally, the line spots in the BGS are restored to normal and the other line is disconnected.

This, in a general way and with many details omitted, is how the experimental Bell Laboratories system works. The system itself will never see actual service, since it was designed strictly as a first step in a development program. In it, however, we can see signs of the new era of telephone switching.

The small size of semiconductor devices requires critical techniques in their manufacture. This is especially true in the fabrication of the diffused-base transistor. Consequently, the Laboratories has developed evaporation and alloying processes that deposit emitter and base contact materials almost atom by atom.

R. J. Gnaedinger, Jr.

Precision Evaporation and Alloying

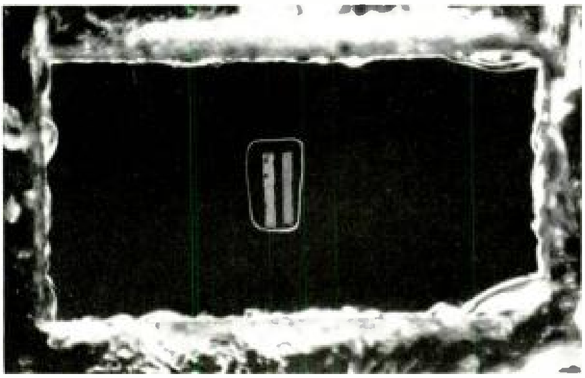
The launching of America's first earth satellite, Explorer I, coincided with the very public debut of a new device from the Bell System — the germanium diffused-base transistor. From its position in the heart of the satellite, this small device was fulfilling an indispensable role in the transmitting equipment of Explorer I by providing the 108-megacycle signal that carried to the ground both the position of the satellite and information on conditions in the upper atmosphere. Thus, in addition to the 1,600-mile apogee it shared with the orbiting satellite, this semiconductor device had scaled a new height in performance for high-frequency transistors.

The new device — a diffused-base p-n-p transistor — was announced by the Laboratories in 1956 (RECORD, *February*, 1956). Its major feature of a 500- to 1,000-megacycle cutoff frequency has since opened up many potential applications that had previously been out of reach of the transistor art. As a manufactured device, its immediate usefulness is apparent in equipment such as broad-band carrier systems, guided missiles, electronic computers, and frequency modulation and television receivers.

High-frequency performance in transistors requires them to have very small dimensions. The p-n-p transistor fulfills this requirement in being a rectangular "wafer" of germanium about the size of an undotted "i" and about the thickness of a sheet of paper. Its actual dimensions are 0.040 inch long by 0.020 inch wide by 0.003 inch thick. On one side of this wafer is located a rectangular "mesa" with an area smaller than the dot of an "i". A tiny pair of "stripes" (each 0.006 inch by 0.001 inch) lie parallel to each other on top of the flat mesa. One stripe is made of aluminum, the other of a gold-antimony alloy; they constitute the emitter and base contact, respectively, of the transistor. The stripes are about 500 atom layers thick — less than half the wavelength of visible light. The base region, upon which these stripes rest, is "doped" with n-type impurities to a depth of around 5,000 atom layers.

The successful development of this device has rested primarily upon the wealth of technical knowledge discovered in the transistor field during the last decade. But it has also required the exploration of new and more precise fabrication techniques. For example, one major obstacle to high-frequency performance was the difficulty encountered in producing transistors with very thin base regions. These regions were required to have a uniform thickness of one micron — about 1/100th the diameter of a human hair. The technique developed to produce this region was that of diffusion of electrically active impurities into the germanium.

The very thinness of this diffused layer, however, raised a second obstacle — finding new



Microphotograph (enlarged 63 diameters) of a germanium wafer outlining the mesa onto which are evaporated aluminum and gold-alloy stripes.

methods to make alloyed electrical contacts to the layer without puncturing or otherwise destroying it. This second problem required a solution just as urgently as did that concerning the thin base layer. For high-frequency performance, these alloyed regions have to be as small and as close together as possible — without electrically shorting. This problem was solved by a vacuum-evaporation technique.

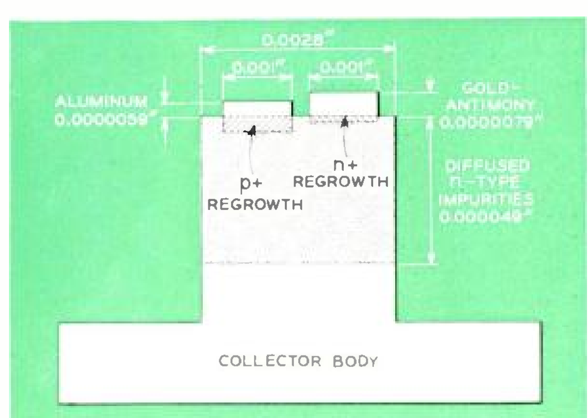
Evaporation is said to occur when a solid or liquid gradually disappears; its atoms or molecules fly out from the surface and apparently vanish into thin air. The speed with which this occurs depends upon how strongly the molecules are held in the solid or liquid. Water evaporates readily at room temperature; gold obviously does not. Now, when any material is heated, its rate of evaporation increases. Thus, gold at a temperature of about 2250°C — far above its melting point — will evaporate as fast as does water at room temperature.

As water evaporates into air, each water molecule that leaves the liquid surface is constantly buffeted about by the large numbers of molecules (mostly of oxygen or nitrogen) in the air. Each water molecule travels, as an average, only about four millionths of an inch between collisions with other molecules. Consequently, these molecules follow a rather haphazard course through the air. In cool air, the vaporized water molecules will condense into fine droplets of water as they collide with each other. In warm air, a cool glass held above the water will condense water molecules from the air onto its surface. Although that portion of the surface nearest the water will get the heaviest coat of water, the more distant and opposite sides will also be bombarded with, and will condense, molecules that have circled behind the glass.

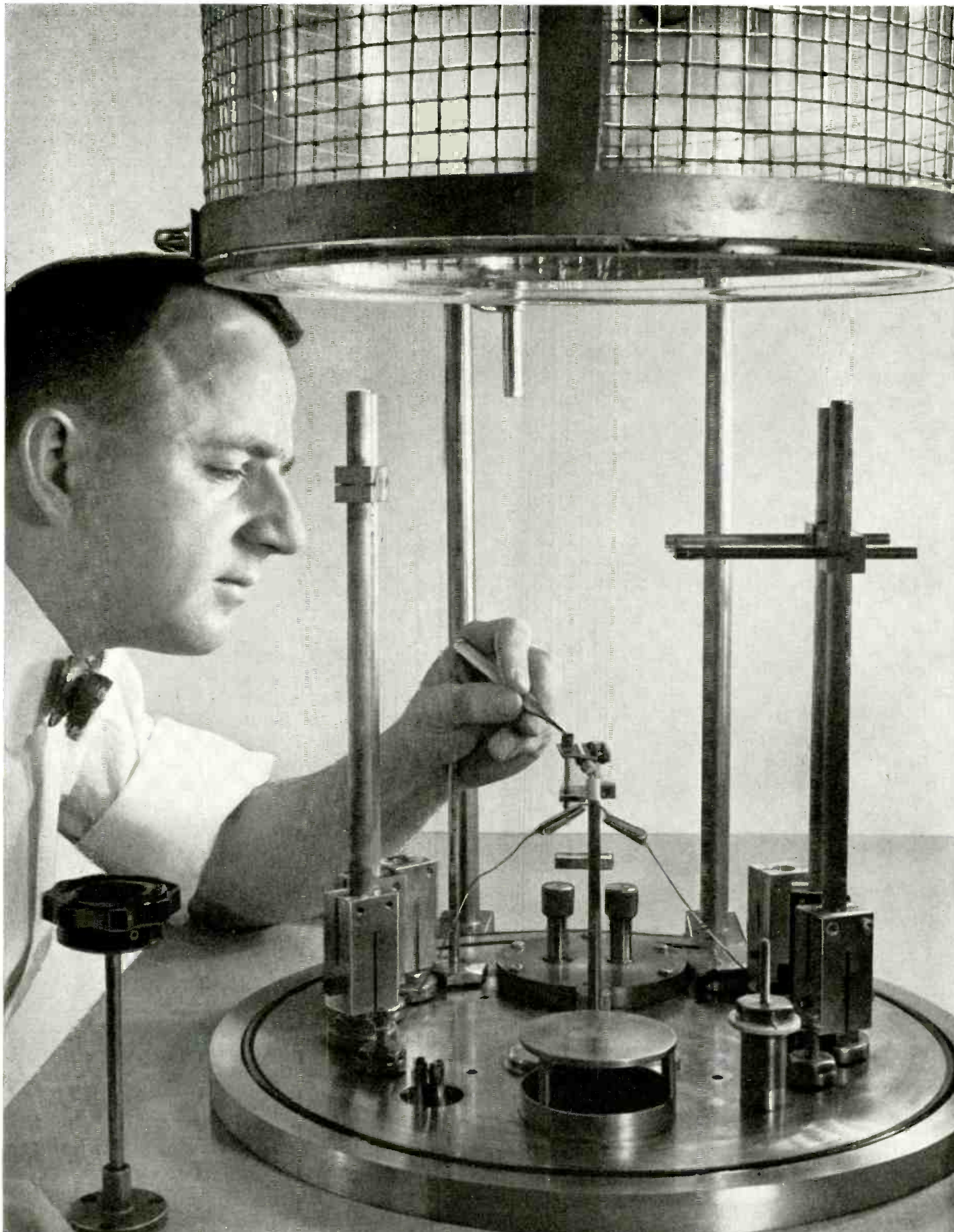
If the water is put into a chamber from which most of the air has been pumped out, however, the evaporated molecules can travel all the way to the cool glass surface without a collision. (The mean distance between collisions, or mean free path, is inversely proportional to the pressure of the ambient gas.) The paths these molecules follow will be straight lines from the water surface to the glass. Since only the molecules hitting the glass will stick to it, only those portions of the glass that are in direct view of the liquid water will now condense water molecules. The other portions of the glass will not do so because none of the water molecules hit them.

The evaporation of metals at higher temperatures behaves in a similar manner. What does the evaporation technique have to offer that makes it superior to other methods? First, it allows the controlled deposition of much thinner layers of material. Second, it is a method for coating with highly reactive materials, such as aluminum, that are difficult to work with in air. Third, it allows greater cleanliness in technique and hence gives a more intimate contact between the layer and the surface upon which it has been coated. Fourth, the fact that the evaporating beams travel in straight lines permits the use of precisely dimensioned "masks" to create similarly precise evaporated patterns.

Techniques for the evaporation of metals in partial vacuum have been known for more than fifty years. More recently, due especially to improved vacuum techniques, the vacuum-metallization process has grown to huge proportions in industry. At Bell Laboratories, vacuum deposition has been used in processes such as capacitor fabrication (RECORD, *December*, 1955), frequency adjustment of quartz-crystal oscillators, and contacts to ferroelectrics, as well as transistor fabrication. The basic equipment for evaporation consists of a vacuum chamber with associated pumps, and a filament or container (usually of tungsten) for the evaporant charge. The container can be heated to a high temperature by resistance or



Schematic cross section of the germanium wafer. Because of the extremely small dimensions involved, placing the two stripes is a critical step.



The author prepares evaporation equipment. This work is done under high-vacuum conditions to avoid contamination and other undesirable effects.

induction heating. A commercial laboratory evaporator usually consists of a metal base plate, to which all necessary electric and water services are supplied and which contains a port leading to the vacuum pumps. The operation requires a bell jar of metal or glass to be lowered onto the base plate. (Usually a rubber vacuum-seal connects the two.) The air within the jar is then removed.

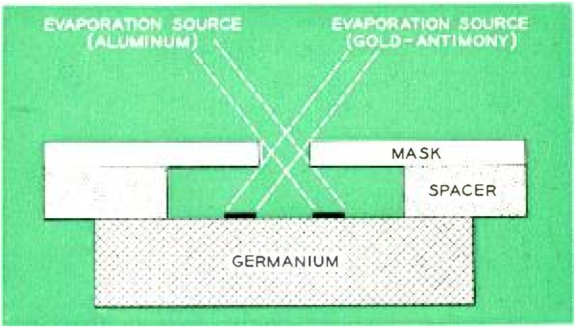
For most ordinary evaporation work, a mean free path of 4 to 40 inches is adequate, requiring pressures of 10^{-6} to 10^{-7} atmosphere. (One atmosphere of pressure corresponds to a density of about 5×10^{20} molecules per cubic inch.) Successful fabrication of the diffused-base transistor, however, requires pressures of about 5×10^{-8} atmosphere to minimize contamination, chemical reaction and atom scattering. When this degree of vacuum has been reached, the filaments in the equipment are heated to incandescence and the charges of aluminum and gold are melted and evaporated in the proper sequence. The amount of evaporation ranges from 0.1 to 1.0 gram.

A pair of stripes is prepared by evaporation through a rectangular hole in a molybdenum mask that is superimposed on top of the germanium surface. The slots are formed in the thin molybdenum sheets by a photoengraving technique developed at the Laboratories. This method first requires a magnified model of the desired pattern to be drawn very precisely. The model is then photographically reduced to 1/100th its original size and this reduced pattern etched into the metal sheet.

Spacers hold the mask a few thousandths of an inch above the germanium surface to produce a pair of stripes from a single rectangular hole (0.006 inch by 0.001 inch). The aluminum and gold evaporation sources are located at different positions to produce a properly separated pair of images of the hole. Each of these stripes, then, is an accurate replica of the pattern in the mask. The offset of the sources and the thickness of the spacers produce the spacing between the stripes. Obviously, the total separation between the germanium surface and the mask has to be maintained constant to give a reproducible stripe separation. This means using metal and germanium surfaces that have been machined or polished flat. Pressure from a spring maintains intimate contact between these surfaces.

An alloying operation follows the evaporation of the aluminum stripe. This step is also critical because it forms the emitter junction of the transistor — a region where the germanium, though still a single crystal, abruptly changes from p-type to n-type. The alloying operation consists of raising the temperature of the germanium until the aluminum (and in a later stage the gold) melts together with a portion of the germanium surface. This is followed by a cooling step during which germanium in the liquid resolidifies onto the unmelted germanium, carrying with it some of the aluminum impurity. It is this resolidification process that creates the emitter p-n junction.

The alloying step proved to be easily disturbed by surface contamination. In an attempt to minimize this difficulty, the germanium was transferred (after cooling) directly from the high-temperature diffusion operation into the



A single rectangular slot serves to evaporate the two patterns. This is made possible by inserting a spacer between the mask and germanium mesa.

evaporation jig. Though this germanium surface looked clean under a microscope it still had sufficient oxide, adsorbed gases or other contamination to cause severely erratic alloy results. It was not until the germanium was heated to above 500°C in vacuum before evaporation that good results were regularly obtained.

Following the process stages just described, the germanium is fabricated into completed transistor units by operations that include mounting on the headers, attachment of leads and placing the units in cans. (A color photograph of the internal structure of a unit of this general type appeared on the cover of the *June*, 1958 issue of the RECORD.) Currently, Western Electric is processing fifty transistor units at a time on a single thin slab of germanium less than ½ inch square.

In addition to these evaporation and alloy techniques, many other precision techniques, such as the preparation of high purity crystals, mechanical polishing and controlled impurity diffusion, go into the manufacture of this device. From these many, critical steps in manufacture have come the transistors that are now circling the earth in Explorer I. This present use is clearly but one of the many, far-flung potential applications for these high-frequency transistors.

"Through-connections" have become very important items in this new era of printed circuits. Bell Laboratories has developed a new eyelet-setting and soldering machine which has been used in the laboratory for making fused-in-place through-connections very speedily and economically on printed-circuit boards.

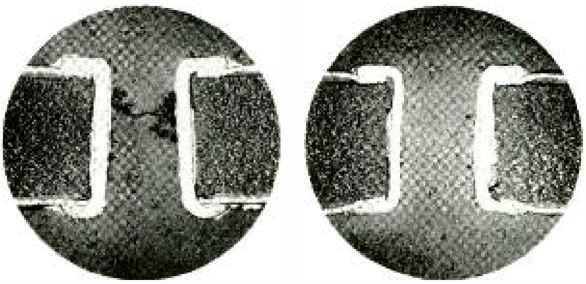
J. W. Buckelew and E. D. Knab

THROUGH-CONNECTIONS FOR PRINTED WIRING

In the use of printed circuits (RECORD, *April,* 1958), continuous electrical contact must often be made between conductors on opposite sides of the circuit board. This means that a connection must be made through the board between particular elements. Such connections must withstand severe conditions of thermal shock, physical shock, vibration, and changes of humidity. This is especially true in the cases where reliability is most important — for example in aircraft and in missiles.

Bell Telephone Laboratories has recently developed a superior method of making fused-in-place "through-connections." A metallic eyelet is simultaneously staked and soldered between "land" areas provided for this purpose. In the past, through-connections have been made by electroplating through a hole in the board, by cold staking and hand soldering an eyelet, or by soldering a short copper wire between the desired printed elements. Each of these methods, however, presents problems — problems of reliability or of economy.

As developed at the Laboratories, the method used for fused-in-place through-connections uses the special eyelet-setting machine shown on the next page plus a special welding transformer and timer. Each was modified somewhat, and certain other accessories were added to make a hand-fed (but otherwise completely automatic) eyelet-setting and soldering machine. A hopper on the machine holds an ample quantity of flanged, soft-copper eyelets that are electroplated with tin, and a raceway guides the eyelets to the assembly position. Flexible leads connect the welding transformer to the forming dies in the eyelet machine



Photomicrograph of conventional eyelet connection (left) and of an eyelet connection flush on one side. These special pictures (magnified 50x) were taken by F. G. Foster of Bell Laboratories.

to make them electrodes as well as dies.

The processes of setting and soldering an eyelet are simultaneous — that is, both operations take place during one operating cycle of the machine (one revolution of the crankshaft). Let us first consider the mechanical operation of setting the eyelet, and then later return to consider the soldering operation.

The hopper feeds the eyelets, one at a time, to the raceway, which delivers them by gravity to a point directly in line with and below a needle. This needle is located coaxially in the upper forming die, which is fixed to a vertically reciprocating ram. The ram, in turn, is controlled by the crankshaft of the machine.

During a partial revolution of the crankshaft, the ram moves down and the needle enters the eyelet. Friction holds the eyelet on the needle as a cam moves the eyelet chute aside. Ram, die and needle — together with the eyelet — continue downward to a position predetermined by a non-repeat automatic clutch and a stop mechanism on the crankshaft.

Directly below the needle, on the same vertical axis, is the other forming die as pictured on this page. This die is spring loaded; the force when depressed is adjustable to between 40 and 100 pounds. The lower die works through a hole in the working table, which is also spring loaded, but by a much lower force.

The printed-circuit board which is shown on the next page is now so placed that the needle is in line with, and about to enter, the desired hole. When the clutch is tripped, the upper die moves downward — inserting the eyelet in the hole — and continues downward until the eyelet is set by the upper and lower dies with a force determined by the spring loading of the lower die. The force selected depends on the size of the eyelet and the condition of flatness required in the end product.

The upper die is now at the lowest point of its excursion, and the needle holding the eyelet in place is retracted as the eyelet enters the hole in the printed-circuit board. Completion of the operation returns the ram to the position where a new eyelet is on the needle ready for another cycle.

If we return now to consider the soldering operation, we see that the essential requirements are that the actual soldering take place as the eyelet is being set; that the setting force be maintained during the soldering operation; and that the soldering current cuts off before the forming dies separate. The soldering operation takes about 0.05 to 0.12 second (three to seven cycles of the 60-cycle current). A micro-switch (operated by a cam on the crankshaft) actuates the timer that controls the soldering current.

To meet these requirements, the crankshaft rotates at not more than 45 rpm. Soldering current is applied about 20 degrees before the ram reaches bottom dead center. This timing assures ample pressure on the eyelet before, during and slightly after soldering.

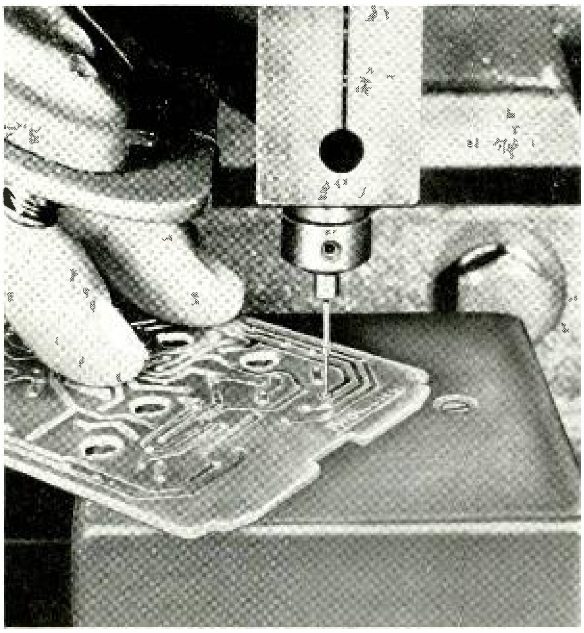
J. W. Buckelew (right) and E. D. Knab examine the new eyelet-setting machine. This over-all view provides an estimate of the machine size in relation to the circuit board and the operator.

The soldering current passing through the electrical resistance of the eyelet generates the required heat. Optimum soldering conditions are determined empirically. First, a medium soldering pressure is used with the power supply at minimum output. A series of tests is then made; the power and time are increased gradually and the pressure is also adjusted until a satisfactory joint is obtained.

Nearly perfect heat balance must be maintained throughout the eyelet to achieve simultaneous fusing and to have similar solder fillets on both sides of the board. To do this, the vertical cross-section through the eyelet and the dies is made as symmetrical as possible. Also, the die material is the same and the surface condition is made as nearly as possible the same for both dies.

Through-connections of this type are, for the present, limited to boards 1/32 inch to ⅛ inch thick. These boards are made by standard methods from commercially available copper-clad epoxy glass laminate or copper-clad phenol fiber laminate. The boards are lightly brushed with a flux before the connections are made. Tin plating on the eyelet is the only metallic bonding agent used in the connection other than a thin film of solder that is "rolled coated" or plated on the printed-circuit elements.

In this fused-in-place through-connection, both ends of the eyelet can be conventionally set, or



The eyelet-setting needle is shown in line with, and about to enter, the correct hole in a printed circuit board. The upper die is about to move downward to insert specific eyelet in the hole.

they can be set flush with the printed circuit elements to which they are fused. This is determined by the heat and the applied force during the soldering operation, and also by the type of laminate material used for the board. A flush connection is often desirable and is specified on manufacturing drawings. The cross section of a flush connection, along with a similar view of a standard type, is shown on page 368.

A feature of this process is that leads of components may be soldered at some later time into the hole in the eyelet. Such soldering would be done at about 375°F.

Sixty boards having fused-in-place connections were environmentally tested. Samples of each of the materials — 1/32 inch and 1/16 inch thick and having a total of 1,800 through-connections — were among the tested specimens. Since each through-connection is soldered at both ends, tests were given 3,600 soldered joints. All of the boards were subjected to thermal shock, and about forty were subjected to physical shock, high-frequency vibration and humidity soaking. No change was observed as a result of the tests.

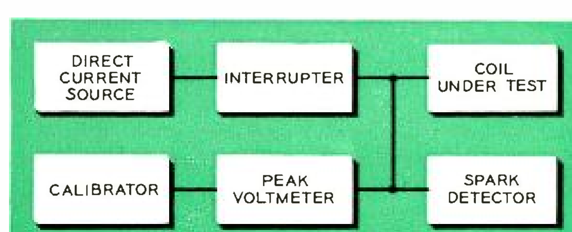
This method of making through-connections is fast and economical, and it results in thoroughly reliable connections. It is a distinct improvement over conventional methods. Although the apparatus has been described as an eyelet-setting and soldering machine, minor modifications would permit its use with tubular rivets and with terminals of various configurations.

A NEW COIL-TESTING METHOD

In apparatus for telephone switching, electrical coils are used principally in relays and switches. They are employed so widely in the Bell System that in 1957 over 50,000,000 units were manufactured. Consequently, trouble-free coils of high quality are most important, and although coil quality is high now, we continually seek higher standards.

Most relay and switch coils are constructed by the cellulose-acetate "fill" process (RECORD, *November*, 1951). The principal feature of this process is the winding of a thin sheet of cellulose acetate over each layer of wire. The wire is wound for a number of coils simultaneously in the form of a stick, and the stick is sawed apart with gang saws. Each filled coil is then slipped over a core and cemented to a spoolhead faced with cellulose acetate. This is done by dipping the coil in acetone. The coils are examined by tests which check for winding direction and resistance as well as voltage breakdown from winding-to-winding and winding-to-core. This method produces coils of high quality, but occasionally field failures occur. They are usually due to either short circuits at the ends of the wire layers, or to intermittent internal breakdown (sparking) caused by transient voltages of low energy content which are generated by the coil when the circuit is opened.

Previous examination for shorted layers in coils during production consisted of a "high-frequency impedance" test, which has been used to a limited extent on some U-type relays. In this test the output of an oscillator, capable of frequencies up to 10,000 cps, is transformed to a high voltage connected to the coil under test. Shorted portions in the coil reduce the voltage reading at the coil terminals, thus indicating the presence of defects. This test, however, lacked the flexibility and adaptability now required for



Principal parts of X-4786 Surge-Voltage Test Set.

The author with a laboratory model of the new equipment for the surge-voltage testing of coils.

the wide variety of coil windings used in electromagnetic apparatus.

A more flexible test was needed to reject the small percentage of potentially defective coils. For testing 100 per cent of the output of cellulose-acetate filled coils for short circuits and sparking, the Laboratories has developed the X-4786 Surge-Voltage Test for inductively wound coils. It is an effective, rapid and economical test that can be applied to the entire filled-coil product. The time required to examine a coil by this method is only about one second.

A coil assembly usually consists of a coil mounted on a magnetic core equipped with spoolheads, and the lead-out wires are connected to terminals on these spoolheads. This assembly represents the most economical point in manufacture at which to apply the Surge-Voltage Test. It is at a stage where it can be readily handled and connected for test, yet defective units can be eliminated before final assembly and adjustment of the relay or switch.

The test equipment generates a self-induced transient peak voltage in the coil, and gives separate indications of short circuits and of sparking through defective insulation. The voltage is produced by electronically interrupting a direct current passing through the coil. An advantage of this method is that the distribution of the testing peak voltage in the coil approximates that occurring in service. Typical test peak voltages, 500, 900, 1,700, or even 3,000 volts, can provide a margin over the voltage developed by a coil in service.

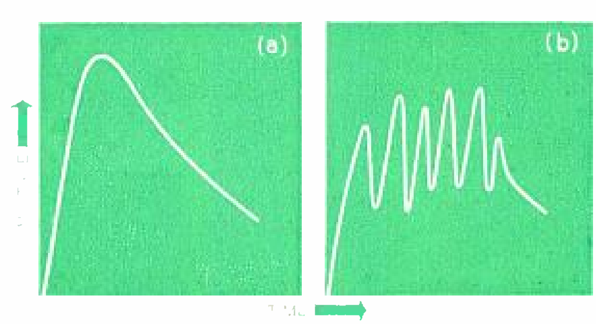
The principal parts of the apparatus that applies the Surge-Voltage Test are shown in the block diagram. The method of operation is briefly as follows. Direct current from the source flows through the coil under test and is interrupted at the rate of ten times a second. A short circuit of two or more layers of wire substantially reduces the peak voltage generated in the coil and is indicated on the peak voltmeter. Sparking, through impared insulation in the coil, generates high-frequency voltages which actuate a neon lamp in the spark detector. Automatic product-rejection devices may be connected to the peak voltmeter and spark detector. A short circuit existing in a considerable number of *turns* of wire, but in less than two *layers* of wire, is not likely to occur in the mass-produced filled type of coil. This is because of the layer-wound construction and the sheet cellulose acetate fill, or insulation, between the layers.

A calibrator is provided with which the peak voltmeter may be quickly calibrated for the particular test voltage used and for the voltage wave shape characteristic of the type of core structure in the coil being tested. Also provided is a method of checking the calibration of the spark detector. The general voltage-time character of the transient, produced when the current in a coil is interrupted, is depicted on this page. Part (b) of this illustration represents the high-frequency transient voltages caused when sparking occurs through faulty insulation.

This coil-testing method is applicable to nearly all inductively wound filled coils. A typical exception is a coil with a noninductive shunt permanently connected in parallel with the inductive winding. In this case, the noninductive winding limits the transient voltage to a value that tends to prevent possible internal breakdown.

The X-4786 Surge-Voltage Test has been used on filled-coil assemblies of the wire-spring relay (RECORD, *November*, 1953; *April*, 1957) for some time, and is being extended to other types of relay and switch-coil assemblies. For the large number of coils used in the Bell System, this rapid and efficient method of testing helps to obtain an even higher coil quality.

D. W. PITKIN
Switching Apparatus Development



Characteristics of transient voltage produced in the coil when current is interrupted (a) without sparking, (b) faulty insulation causes sparking.

In many central offices, telephone traffic is not heavy enough to justify the complex automatic billing equipment that records the charge details of messages. For this reason, Bell Laboratories developed equipment that uses a centrally located No. 5 crossbar office as a tandem switching point and also gathers billing information for the surrounding offices.

G. A. Hurst

Extending CAMA with No. 5 Crossbar

In the telephone system, direct dialing of station-to-station toll calls requires the use of AMA (Automatic Message Accounting). Calls originating in individual offices, however, are often insufficient in number to justify installing AMA equipment in each office. This problem is resolved by the use of CAMA (Centralized Automatic Message Accounting). With CAMA (RECORD, *July*, 1954), the traffic from several local offices is trunked into a tandem office containing the equipment needed for billing purposes.

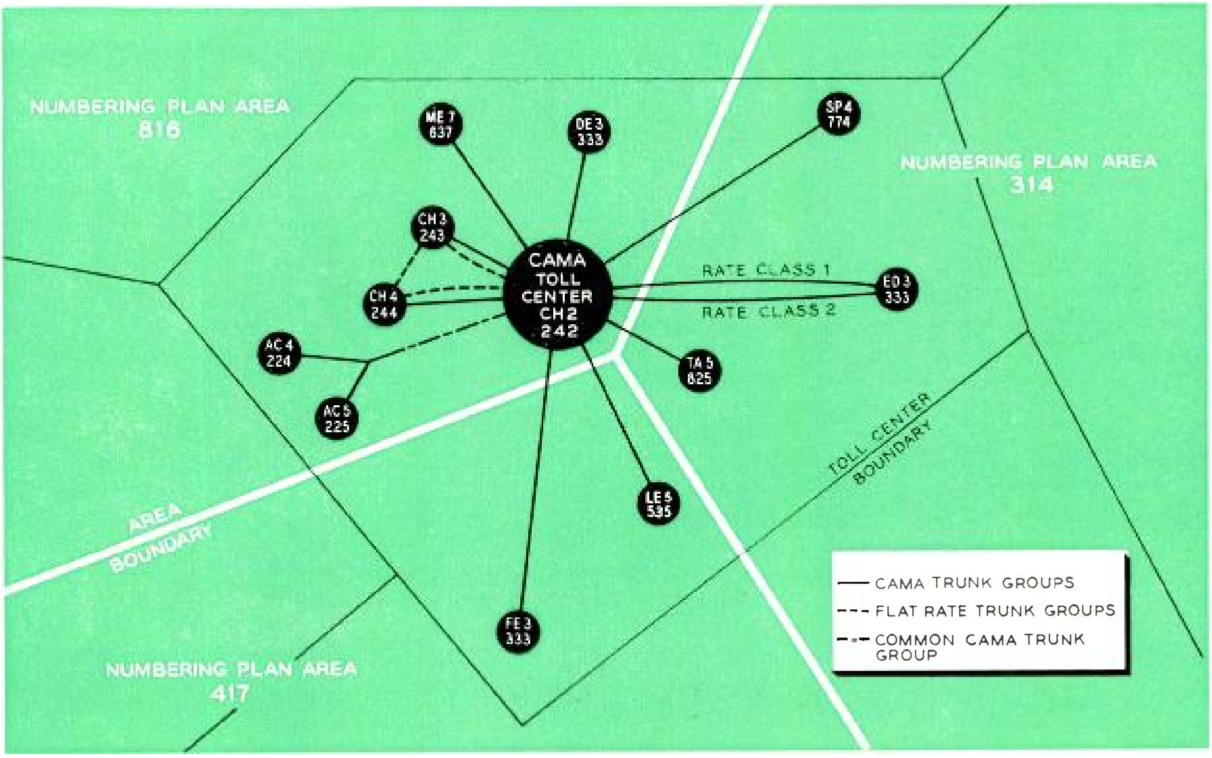
The crossbar-tandem system serves as a tandem switching center to complete toll connections originated by, or destined for, customers served by the various local central offices in the area. It has also been arranged to record on AMA tape the billing data for toll calls originated by these customers when the originating office does not have AMA facilities. Fifty-three installations employing CAMA facilities associated with crossbar tandem offices are now operating in or near 47 of the larger cities in 15 of the Operating Company areas. Two additional installations are scheduled for this year.

The Laboratories has now developed features which, when added to a No. 5 crossbar office, will enable it to become a CAMA tandem switching point. This function is in addition to the recording of AMA calls originated by the local customers the No. 5 office serves.

CAMA arrangements for the No. 5 crossbar system have been developed in two stages. In the first stage, it is necessary for an operator to request the customer to identify the calling number. In the second stage, the number information is obtained automatically at the originating office. It is then sent to the CAMA office in the form of multifrequency signals from the originating office.

Let us consider a typical example of CAMA at a No. 5 crossbar office. A No. 5 office selected for a CAMA location would be a toll center where switchboard facilities ordinarily would be needed to handle extra-charge calls. These calls would be originated by customers in the tributary offices dialing a special-service or toll-operator code. The tributary offices might all be located in the same national numbering-plan area or, as shown in the figure on the next page, they might be associated with several such areas.

The new design is arranged to accept originating CAMA traffic from a total of 48 offices that may be distributed among a maximum of three numbering-plan areas. Because there are no re-



Distribution of originating offices for a CAMA point that serves three national numbering-plan areas. In this arrangement, forty-eight offices may be distributed among a maximum of three areas.

strictions on central office (ABX) code assignments among the 48 offices, conflicting codes may appear in two or three of the areas. For example, the illustration shows code 333 associated with offices DEerfield 3, EDgewater 3, and FEderal 3, each of which is in a different area. For accounting purposes, such code conflicts are resolved by assigning the associated incoming trunks to different AMA recorder circuits.

A call from a customer in one area to a customer in another area ordinarily requires the dialing of a three-digit area code (X0X or X1X) ahead of the called-office code. Where there is a community of interest between offices on opposite sides of an area boundary, however, the system can be arranged to handle calls between such offices without requiring an area code. For example, if there were no office with code 825 assigned to it in all of area 816, (the drawing shows only a part of the area) the customers in the TAlmadge 5 office in area 314 could be made to appear, for accounting purposes, as a part of area 816.

The addition of CAMA operation to a No. 5 office presupposes the use of LAMA (Local AMA) facilities for completing DDD (Direct Distance Dialing) traffic from the individual and two-party line customers served locally by the No. 5 office. This permits advantages of economy over an entirely separate CAMA switching installation. Examples include joint use of the master timer circuit already in operation, the filling-out of unused trunk capacity in the existing recorders, and more efficient use of expanded outgoing trunk groups for the combined LAMA and CAMA loads. The added CAMA features also permit DDD facilities to be used, with operator identification of the calling number, for the four-party and rural-line customers in the local office which the LAMA equipment is not arranged to serve.

Where two or more originating offices are located in the same tributary building, a common trunk group may serve both offices. On the other hand, if a given single tributary office code serves customers who require different rate treatments on bulk-billed calls routed via CAMA, each rate class must have separate trunk groups. A maximum of three rate classes are possible among the customers in each of the originating offices.

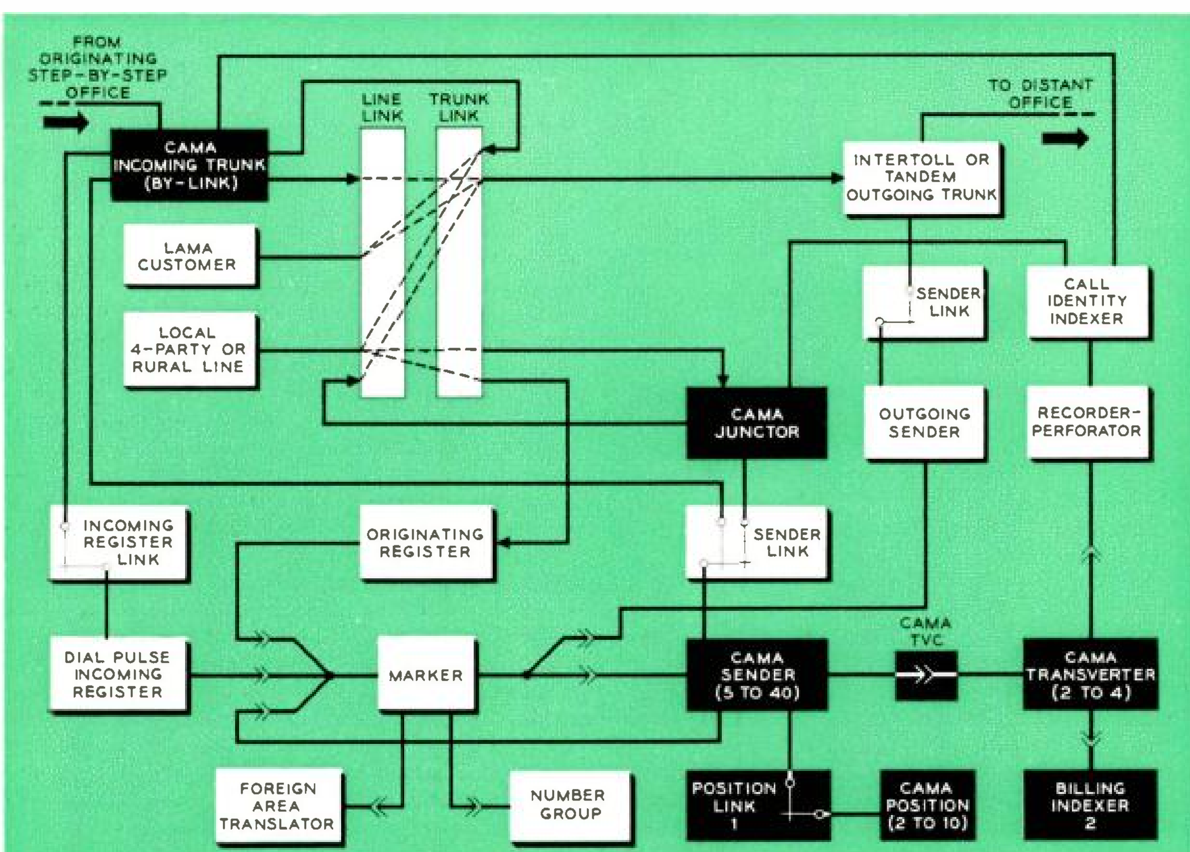
In originating offices that use the step-by-step switching system, the customer first must dial an access code to reach the route to the CAMA office. Dialing errors that occur in the succeeding digits may result in calls with area codes or office codes either not in use or associated with destinations that customers are not permitted to reach by DDD. The system is arranged to examine all calls for such errors and to divert as many as possible to an operator who intercepts the call, or to a recorded announcement, before the call progresses to a CAMA operator.

A similar situation arises where a step-by-step customer attempts to use the CAMA route to complete a non-charge call — that is, a call from one customer to another within the flat-rate calling area. In the plan shown in the first drawing, it has been assumed that the CHerry 3 office and the CHerry 4 office each fall within the flat-rate area of the other. It has also been assumed that the customers in the CHerry 2 office (the CAMA office) are also within the flat-rate areas of both CHerry 3 and CHerry 4. Trunk groups entirely separate from the CAMA groups are required for this traffic. If, for example, a customer in CHerry 3 should attempt to reach a customer in either CHerry 2 or CHerry 4 via the CAMA point, the call would be diverted to an intercepting operator or to a recorded announcement. In this case the call progresses beyond the stage where the CAMA operator is engaged before it can be diverted. This is because the calling office must be identified before the restricted combination of calling and called offices can be recognized.

The block diagram below shows how the new CAMA circuit units, shown in black boxes, are interconnected with each other and with the existing circuits in the system. The range in quantities of each of the common-control circuits required for a given installation is shown in the respective blocks.

The system operates in the following manner. A call enters the office through an incoming trunk — in the case illustrated, a trunk from a step-by-step type tributary office. The trunk is connected through a link circuit to an incoming register. When the customer has completed dialing the called number, the marker transfers the information to a CAMA sender and connects the trunk and sender through a link circuit; the marker then releases. If an operator is needed to identify the number of the calling customer, the CAMA sender reaches a CAMA position through a position link; the operator then "keys" the number into the sender. Otherwise, the call-

Circuits of a No. 5 crossbar switching office that has been arranged for CAMA services. CAMA units are indicated in black — numbers in these blocks indicate quantities that may be required.



ing number information is received automatically over the trunk and is stored in the sender.

When all information is available the CAMA sender engages a CAMA transverter and a CAMA recorder to perforate the call details on the AMA tape. The CAMA billing indexer is also engaged to determine that the call is acceptable and to furnish information to be included in the perforated record about the charges for the call. As soon as the record is completed, the CAMA sender directs the call to the marker for the second time; then the sender releases. The marker selects a trunk to or towards the called office and attaches an outgoing sender to pulse the called number forward. The incoming and outgoing trunks are also linked together via the line-link and trunk-link frames at this time. Subsequent timing entries are perforated on the tape under control of supervisory relays in the incoming trunk at the time the call is answered and at the time it is disconnected.

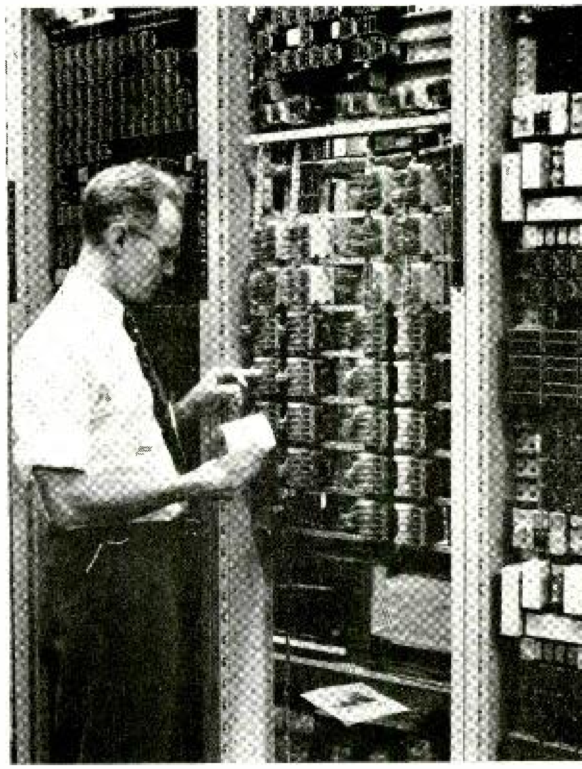
On an incoming call to a customer in the CAMA office, no outgoing trunk is involved when the call is directed to the marker for the second time. At this point the incoming trunk is linked to the customer's line via the trunk-link and line-link frames.

The block diagram also indicates the routing of a call originated by a customer on a four-party or rural line within the CAMA office. In this case when the customer completes dialing, his line is connected through a CAMA junctor to a CAMA sender, and an operator is engaged to identify the calling number. From this point the operation is similar to that described previously, with the junctor serving as the equivalent of the incoming trunk.

From No. 5 crossbar originating offices, the incoming trunk may be arranged to connect to a multifrequency incoming register instead of a dial-pulse register. Both the dial-pulse and the multifrequency registers are the same as used heretofore. Registers may be used jointly for CAMA and non-CAMA traffic, or may be furnished in separate groups. The use of available incoming register circuits and separate CAMA senders was found to be more desirable than an alternative plan in which the functions of the register and CAMA sender were combined in a single circuit unit.

The AMA recorders, on whose tapes the CAMA call records are perforated, may be separate from those used for the LAMA records, or they may be used in common. In either case a single recorder can accept the records of calls from a maximum of 10 originating offices.

Trouble indicating features are required on a large number of additional circuit points as an aid to the maintenance forces in locating trouble conditions. These indications, however, could not be accommodated on the original trouble-recorder card form. Laboratories engineers therefore devised a new card form printed on both sides. One side is used on failures involving the AMA stages of a CAMA or LAMA call; the other side of the card is used when call failures occur at other stages.



A view of a part of the laboratory set-up for testing new CAMA system with No. 5 crossbar.

Switching engineers have modified existing facilities for testing as required to maintain the CAMA equipment. The basic CAMA incoming-trunk design, in conjunction with an outgoing circuit in the originating office, permits taking a trunk out of service by action initiated at the CAMA point if the trunk should become involved in trouble. This feature is particularly useful when the originating office is not attended at all times. Except for a reduction in the number of customers in the territory to be served and a smaller volume of calls which these fewer customers would be expected to originate, the CAMA design requirements for the No. 5 system are similar to those for crossbar tandem.

The use of the No. 5 crossbar system to make centralized automatic-accounting methods available for light-traffic central offices is an example of the versatility possible with modern telephone switching offices. Arrangements such as these are helping the Bell System to attain its goal of complete mechanization of toll traffic.

For carrying large amounts of information over telephone lines, Bell Laboratories in recent years has developed several high-speed data transmission systems. The A1 Digital Data Signaling System, designed for the Air Force SAGE project, transmits at speeds as high as 1600 bits per second over specially arranged voice-bandwidth telephone channels.

E. A. Irland

A High-Speed Data Signaling System

In the spring of 1956, field trials began on one of the fastest signaling systems ever designed by the Laboratories for use on Bell System facilities. Usually called the SAGE data system because its first application will be in the Air Force SAGE (Semi-Automatic Air-Ground Environment) project (RECORD, *October*, 1957), the official designation is A1 Digital Data Signaling System.

Fundamentally, the transmission of digital data is not at all a new activity in the Bell System. In fact, the first dial telephone sent "digital data" into its associated central-office switches in the form of current pulses from a metallic contact. Actually, the term "digital data" is a very broad one and covers just about any information expressible in numbers. Any number, in fact, can be written as an equivalent "binary number" — a number containing only two kinds of digits, say 0 or 1. Such binary digits are usually called by the abbreviation "bits."

Granted that this is possible, why would one want to convert a simple number like 22 to its relatively unfamiliar binary equivalent 10110? The answer is that in electronic circuits the binary number is easily stored in "on" or "off" devices. It is also easily transmitted, since each digit value can be represented as the presence (1) or absence (0) of a pulse. Following telegraph nomenclature, these values, when transmitted as pulses, are often called "marks" and "spaces" respectively.

High-Speed Operation

Compared to ordinary dial speeds of 10 to 20 pulses per second for setting up telephone calls, the SAGE speeds — 1,300 or 1,600 bits per second, with an error-rate objective of 1 error in 100,000 bits — represent one answer to the ever-growing need for high-speed data communication. While the Air Force needs such speeds to transmit coded, television-like signals derived from radars, the Bell System may also have many applications for such services. One such use might be for signaling between high-speed electronic switching offices; another might be to permit customers to share the services of remotely located computers.

In the present SAGE system, large groups of data pulses (50 to 300 bits), form what is called in computer jargon a "word." In any given application, however, the word length will be fixed, and a "start" pulse is sent to mark off the beginning of each word. These start pulses assure that the customer's receiving equipment reads the words in step with the transmitting machinery, even if a transmission impairment or equipment failure has deleted some of the data bits.

The first of the two drawings is a block diagram of the signaling system. Fundamentally, it consists of a "Digital Data Transmitter" (DDT) into which the data signals are fed over three lines, and a "Digital Data Receiver" (DDR) connected to the DDT over any voice facility that has the proper transmission characteristics. The output of the DDR again feeds three lines which deliver the same type of signals to the customer as appear at the DDT input. It will be noticed that this diagram indicates duplicate transmitters, receivers and transmission lines, and also shows a trouble detector and a transfer and control circuit. The significance of these features will be explained after some additional description of the system.

The data pulses applied to the transmitter are formed by pulsing a sine wave of the same frequency as the bit rate so that one complete cycle is sent to denote a data "mark." During data "spaces," nothing is sent. Thus, receiving the pulses requires a method of timing so that blank periods may be measured off to determine the number of spaces sent. This timing is accomplished with a continuous sine-wave signal, also of the same frequency as the bit rate and applied to the transmitter as another input. "Start" pulses are the same as data marks and are applied as the third input to the transmitter.

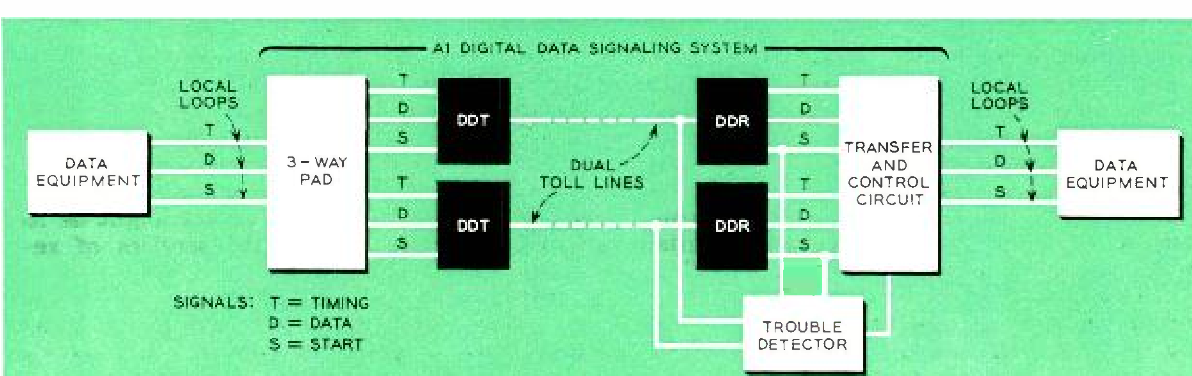
E. G. Spack (left) and the author inspecting circuit assembly used in the SAGE data signaling system. Communication over system is at the very fast rate of 1,300 or 1,600 bits per second.

The Data Transmitter

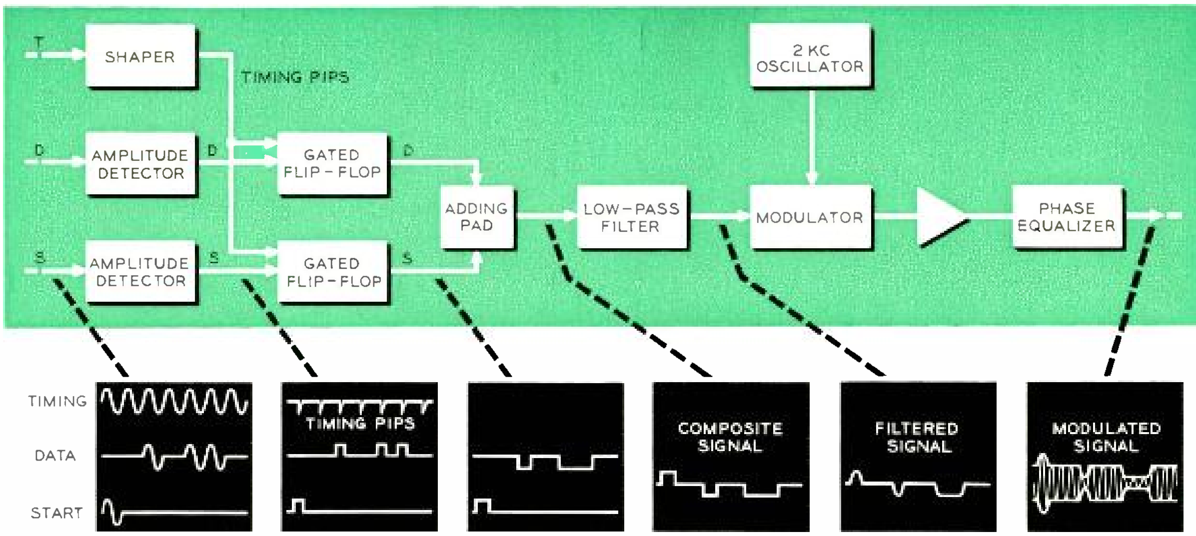
The second drawing is a simplified block diagram of the DDT. Also indicated are typical wave-shapes of sine-wave pulses arriving at the data and start inputs. These operate amplitude detectors which produce short rectangular pulses. There is also a continuous sine wave used for timing. The timing wave is altered by the "shaper" into periodic "pips" (short pulses), and is then applied to a pair of gated "flip-flops." These are circuits which "flip" from one output voltage to another under the influence of both data (or start) pulses and timing pips. The output of either gated flip-flop is a rectangular wave whose transitions will occur in step with the timing pips.

These two types of regenerated pulses are added, with the start pulse going positive and the data pulses going negative. Thus, as indicated in the second diagram, the two types of signals are still distinguishable in the composite or added wave.

After filtering to remove high-frequency components which would produce unwanted modulation products, the composite wave modulates the



Block diagram of the A1 Digital Data Signaling System. Data equipment units, left and right, are at remote locations; dual toll lines and other duplicate facilities serve to increase reliability.



Digital Data Transmitter: the three constituent signals at the left are operated upon in such a way as to produce the transmitted signal, right, an amplitude-modulated 2,000-cps carrier.

amplitude of a locally generated 2,000-cycle carrier. The output of the modulator, after additional filtering, is applied to the transmission channel.

At this point, the special filtering problems associated with high-speed data signaling should be mentioned. The rectangular data pulses contain frequency components of considerable amplitude, up to at least three times the bit rate. For a 1,600 bits-per-second rate, the pulses have strong frequency components up to 4,800 cycles. It is also true that very low frequencies are present, since the wave is at most repetitive only at the word rate of the start pulses. This rate may be as low as five pulses per second. But many voice-grade telephone circuits do not transmit well below about 250 cycles nor above about 3,000 cycles. As an additional complication, data signals will not tolerate much envelope delay distortion nor any frequency shift. Both of these may be present in Bell System voice circuits, but they have no adverse results on speech because of the insensitivity of the human ear to these effects. Frequency shift is introduced whenever the transmission is through a non-synchronized carrier system, and envelope delay distortion is generally present on voice-grade circuits used for data transmission.

Vestigial Sideband System

These difficulties are not insurmountable, however. Use of a separate carrier, 2,000 cycles, to carry the data pulses eliminates frequency shift and raises the very low frequency components to nearly 2,000 cycles. Filtering of the rectangular data wave results in limiting the bandwidth of the over-all system to half the bit rate, in this case to 800 cycles. Thus, it is possible, by using the lower sideband only, in a vestigial sideband system, to place the data-carrying energy in the best part of the transmission band (from 1,200 to 2,000 cycles). This pre-filtering of the data also alleviates the effects of distortion, which can arise when the modulating signal contains frequencies in the part of the spectrum occupied by the modulated signal. Special correction is applied to the circuits so that they do not exceed a maximum of 500 microseconds envelope delay distortion between 1,000 and 2,600 cycles.

An important problem also exists in removing envelope delay distortion introduced in the data-filtering and vestigial-sideband filtering. To obtain the maximum possible noise reduction, the vestigial-sideband filtering is done at the receiver rather than at the transmitter. Then, instead of phase-correcting each individual filter, a single delay-correcting network corrects the delay distortion of both the DDT and DDR. This network is associated with the output of the transmitter.

The last of the three drawings (*page* 380) shows the DDR. It can be seen here that the process is the reverse of that in the DDT — the modulated signal is eventually converted to the separate timing, data and start signals. The signal from the transmission channel is amplified, and is then demodulated by rectifying and filtering. The output wave is very similar to the filtered signal shown for the transmitter. Since the start pulse is the most positive peak in the signal, and is recurrent, it is used for an automatic gain control. Via the "start-peak detector," the gain of the input amplifier adjusts itself until the start-pulse peak is set to a preassigned value.

The amplitude-adjusted wave then operates a pair of amplitude detectors which sort out and generate pulses corresponding to the start and data pulses. These are regenerated by a sampling process identical to that used in the DDT. There is a considerable additional complication here, however, since the timing wave transmitted to the input of the DDT is not available at the DDR. It must be recovered from the nature of the incoming wave.

Uses Precise Oscillator

Of course, the timing wave must agree perfectly in frequency with the one used in the transmitter; otherwise, the timing will "wander" with respect to the data pulses. It is this fact which is used in recovering the timing wave. First, the originating timing wave is produced with a very precise oscillator. By using a variable oscillator of high nominal precision in the receiver, it is assured that the derived timing pips will wander very slowly and only a small amount during a word. Since the start pulse is recurrent, it is chosen as the one to examine. The phase detector, indicated in the right part of the third of the diagrams examines each start pulse and, in effect, measures the time from the leading edge to the associated timing pip, and from the pip to the trailing edge. If the frequency and phase are both correct, these two times will be equal. But if the pip wanders toward one or the other edge, the detector produces a corresponding voltage. This voltage is applied to the variable oscillator to bring it in synchronism with the timing wave used at the transmitter.

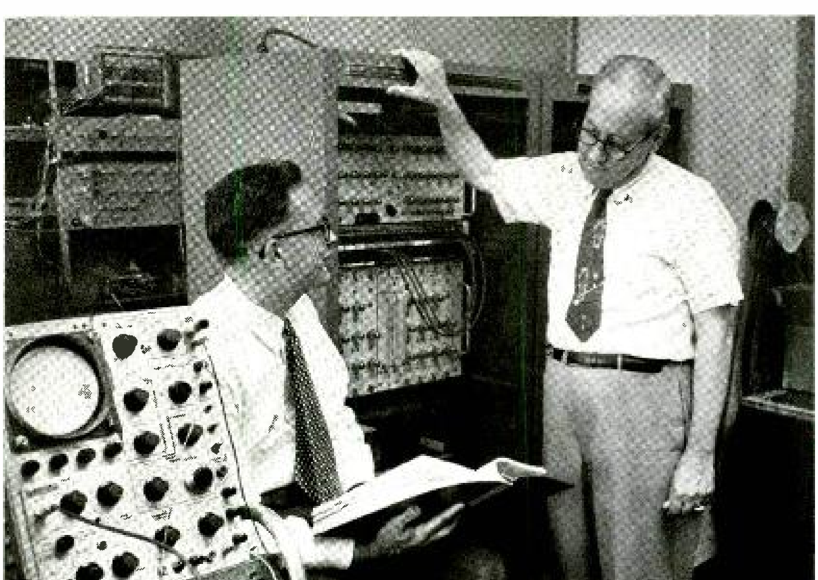
With the synchronous timing wave and with the output of the amplitude detectors, the same regeneration technique used in the DDT produces rectangular pulses of widths that are multiples of the timing-wave period. When these pulses, with the timing wave, are applied to modulators, the result is a series of sinusoidal pulses of the same form as those that were applied at the input to the DDT.

As mentioned earlier, some circuits may work over dual facilities. To improve reliability two transmitters are driven in parallel and they operate two receivers over separate channels.

Trouble Detection

Filtering at the output of the transmitter attenuates signal energy in a band about one hundred cycles wide at 450 cycles. The trouble detector bridges the line at the receiver and, by means of a narrow band-pass filter and rectifier, measures the energy received in this low-frequency band. If the noise is high enough in level to interfere with signaling, the trouble detector causes the transfer and control circuit to switch to the other channel, provided the noise level is tolerable on the alternative line. If a line goes open, or if for any other reason the signal is lost, the start signals are also lost on the line to the receiving data equipment. The trouble detector monitors these lines and reacts to the loss of start signals in the same way as to excess noise — that is, by switching to the alternative channel.

Three circuits have been designed for use in lining up and trouble-shooting DDT's and DDR's. They are a "word generator," a "parity checker,"



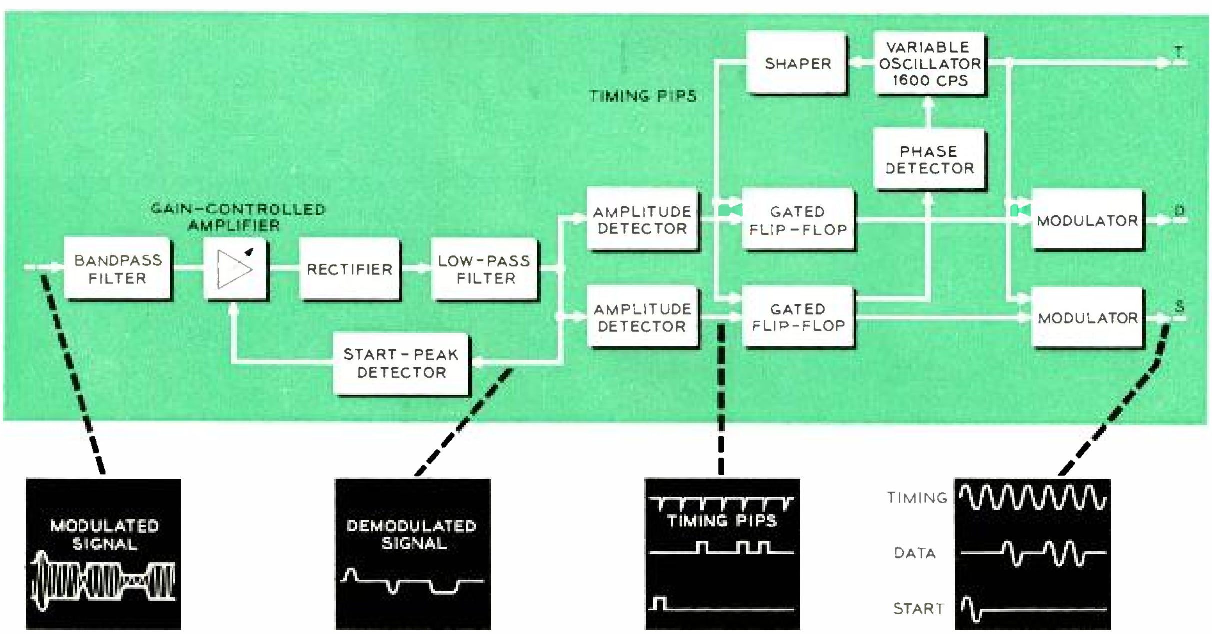
The author (left) and F. A. Hubbard discussing circuit designs for the data-transmission system. Mr. Hubbard is standing in front of equipment under test at Bell Laboratories.

and a "matching and error-counter circuit."

The first of these, the word generator, generates a repetitive pattern of a 16 data-pulse word, which may be set arbitrarily by means of 16 toggle switches. The output is in the correct form to drive a transmitter. To check the output of a receiver, a second word generator is operated and is set to produce the same word. This unit is synchronized to the DDR by means of the start pulses and the timing wave. The matching circuit then compares the output of the second word generator to the output of the DDR. Errors are counted, and the number of errors is displayed by a series of neon lamps and by an electromechanical counter.

A much simpler method of checking the output of a DDR is afforded with a "parity checker." This circuit counts the data marks in each word with a single binary counter stage and thus can determine whether an odd or even number of marks were received. If the errors are occurring only very sparsely, usually no more than one error will occur in any given word. If all words are intended to have an odd number of marks, for example, an error is scored whenever an even number of marks is recorded. This method suffers from being inaccurate in the face of a high error rate, but it has the advantage of being operable on actual signals if these are "doctored up" with a parity digit so that they always have, for example, an odd number of marks per word.

The preliminary field trial showed that the A1 Digital Data Signaling System has met its initial requirements. The importance of high-speed data transmission, however, will assure that other trials and associated development will continue in the effort to obtain the utmost in reliable operation for this equipment.



Digital Data Receiver: process here is the reverse of that in transmitter. An amplitude-modulated signal, received at the left, is separated into the three original timing, data and start signals.

Engineers at Bell Laboratories have developed a small, efficient speech amplifier, designed around the junction transistor, to aid telephone operators in their important work. By maintaining the operators' hearing efficiency, this simple device will allow experienced operators with impaired hearing to continue on their jobs.

A. J. Chase

A Transistor Amplifier For Operators' Headsets

"The voice with a smile" is a bright, pleasant part of the telephone tradition. To everyone, the telephone operator's good manners and calm efficiency are synonymous with quality service. In a large measure, this efficient service depends on the hearing of the operators. In the past, when some slight impairment has reduced an operator's hearing efficiency, it has been necessary to assign her to other duties. Generally, in such cases the Bell System gained a fair clerk or typist, but lost an excellent operator.

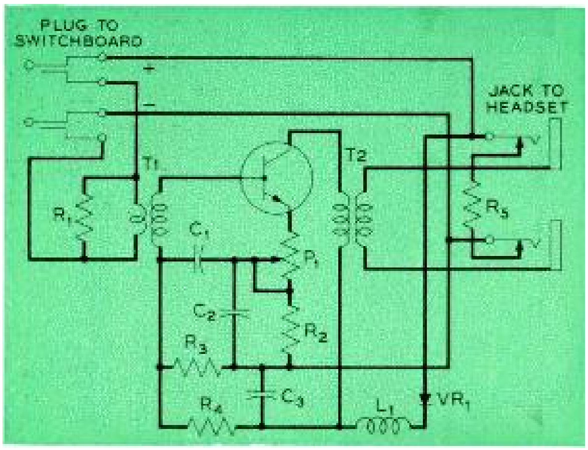
At various times, the A.T.&T. Company has received requests for an amplifier which could be used by operators with impaired hearing. The more specific requirements for these amplifiers were that they be small and inconspicuous, that they offer moderate gain, and that the amplifier be either a part of the headset or an auxiliary device that plugs in at the switchboard.

These requirements were forwarded to Bell Laboratories, and an early attempt to meet the need for headset amplifiers resulted in the design of a special headset telephone. Early sets included a small amplifier of the type originally designed for hearing aids. The principal parts of these early units — amplifier, gain-control equipment and batteries — were contained in a leather case which could be easily worn or carried. Wires connected the encased unit to the headset.

This amplifier was not adopted as standard Bell System equipment because the demand for it was not sufficient to warrant formal production. Instead, the amplifiers were assembled by the Operating Companies from detailed instructions contained in an Engineering Letter. About fifty such amplifiers have been made over the past ten years, and continuing requests have lent additional emphasis to the need for some improved form of operator's amplifier.

The junction transistor, which has proved to be particularly suited for modern hearing aids, is the basic component of the new headset amplifier. With the junction transistor, it is possible to build a plug-in amplifier that is small, stable and, even more important, powered directly from the standard operator's battery supply at the switchboard. With this device, maintenance is simplified, the size is considerably reduced, and the use of local batteries is no longer required.

The electrical design of the amplifier — designated 153A — was based on a transistor amplifier invented at the Laboratories by R. E. Yeager. The schematic diagram of the new circuit is shown at the top of page 382. In the



Schematic diagram of the transistor amplifier circuit. Both the switchboard plug and the headset jack are transformer-coupled to the amplifier portion which is centered around transistor.

plug that fits into the switchboard jacks at the operator position (left on the diagram) the tips provide the battery supply and the sleeves provide the input from the talking circuit. A pair of jacks at the rear of the housing (right on the diagram) accommodate the plug from the operator's headset. The input transformer (T1) serves an important dual purpose. First, it matches the rather low impedance of the operator circuit to the high input impedance of the transistor. The second purpose — isolating the transmitter portion of the operator's circuit from the receiver portion — is important because, for the most efficient and quiet operation, the receiver circuit must remain balanced to ground.

The transistor is the same type — 4D — as that used in the 151-type amplifier for the volume-control telephone set, and is operated in a common-emitter circuit (emitter grounded). The circuit is designed for a constant collector current rather than a constant base current, and hence has a fixed operating point. The operating point is secured by bias through a voltage-divider arrangement of three resistors (R2, R3, R4). Since emitter current tends to be self-regulating, changes in the saturation current of the collector due to different temperatures or changes in the transistor have little effect upon the operating point.

Biasing is arranged for collector currents of three to five milliamperes within the range of battery voltages available in both the operator circuit and the central-office lines of existing telephone systems. Collector current is obtained, with negligible transmission loss, by diverting about five per cent of the current in the operator's transmitter circuit.

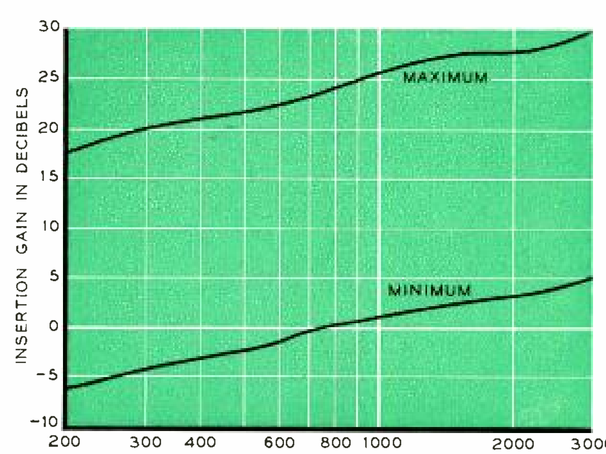
A simple filter network (L1, C3) gets rid of unwanted audio-frequency voltage from the battery supply and eliminates positive feedback. The varistor in the circuit (VR1) protects the transistor from reverse bias if the amplifier is plugged in upside down or if the switchboard jacks are wired in reverse. The operator can adjust the gain — from zero to about 25 db — with a 500-ohm potentiometer. This gain level is above the normal level of the attendant's position equipment. At any gain setting less than maximum, there is negative feedback in the portion of the potentiometer not by-passed by an emitter capacitor (C2) of low impedance. This arrangement gives the circuit a measure of operating stability beyond that already provided by the emitter resistor (R2).

The operator's receiver is transformer-coupled to the transistor at a ratio which provides a maximum of output power for the available biasing voltage — about 3.5 volts. The jacks of the amplifier are bridged by a 50-ohm resistor to close the transmitter-supply circuit when the operator's headset is not plugged in. This is a safety measure to prevent more than 5 volts from going to the transistor if the amplifier is plugged into the switchboard before the operator plugs in her set.

Gain Characteristics

The performance of this simple, small, and efficient amplifier can perhaps best be illustrated by the accompanying gain-characteristic curves. These curves indicate the maximum and minimum gains in received level when the amplifier is used with a 52A headset. The steep rise in gain with frequency, characteristic of both the high and low ranges, is generally desirable in amplifiers designed to compensate for hearing loss.

In the mechanical design of the 153A ampli-

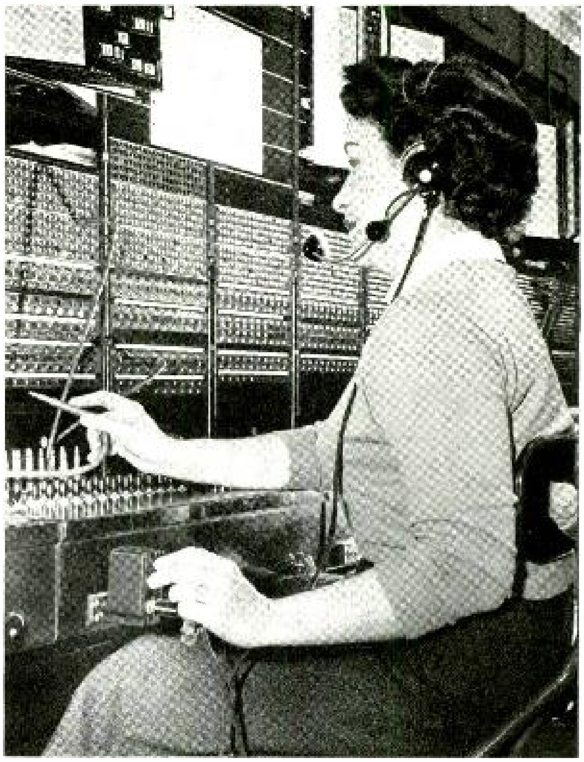


Maximum and minimum gain-characteristic curves showing gain increase with frequency.

fier, there was very little in the way of precedent, so some exploration and testing of possible designs was undertaken. As a starting point, it was obvious that the housing should be as small as possible to be consistent with the choice of electrical components. Another important consideration was standardizing the design so that the amplifier would fit all of the various switchboards and test desks in service throughout the Bell System. The physical size and shape of the amplifier also had to prevent hazard and offer a minimum of interference with the normal procedures of the operators. So as not to interfere with the normal use and availability of operator sets, the packaged amplifier had to be an auxiliary, plug-in device rather than a permanent part of the headset.

Models Carefully Tested

Within these parameters, a number of dummy models were built, embodying several possible forms and component arrangements. All were designed to the required size of a working model, but none actually contained an amplifier. Instead, the plugs and jacks were wired straight through so that the designers could get a functional appraisal of the dummy models from any operator. A series of trials of these models was arranged through the cooperation of the A.T.&T. Company. In the tests, the dummy amplifiers were tried at a wide variety of switchboards, and the operator's comments were carefully noted and analyzed.



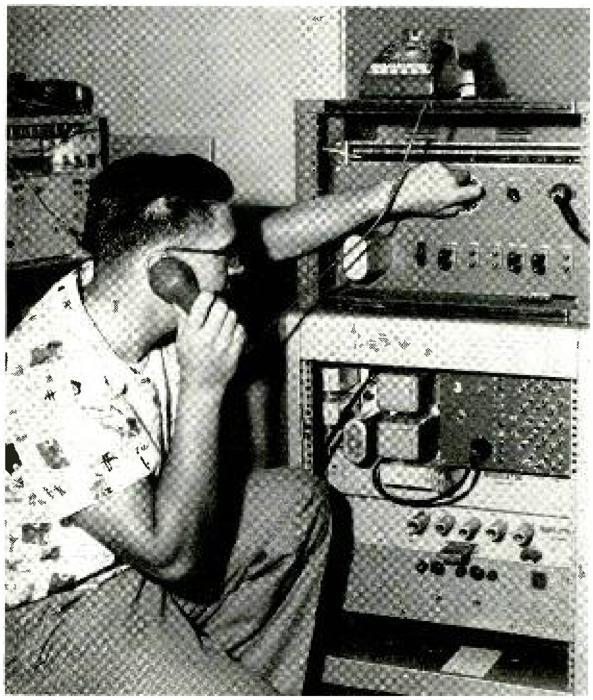
The new headset amplifier in actual use. Mrs. R. Dixon is adjusting by feel the gain-control knob. Final design of the amplifier unit was chosen only after trials to determine the best model.

The model which proved to be the most practical for a variety of switchboards, and which received the most favorable comments from the operators, is the one shown plugged into a typical switchboard position in the accompanying photograph. Inside, the components are mounted between two parallel plates, making an assembly which slips into the center of a plastic housing, which is made in three pieces. Short jacks, specially designed for this amplifier, permit the plugs and jacks to mount in an almost straight horizontal line — an important operating prerequisite — without making the housing too deep. The over-all dimensions of the unit, excluding the plugs, are about 1¾ by 2 by 3 inches. The gain control is a small knob with an index so that the operator may pre-set it to her accustomed setting before plugging into the board. She may also adjust it readily with her thumb when the amplifier is in use and when the index marks are out of sight.

It is hard to predict, but nevertheless interesting to estimate, the probable demand for this amplifier. Measurements made at the San Francisco World's Fair in 1939 revealed that about 0.7 per cent of the people tested had hearing losses which subsequent experience has indicated were sufficient to require some amplification for satisfactory hearing over the telephone. If we assume that this same distribution applies to the more than 500,000 central-office and PBX operators and attendants in the Bell System, it appears that there may be some 3,000 to 5,000 operators who would benefit from this new amplifier.

The 153A amplifier has been in production for over six months and is currently rendering very satisfactory service. Through this service to the operators, the junction transistor is thus helping to maintain the high quality and efficiency of telephone service by keeping experienced operators at their important work of serving the telephone customer.

Telephone Circuits Tested For Data Transmission



A. T. McLaughlin makes final settings on special, mobile data subset prior to transmission of data.

Systems engineers at Bell Laboratories, in conjunction with A.T.&T. Co. and Operating Company engineers, have recently begun the first large-scale evaluation of the data-transmission capabilities of the Bell System telephone network. Information gathered from these comprehensive, long-term tests will be used as the basis for the design of future Dataphone equipment.

Dataphone is a high-speed communication service for sending and receiving data over regular telephone lines (RECORD, *April,* 1957; *September,* 1957; *April,* 1958). At the present time, the service is being offered on only a limited scale. Dataphone can send information over standard telephone facilities at about an 800 words-per-minute rate — eight times as fast as conventional telegraph methods.

In view of its vast potential application, long-range plans are currently under way to increase Dataphone-type services. Evaluation of the capabilities of the Bell System telephone plant to provide such services is an important part of this long-range planning.

The subsets used in present Dataphone service are of two types: the Digital Data Subset for immediate transmission of data as it is generated by business machines or computers; and the Recorded Carrier Subset which permits storage of information for transmission at a later time. Both of the subsets can be used wherever there is a telephone and a standard electrical outlet.

For the evaluation, specific plans have been made to test data-transmission capabilities; such tests are needed because of the entirely different character of data transmission and voice transmission. In data transmission, for example, the delay characteristics of telephone lines — relatively small variations in propagation time at different frequencies — severely effect speed. Also, very short bursts of noise, which cannot be heard by a telephone customer, can cause errors in data transmission. Thus, when circuits designed primarily for speech transmission are used for transmitting data, tests substantially different from any made in the past must be performed.

The test program will take several months to complete, and will cover major metropolitan areas from coast to coast where the demand for data service is likely to be greatest. From these tests, systems engineers at the Laboratories hope to find answers to such questions as: What bit-rate, or speed of transmission, is feasible over existing circuits? What is the probability of getting an error during transmission? How are errors distributed in time? How much (and in what ways) can the error rate be reduced? What parameters of the existing plant must new systems be designed for, or must some of these parameters be changed?

The test program was initiated and planned by a joint A.T.&T.Co.-Bell Laboratories "task force," headed by A. A. Alexander of the Operation and Engineering Department of A.T.&T. Equipment for implementing the tests was designed and built under the direction of R. C. Matlack, Data Systems Engineer at the Laboratories.

The test equipment consists of six transmitting units, containing data originating and transmitting circuits, and two trucks equipped as mobile receiving units. The transmitting units, shown in the photograph above, will be shipped to several Operating Companies in various areas of the country. Telephone Company personnel will connect the transmitting units to different typical telephone lines each day, and will conduct tests in cooperation with the mobile receiving units.

The two trucks equipped as mobile data-receiving units contain equipment for receiving, comparing and automatically recording information on data-transmission tests, and various electronic devices for measuring the transmission characteristics of telephone circuits. Two-man test teams from the Laboratories will operate the equipment in the trucks. As shown in the photograph below, the equipment in the truck is permanently shock-mounted and wired together.

In a typical test, the test team takes the truck to a location (not a central office) pre-arranged by Operating Company engineers. At this location, two telephone lines have been made available — one for data transmission and one for voice communication for coordinating the tests.

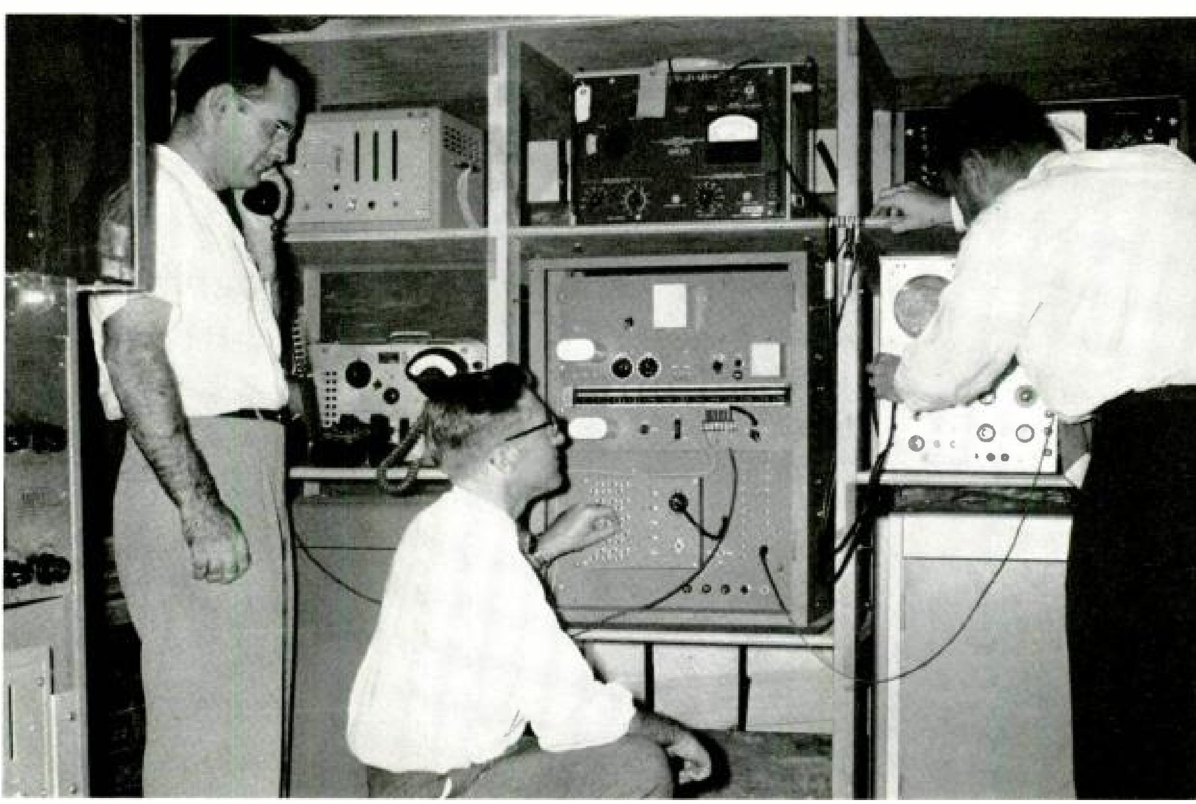
They then call the location where the transmission test is to originate, indicating to the Operating Company engineers that they are ready to receive data. As the data is received, one man might monitor the automatic receiving and recording equipment, while the other checks and regulates equipment preparatory to measuring transmission characteristics. These measurments follow the transmission test.

From this single location, test data might be received from several local locations, other locations in the same city, short-haul toll locations and long-haul toll locations. Calls for the tests are placed in the same way as for voice messages — by direct distance dialing, if that is available, or through a long-distance operator. In some cases tests will be made from PBX extensions, since this would be a typical Dataphone location. Transmitting equipment will, in all cases, be set up and moved from location to location by Operating Company engineers.

The first of two proposed test trucks is currently conducting tests in New York City. From there it will go to Chicago and the West Coast. When equipped, the other truck will perform tests in the South and West. The test program is expected to go on for some time to make it as comprehensive as possible. Data relating to accuracy of transmission will be sorted and analyzed on the large-scale digital computer facility at the Murray Hill location of the Laboratories.

The evaluation tests have been designed to measure the performance of existing subsets by recording errors in transmission and pinpointing the distribution of these errors. Transmission can be analyzed to determine such characteristics as noise, delay and attenuation. These characteristics can then be used in predicting the performance of future data subsets.

This evaluation of the transmission characteristics of Bell System telephone circuits will of course be very valuable in other phases of research and engineering at the Laboratories.



Photograph taken inside of receiver truck shows arrangement of test equipment. G. J. McAllister (l) confirms test arrangements on telephone; N. E. Snow and D. W. Nast (r) adjust equipment.

"FLASH PYROLYSIS"

New Flash-Heating Technique Initiates Thermal Reactions

A new technique for basic research on high-temperature reactions was described at the American Chemical Society meeting in Chicago last month by L. S. Nelson and J. L. Lundberg of the Chemical Research Department. In this technique, a high-intensity, high-speed flash lamp is used to induce almost instantaneous heating of finely divided, "black-body" particles or filamentary materials immersed in transparent thermal insulators of various types. The authors have easily obtained temperatures of several thousand degrees centigrade.

The value of the flash technique lies in the fact that only a few milliseconds elapse between initiation and quenching of the thermal reactions, so that intermediate products formed in the reaction do not undergo the usual degradation and condensation reactions which normally occur under longer exposure to heat. In many

L. S. Nelson, left, and J. L. Lundberg observe a flash-heating experiment. Helical flash lamp is in center of photograph. Tube, filled with "black-body" particles in insulating medium, is inside coil.

cases, therefore, chemists will be able to investigate a much simpler set of reaction products.

"Flash pyrolysis," as the method is sometimes called, grew out of fundamental studies of photochemical reactions in polymers at very high light intensities. As the light intensity was increased, the thermal effect of the flash was soon found to exceed greatly the photo effect when insulated black bodies were present. The predominance of the thermal effect resulted both from the high light intensities used, and the more efficient use of the lamp output by black-body absorption than by normal photochemical absorption.

The new technique is applicable to the study of thermal reactions in solids, liquids, and vacuum gases. Basically, it uses black-body heating of finely-divided or filamentary material to decompose either the black body itself or the medium in which the particles are dispersed. For instance, fine fibers of black tungsten can be suspended in mineral oil sealed in a tube. When this suspension is placed within the helix of a coil-shaped capacitor flash lamp, and flashed at about 1150 microfarads at 4000 volts, large deposits of carbon form from the pyrolized mineral oil. If mineral oil without suspended black bodies is flashed, no discernible reaction occurs.

If black-body particles such as carbon or dust are immersed in a plastic such as polyethylene and flashed, the area immediately around the heat-absorbent particle is pyrolyzed, giving off gases. These gases form bubbles in the viscous polymer. This flash technique, then, can be used as a rapid test for determining the amount of gaseous (and other) impurities present in an apparently pure plastic material.

Chemists at Bell Laboratories are currently using such tests in fundamental research on polymers. In such studies, the black body acts as an inert heat absorber, while the matrix reacts. Sometimes the black body itself can enter into the reaction. For instance, if powdered coal is placed in an evacuated tube and flashed, it decomposes in an unusual fashion. Combustion products obtained in experiments of this type are all short-chain hydrocarbons, typical of intense heating of organic compounds.

Powdered metals can also be flashed in a vacuum or in a gas, and deposited on the walls of the tube in the form of a mirror. If certain powdered metals were flashed in the presence of hydrocarbon gases, metal alkyl compounds should result, along with a rich yield of free radicals.

Many of the pyrolized compounds exhibit fluorescence. This in true of the areas around flashed dust spots in polyethylene, for instance, as well as with the flashed mineral oil. The structure of these materials has not been determined.

While much additional work remains to be done, this new technique promises to be of great interest to chemists studying high-temperature, high-speed reactions.

WESLEY FULLER, who as Assistant Director of Publication at Bell Laboratories took an active interest in the publication of the RECORD, died suddenly on September 13.

Mr. Fuller was born in New York City and was graduated from Harvard University in 1933 with the A.B. degree. After a short period with the *Boston Traveler*, he became associated with the *Boston Herald* in 1934 and served that newspaper in various capacities until 1943. During this period, in 1938 and 1939, he was a Nieman Fellow in journalism at Harvard.

— Fabian Bachrach

Wesley Fuller

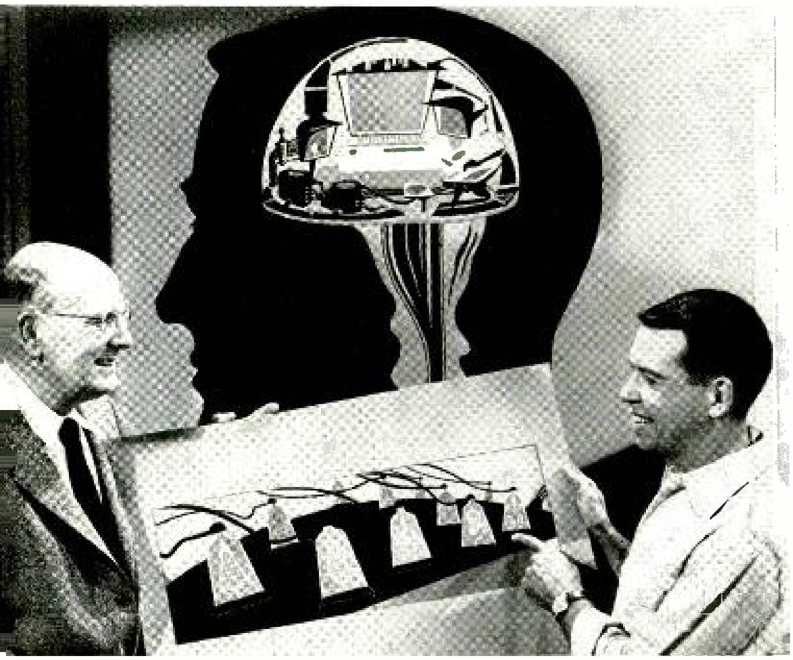
His journalism experience included reportorial, editorial and science writing. In addition to his duties with the *Boston Herald*, he was part-time correspondent for the Associated Press, *The New York Times*, *This Week* magazine, and the *Scientific Monthly*, and was Boston correspondent for Science Service.

During the early years of World War II, Mr. Fuller was director of the Boston Red Cross blood-donor center and public information director for the Boston Red Cross organization. He later joined the Marine Corps as an intelligence officer, and at the time of his death was a captain in the Marine Corps Reserve.

After the war, Mr. Fuller joined Bell Telephone Laboratories as Information Manager in 1946. He became acting Director of Publication in 1954 and Assistant Director in 1956. In this latter position, he had the responsibility for the general supervision, under the Director of Publication, of all activities of the Publication Department. He was a member of the Society of Nieman Fellows, the National Association of Science Writers, and the Harvard Engineering Society.

"GATEWAYS TO THE MIND"

Latest Science Program to Show Senses at Work



Bill Idelson, right, in role of movie animator, shows Dr. Baxter a diagram of nerves from sensory receptors — animated as TV control room.

"Gateways to the Mind", latest of the Bell System Science Series programs, shows not five but at least fourteen human senses at work. This new show will be telecast in color over the NBC network, Thursday evening, October 23. In this fifth of the Science Series programs, Dr. Frank C. Baxter shows that the human senses are the means through which man maintains his contact with the world about him.

"Gateways to the Mind" is the first Bell System Science Series program to be made by Warner Brothers. Owen Crump was both producer and director. Frederick R. Kappel, president of the A.T.&T. Company, introduces the new program to the television audience. In the film, Dr. Baxter shows what science has learned about the human senses and how they function.

For centuries it was thought that there were only five senses—sight, sound, smell, taste and touch. Scientists now know, however, that there are many others. There are, for instance, four senses of taste. In the skin there are senses of cold, heat, pressure, touch and pain. There may be at least five senses of sight. Muscular balance and muscular tension are also true senses.

The way in which the brain handles the signals from the sensory receptors is shown by an animated diagram of the control room of a television station. The nerve fibers from each of the sense organs are pictured as ending in electronic tubes that project on a screen the image of what the organs are picking up. The "brain control operator" keeps track of what is being received, calls on the memory bank when necessary, and then sends orders to the muscles of the body to take appropriate action.

One sequence compares the eye to a motion picture camera, but Dr. Baxter soon shows that the eye is a far more complicated mechanism. Light passing through the lens of the eye strikes the curved surface of the retina, which contains more than 125 million cells, each capable of sending a signal to the brain. Most of these are rods which transmit bright-light vision and color vision. The program shows how the cones and rods are stimulated by light bleaching the pigment at the tip of each.

"Gateways to the Mind" also shows two experiments by Dr. Hadley Cantril of Princeton University. One demonstrates how a trapezoid creates an optical illusion because the brain, using its memory function, interprets the trapezoid as a square. The second illusion is produced by a distorted room in which a boy looks larger than a man because the brain applies its experience in perspective to see the image incorrectly.

Additional proof of the brain's role in sensory perception is shown by Dr. Wilder Penfield, a brain surgeon of McGill University. He shows that electrodes applied to certain areas of the brain can elicit sensory impressions without the actual sensory receptors being stimulated at all. A touch at one point of the brain and the patient hears music.

Like the four Bell System Science Series programs produced by Frank Capra, "Gateways to the Mind" was made under the general supervision of the Scientific Advisory Board whose members include J. R. Pierce, Director of Research in Electrical Communications at Bell Laboratories, advisor for electronics and acoustics, and Dr. Ralph Bown, former Vice President of research at the Laboratories, advisor for engineering. Dr. Bown also serves as Chairman.

After the telecast on October 23, Bell Telephone Companies will make "Gateways to the Mind" available on 16-mm. color film to schools and other interested groups. The first four Science Series programs have already been seen by some 12,500,000 people in special showings.

J. P. Molnar Elected President of Sandia; McRae and Crosland Named Vice Presidents of A.T.&T. Company

J. P. Molnar

J. P. Molnar, Vice President of the Laboratories in charge of one of the areas devoted to military programs, was elected a Vice President of Western Electric and President of the Sandia Corporation, a Western subsidiary, on August 20. The Sandia Corporation manages the Sandia Laboratory of the Atomic Energy Commission on a non-profit basis, and develops, designs and tests atomic weapons.

Prior to the action of the Western board, J. W. McRae and E. S. Crosland were elected vice presidents of the A.T.&T. Company.

Mr. McRae, currently a Vice President of the Western Electric Company and President of the Sandia Corporation, will be coordinator of defense activities for the Bell System.

Mr. Crosland, Assistant to the President of A.T.&T., will continue to be responsible for regulatory matters involving the Federal Communications Commission and the National Association of Railroad and Utility Commissioners. Mr. Crosland's change was effective immediately, the others on October 1.

Mr. Molnar joined Bell Laboratories in 1945 and was appointed Vice President in August, 1957. Mr. McRae also began his Bell System career at the Laboratories, in 1937; he was elected Vice President of the Laboratories in 1951 and President of Sandia in 1953. Mr. Crosland entered the Bell System in 1946 with the Southern Bell Company and was appointed Assistant to the President of A.T.&T. in 1955.

J. W. McRae

E. S. Crosland

NEWS BRIEFS:

B. McMillan to Serve on "Killian Committee"

B. McMillan, Assistant Director of Systems Engineering I, has been named to the staff of Dr. James R. Killian, President Eisenhower's Special Assistant for Science and Technology.

Mr. McMillan will serve with one of the committees impaneled to consider various scientific problems facing the nation. He reported to Washington in mid-September and will be on loan from the Laboratories for a six-months period.

Mr. McMillan joined the Laboratories in 1946 as a research mathematician and has been concerned with network theory, statistics and communications theory. In 1955 he became associated with the engineering planning of communications systems. He is a member of the American Association for the Advancement of Science and is Vice President of the Society for Industrial and Applied Mathematics.

A. G. Jensen Awarded High Danish Decoration

A. G. Jensen, Director of Visual and Acoustics Research at Bell Laboratories, has been made a Knight of the Order of Dannebrog by King Frederick IX of Denmark. The award was conferred on Mr. Jensen in recognition of his work as a scientist and as an expression of appreciation for his assistance to Danish scientists and engineers who have visited the United States.

The Order of Dannebrog, considered Denmark's highest civilian decoration, is made by the King on special occasions, usually to people of Danish descent. "Dannebrog" is the national flag of Denmark and, according to a legend, it was adopted by King Valdemar in the year 1219.

Mr. Jensen was born in Copenhagen, Denmark, and was graduated from the Royal Technical College there with a degree in electrical engineering. He came to the United States in 1921 for post-graduate work at Columbia University, and in 1922 joined the Western Electric Company's engineering department. During his Bell System career he has specialized in research on radiotelephony, television and acoustics, and has achieved international recognition as a leader in these fields.

His contributions have been recognized by a number of honors, including the David Sarnoff Gold Medal of the Society of Motion Picture and Television Engineers, the G. A. Hagemann Gold Medal for Industrial Research of the Royal Technical College of Copenhagen, and the rank of Fellow in the Television Society of London, the Institute of Radio Engineers, and the Society of Motion Picture and Television Engineers.

The Order of Dannebrog was also conferred, in 1954, on H. T. Friis, Director of Research in High Frequency and Electronics. Mr. Friis retired from Bell Laboratories earlier this year.

High-Speed Diode for Switching and Computer Applications Announced

A high-speed, switching diode made of diffused silicon was described in a paper presented at the recent WESCON meeting by J. H. Forster and P. Zuk of Bell Laboratories.

Modern high-speed computers require devices that switch in millimicroseconds. And this diode, known as the 1N696, has a switching time of about one millimicrosecond. Other desirable characteristics include low capacitance, low forward dynamic resistance, low dc reverse current and high reliability. Diffusion techniques developed at the Laboratories play an important part in achieving these favorable characteristics.

The p-n junction is formed by diffusing boron into n-type silicon. Capacitance is kept small by limiting the junction to a diameter of about 0.005 inch.

Low forward dynamic resistance is achieved by starting with silicon having a resistivity as low as possible consistent with other limitations.

Recovery time in a junction diode can be shortened by the addition of suitable recombination centers. Gold acts as an effective recombination center in silicon, and in the 1N696 diode, gold atoms are introduced by solid-state diffusion.

For long life, the diodes are vacuum baked at over 300°C, and the enclosures are hermetically sealed. Life tests indicate a life expectancy of more than 100,000 hours based on an exponential failure rate.

This diode represents a valuable contribution to the long list of components developed to advance the fields of high-speed switching and computing.

A.T.&T. Co. Announces Organization Changes

William C. Bolenius, Vice President — Accounts and Finance, was appointed an Executive Vice President of the A.T.&T. Co. on September 17. Mr. Bolenius will continue in charge of finance with the comptroller and treasurer reporting to him, and will perform such other duties as the president may assign. On the same date the A.T.&T. Board of Directors accepted with regret the resignation of James F. Bell, who had served on the Board for 24 years. George F. Smith, president of Johnson & Johnson, New Brunswick, N. J., was elected a director.

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

WESCON, Los Angeles

Ashkin, A., see Bridges, T. J.

Bridges, T. J. Ashkin, A., Louisell, W. H., and Quate, C. F., *Parametric Electron Beam Amplifiers.*

David, E. E., Jr., Mathews, M. V., and McDonald, H. S., *Description and Results of Experiments with Speech Using Digital Computer Simulation.*

DeGrasse, R. W., *Slow-Wave Structures for Unilateral Solid-State Maser Amplifiers.*

Easley, J. W., *Comparison of Neutron Damage in Germanium and Silicon Transistors.*

Forster, J. H., and Zuk, P., *Millimicrosecond Diffused Silicon Computer Diodes.*

Graham, R. E., and Kelly, J. L., Jr., *A Computer Simulation Chain for Research on Picture Coding.*

Graham, R. E., *Predictive Quantizing of Television Signals.*

Grubbs, W. J., *The Hall Effect Circulator—A Passive Transmission Device.*

Irvin, H. D., *Sibyl: A Laboratory for Simulation Studies of Man-Machine Systems.*

Kelly, J. L., Jr., see Graham, R. E.

Louisell, W. H., see Bridges, T. J.

Marcatili, E. A., *Mode Conversion Filters.*

Mathews, M. V., see David, E. E., Jr.

McDonald, H. S., see David, E. E., Jr.

Miller, L. E., *The Design and Characteristics of a Diffused Silicon Logic Amplifier Transistor.*

Monk, N., *Personal Signaling, A New Telephone Service.*

Myers, G. H., and Saxton, G. A., Jr. (U. of Ill.), *A Servomechanism for Automatic Regulation of Breathing.*

Priebe, H. E., Jr., see Shafer, W. L., Jr.

Quate, C. F., see Bridges, T. J.

Rowe, H. E., see Warters, W. D.

Shafer, W. L., Jr., Priebe, H. E., Jr., and Toy, W. N., *A Small High-Speed Ferrite Core Memory.*

Talley, H. E., *A High-Speed Diffused-Base Germanium Switching Transistor.*

Toy, W. N., see Shafer, W. L., Jr.

Uhlir, A., *Power Requirements for Silicon Diode Reactance Amplifiers.*

Warters, W. D., and Rowe, H. E., *The Effects of Mode Conversion in Long Circular Waveguide.*

Zuk, P., see Forster, J. H.

AMERICAN MATHEMATICAL SOCIETY, Cambridge, Mass.

Benes, V. E., *The General Queue with One Server.*

Frisch, H. L., see Miranker, W. L.

Kimme, E. G., *Note on the Convergence of Sequences of Stochastic Processes.*

Miranker, W. L., and Frisch, H. L., *Analysis of the Non-Linear Stefan Problem.*

Riney, T. D., *Coefficients in certain asymptotic factorial Expansions of the Second Kind.*

AMERICAN PHYSICAL SOCIETY Vancouver, Canada

Bowers, K. D., and Mimis, W. B., *Paramagnetic Relaxation Studies in (Zn,Ni)SiF_6 $6H_2O$.*

Dransfeld, K., *Experiments on Spin-Phonon Interaction in Ruby.*

Kohman, G. T., see McAfee, K. B.

Lax, M., *One Dimensional Impurity Bands.*

McAfee, K. B., and Kohman, G. T., *Separation of Gases by Diffusion in Silica Glass.*

Mimis, W. B., see Bowers, K. D.

INSTITUTE OF MATHEMATICAL STATISTICS, Cambridge, Mass.

Benes, V. E., *Generalization of Palm's Loss Formula for Telephone Traffic.*

Roberts, S. W., *Properties of Some Control Chart Tests for Detecting Shifts in a Process Average.*

Sobel, M., *Comparison of Statistical Ranking and Selection Procedures.*

Sobel, M., *On A Solution of Dorfman's Mass-Testing Problem.*

Wilk, M. B., *Confidence and Significance Procedures for Nonlinear Models.*

1958 INTERNATIONAL CONFERENCE ON SEMICONDUCTORS, Rochester, N. Y.

Allen, F. G., *Work Function and Emission Studies on Clean Silicon Surfaces.*

Boyle, W. S., *Far Infrared Magnetooptic Effects from Impurities in Germanium.*

Feher, G., *Donor Wavefunctions in Silicon by the ENDOR Technique.*

Flood, W. F., see Haynes, J. R.

Geballe, T. H., *Phonon Drag Thermoelectric Effects in n-Germanium.*

Hagstrum, H. D., *State Density in the Valence Band of Silicon.*

Haynes, J. R., Lax, M., and Flood, W. F., *Analysis of Intrinsic Recombination Radiation from Silicon and Germanium.*

Lax, M., see Haynes, J. R.

Phillips, J. C., *Energy Bands of Silicon and Germanium.*

Weinreich, G., *Structure and Chemical Shift Donor States in Germanium.*

CONFERENCE ON ELECTRONIC STANDARDS AND MEASUREMENTS, Boulder, Colorado

Koerner, L. F., *Method of Measuring the Parameters of Piezoelectric Vibrators.*

Mason, W. P., *Uses of Internal Friction Measurements in Determining the Causes of Frequency Instabilities in Mechanically Vibrating Frequency Standards.*

Warner, A. W., *Ultra-Precise Quartz Crystal Frequency Standards.*

CONFERENCE ON ELECTRONIC PROPERTIES OF METALS AT LOW TEMPERATURES, Geneva, New York

Anderson, P. W., *The Random Phase Approximation in the Theory of Superconductivity.*

Bömmel, H. E., *Oscillatory Magnetoacoustic Effects in Metals at Low Temperatures.*

Boyle, W. S., *Magnetooptic Measurements on Bismuth in the Far Infrared.*

Devlin, G. E., see Schawlow, A. L.

Galt, J. K., and Brailsford, A. D. (Ford Motor Co.), *Cyclotron Absorption in Bismuth—Theoretical.*

Galt, J. K., *Cyclotron Absorption in Bismuth—Experimental.*

Schawlow, A. L., and Devlin, G. E., *Effect of the Energy Gap on the Penetration Depth of Superconductors.*

Suhl, H., *Spin Exchange in Superconductors.*

66th ANNUAL CONVENTION OF AMERICAN PSYCHOLOGICAL ASSOCIATION, Washington, D. C.

Deutsch, M., and Solomon, L., *Reactions to Evaluations by Others as Influenced by Self-Evaluations.*

Gerard, H. B., *Expectation, Performance, and Self-Evaluation.*

Israel, J., *Attitudes Toward the Self—An Attempt for a Conceptual Clarification.*

Solomon, L., see Deutsch, M.

SPECIAL TECHNICAL CONFERENCE ON NONLINEAR MAGNETICS AND MAGNETIC AMPLIFIERS, Los Angeles, Calif.

Bobeck, A. H., see Title, R. S.

Gianola, U. F., *Magnetic Networks for Performing Logic.*

Goldstein, H. L., *Observation of Transients in the Series Connected Saturable Reactor with High Impedance Control Source.*

Jewett, W. E., and Schmidt, P. L., *A More Stable Three-Phase Transistor-Core Power Inverter.*

Schmidt, P. L., see Jewett, W. E.

Title, R. S., and Bobeck, A. H., *The Twistor—Its Use in a Memory Array.*

OTHER TALKS

Bennett, W. R., *Noise,* Ramo-Wooldridge Corporation, Los Angeles, Calif.

Dickieson, A. C., *Microwave Communication Systems; Some Aspects of Microwave Propagation,* Case Institute of Technology, Cleveland, Ohio.

Hartmann, W., *Qualitative Spectrochemical Analysis,* Rocky Mountain Spectroscopy Society Meeting, Denver, Colo.

Kaminski, W., *Transistors and Transistor Circuitry,* Tri-County Amateur Radio Association, Clinton School, Plainfield, N. J.

Levenbach, G. J., *Some Problems in the Analysis of an Experiment with the Treatments Assigned at Random,* Summer Statistical Seminar, M.I.T., Dedham, Mass.

Liehr, A. D., *Band Intensities in Tetrahedral Complexes, Symp. on Molecular Structure and Spectroscopy,* Columbus, Ohio, (June).

McMillan, B., *A Descriptive Introduction to the Statistical Theory of Communication,* International Summer School on Information Theory, Varenna, Italy.

Mottram, E. T., *Submarine Cables,* Univ. of Pennsylvania, Philadelphia, Pa.

Pellegrinelli, A., *Carrier Systems,* Lincroft-Holmdel Kiwanis Club, Lincroft, N. J.

Sinclair, W. R., *Measurements of Diffusion in the System TiO_2-SnO_2,* Conference on Kinetics of High-Temperature Reactions, Dedham, Mass.

Slichter, W. P., *Defects in Crystallites of High Polymers,* International Conference on Crystal Growth, Cooperstown, N. Y.

Strack, W., *Systems Engineering of Personal Radio Signaling Systems,* A.I.E.E. Summer Meeting, Buffalo, N. Y.

Thomas, B. J., *How a Radar Works,* Civitan Club, Burlington, N. C.

PAPERS

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

Ballhausen, C. J. and Liehr, A. D., *Intensities in Inorganic Complexes II: Tetrahedral Complexes*, J. Molecular Spectroscopy, 2, pp. 342-360, Aug., 1958.

Brown, A. B., and Meyers, S. T., *Evaluation of Some Error Correction Methods Applicable to Digital Data Transmission*, I.R.E. Nat'l Convention Record, Part 6, pp. 37-55, Mar., 1958.

Chynoweth, A. G., *Barkhausen Pulses in Barium Titanate II Domain Nucleation*, Phys. Rev., 110, pp. 1316-1332, June 15, 1958.

Chynoweth, A. G., and Pearson, G. L., *Effect of Dislocation on Breakdown in Silicon p-n Junctions*, J. Appl. Phys., 29 pp. 1103-1110, July, 1958.

Corenzwit, E., see Matthias, B. T.

Durand, J. L., *Automatic Calibrator for Chart Recorders*, Rev. Sci. Instr., 29, pp. 534-535, June, 1958.

Ferrell, E. B., *Control Charts For Log-Normal Universes*, Ind. Qual. Cont., 15, pp. 4-6, August, 1958.

Flaschen, S. S., see Luke, C. L.

Gerard, H. B., *Some Effects of Involvement Upon Evaluation*, J. Abnormal & Social Psychology, 57, pp. 118-120, July, 1958.

Gerard, H. B., *Some Effects of Status, Role Clarity, and Group Goal Clarity Upon the Individual's Relations to Group Process*, J. of Personality, 25, pp. 475-488, June, 1957.

Germer, L. H., *Physical Processes in Contact Erosion*, J. Appl. Phys., 29, pp. 1067-1082, July, 1958.

Goldstein, H. L., *Observation of Transients in the Series Connected Saturable Reactor with High Impedance Control Source*, 1958 Proc. Non-Linear Magnetics & Magnetic Amplifiers, pp. 47-61, 1958.

Herrmann, D. B., see Lanza, V. L.

Ketchledge, R. W., *An Introduction to the Bell System's First Electronic Switching Office*, Proc. Eastern Joint Computer Conf., 1957, pp. 204-208, 1957.

Kiernan, W. J., *Color in Telephones*, Inter-Society Color Council News Letter, 136, pp. 16-17, July, 1958.

Lanza, V. L., and Herrmann, D. B., *The Density Dependence of the Dielectric Constant of Polyethylene*, J. Polymer Science, 18, pp. 622-625, April, 1958.

Lax, M., *Optical Properties of Diamond Type Crystals and Parity Conservation*, Phys. Rev. Letters, 1 pp. 131-132, Aug. 15, 1958.

Lax, M., *Quadrupole Interactions and the Vibration Spectra of Diamond Type Crystals*, Phys. Rev. Letters 1, pp. 133-134, Aug. 15, 1958.

Lee, C. Y., *Some Properties of Nonbinary Error-Correcting Codes*, Trans. I.R.E., IT-4, pp. 77-82, June, 1958.

Liehr, A. D., see Ballhausen, C. J.

Liehr, A. D., *Interaction of the Vibrational and Electronic Motions in Simple Conjugated Hydrocarbons II. Algebraic Evaluation of the Integrals*, Z. Naturforschung, 13A, pp. 429-438, June, 1958.

Liehr, A. D., *Errata: Interaction of the Vibrational and Electronic Motions in Some Simple Conjugated Hydrocarbons I: Exact Circulation of the $1_{A_{1g}}$, $1_{B_{1u}}$, $1_{B_{2u}}$ Vibronic Transitions of Benzene*, Z. Naturforschung, 13A, pp. 596-597, July, 1958.

Luke, C. L., and Flaschen, S. S., *Determination of Boron in High Purity Silicon Using the Principles of Hydrothermal Refining*, Anal. Chem., 30, pp. 1406-1409, Aug., 1958.

Luke, C. L., *Determination of Traces of Boron in Nickel*, Anal. Chem., 30, pp. 1405-1406, Aug., 1958.

Matthias, B. T., Suhl, H., and Corenzwit, E., *Spin Exchange in Superconductors*, Phys. Rev. Letters 1, pp. 92-94, Aug. 1, 1958.

Meyers, S. T., see Brown, A. B.

Miranker, W. L., *A Free Boundary Value Problem for the Heat Equation*, Quart. Appl. Math., 16, pp. 121-130, July, 1958.

Nelson, L. S., and Spindler, G. P., *Sealing Glass to Sapphire*, Rev. Sci. Instr., 29, pp. 324-326, Apr., 1958.

Pearson, G. L., see Chynoweth, A. G.

Slepian, D., *Some Comments on the Detection of Gaussian Signals in Gaussian Noise*, Trans. I.R.E., IT-4, pp. 65-68, June, 1958.

Slichter, W. P., *The Study of High Polymers by Nuclear Magnetic Resonance*, Fortschritte der Hochpolymerenforschung (Advances in Polymer Science), 1, pp. 35-74, 1958.

Spindler, G. P., see Nelson, L. S.

Suhl, H., see Matthias, B. T.

Wertheim, G. K., *Electron-Bombardment Damage in Silicon*, Phys. Rev., 110, pp. 1272-1279, June 15, 1958.

Wolontis, V. M., *What Is Automatic Programming?*, Proc. of Short Course and Conf. on Automation and Computers, Univ. of Texas, 2, p. 94, June 2-4, 1958. (Abstract only.)

Wood, D. L., and Mitra, S. S. (Nat'l Research Council of Canada), *The Effect of Convergence on the Infrared Spectra of Anisotropic Substances*, J. Opt. Soc. Am., 48, pp. 537-542, Aug., 1958.

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. — *Ferromagnetic Translating Apparatus* — 2,843,838.

Ashkin, A. — *Electrostatic Focusing of Electron Beams* — 2,843,793.

Barkoff, L. E. and Walther, H. — *Counterbalance Assembly* — 2,843,808.

Bond, W. L. and Kelly, E. M. — *Vapor Deposited Metal Films* — 2,842,463.

Cioffi, P. P. — *Electron Beam Focusing System* — 2,844,754.

Collins, R. W. — *Radio Telephone Dispatch Control and Signaling Circuit* — 2,843,675.

Collins, R. W. — *Mobile Radio Telephone System* — 2,842,659.

Cornell, W. A., McGuigan, J. H. and Murphy, O. J. — *Magnetic Data Storage System* — 2,845,610.

Cutler, C. C. — *Traveling Wave Amplifier* — 2,843,790.

Doherty, W. H. — *Electrical Conductor Having Transposed Conducting Members* — 2,845,473.

Edson, J. O. and Scheideler, C. E. — *Directional Array Employing Laminated Conductor* — 2,841,792.

Fox, A. G. — *Guided Wave Transmission System* — 2,844,799.

Hermance, H. W. — *Rotary Cleaning Tool* — 2,843,869.

Hines, M. E. — *Electron Discharge Devices* — 2,844,722.

Ilgenfritz, L. M. — *Repeater Testing System* — 2,843,668.

Kelly, E. M., see Bond, W. L.

Ketchledge, R. W. — *Multiple Connection Electronic Switching Network* — 2,843,674.

McGuigan, J. H., see Cornell, W. A.

Murphy, O. J., see Cornell, W. A.

Oliver, B. M. — *Probability Oscillograph* — 2,843,447.

Pfann, W. G. — *Manufacture of Semiconductor Devices* — 2,842,831.

Pfann, W. G. — *Electromagnetic Switching* — 2,844,688.

Pierce, J. R. — *Traveling Wave Tube* — 2,843,791.

Pierce, J. R. — *Traveling Wave Tube* — 2,843,792.

Pierce, J. R. — *High Frequency Amplifier* — 2,841,738.

Pierce, J. R. — *Electron Beam Systems* — 2,841,739.

Prince, M. B. — *Method of Producing Cavities in Semiconductive Surfaces* — 2,844,531.

Quate, C. F. — *Traveling Wave Tube* — 2,844,753.

Rieke, J. W. — *Shunt Clamper of the Feedback Type* — 2,843,662.

Rieke, J. W. — *Method for Frequency Modulated Color Television Transmission* — 2,841,638.

Rieke, J. W. and Slocum, A. — *Envelope Detector* — 2,844,719.

Rigterink, M. D. — *Wire-Wound Vitreous Enamel Resistors* — 2,844,693.

Scheideler, C. E., see Edson, J. O.

Slocum, A., see Rieke, J. W.

Smith, D. H. — *Tone Generator* — 2,843,745.

Stammerjohn, L. W. — *Magnetic Amplifiers* — 2,843,813.

Talpey, T. E. — *Electron Discharge Devices* — 2,843,786.

Thomas, D. E. — *Self-Starting Transistor Oscillators* — 2,842,669.

Tien, P. K. — *Traveling Wave Tube Electron Gun* — 2,843,776.

Trent, R. L. — *Bistable Transistor Trigger Circuit* — 2,843,762.

Walther, H., see Barkoff, L. E.

West, F. — *Pulse Series Analyzer* — 2,844,668.

West, J. W. and White, A. D. — *Gaseous Discharge Device* — 2,845,568.

White, A. D., see West, J. W.

Yaeger, R. E. — *Cascade Transistor Amplifiers* — 2,844,667.

Contents of the July, 1958, Bell System Technical Journal

The July, 1958 BELL SYSTEM TECHNICAL JOURNAL contains the following articles:

Transmission Characteristics of a Three-Conductor Coaxial Transmission Line with Transpositions, by G. Raisbeck and J. M. Manley.

Synthesis of Series-Parallel Network Switching Functions, by Warren Semon.

Circular Waveguide Taper of Improved Design, by Hans-Georg Unger.

The Nonuniform Transmission Line as a Broadband Termination, by Ira Jacobs.

Using Contact Resistance to Measure Adsorption of Gases on Metals, by P. Kisliuk.

Shot Noise in p-n Junction Frequency Converters, by A. Uhlir, Jr.

Gain and Noise Figure of a Variable-Capacitance Up-Converter, by D. Leenov.

Nonstationary Velocity Estimation, by T. M. Burford.

Amplitude Modulation Suppression in FM Systems, by C. L. Ruthroff.

Oxide Semiconductors with Partially Filled 3d Levels, by F. J. Morin.

THE AUTHORS

A. E. Joel, Jr.

A. E. Joel, Jr., a native of Philadelphia, received the B.S. degree from Massachusetts Institute of Technology in 1940 and the M.S. degree, also from M.I.T., in 1942. After joining Bell Laboratories in 1940, Mr. Joel worked for a time in the fields of relay engineering and crossbar testing, and later engaged in fundamental development studies, work on circuits for relay computers, and the teaching of switching design. Subsequently, he was concerned with designing AMA computer circuits and making fundamental engineering studies on new switching systems, and presently is Switching System Development Engineer responsible for systems coordination of the exploratory development of an experimental electronic switching system. Mr. Joel, whose inventions have resulted in twenty-six issued patents, is a member of the A.I.E.E., I.R.E., Sigma Xi and the Association for Computing Machinery.

R. J. Gnaedinger, Jr., a native of Oak Park, Illinois, received his B.S. degree in 1945 and his Ph.D. degree in Physical Chemistry in 1951 from the University of Chicago. After a period as Research Associate in the Solid State Physics Group at the University of Illinois, he joined the Laboratories in 1954. His research work has included studies of color centers in alkali-halide crystals and lattice constant measurements on metals containing quenched-in defects. At the Laboratories, he has been engaged in transistor development, particularly thin-film evaporation and alloying. Mr. Gnaedinger was a Gustavus Swift and Atomic Energy Commission Fellow at the University of Chicago and is a member of the American Physical Society, the American Chemical Society, and Sigma Xi. The article on precision evaporation and alloying is by Mr. Gnaedinger.

R. J. Gnaedinger, Jr.

J. W. Buckelew, a native of Jersey City, N. J., has been with the Laboratories since 1953. Prior to this time he completed a three-year machinist apprenticeship with the Westinghouse Lamp Division. From 1942 to 1945, Mr. Buckelew served as a Navigator and B-29 Flight Engineer in the USAAF, with a rating of Second Lieutenant. After the war he attended the evening sessions of the Newark College of Engineering for three years and is presently attending Fairleigh Dickinson University evening sessions. His work at the Laboratories has been mainly concerned with ball bearings and dynamic balancing problems. He has also been involved with potentiometer slip ring studies and certain reliability tests of seals for rotating shafts. At present he is working on a study of gyro precision instrument bearings. Mr. Buckelew is co-author of the article, "Through-Connections for Printed Wiring," in this issue.

J. W. Buckelew

E. D. Knab, a native of Massachusetts, joined the Western Electric Company as an instrument maker in 1941. A year later he transferred to the Laboratories where he continued as an instrument and tool maker until 1951, at

E. D. Knab

AUTHORS (CONTINUED)

which time he joined the engineering department as a technical aide. In this capacity he was assigned to the Mechanical Laboratory in Whippany where he engaged in problems dealing chiefly with mechanical design analysis, and standardization of design for such items as gears, gear reduction units, bearings, split-hub clamps, etc. Among his particular projects has been the design and development of a high-speed rotary switch, a helix angle measuring device, a dynamic torque meter, and a coaxial tool for beading. Mr. Knab has studied at the Newark School of Fine and Industrial Arts, and graduated from there in 1934. He is co-author of "Through-Connections for Printed Wiring," in this issue.

G. A. Hurst

G. A. Hurst ("Extending CAMA with No. 5 Crossbar") was born in New York City and attended evening classes at Cooper Union. He joined the Western Electric Company engineering department in 1920 and was concerned initially with preparations for laboratory testing of early panel dial system designs. This work carried him into a field where later, with the Laboratories, he specialized in observing the service trials of various dial central office systems, including panel sender tandem, No. 1 crossbar, local office AMA arrangements, and No. 5 crossbar. Following this, he was engaged in formulating maintenance requirements for the several local systems and, more recently, with general switching requirements for No. 5 crossbar.

E. A. Irland

E. A. Irland, a native of Lewisburg, Pa., received the B.S. degree in Electrical Engineering from Bucknell University in June, 1950, and joined the Laboratories the same month. After a period of rotational assignments, he joined the Switching Systems Development Department, where he was engaged in the design of circuits for Crossbar Tandem offices and later for toll signaling applications. Since March, 1958, he has been engaged in exploratory signaling development in the Telegraph, Signaling, and Special Systems Development Department. He graduated from the Communications Development Training Program in 1953 and recently received the M.S. degree in Mathematics at Stevens Institute of Technology. In this issue of the RECORD, the article "A High-Speed Data Signaling System" is by Mr. Irland.

A. J. Chase was born in Brooklyn, New York, and received the B. of E.E. degree from New York University in 1938. He joined the Laboratories in 1930, and until World War II was involved in economic and maintenance studies of station apparatus. During the war, he was engaged in developing underwater sound reference instruments as well as an electromechanical system for guiding torpedoes. Following the war, he was concerned with the development of special facilities for appraisal tests and service trials of newly developed station apparatus as well as transistorized equipment for station use. Since transferring to the Apparatus Development Department at the Indianapolis Laboratory in 1956, he has worked on the design of audio signaling apparatus. Mr. Chase, the author of "Transistor Amplifier for Operators' Headsets" in this issue, is a member of Iota Alpha and Eta Kappa Nu.

A. J. Chase