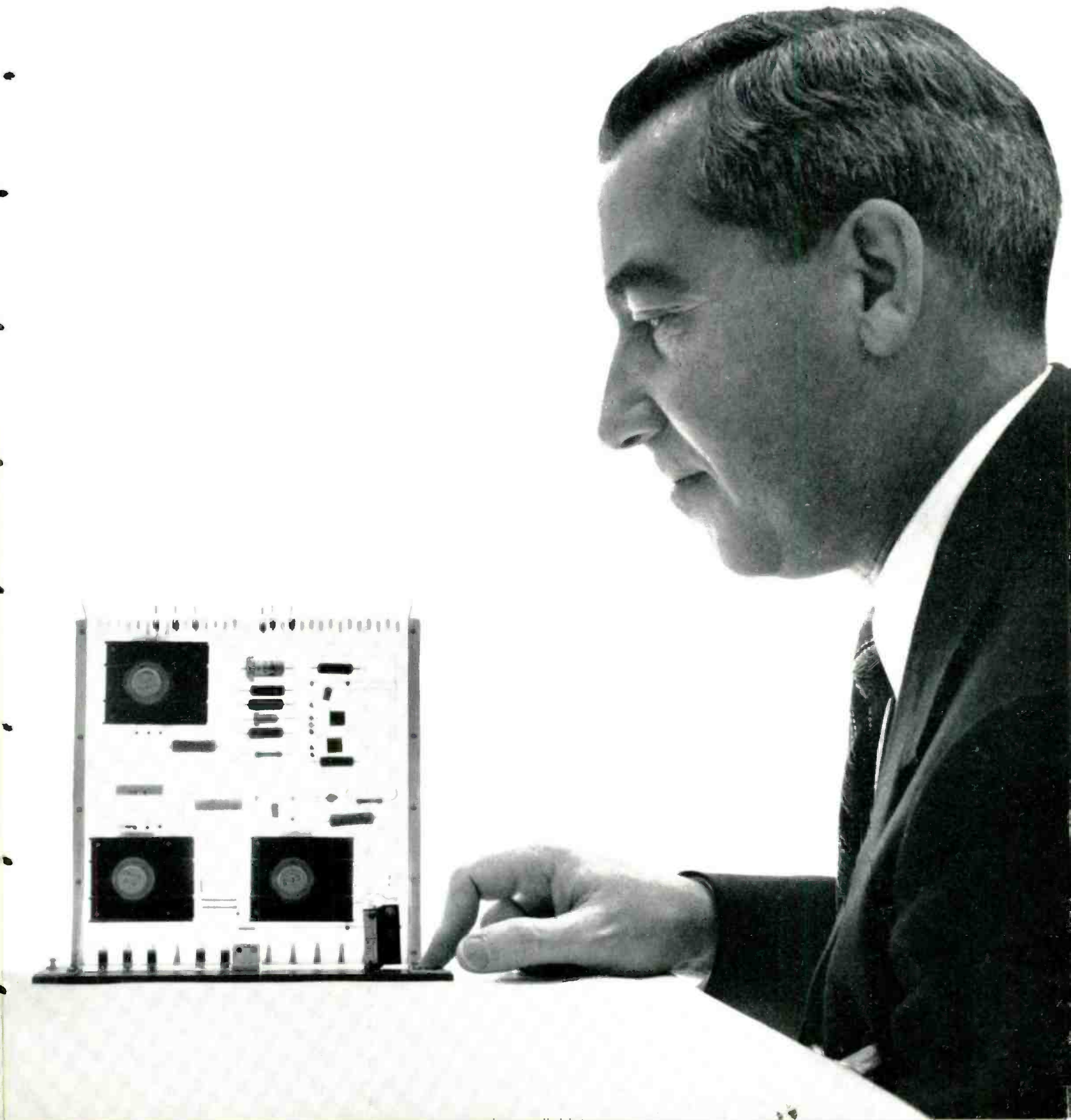
December 1958

Bell Laboratories RECORD



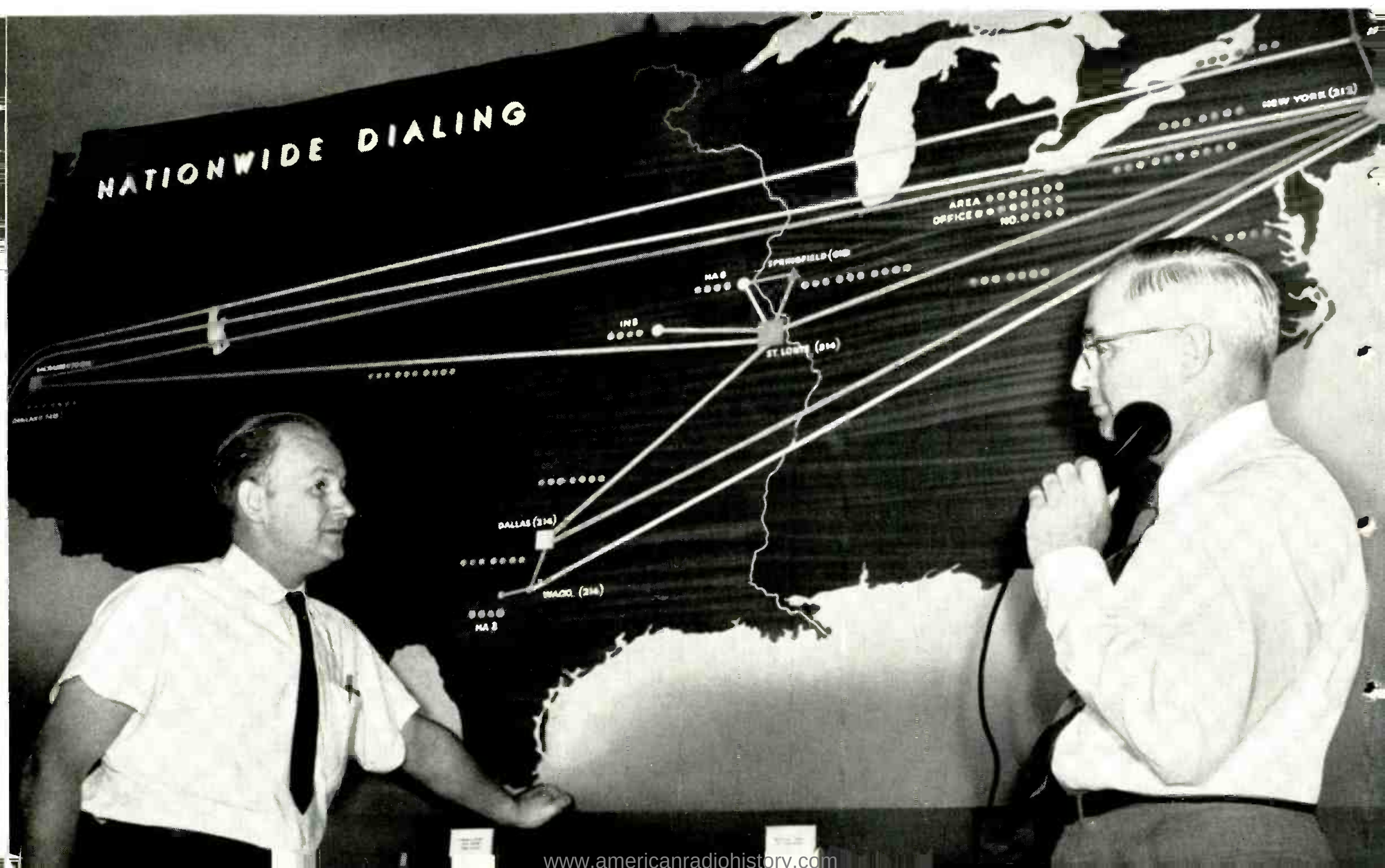
Many customers today can dial directly to millions of telephones all over the continent. In establishing these connections, how does automatic telephone equipment function? The circuits are extremely complex, but they are controlled by signals having a surprisingly simple pattern—a pattern beginning when you remove your telephone handset from its switchhook.

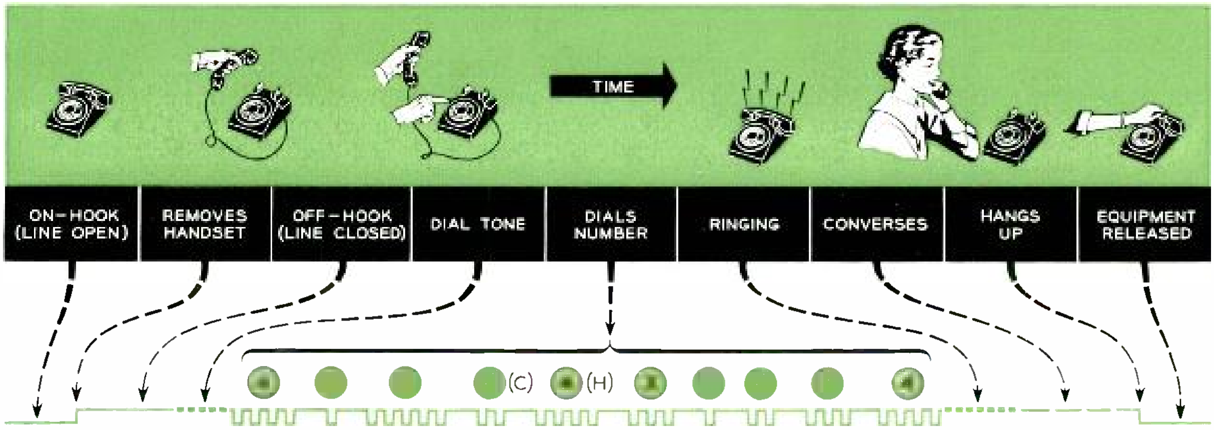
J. W. Gorgas

ON-HOOK, OFF-HOOK

Signaling over the Telephone Network

The author (right) and M. T. Erchard using test display to study the action of network signals.





Sequence of electrical "steps" when you place a long-distance call. Much information is sent to the central office, but at any one instant, the line can be in only one of two discrete states.

You pick up your telephone handset and dial a number, and in a few seconds a distant telephone bell rings — "across the street or across the nation." If you are an average telephone user, this event is merely a convenient service, and you needn't be concerned with the mechanisms that operate to establish the connection. But you might wonder, particularly for a customer-dialed long-distance call, just how the information needed to establish the connection is carried from your dial to your telephone office and through other offices from city to city until, out of the millions of telephones that can be reached by dialing, the desired one is selected. You rightly surmise that a lot of information has to be transmitted before the conversation between you and the person called can take place.

The call may have progressed through four or five switching centers, each having to respond either to the customer's original commands or to a suitable echo of them. How are these commands, all this information, carried over the wires? We shall find that much of the information is transmitted by the simplest of methods — in fact, by arranging the customer's line and the trunks between offices to be capable of assuming one or the other of two states recognizable at the distant end.

The use of these two states or values for carrying information over telephone circuits is to be expected, since many two-valued devices — relays, switches, diodes, transistors and others — are widely used throughout the computer, switching and data-transmission arts. One of these devices may be said to be in the *on* or *off* state at any particular instant. By changing from one state to another, it can deliver a "bit" of information for use elsewhere. Or, by remaining in a particular state for controlled intervals of time, additional bits of information may be indicated. Let us see how this control is applied to the customer's telephone line.

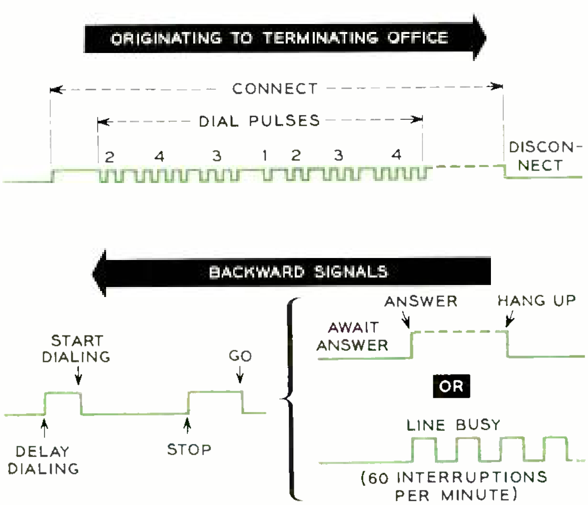
When your handset is resting in its cradle, the line from the central office is open to direct current. That is, the circuit is broken and no direct current can flow. When you pick up the handset, you release the switchhook to close the circuit, and continuous direct current flows around the line. You have changed the state of the line from on-hook to off-hook, and you have generated a "bit" of information to be used by the telephone system.

When you hear dial tone, you begin to dial a number. Say you are somewhere on the east coast and are dialing a number in San Francisco, in which case the first digit you dial will be a "4," the start of the area code 415. You spin the 4 over to the stop position, and as the dial unwinds back to the rest position, a set of contacts in the dial interrupts the direct current four times. The state of the circuit has been rapidly switched four times between the off-hook and on-hook conditions, and the central office recognizes that a "4" has been dialed. In other words, the number of on-hook's is equal to the value of the digit that was dialed. The first of the drawings with this article (above) is a diagram showing how the condition of your line changes as you dial the called number.

Another important element contributing to the passing of information by off-hook and on-hook signals is time duration. After you dial the "4," you next dial the "1" of the 415 code. How does the central office tell that you have dialed a "4" and *then* a "1," rather than a "5"? The answer is that it takes time for you to spin the "1," and even if you do it very rapidly, the time lapse between the two digits will always be significantly longer than the times between the on-hook pulses for a single digit. A speed governor on the dial controls the pulses so that the off-hook time between pulses is uniform and does not exceed about 40 thousandths of a second, whereas, even if you dial rapidly, you normally will not be able to dial the second digit sooner than about 300 thousandths of a second after you have dialed the first digit. Because of its ability to make these time discriminations, the central office gathers additional information from the simple on and off conditions generated by your telephone dial.

Now suppose the connection is completed and you are talking to your party. The off-hook condition is continuous, and the conversation appears on the local wires as fluctuations in the direct current. Suddenly, the central office detects that the state of the circuit has changed from off-hook to on-hook. Have you hung up, or have you merely accidently touched the switchhook for an instant? Again the central office measures the duration to get more information. It assumes that if this on-hook condition persists for a certain period of time, you have finished the conversation and have hung up. And the central office is prepared to measure this period of time at any stage, for a user might decide to hang up before he has completed dialing or before the called party answers.

It will be noticed from this example that some meanings of on-hook and off-hook are derived by relating them to conditions in the central office. For example, when no connection is established through the office, sustained on-hook merely means that the telephone line does not require service. When a connection exists, however, sustained on-hook means that the call has terminated and should be quickly disconnected so that another call can be served. A typical central office derives fourteen separate meanings from the two elementary on-hook, off-hook states. These meanings are listed in the table on the next page, which shows how they are derived from off-hook and on-hook signals.



Signaling between offices looks much like that between a telephone and the local office. Offices, however, need additional signals not ordinarily encountered by the telephone user.

Thus far we have considered only the signals between a telephone and the local office serving it. Similar signals are used, however, to pass information from one office (switching center) to another as a call is advanced along its route. The diagram shown below indicates the interoffice signals required in both directions — that is, forward from the originating office to the terminating office and backward from the terminating office to the originating office. This diagram is based on the use of dial pulsing as the means for passing the called customer's number, assumed to be CH 3-1234 (that is, 243-1234).

For interoffice signaling, various methods are used for transmitting on-hook and off-hook signals besides the simple open- and closed-loop method used on customers' lines. On longer trunks the two states are provided by single-frequency signaling systems (RECORD, *February*, 1954). With these systems, on-hook is "tone on" and off-hook is "tone off."

As compared to local signaling, we encounter with interoffice signaling some similarities and some differences. In the local area, you as a user have only two responsibilities: you must wait for dial tone and then you must dial the number. After that, you merely wait until you get a response — a ringing signal, a completed connection, or a busy tone.

In a sense, the central office in extending a connection to another office has the same job to do. It may receive from the second office a "delay dialing" signal, which is equivalent to the absence of dial tone to the user's telephone. It then receives a "start dialing" signal, equivalent to dial tone, after which it starts sending the dial-pulsing on-hook and off-hook signals to the second office.

Here, however, the sending office may encounter a complication unknown to the telephone user. The second office may receive part of the telephone number even though it is not immediately prepared to receive the entire number. This means that additional signals are required. The second office may have to send back to the first office a "stop" signal, and later, after it is prepared to receive the rest of the number, a "go" signal. Further, in addition to the busy signal to indicate that the called telephone is in use, there is also the possibility that all possible trunks between two offices are in use, which requires a separate "all-trunks-busy" signal. Finally, the local office must again be able to detect the fact that the telephone call has been answered, and later that the call has been terminated.

Like the other signals we have discussed, all of these are derived from the basic on-hook and off-hook language. To do this, telephone

STATE OF LINE AND DERIVED MEANINGS

Condition of Line in Central Office	Meaning of Signal	
	Customer's Line, On Hook	Customer's Line, Off Hook
No connection on this line.	1. No service desired. (No action required.)	9. Service desired. (Prepare equipment to receive dial pulses.)
Line connected for registration of dial pulses.	2. Dial pulse if short. 3. Disconnect if long (more than about 0.3 sec.).	10. Between pulses if short (less than about 0.1 sec.). 11. Before, after, or between digits if long.
Line connected to originating end of transmission link.	4. Flash if short (ignored by machine). 5. Disconnect if long.	12. Hold connection. (No action required.)
Line being alerted by incoming call.	6. Continue ringing. (No action required.)	13. Trip ringing.
Line connected to terminating end of transmission link.	7. Flash if short (ignored by machine). 8. Disconnected by machine if it persists about 13-32 sec. (timed disconnect).	14. Time for charging purposes.

equipment must incorporate circuits to detect different values of time. This has not been a great difficulty, however, since the various intervals are sufficiently distinct to provide ample margins. There is little chance of a mistake.

The frequency of repetition of flashing signals, such as "line busy" (60 interruptions per minute), is another way of giving meaning to two-state signals, especially for human recognition of signals. The customer can hear the tone that accompanies the off-hook portion of the flash or, if an operator is in on the connection, she can visually observe the rate of flashing of the switchboard cord lamp. Other flashing rates are 30 IPM to indicate that no circuits are available and 120 IPM to indicate that the call should be originated again.

Two-state flashing signals are in wide use today, but a program is under way to change them to a "tone-only" form. This change, which will take place over a long period of time, is to effect economies in switching equipment.

An important characteristic of the two-state signals used in the Bell System is that, except for digital information, they are sustained-type rather than spurt-type signals. Sustained signals are maintained as long as the meaning they convey applies, whereas spurt signals are momentary and require means at the receiving end of the trunk for locking in a memory of the signal. When the meaning no longer applies, a second spurt is required to unlock or change the memory.

Sustained-type supervisory signals have advantages of simplicity of operation and of equipment over spurt-type signaling systems used in some other telephone administrations. In addition they are less vulnerable to momentary interferences. They have proved to be a sound method of carrying the supervisory information needed for continent-wide dialing.

When dial pulsing is the method used to transmit digital information, two-state signaling can carry all of the information necessary to control direct-distance dialed calls. The Bell System has found, however, a very efficient combination in using multifrequency pulsing for digital information and the on-hook, off-hook conditions for all other control information. Multifrequency pulsing (RECORD, *June*, 1954) uses voice-frequency pulses that can pass through any line facility suitable for voice currents. Six frequencies are used, in combinations of two for each digit, to form the pulses. Electronic receivers detect the pulses and transfer the information received to control equipment which establishes connections through the switches. The principal advantages of multifrequency pulsing are speed, accuracy, and a range equal to that for voice.

The range of on-hook and off-hook signals, when transmitted by the single-frequency method, is also equal to the range for voice. The use of single-frequency signaling, with its simple on-off language — either alone or in combination with multifrequency pulsing for digital information — can carry the signals needed to establish telephone connections anywhere the voice can be carried — across the nation or even across oceans and to other continents.

As evidence of its maturity, the transistor has recently become the basic element in the design of entire systems. For such "all-transistor" systems, power engineers have developed "new-art" voltage regulators that are as versatile, small and efficient as the circuits they are designed to serve.

G. W. Meszaros

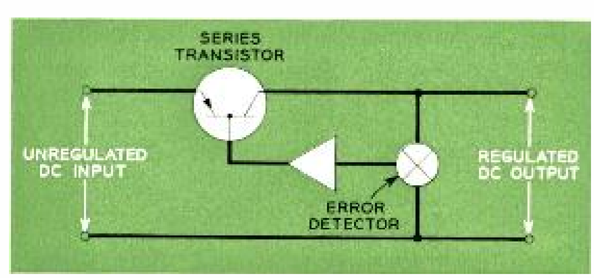
Transistor Voltage Regulators

Designers of electronic equipment, both at the Laboratories and elsewhere, have found it practical and profitable to use semiconductor devices to perform many functions formerly accomplished by electron tubes. To keep pace with this trend, power engineers have also had to use semiconductor devices in the design of sources of regulated power for modern, low-voltage equipment. Operating voltages for the transistor logic circuits in the Leprechaun computer (RECORD, *July*, 1957), for example, are as low as two volts, dc. It would of course completely defeat the purpose of miniaturized equipment like Leprechaun to have to use bulky and inefficient electron-tube circuitry to supply regulated power.

Fortunately, power engineers at the Laboratories have been able to design voltage regulators which compare favorably in both size and efficiency with the transistor circuits they serve. They have succeeded in this mainly because semiconductor devices important in voltage-regulator circuits — power transistors, power-rectifying diodes and reference-voltage diodes — have become available along with the many new amplifier-type transistors.

Semiconductor devices alone, however, cannot lay claim to the great strides that have been made in reducing the size of power supplies. Three other "new art" techniques are also very important. First, outputs of the newer circuits are usually below fifty volts, so that it is possible to use tantalum capacitors (RECORD, *October*, 1957). These miniature components, developed recently at the Laboratories, are much smaller than their oil-and-paper or aluminum counterparts. Second, all of the resistors can be much smaller because of the reduced power-dissipation in low-voltage circuits. Third, the reduction in size of all of the parts allows designers to use small, "pig-tail" elements that lend themselves to building the regulators by printed-wiring techniques. Such assemblies, besides being compact and rugged, usually have the additional advantage of low cost.

With these devices and techniques available to him, then, the power engineer's basic job is to design a power supply which will furnish a required output voltage, regulated within prescribed limits. A number of voltage-regulator circuits using transistors are possible, and some of these have been described briefly in a previous article in the RECORD (*September*, 1955). The present purpose is to describe in some detail two basic types of regulator circuits in use in Lab-



Circuit diagram of basic series-transistor regulator. Detector and amplifier details are omitted.

oratories-developed transistor equipment, and to highlight some of the special problems involved in the design of voltage regulators employing transistors and other semiconductor devices.

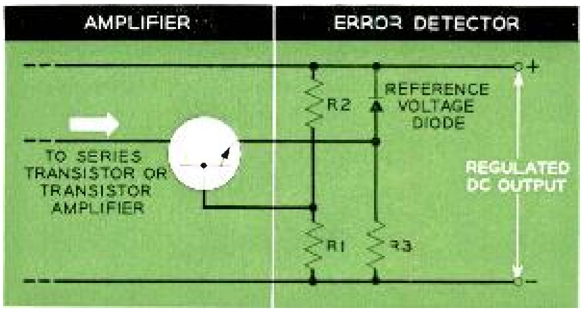
Voltage regulators are basically circuits designed to detect changes in voltage and to counteract those changes by using the "feedback" principle. Among these circuits, the "series-transistor" regulator is the most frequently used because it is both efficient and flexible. A simple series-transistor arrangement is shown at the bottom of the previous page. It consists of an error detector, a transistor amplifier and a power or series transistor.

If we assume a change in the output voltage caused either by a variation in the connected load or a shift in the input voltage, this change would be sensed by the error detector, which would produce a current signal proportional to the change in output voltage. This current is then amplified and becomes the base, or "driving" current of the series transistor. The value of the base current determines the series transistor's collector current, or its collector-to-emitter voltage, and maintains a steady output voltage. Because of the feedback action, changes in output current or input voltage do not affect the nominal output voltage.

The error detector, not shown in detail in the simplified schematic on page 442. uses as its basic element another solid-state device — the silicon junction diode (RECORD, *June*, 1954). This diode functions as a reference voltage. Electron-tube detectors generally use cold-cathode, gas-filled tubes for this purpose. The silicon-diode reference element in an error detector is about the size of a one-watt resistor, and is available in voltages as low as 3.5 volts, as compared to a minimum of 75 volts for a gas tube.

The common-emitter error detector, diagrammed above (right), is only one of many possible detector configurations. This particular circuit is usually used because the change in voltage with temperature of the reference diode is to a large extent compensated for by the temperature sensitivity of the transistor. The effective base-to-emitter voltage on the transistor is the portion of output voltage appearing across resistor R2, minus the constant voltage across the diode. If the base voltage of the transistor is slightly more positive than the emitter voltage, a decrease in the output voltage of the power supply will increase the base-to-emitter voltage and thereby increase the base current. The collector current will now increase by an amount equal to the change in the base current multiplied by the current gain, β, of the transistor.

The product of these two quantities — a current — can be used as a feedback signal to control the characteristic of the series transistor in circuits like the series regulator illustrated at the bottom of page 442. Resistor R3 serves to "set"



Circuit arrangement of a typical common-emitter error detector. Circuit works in series regulator.

the current in the reference diode in the operating region where its voltage is most constant. To improve the regulating action of the power supply, an additional transistor can be interposed between the amplifier transistor of the error detector and the series transistor.

Physically, a circuit which combines the components and wiring shown in the two schematics (top of this page and bottom of page 442) can be made into quite a small package. A prototype voltage regulator designed for an experimental electronic switching system is shown in the photograph on page 444. This regulator, designed to regulate between 14 and 20 volts, will deliver up to 400 milliamperes while maintaining the output constant within 50 millivolts. Ripple from the rectifier is reduced by the feedback action to 2 millivolts at the regulator output. Changes in ambient temperature cause the regulator output to drift only about 1 millivolt per degree F.

In use, these regulator "cards" are mounted adjacent to the circuit cards for which they supply power. By mounting the regulator and the "active" circuit side-by-side, the impedance of the wiring between the two units is kept to a minimum. This arrangement also permits the rectifier, which is generally rather bulky, to be located in a position remote from the transistor regulators. The cards are designed to plug into position to facilitate replacement in the event of trouble, but some trouble-shooting can be done while the card is in service, through the test points on the front of the card.

Regulators for the present experiments in electronic switching use a 6A transistor (p-n-p) for the series element. Although this transistor has a maximum current rating of 0.8 ampere, the regulator was designed not to exceed 0.4 ampere, because of the low heat-dissipating ability of the transistor mounting. The power-dissipation capabilities of a transistor and its mounting surface determine two important characteristics of the regulator: the current capacity and the permissible variation in the dc input voltage. When the 6A transistor is mounted on an adequate heat-

The author points out to Mrs. S. Kolota the 6A transistor used in voltage regulator for experimental electronic switching circuits. The small transistor performs the same function as the electron tube on the regulator in the foreground.

sink, it can safely dissipate 4 watts in temperatures up to 40°C. The parameter that limits power dissipation is the maximum collector-junction temperature, conservatively rated at 80°C in germanium transistors.

The power-dissipation capability of the series element in a regulator is an important design consideration. Four watts, therefore, seems like a low figure of merit when compared to 26 watts for an electron tube like the Western Electric 421A, and 60 watts for the Chatham Electronics 6336 tube, both of which are frequently used as series tubes in regulators. But a straight power comparison is not a true yardstick. When the transistor and the electron tube are compared on the basis of current — for example, 0.8 ampere — a 6336 tube would require 70 volts across the tube, whereas only one volt across a 6A transistor would suffice. With the 421A tube, three tubes operating in parallel at a plate potential of 50 volts would be required to pass 0.8 ampere. To the power engineer, such a comparison reveals a great deal about the efficiency of the transistor. Furthermore, the electron tube as a series element would require considerable filament power (30 watts or more) and some warm-up time, while the transistor needs neither.

Another important consideration in the design of transistor voltage regulators is the collector-junction leakage current of the series transistor. This leakage current plays an important part in determining the *minimum* load current of the regulator. With no base current applied to the series transistor, the current flow at the output of the series transistor would be β (the current gain) times the leakage current. If the load current is smaller than this, the voltage drop across the emitter and the collector cannot be controlled by the base current, and the regulator will not function properly.

For high-temperature operation, minimum load current may be fairly large, because the leakage current increases at the rate of about 8 per cent per degree C. To correct this condition, the base of the series transistor is biased with a current equal to the leakage current at the minimum-load condition. A simple remedy for this would be a resistor connected between the emitter and the base of the series transistor.

In addition to power and current limits, there are maximum voltages beyond which the transistor will not operate. This maximum cannot be exceeded without risking destruction of the transistor and hence the effectiveness of the regulator. The operating voltage, or rather the restraint on it, determines the maximum amount the input voltage to the regulator may vary, and indirectly limits the output voltage.

For example, in a regulator designed to stabilize changes in ac input voltage of plus or minus 15 per cent, it would be imprudent to design a regulator to deliver more than 40 volts without taking precautionary measures. If the regulator used in the experiments in electronic switching were modified for 40-volt operation, the first time the power was applied to the input the transistor would have to absorb about 50 volts until the output capacitors charged. This would be sufficient potential to cause a "punch through" on the 6A transistor, which has a collector-to-emitter rating of 40 volts.

To overcome this initial-overload condition, a small junction diode — acting as a voltage limiter (RECORD, *December*, 1956) — can be connected in parallel with the series transistor. This diode will "break down" and conduct before the maximum safe operating voltage for the transistor is attained, and will by-pass the transistor until the voltage level is lowered. With this technique, series-transistor regulators have been designed with outputs as high as 150 volts.

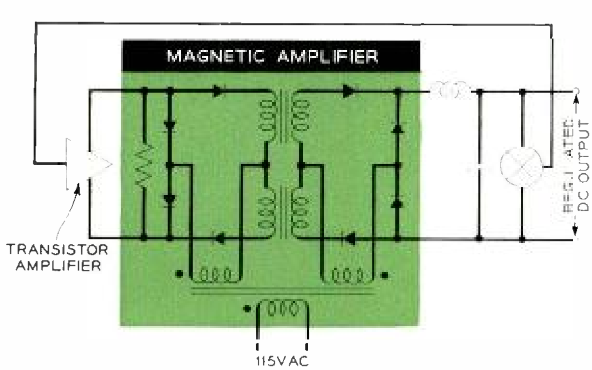
Where the load current always exceeds the rating of the series transistor, several alternatives in regulator design may be used. For example, where it is practical to split the load into several parts, two or more regulators can be arranged to operate from a single rectifier. Two regulators designed to operate this way are shown in the middle of page 445. Sometimes this approach offers the additional advantage of preventing crosstalk or "crossfire" between the loads. The prevention of noise may be an additional requirement in some systems even though the impedance of the regulator is only a fraction of an ohm. Another expedient for exceeding the current rating of the transistor, frequently used when load currents exceed one ampere and cannot be divided, consists of operating several power transistors in parallel within the regulator. This requires special circuitry, however, to ensure equal division of the load current among the paralleled transistors.

Both alternatives point up the fact that the higher-power transistors now being developed will be welcomed by power engineers. Using transistors with higher current, voltage and power capabilities, designers could extend the limits of the dc output of series-type regulators well beyond the ranges discussed here. And this could be done easily, without recourse to special arrangements or extra circuitry.

An entirely different form of voltage regulator was designed for the TRADIC and *Leprechaun* digital computers, developed at Bell Laboratories for the Air Force. The design of these regulators was largely dictated by the high (for transistor circuits) current drains — up to 8 amperes. The regulator combines a magnetic amplifier (RECORD, *January*, 1958) with a transistor amplifier as shown in the simplified schematic below. The magnetic amplifier is a full-wave type circuit. It consists essentially of two toroidal cores that have rectangular hysteresis loops and a number of rectifying diodes. Each core has a control winding and a power winding. The ac-input voltage is stepped down to the desired level by a transformer, rectified by the silicon diodes on the right of the diagram, and smoothed by the L-C filter arrangement.

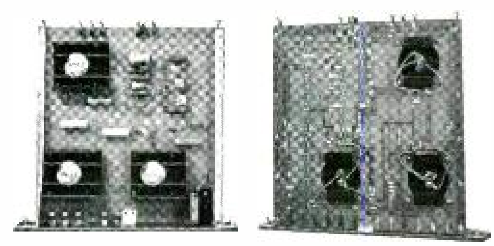
The principle of operation of this regulator is quite simple. The level of the output voltage can be changed by controlling the amount of voltage absorbed in the power windings of the magnetic amplifier. The power windings appear at the right of the cores in the schematic and are in series with the load.

The cores of the magnetic amplifier alternate in furnishing load current during one-half of the ac cycle of input and in absorbing control intelligence during the other half cycle. The cores possess a high value of remanence so they are capable of "remembering" flux. A change in the voltage applied to the control windings during non-conducting half cycles therefore determines the amount of reset flux in the cores and the amount of ac conducted in the next half cycle of the power wave. The control voltage for the magnetic amplifier is regulated — through a bridging resistor — as a function of the output current of the transistor amplifier. An increase in the current that determines the control voltage will cause the dc output to increase, while a drop in current will lower the dc output.



Transistor magnetic-amplifier regulator used to supply power to Leprechaun transistor computer.

To complete the regulatory feedback loop, an error detector similar to the type shown at the top of page 443 is connected across the output. The error signal of the detector is increased by an amplifier which terminates in a power transistor. In this circuit, the collector current of the power transistor does not exceed 100 milliamperes, but this small current is capable of controlling a load current 100 times as great.


Front and back of regulator packages designed in "slide" form to operate side by side from a single rectifier. Heat-sinks conduct heat away from transistors and make them more efficient.

Although this regulator is very efficient and precise, its dynamic response is not as fast as the series-transistor type because of the response limitations inherent in magnetic amplifiers.

These two basic power circuits — the series-transistor type and magnetic-amplifier type — are merely representative examples of the many methods by which transistors and silicon diodes can be used to control dc power. These designs are very flexible and have been used to furnish regulated dc power as low as 2 volts and 8 amperes in TRADIC and *Leprechaun*, and as high as 150 volts at 1.2 amperes for experimental electronic switching circuits.

Power limits will undoubtedly be extended when new solid-state devices made by the diffusion technique (RECORD, *February*, 1956) become available. By using this new technique of diffusing gaseous impurities into semiconductor surfaces, it may soon be possible to develop transistors that have much higher power-handling capacities than those now available.

Gas-filled diodes are useful, electronically controllable switch elements. Like transistor switches, they could conceivably be used to interconnect signal-carrying circuits such as telephone lines or trunks. New, miniature "talking-path" diodes developed at Bell Laboratories also have a usable "negative resistance" to ac signals like voice waves and ringing tones.

A. D. White

AN EXPERIMENTAL GAS DIODE SWITCH

Cold-cathode gas tubes are used in many areas of the telephone system as switches and as control devices. For example, several million of these tubes are used as the "trigger" elements in the selective-ringing circuits for four-party arrangements. Other types of gas tubes serve as voltage stabilizers and as reference tubes in regulated power supplies; they also protect against undesirable surges of voltage in undersea cables.

Gas tubes make valuable switching elements primarily because they have two stable states—one at zero current and one at high current. Further, such tubes can transfer to the high-current state in a fraction of a millisecond by the application of a voltage pulse of short duration. Basically, gas diodes are switched on by momentarily raising the voltage to the point where ionization — in "avalanche" proportions — occurs in the gas between the anode and cathode.

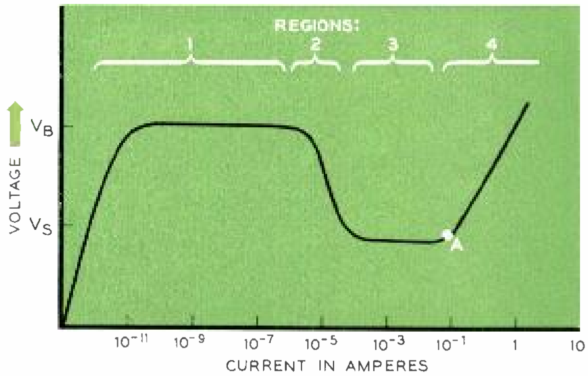
In experimental equipment for electronic switching — currently under study at Bell Laboratories — gas diodes have been used in the switching network to interconnect telephone lines and trunks. The miniature gas diodes for these experimental networks were developed by the Electron Device Development Department.

The switching properties of a gas diode are a consequence of the "breakdown" properties of gases between metallic electrodes. As an illustration of this property, consider the current-voltage characteristics, shown opposite (top), of a very simple gas diode. This tube is filled with a noble gas at a pressure of about 1/10 of an atmosphere, and has electrodes that are plane-parallel disks spaced about 2 millimeters apart.

The breakdown voltage (V_B) is the voltage at which an ever-present but very small value (about 10^{-11} amperes) of "residual" current in the tube multiplies by many orders of magnitude. At this voltage (*region 1 of the curve*), the current flow between the electrodes is maintained by both avalanche ionization in the gas and secondary emission of electrons from the cathode caused by returning ions.

At a somewhat larger current (10^{-6} amperes), however, a positive space-charge begins to form at the cathode, enhancing both the ionization and secondary-emission processes, and the discharge makes an abrupt transition (*region 2*) to a low-voltage, high-current state. The voltage necessary to sustain this state (*region 3*) is largely independent of current. As the current increases, the discharge spreads over the cathode, with complete coverage (saturation) occurring at point A. Beyond point A, both the current density and the tube voltage increase with increasing current (*region 4*).

In either the low- or high-current state, the operating voltage of the discharge is determined by this simple criterion: the discharge must be



"Breakdown characteristic" of a typical, elementary cold-cathode gas diode. Current is plotted logarithmically. V_B is the point on the voltage scale at which breakdown occurs. V_S is the stable operating voltage in the high-current state.

self-sustaining. In other words, each electron leaving the cathode (as a consequence of ion-induced emission) must create enough ions in the gas to replace itself.

With typical gases and cathode materials, this happens with about 100 volts across the electrode gap when the current density is high enough to produce space charge at the cathode (*region 3*). With no space charge, as at low currents, the minimum voltage is about 145 volts (*region 1*). If the current density is too high, however, ionization efficiency is again reduced and the electrons must be given additional energy (voltage) to create the number of ions required for sustaining the discharge. This accounts for the increase in discharge voltage beyond point A.

All cold-cathode gas tubes have a typical breakdown behavior similar to the one we have been discussing. Changes in gas content or electrode design shift the characteristic curve up or down the voltage axis, but do not appreciably influence its form.

The switch-like behavior of a tube with this breakdown characteristic can be demonstrated by connecting a gas diode and a suitably low resistance to a voltage source several volts less than the breakdown voltage of the tube. Under these conditions, only the very small residual current of the tube will flow. For all practical purposes, the tube is an open circuit, analogous to a relay with its contacts open.

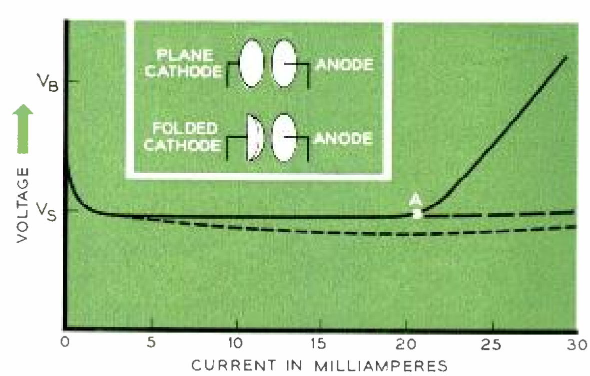
If the source voltage is momentarily raised to a value higher than the breakdown voltage, the tube will quickly break down. The current through the tube will increase rapidly (by a factor of approximately 10^9 in a typical case) until the voltage drop in the resistor equals the difference between the source voltage and the tube voltage. The tube will remain at this stable point — analogous to the energized, or closed-contact state of a relay — until the current is momentarily interrupted.

An additional requirement for the switches in a telephone system is the ability to carry voice and ringing signals — transmission. For gas-tube switches, this means superimposing these ac signals on the steady-state discharge current. Consequently, much of the development work on these experimental gas diodes was concerned with their transmission properties.

If the voice signals through a switching network are to remain unattenuated, the impedance of each switch in the path must be kept as low as possible. Offhand, one might suppose that the best that could be done in this respect would be to duplicate the very low impedance offered by the short-circuit condition of metallic contacts. This is not quite the case, however. By exploiting the properties of a so-called "hollow-cathode" discharge, tube engineers at the Laboratories have developed a switching diode with a usable "negative resistance" to alternating current.

Negative resistance, which implies a gain in signal power, is possible in the gas-tube switch only because energy — in the form of dc power — is supplied to the discharge. For telephone switching, negative resistance is potentially valuable because it permits the use of high-loss components elsewhere in the talking path, with little sacrifice in transmission quality.

Before discussing the resistance or impedance properties of the hollow-cathode discharge, it would be well to explain first some details of the impedance properties in the high-current (or "on") state of the simpler, plane-electrode tube. The current-voltage characteristic of this tube, this time plotted linearly, is shown below. The slope of this curve at 10 milliamperes would seem to indicate that the dynamic, or ac-discharge resistance is practically zero.



Current-voltage characteristic of plane-cathode tube in high-current state, current plotted linearly. Inset shows plane cathode, top left, and single hollow cathode made by folding plane type.

An important phase of gas tube research. Author adjusts lens which focuses light from the discharge tube preparatory to spectroscopic analysis.

This is only true at low frequencies, however, where the current changes are slow enough for the discharge to spread over the cathode (as in *region 3* of the characteristic on page 447). At high frequencies (above 500 cps), the discharge operates with the discharge area fixed in size. Under this condition, the voltage increases with current (as at point A), implying a discharge with positive resistance.

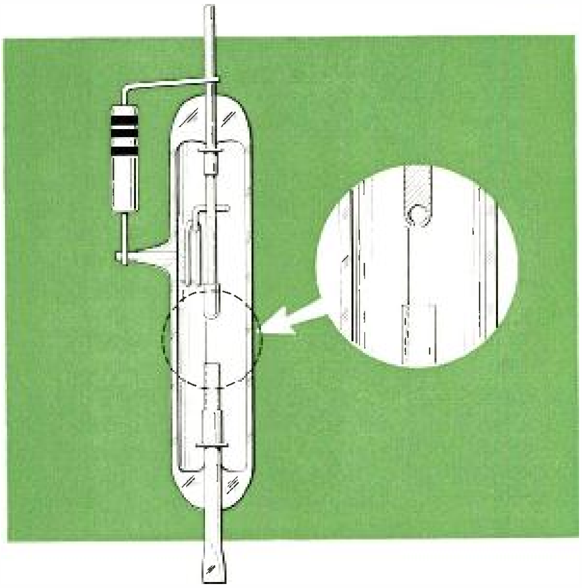
Actually, all stable discharges between plane electrodes in rare gas, at 10 milliamperes, have a dynamic resistance of about 300 to 500 ohms at frequencies in the speech band. If the cathode remains unsaturated, doubling the discharge current doubles the glow area, and consequently halves the resistance of the discharge. This method of reducing the discharge resistance has limitations, however. To achieve a discharge resistance of 3 ohms, for example, a plane-cathode tube would have to have a discharge current of nearly 1.0 ampere and a cathode area of more than 500 square centimeters. Obviously, the plane-cathode tube is not the answer to low discharge impedance.

Physicists who work in gaseous electronics have known for some time that the high-current behavior of a glow discharge can be modified considerably by changing the geometry of the cathode. For example, if the disk-type cathode shown in the inset above the set of curves (see drawing at bottom of page 447) is folded on itself to form the adjacent "bent-penny" structure, the glow-discharge characteristic is both flattened and extended, as shown in the broken line in the same set of characteristic curves.

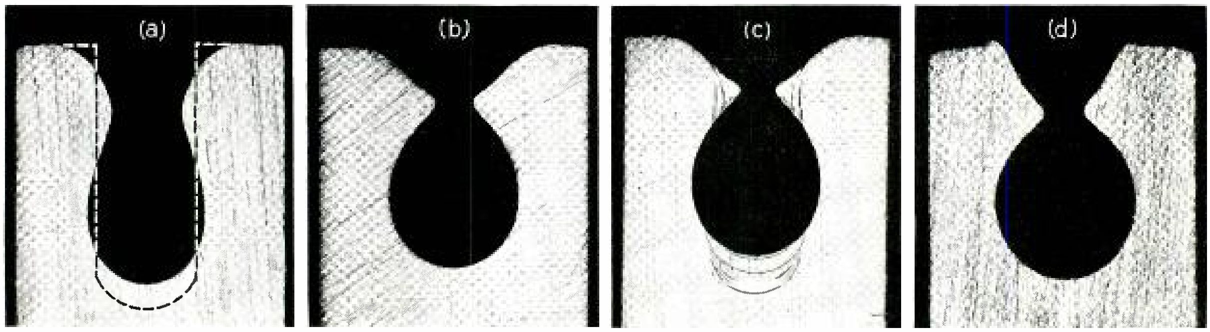
An equally significant change occurs in the density of the operating current at the cathode surface. Depending on the gas pressure and cathode spacing, the current density may rise by a factor of twenty to values of $\frac{1}{3}$ to $\frac{1}{2}$ ampere per square centimeter. This is an extremely high current-density by glow-discharge standards. Most of this current is carried by heavy gas ions which bombard the cathode at high velocity.

Of greatest interest to the tube designer, however, are the changes a hollow cathode produces in the impedance of the discharge. By careful control of the cathode dimensions and gas pressure, for example, it has been found possible to produce a discharge characteristic with a small but clearly defined negative slope—as shown by the dashed line in this same set of curves. Negative-discharge characteristics of this type were first observed in a folded-cathode structure invented by M. A. Townsend at Bell Laboratories.

Unlike the characteristic of the plane-cathode tube, this slope represents the ac resistance of the discharge at all frequencies up to 30,000 cycles per second. Equally important is the fact that this resistance is quite stable, easily reproducible and low enough in magnitude (about — 300 ohms) to be applicable to circuits that can be used for telephone transmission.



"Production" model of talking-path diode, left, and a portion of tube cut away to show the cathode construction. Tube is about 1½ inches long. Resistor and deposit on inside of tube ("getter flash") provide small photoelectric priming current to initiate rapid breakdown in main gap.



This series of photomicrographs (about 45 diameters) shows effect of sputtering on cathode structure. A cathode with cylindrical hollow (a) is transformed by sputtering into spherical shape shown in (b) and (c) but spherical cavity (d) is unchanged. (Micrographs by F. Gordon Foster.)

At the present time, the reason for this peculiar but useful behavior of the hollow-cathode discharge is largely a matter for speculation. The hollow-cathode discharge, even in its simplest manifestation, comprises a whole spectrum of atomic processes and interactions, and only a few of these are understood in any detail. A thorough understanding of the discharge phenomenon is made even more difficult by the fact that most of the discharge processes do not act independently.

Physicists at Bell Laboratories are investigating the various complex processes involved in the discharge and their interdependence, and progress toward a more complete understanding is being made. One concept that is currently receiving considerable attention is the role played by "metastable" atoms, believed to exist in large numbers in the hollow-cathode discharge. Preliminary calculations indicate that if their concentration is high enough, collisions among these long-lived, highly excited atoms lead to a negative-resistance characteristic.

The negative-resistance property of the hollow-cathode discharge was an ideal answer to the successful transmission of voice-frequency currents through a "talking-path" gas diode. Mechanically, however, the simple, folded hollow-cathode has a serious disadvantage: it is subject to rapid deterioration by "sputtering," or high-velocity ionic bombardment. The design of an erosion-proof, hollow cathode was another important aspect of the development of the talking-path diode.

The erosion problem was solved by making the cathode with a nearly spherical cavity having a small aperture that opens toward the anode. In a hollow cathode of this type, erosion is practically non-existent since the sputtered atoms are trapped and redistributed evenly over the interior surface of the cavity. Some forms of non-spherical hollow cathodes may be eroded by many hours of operation to end up with a spherical "cavity."

As the set of photomicrographs (above) shows, a cathode with a cylindrical hollow (a) may be rapidly transformed by erosion into a cathode with a spherical cavity (b). The third cathode of this group (c) has been etched to illustrate the areas of deposited sputtered material. The cathode at the far right (d) is similar to the final design of the cathode for the talking-path diode. This cathode has been operated for nearly 15,000 hours — corresponding to more than a century of service life.

The talking-path diode which the Western Electric Company manufactured in limited quantities for experiments in switching-network design is shown enlarged and cut-away on the preceding page. The discharge operates almost entirely within the cavity at current densities of more than ½ ampere per square centimeter. At the usual operating current of 10 milliamperes, the tube has a negative resistance of about 225 ohms. The anode is made in the form of a fine wire to achieve the high breakdown voltage required for operation of the diode as a switch.

This gas diode meets both the switching and transmission requirements of experimental electronic switching systems, but in some respects the optimum characteristics of the device have not yet been achieved. For example, it would be possible to design simpler and more economical switching circuitry if the negative resistance of the tube did not depend so strongly on the direct current of the discharge. Recent developments resulting from experiments with gas mixtures and new cathode materials indicate that substantial improvements can be made in this and other characteristics of the tube.

To conduct modern electronics research, engineers often need special measuring equipment. Typical of such equipment is a broad-band oscilloscope tube, built by Bell Laboratories as an aid in observing high-speed repetitive phenomena.

D. J. Brangaccio

New Broad-Band Oscilloscope Tube

Ultra-short pulses of electrical energy are being used more and more in our work of communications. Examples range from the testing of waveguides to applications in pulse code modulation systems. Until recently, crowding more information into a particular time "slot" was impractical because no equipment existed to measure this information. Such equipment now exists, however, in the form of a new broad-band oscilloscope tube built at Bell Laboratories.

Although the ultra-short pulses last only a few milli-microseconds in time, they comprise a frequency spectrum that extends toward a thousand megacycles. Therefore, the equipment necessary to measure and display these pulses must be able to deal with band-widths that extend into this high range. The ordinary type of oscilloscope, however, cannot handle signals much in excess of 100 mc because the picture size decreases rapidly above this frequency.

In a conventional oscilloscope tube, where the beam is deflected by a single pair of parallel plates, there is an upper frequency limit of operation determined by the time an electron spends in the deflection region. For example, assume that the electron requires 0.01 microsecond to pass through this region. If a signal of 10 mc is now applied to the deflecting region, the electron will pass these plates in one-tenth of an RF cycle. During this period it will experience a nearly uniform deflection. An increase in frequency of the signal to 100 mc, however, causes the RF voltage across the plates to go through a complete cycle during the electron's transit. Thus the electron is deflected upward during one half of its path and downward during the other half — the total deflection is zero. This effect is the major reason that scientists made investigations in a traveling-wave deflection system.

The disadvantages of oscilloscopes possessing narrow-band characteristics have been overcome in a traveling-wave oscilloscope. This new broad-band tube can handle signals up to 500 mc and is capable of displaying repetitive pulses which last only a few milli-microseconds. Features of the latest version of the tube include a trace width (actual width of line on the screen) of about 0.01 inch, and a requirement of 50 millivolts on the 76-ohm input line to deflect the beam by one trace width. The tube also requires 0.4 milliwatt of RF power to produce a peak-to-peak deflection of ten trace widths. The most noteworthy feature of this tube is the vertical deflection system, which consists of a helix wound of flat tape. In this section, each turn of the flat helix acts as a small deflecting plate and produces a cumulative deflection of the beam.

To understand the advantages of this new tube, it would be well to examine the general aspects of traveling-wave tubes. In these tubes, the electron travels at a speed equal to about one-tenth the velocity of light, depending on the accelerating voltage. On the other hand, the RF field travels along the helical tape at the speed of light. Therefore, if the circumference of the helix is made equal to ten times the distance between turns, the velocity of the wave along the axis will also be one tenth the velocity of light and will thus be equal to the velocity of the electron. With this arrangement, the electron and the wave travel at the same speed through the deflection system. The electron thus experiences a constant deflecting field and the system overcomes its transit-time problem, wherein the electron experiences a changing RF field.

In such a system, the electron deflection increases with distance to the point where the electron will strike the helix. This determines the limiting angle of deflection, which is 3.7 degrees in the new tube. Actually, one could argue that while the electron is directly beneath one section of the tape, it is in a field very similar to the parallel-plate field of conventional tubes. The tape width, however, can be made much narrower than is possible with a single pair of plates. It is this small width that permits the electron to spend a much shorter time in the deflection field; the upper frequency determined by this effect is about 2,500 mc. Narrow tapes result in a very small deflection per section, although the large number of sections gives an over-all deflection that is relatively large.

Physically, the new broad-band oscilloscope tube is 2 inches in diameter and 23 inches long from screen to coaxial lines. It consists of an electron gun, drift space, lens, helix-type vertical-deflection system, parallel-plate horizontal-deflection system, post-accelerating region and viewing screen. The mechanical design of this tube is similar to that of a conventional cathode-ray tube in that the various electrodes that make up the tube are mounted in cylinders supported from ceramic rods.

The functions of the various parts of this tube can best be understood by examining an electron beam as it travels through the tube. An electron beam is generated by an electron gun employing a type "B" Philips impregnated cathode button capable of a current density greater than one ampere per square centimeter. The gun design is one in which the cathode is not easily affected by secondaries — unwanted electrons that return to the cathode. This is accomplished by the first anode — a low-voltage electrode placed in front of the cathode surface — through which the beam passes after leaving the gun (see accompanying drawing). The beam then passes through a second anode, which defines the beam diameter, and through a "drift" region to the unipotential lens. This lens, which serves to focus the electrons on the screen, is followed by the helical deflection system. (This new and important system will be discussed in detail below.)

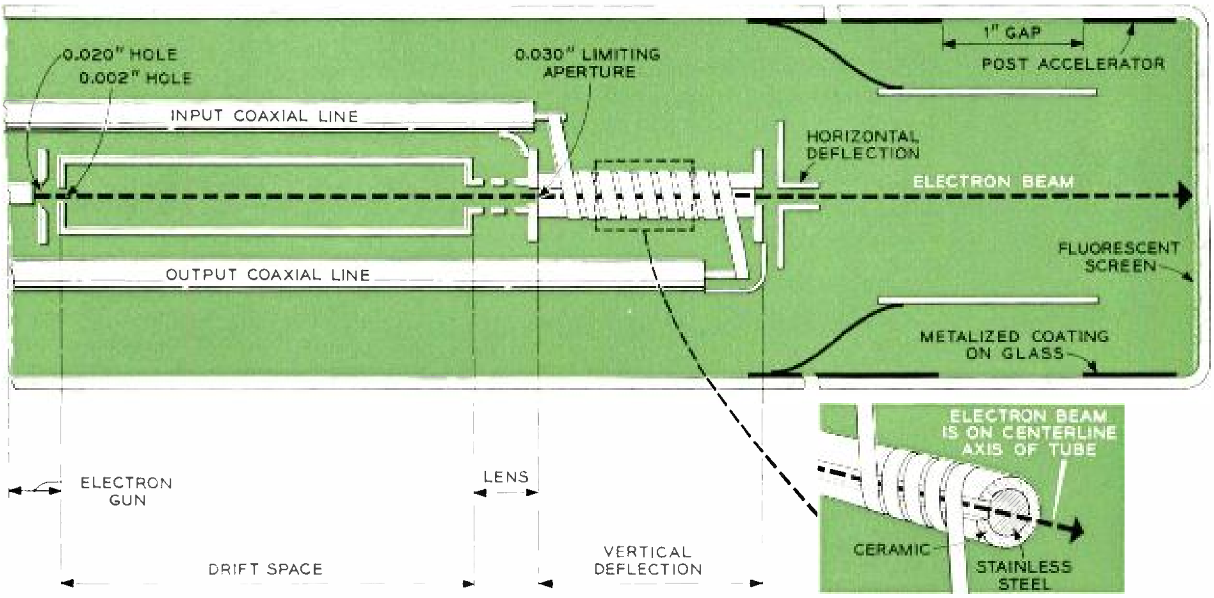
The beam then enters the horizontal-deflection system, which consists of two parallel plates. These plates are usually short, because normally the horizontal signal will be a sine wave of much lower frequency than that of the applied vertical signal. Consequently, the horizontal-sweep circuit may be resonated and large sweep voltages obtained from a small amount of input power. After it leaves the horizontal deflecting system, the beam travels about eight inches to where it passes through a simple post-acceleration lens near the screen. This system has the disadvantage of decreasing picture size as the voltage is increased; therefore the accelerating voltage is limited to a range of from 3,000 to 4,000 volts.

The helix-type vertical deflection system comprises one of the major innovations of this device. The helix is a gold-plated molybdenum tape which is 0.115-inch wide. Nine turns of this tape are wound on a ceramic tube (supported from a stainless steel arbor) with a pitch of eight turns per inch. A section of the ceramic tube is removed to allow the beam to pass between the tape and the steel arbor. One portion of the steel arbor is machined flat to permit the beam to "see" a rectangular cross section 0.108-inch wide by 0.044-inch high. The two ends of the tape are welded to the inner conductors of the input and output coaxial lines. The outer conductor is connected to the body of the vertical deflection system.

Energy is fed into and out of the broad-band tube through 76-ohm coaxial lines; the inner conductors of the lines are welded to the tape and the outer conductor is welded to the steel arbor. Thus the coaxial line is essentially turned inside out — the outer conductor becomes the inner conductor of the deflecting system; the inner conductor of the coaxial line becomes the outer conductor.

Extremely precise physical measurements are required in the construction of the broad-band oscilloscope tube. The assembler must ensure that the various sub-assemblies — the gun, focusing lens and RF structure — are properly aligned and mounted as a unit from the coaxial lines. Before the tube is sealed in its envelope, he must measure

H. R. Hartford, left, and the author with model of broad-band oscilloscope built at the Laboratories.



An important aspect of the new broad-band tube is the "multiple" vertical deflecting plates which limit the time the electron spends in a single deflecting field. Note (inset) rectangular area notched from ceramic cover in order to confine the electron beam to a specific dimensional path.

the RF "match" of the helix circuit. When the electrical tests have been completed, he must check the alignment of the entire structure with an optical comparator. The alignment of the drift tube, focusing electrodes and RF structure is acceptable only when the axial deviation is less than one part in five thousand. Furthermore, the cathode assembly must be aligned axially to within three thousandths of an inch.

Other features of interest in this new tube include the spot size and sensitivity, and the writing speed. The spot size, as imaged on the fluorescent screen, is determined by a 0.002-inch hole located in front of the cathode. The size of the image at the screen is determined primarily by the intervening lens system. The image actually measures 0.01 inch; theoretically it should be 0.007 inch.

Sensitivity of a cathode tube "spot" is best expressed as trace widths of deflection per volt of applied signal. This is because the amount of information that can be obtained from a picture depends not on the absolute height, but rather on the number of elements (trace widths) which make up the picture. Therefore, the spot size should be as small as possible. As stated earlier, the vertical sensitivity of this tube is 50 millivolts per trace width and the field is about 100 trace widths both horizontally and vertically. A 25-milliwatt sinusoidal signal will give the maximum vertical deflection. The horizontal sensitivity is 0.42 volt per trace width, or 42 volts per inch.

One of the most important considerations in high frequency oscilloscopes is the writing speed of the instrument. This factor tells how fast the sweep can travel and still give recordable information, and is usually expressed in trace widths per second. To measure the writing speed of the broad-band oscilloscope, a square wave with a 50 milli-microsecond "rise time" was applied to the tube and the repetition rate of the square wave was lowered until the rise-time portion could no longer be observed. With 2,000 volts of post-acceleration and a square wave with a height of 100 trace widths, rise time was still visible at a repetition rate of 50 times a second. In other words, the writing speed is 2×10^9 trace widths per second when repeated 50 times a second.

To compare this with the conventional method of stating writing speeds, the number of "frames" instrumental in forming an image must be known. The persistence of vision of the human eye is approximately 1/20 second. This means that a certain minimum number of events must occur in this period to form an image—any greater number is superfluous. Using the above numbers, our writing speed becomes 10^8 trace widths per second. The writing speed of this tube may be compared to that of 10^{11} trace widths per second available in special high-speed oscilloscopes.

It is the relatively low writing speed of the new broad-band oscilloscope that makes it more useful in observing recurrent phenomena rather than transients (or single pulses). The tube will thus find application in fields where conventional oscilloscopes cannot be used—mainly the observation of short pulses and other high-speed repetitive phenomena. At present, the Laboratories is using this device to study milli-microsecond pulses.

More than a billion and a half messages a year are now processed by Automatic Message Accounting. To keep pace with this rapidly increasing load, engineers at Bell Laboratories are constantly alert to the need for improving or replacing AMA equipment. This kind of dynamic research and development has led to the great improvements in service and the savings brought about by AMA.

R. G. Ruwell

Ten Years of AMA

Since 1948, when the first Automatic Message Accounting (AMA) Center was put into service in Philadelphia, many changes and improvements have been incorporated in this ever-growing system. Large or small, spectacular or run-of-the-mill, all of the new features reflect increasing activity in the field of direct customer dialing.

The AMA system consists basically of recording equipment for perforating on paper tape all data required for billing purposes, as well as processing machines to compute, sort and summarize charges. AMA was originally designed to make possible economies and improvements in telephone service through a wide expansion of customer dialing. Not only did AMA help to extend dial service to nearby points, it also contributed in large measure to the feasibility of direct distance dialing (DDD).

In addition to providing improved service to millions of customers, AMA has also resulted in large operating savings and expedited the job of message accounting. As a consequence, the Bell System has saved millions of dollars in traffic and accounting expense. In this respect AMA is an outstanding success.

As the demand for customer dialing has increased, new developments in the switching art such as centralized automatic message accounting (CAMA), DDD, and modified automatic ticketing (MAT) have extended the scope of AMA and necessitated the introduction of many changes and improvements in the accounting centers.

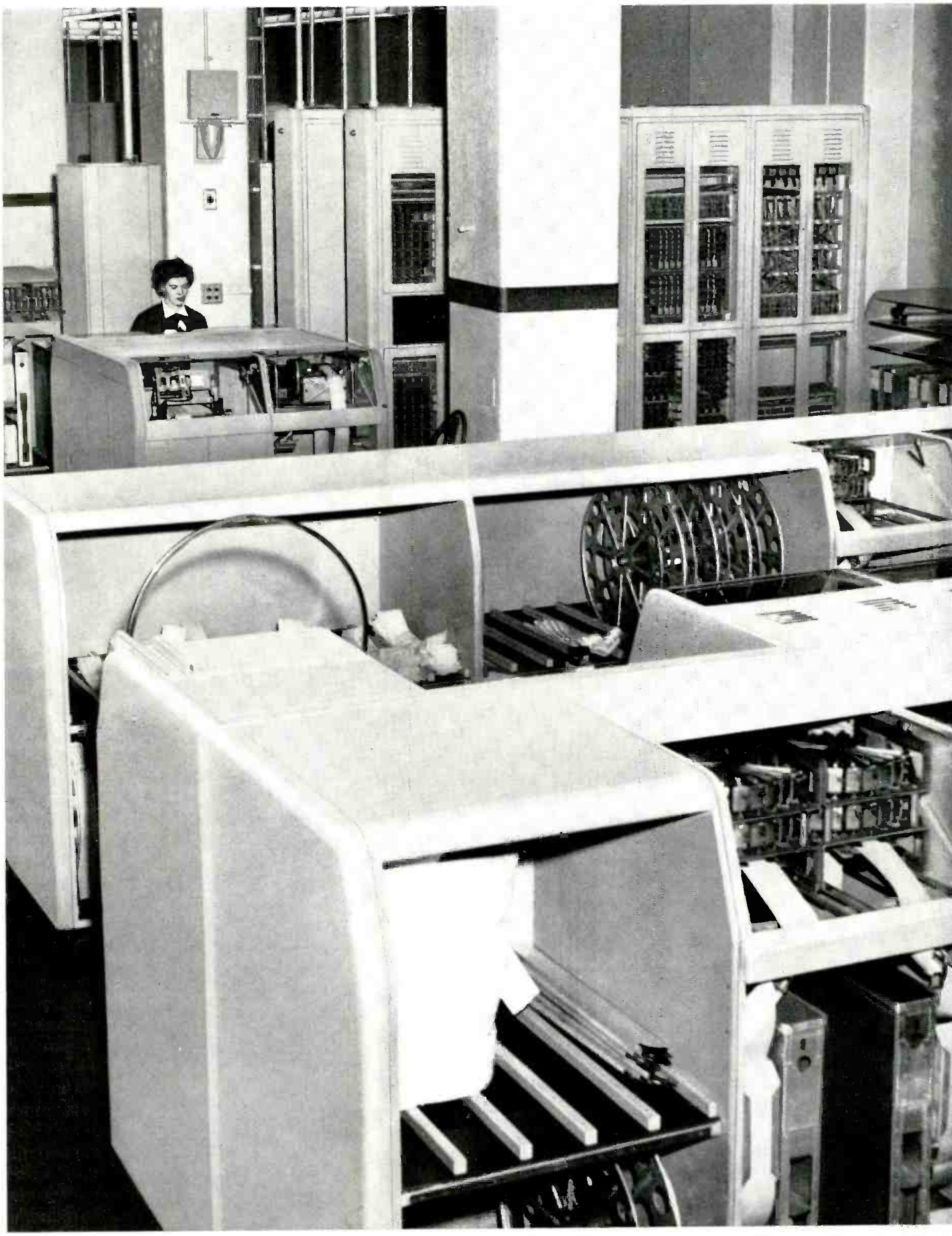
New processing machines, such as the tape-to-card converter, assembler-computer, and the printer-comparer-scanner, have been designed. (These new machines have all been explained in some detail in previous articles in the RECORD—respectively, *September*, 1953; *October*, 1957; and *December*, 1957.) At the same time, many new features have been developed for existing AMA equipment. All of these changes and improvements have been carefully coordinated to ensure continued operation of the accounting center while new equipment is being installed.

When the AMA system was first introduced, all message units (MU) were processed in the sorter and summarizer stages on what was called a "fixed-round" basis. A "round" is an interval of a given number of days, during which the MU output is accumulated for further processing. The rounds at that time were either three or five days.

There were, therefore, either ten or six rounds per month, but this rigid method of processing did not fit in well with service accounting procedures. As a consequence, all AMA machines were modified for "flexible-period" processing, in which the length of the round can be varied at the discretion of the AMA supervisory force. These modifications enable them to gear the length of the rounds to their own processing needs.

When the "fixed-round" feature was removed from the AMA machines, certain checks having to do with the "round" and "day of round" were of necessity also removed. To prevent increased susceptibility to human error as a result of the removal of these checks, "call count process control" was made available.

This system consists of a group of registers



Automatic message accounting center similar to the one installed at Philadelphia in 1948. Guard in left foreground locates splicing table now partially replaced by portable splicing dolly.

in the central office to count the total number of good initial AMA entries that have been perforated. The daily readings of these registers are noted on the form accompanying the AMA tapes sent to the AMA center. In the accounting center, at the output of the computer stage, there is another set of registers which count (1) the number of toll calls and (2) the number of message-unit calls processed. For a given set of central-office AMA tapes, the sum of these two readings should check, within very close limits, with the number of initial AMA entries recorded in the central office.

There are similar registers or counters on most of the other types of AMA machines, and these are used to make a stage-by-stage check of the number of messages or entries on a given set of tapes as it is processed. Call-count process control, carried through the entire billing process, might therefore be termed a "cradle-to-grave" security system for insuring the integrity of AMA data.

When CAMA was first introduced in Washington, D. C., in November 1953, many changes were required in the AMA center (RECORD, *July*, 1954). With local AMA (LAMA), there were one, two, or at the most four central offices per marker group. With the advent of CAMA, the term "marker group" was changed to "recorder group". (The term "recorder group" is considered preferable, since it is applicable to both LAMA and CAMA installations). Instead of a maximum of four offices, it was now necessary to provide for a maximum of ten offices per recorder group.

Another new requirement added by CAMA was the need for a capacity of 100 recorder groups per accounting center instead of 50 as originally contemplated. This increased capacity was required because each CAMA installation for crossbar tandem adds a potential total of 20 recorder groups, whereas an LAMA installation adds only a single recorder group.

Where CAMA is used to handle toll messages originated by four-party customers in a central office having LAMA for its individual and two-party customers, or where a central office has access to two or more CAMA locations, it was found desirable to translate the CAMA recorder group and central-office index to those used for the LAMA office. The converter was therefore arranged for translating the recorder group and central-office index for as many as 52 recorder groups with a capacity up to ten offices per recorder group.

For central offices with MU traffic, having access to two or more recording locations, an MU tape-merging feature has been made available for the sorter. For instance, MU calls from a given central office may be recorded as "recorder-group 50" "office-index 2" at one CAMA location, and as "recorder-group 71," "office-index 8" at another CAMA location.

With the MU merging feature, these two tapes are read serially, and the output tape carries only the master recorder-group and office-index designation, which would be recorder-group 50 and office-index 2 in the example given. This feature is operative only on the first pass through the sorter, and enables the sorter to merge the data from as many as four recording locations on a single tape.

The MU tape merger consists of a maximum of forty switches and associated cross-connections mounted in a narrow, 15-inch cabinet. Each merging switch has five working positions, and is arranged to merge the tape outputs associated with five originating offices. This decreases the number of tapes to be handled by the accounting center personnel, which in turn results in economies in clerical effort and in the loading time of sorters and summarizers.

Another development which came about indirectly as a result of the introduction of CAMA was the portable splicing dolly. In the original AMA system, the ten output bins of the perforators in the AMA assembler, computer and sorter were taken out of the perforator cabinets and placed in a bin dolly. This bin dolly was then

Mrs. B. Danklefs, of the New York Telephone Company, Toll Clerk at the Brooklyn, N. Y., AMA Center, operating the new portable splicing dolly.

Structure of Called Number	Called-Number Index	
	Automatic Identification	Operator Identification
Three digit	0	3
Four digit (With or without station)	1	4
Five digit	2	5

wheeled to a splicing table where the ten output tapes were spliced together serially. Then the dolly was wheeled back to the machine, and the bins replaced in the perforator cabinets. With the shorter tapes which resulted from CAMA operation, this could have become a time-consuming and burdensome operation for the people at the accounting center.

To speed this splicing operation, engineers at Bell Laboratories developed the portable splicing dolly. This device can be wheeled alongside the perforator bins, and the tapes from adjacent bins can be spliced together without moving the bins. This is an example of how Mohammed was brought to the mountain rather than having the mountain brought to Mohammed.

Another modification brought about as a result of CAMA was a method for distinguishing between automatically identified and operator-identified AMA messages. The purpose of this distinction is to provide Commercial Departments with information which will aid them in their treatment of customer inquiries on AMA-billed messages.

For this purpose, the called-number index which denotes whether the called number has three, four or five digits, was modified. (Actually, the three-digit, called-number structure has never been used, since customer dialing to three-digit offices on an AMA basis has never been permitted. Three-digit, community dial offices are being converted to four-digits.) The table above shows the new arrangement using the called-number index for the dual purpose of indicating called-number structure and type of identification.

With the introduction of DDD, additional changes were required in the AMA center. The three-digit, numbering-plan area code caused this change, because to accommodate it, an extra line had to be added on the initial entry for calls to the more distant numbering-plan areas. Accordingly, changes were made in the AMA machines wherever this extra line was to be processed. The assembler-computer incorporated this feature in the initial design.

Another feature which came about as a result of handling longer-haul traffic through AMA was the "day-night" coding feature in the converter. This code — a punch in the output card — indicates whether the call should be charged as a station-to-station day call or whether it should be charged at the reduced rates which prevail nights, Sundays, and certain holidays. The day or night period is determined directly from the start time shown on the AMA tape. Transition from night to day is established in the converter by cross-connections at any hour or half-hour between 4:00 A.M. and 8:00 A.M. as determined by tariffs. Similarly, the transition from day to night is established for any hour or half hour between 5:00 P.M. and 11:30 P.M.

Reduced rates also apply to toll calls made on Sundays and certain holidays. A "set-up" panel containing 38 keys and a 12-position switch was provided to take care of this condition. Thirty-one of these keys are associated with days of the current month, and the other seven with days of the succeeding month. The 12-position switch is used to set the current month, and certain of the 38 keys are operated as required to denote Sundays and reduced-rate holidays as they occur during the month and seven days immediately following in the succeeding month. Day-of-the-month keys are reset once a month.

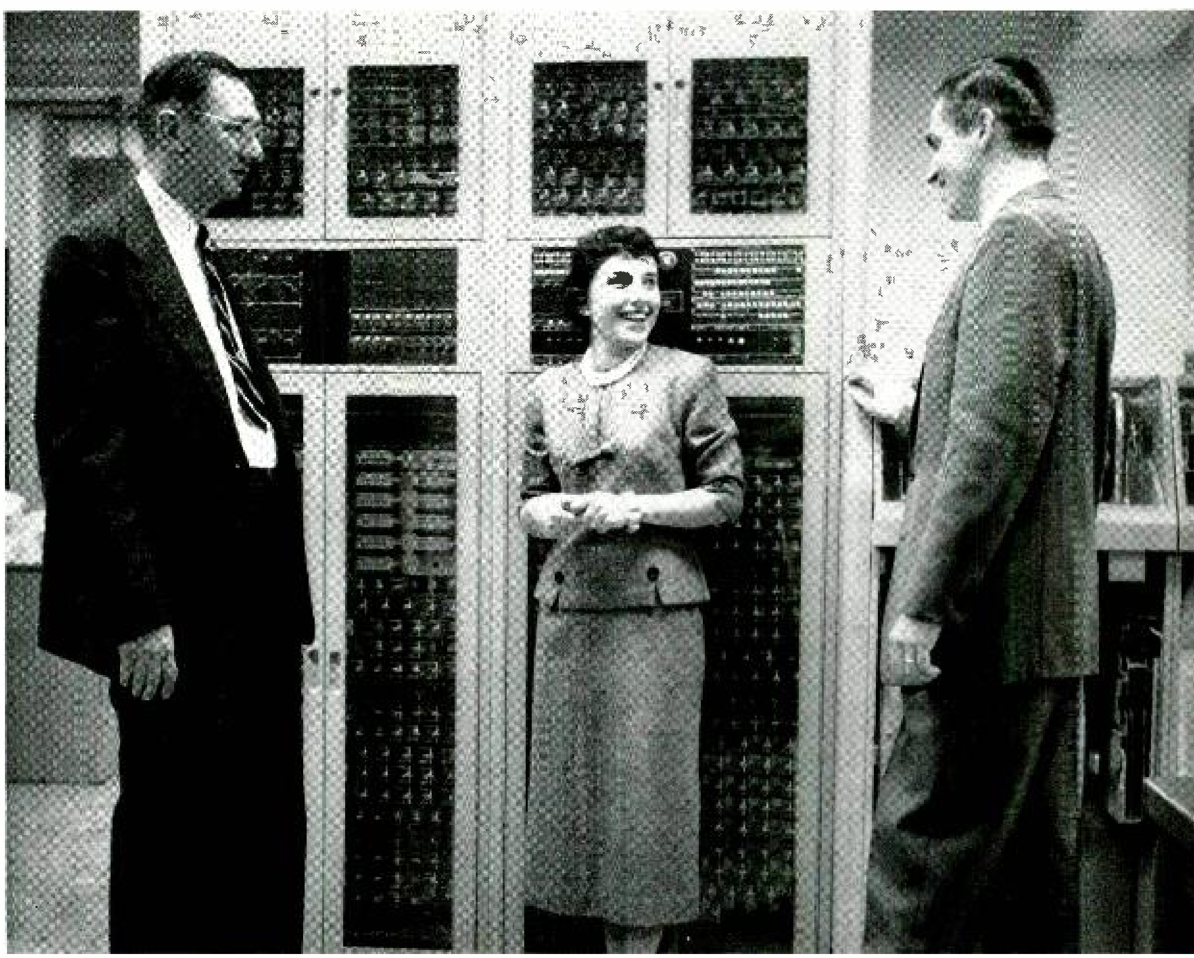
As AMA was introduced into the more sparsely settled areas of the United States, other new problems were encountered. For example, in areas where only very scattered message-unit traffic was to be processed, it appeared uneconomical to buy AMA sorters and summarizers. The assembler-computer was therefore modified to process MU traffic by the "message-unit detail" method, a feature hitherto used only as a source of reference data in the event of customer inquiries. Although this system for handling MU traffic requires a business-machine card for each MU message and results in slightly higher processing costs, an over-all saving will result in areas with only scattered MU traffic due to the substantially lowered initial investment in AMA machines.

At the other end of the population-density spectrum, plans were made to introduce No. 5 crossbar with AMA into the heart of large cities, such as New York, where the volume of single message-unit traffic without overtime charge is large. Here, certain economies could be effected by perforating only the initial and answer entries on the AMA tape and by omitting the disconnect entry on such messages. (Ordinarily, both an answer and a disconnect entry are perforated on all completed messages recorded by AMA machines.)

While this change involved primarily the outgoing trunk circuits of No. 5 crossbar, it also required a minor modification in the AMA assembler-computer to recognize calls of this type and not transfer them to the "straddle" tape as would ordinarily be done with calls having only a single timing entry. A great number of these single timing entry calls without corresponding disconnect entries would have resulted in too much time spent by accounting-center personnel in a vain attempt to associate them with non-existent disconnect entries.

While these changes are some of the more important ones since the inception of AMA, many other less spectacular changes have been made in the design of AMA equipment and its power system. For example, an improved chute for paper tape was designed for the printer, and changes have been made in the design of the aluminum tape reels to improve their ruggedness. A new power rectifier has been designed which has a response fast enough to permit its use without a regulating battery. This change will bring about savings in floor space, first cost and maintenance expense. A new storage cabinet was also introduced to take care of the many short, intermediate tapes resulting from CAMA operation.

In ten years, the number of AMA centers has grown from the original installation at Philadelphia to a total of 33. The total investment in AMA recording and accounting center equipment is now over 96 million dollars and is growing at the rate of 10 million dollars per year. It is estimated that over 1 billion MU messages and 500 million toll and long-distance messages per year are being processed by AMA. The result is a considerable annual net saving in Bell System traffic and accounting costs, together with vastly improved service for telephone customers.



The author, left, discusses functioning of the AMA computer with Miss M. De Bella, AMA supervisor, and F. Baurenfiend, both of New York Telephone Company, at the Brooklyn, N. Y., AMA Center.

An important design consideration for modern electromechanical switching systems is compactness of equipment. The "two-in-one" type of wire-spring relay has been developed using two independent relays with five contact positions each, mounted as a unit in the same space required for the twelve-position type.

T. H. Guettich

THE "TWO-IN-ONE" WIRE-SPRING RELAY

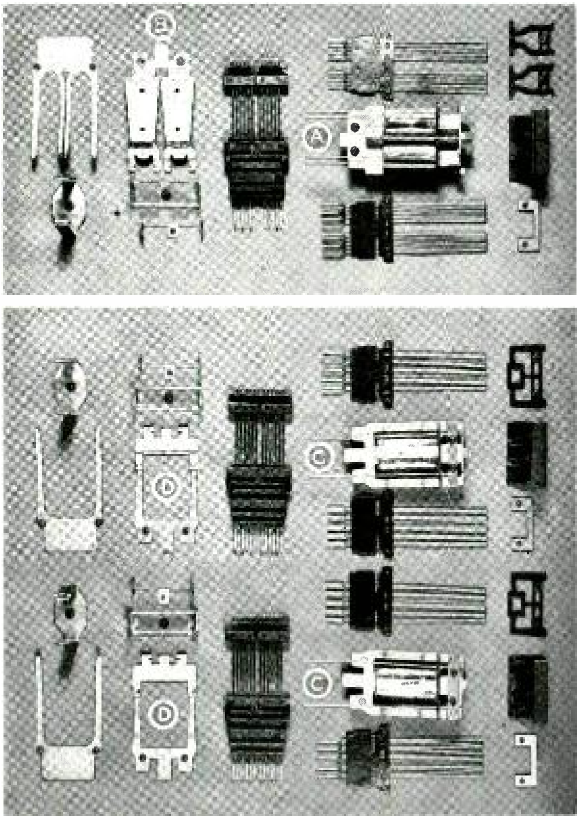
Wire-spring relays, because of their excellent performance, long life, high operating speed and low cost, are rapidly being incorporated into new telephone switching systems. The operating principles of the general-purpose wire-spring relay (RECORD, *November*, 1943), and the number of automatic processes for manufacturing it, have proved so attractive that other relays have been designed using the same principles. One example is the wire-spring multicontact relay (RECORD, *April*, 1957). The latest member of this growing family is a "two-in-one" general-purpose unit, known as the AK-type relay shown on page 460. This occupies the equivalent space and mounts interchangeably with the "single" wire-spring general-purpose relays now in service.

Although the "single" general-purpose relay has twelve contact positions available, many of the circuits in which it is or may be employed require contacts at fewer than six of these positions. Since, in the design of modern telephone equipment, space conservation, like time of operation, is "of the essence," the logical decision was to provide a unit consisting of two relays, each having five contact positions which fit in the same space required by the twelve-position relay.

It was recognized at the outset that, to make this structure economically possible, the molded wire-spring assemblies of the twelve-position relay would have to be used in the new units without major change. Existing manufacturing processes and facilities could then produce wire-spring components for both relays. By designing around these wire-spring molded assemblies as basic building blocks, the objective of a "two-in-one" design has been achieved. In effect, two relays, each having five available contact positions, are constructed on a common core or base to form an integral unit.

The other parts, except for the armature assemblies, are either identical with, or variants of, the corresponding "single" general-purpose relay parts. This similarity of new and existing parts presupposes the use of similar tools, machinery and processes which has the economic advantage of minimizing the expense and effort of manufacturing development. The similarity of components is seen in the photograph on the next page, which shows a comparison of the parts of the "two-in-one" relay with those of the two general-purpose relays that would otherwise be required to provide equivalent contact capacity. Most of the parts have been combined into integral designs that serve a common function for both halves of the new unit. Where parts must function independently — the contact-operating cards and the armature — such parts are identical for both halves. Thus fewer different parts are needed per unit.

An example of how modifications of an existing design have been used to advantage in the new relay is found in the design of the plastic contact cover. To design a cover suitable for the "two-in-one" unit, it was only necessary to widen



A striking comparison of the parts of the "two-in-one" relay (upper) with those of the two general-purpose relays formerly required to give an equivalent contact capacity for switching.

the center slots of the cover design used for the earlier relay. In this way, suitable clearances were obtained for the center legs of the restoring spring and for the struts of the operating cards in the new design.

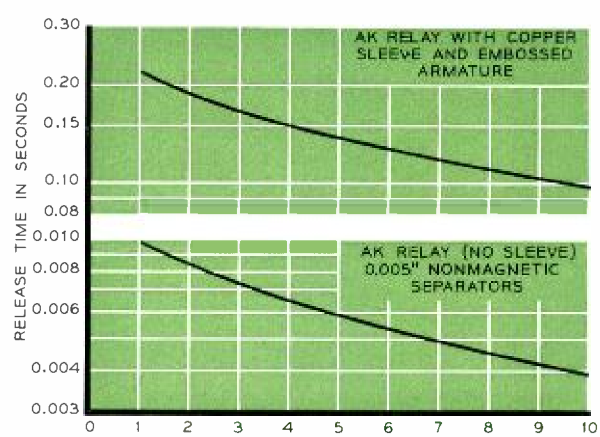
The design resulting from the foregoing approach might appear to be the same as that of the twelve-position relay. However, closer examination will reveal that the use of separate armatures, contact-operating cards and windings, has actually resulted in two functionally independent relays which will mount in the same space now occupied by the single relay.

Still closer inspection also reveals a major difference in the magnetic circuits. In place of an E-type core, single flat armature and single winding, the new unit has a U-shaped core, two formed, rather than flat armatures and two separate windings. The magnetic circuits are illustrated in the photograph above. The core and armature assemblies respectively designated A and B are employed in the "two-in-one" relay, those marked C and D in the "single" relay. The flat steel plate indicated is interposed between the two windings and the armatures of the new relay to act as a shield that substantially eliminates magnetic interference between two essentially separate magnetic circuits.

Formed armatures of the configuration shown in this photograph were chosen as the return paths of the magnetic circuits to permit maximum winding volume within a limited space. The two armatures are attached to a common hinge spring of a design that permits their independent operation. The method of attaching this hinge is an example of how component design of the new unit has benefited from the solution of similar problems encountered in the development of the twelve-position relay. It is necessary to wrap a portion of the spring around the armature before spot-welding the two together. This tends to "bulge" the spring where it is interposed between the armature and the core, thereby increasing the reluctance of the airgap at that point with a consequent reduction in the operating capability of the magnetic circuit. Considerable development effort on the earlier design relay resulted in a method of obtaining a tight wrap that achieves the desired spring flatness. This method is also used in the new relay, but is applied to a spring of a different design.

To complete this picture of two independently operable relays, each armature has attached to it a "lyre-shaped" contact-operating card. One end of the card engages two legs of a four-legged restoring spring. This arrangement enables each card to control the contacts in its associated group of five positions independently of those in the other half of the unit. The restoring spring is also of design interest, since by the addition of two center legs, the functions of two of the "single" general-purpose relay springs have been combined into one part.

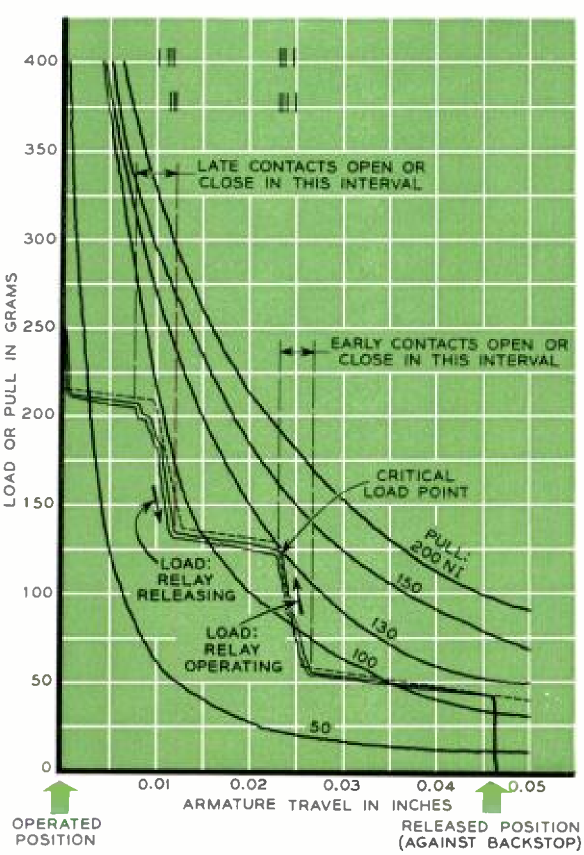
Characteristic load and pull curves for one half of an AK "two-in-one" relay are illustrated



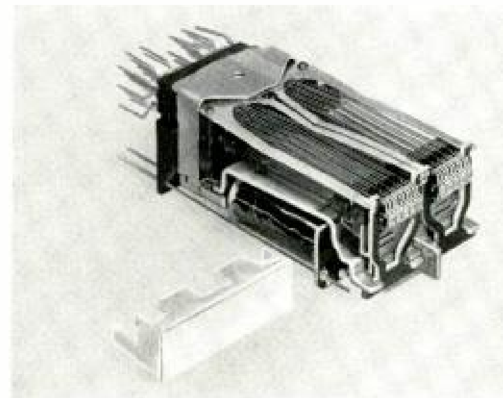
Typical release-time curves for basic and slow-release types. The AK relay (no sleeve) is represented by the lower curve and the AK relay (with copper sleeve) is indicated by the upper curve.

in the diagram on page 460. The regular curves relate load in grams on the armature versus its travel in inches, in both the operate and release directions. The area between these two curves is a measure of the friction in the relay. As can be seen, friction is low and represents a very small fraction of the spring load at all values of armature travel. The values of load are about the same as would be expected from a single general-purpose relay having the same number of contacts. The smooth curves show the pull in grams resulting from several values of ampere turns — that is, for different values of current in the winding. Because of limitations in winding space, the pull capability of the new relay is not as great as that of the "single" unit, but it is nevertheless adequate for present applications.

The end result of these important changes in the design of the components is a relay with the inherent performance and manufacturing advantages of the earlier unit. Furthermore, as mentioned previously, all components except the contact-operating cards, the windings and the armatures, are common to both halves of the unit.



Typical load and pull curves for the "two-in-one" unit. Irregular curves relate load in grams on the armature vs *its travel in inches, in both the operate and release directions for this spring relay.*



"Two-in-one" wire-spring relay with lyre-shaped cards and formed armature; contact cover at left.

Because of this reduction in the number of parts required to produce two relays, a substantial saving can be expected in manufacturing and assembly costs as compared to those of two comparable twelve-position relays.

In addition, the AK relay is particularly attractive for use in equipment where space conservation is a major factor. The first use of this "two-in-one" unit will be in the small, modern 756A PBX (RECORD, *December*, 1957) and in the 1A1 Key Telephone System.

A slow-release version of this unit, coded AK1 has also been developed, primarily for the 1A1 Key Telephone System (For discussion of slow-acting relays, see (RECORD, *April*, 1948). This is of interest because it demonstrates the flexibility of the new design. The slow-release feature was attained, at very little cost, by incorporating two changes in the basic design: a comparatively minor modification of the armature, and the addition of a copper sleeve assembled over the core leg and within the winding. The change in the armature consists of the elimination of the conventional nonmagnetic stop disks and the substitution of a shallow hemispherical embossing, thereby reducing the magnetic circuit reluctance when the relay is in its operated position. It also reduces variations in reluctance caused by small angular misalignments between the armature and core. This feature proved to be of great value when it was first incorporated in Y-type relays and more recently into AG wire-spring types.

To maintain a nonmagnetic gap between the core and the embossed hemisphere of the armature, both components are given a wear-resistant chromium-plate finish. In the initial application, the slow-release feature has been used with only one half of a "two-in-one" unit, but there is no technical reason prohibiting the use of slow-release with both halves. The curves on page 459 show typical release times for the basic relay and for the slow-release version.

One of the century's most exciting engineering feats, the transatlantic submarine cable from Newfoundland to Scotland, called for an astute gathering of old and new electronic equipment. Past and present terminal equipment was successfully combined to meet the new design requirements for the long-life cable.

W. F. Miller and C. A. W. Grierson

Carrier Terminals for the Transatlantic Telephone Cable

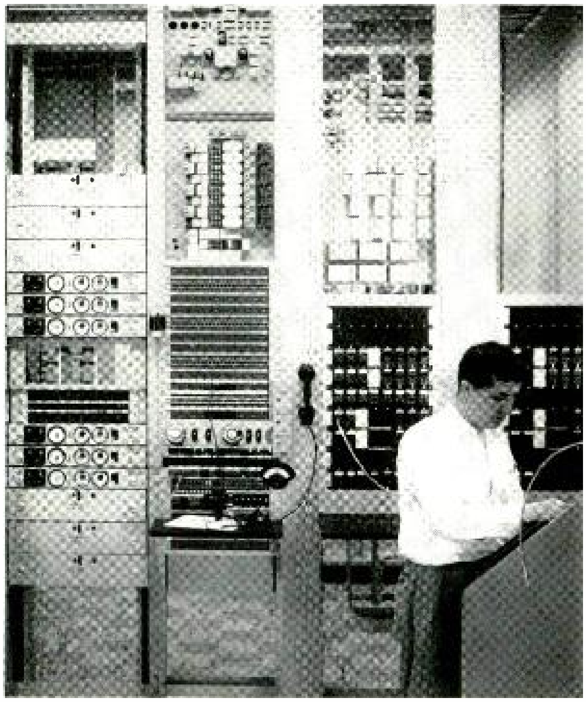
Among the new designs required for the transatlantic submarine cable system (RECORD, *February*, 1957) were those for the terminal equipment used at Sydney Mines, Nova Scotia, Clarenville, Newfoundland, and Oban, Scotland. Fundamental design principles for these terminals, as well as other elements in the system, were specified in early design conferences.

One such principle was that standard equipment, or modifications of standard equipment, would be used wherever possible to minimize design effort. To simplify supply and maintenance procedures, it was further decided that, insofar as possible, Bell System equipment would be used at Sydney Mines and Clarenville, and that British Post Office equipment would be used at Oban. Moreover, to obtain the necessary reliability, all terminal equipment at these three remote locations was to be provided in duplicate with provisions for quick changeover if it became necessary.

The design of the cable system, particularly the terminal equipment, was simplified to a considerable extent because British carrier telephone equipment and Bell System equipment are compatible. Both systems use 4-kc spacing between channel carriers, 12 channel groups in the 60- to 108-kc band, and "supergroup" allocations between 312 and 552 kc.

This compatibility made it possible to interconnect the American and British systems at standard group or supergroup frequencies. Also, compatible design prevented the distortion that would have been introduced if it had been necessary to modulate the channels down to voice frequencies at intermediate points.

The thirty-six message channels in the deep-sea cable were divided with twenty-nine message channels extended to White Plains, N. Y., and six to Montreal. (RECORD, *February*, 1957). The one remaining channel was split — half the space was assigned to Montreal and half to White Plains. The half of this message channel assigned to Montreal provides that city with six telegraph channels to London. No initial use was contemplated for the half assigned to White Plains. The Montreal-to-London channels were located in the 68- to 94-kc part of the deep-sea submarine cable frequency band (20 to 164 kc) to obtain about the same average channel noise as that for the White Plains-to-London channels. Since the 68- to 94-kc band corresponds to group frequencies of 60 to 86 kc, it was necessary to split a 60- to 108-kc group frequency band into two parts. The portion of the band from 60 to 86 kc is assigned to Montreal-London and the remainder from 86 to 108 kc to White Plains-London circuits. Group-split-



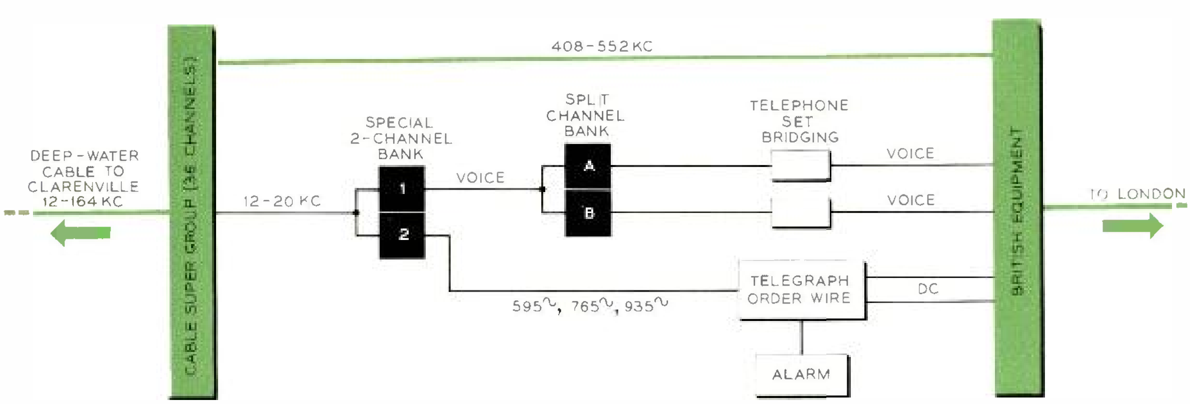
Part of the terminal equipment at Clarenville, Newfoundland. Bays at the left contain the monitoring equipment; the 92-kc pilots continuously monitor transmission between the cable terminals.

ting filters are used at the Sydney Mines terminal to separate these channels.

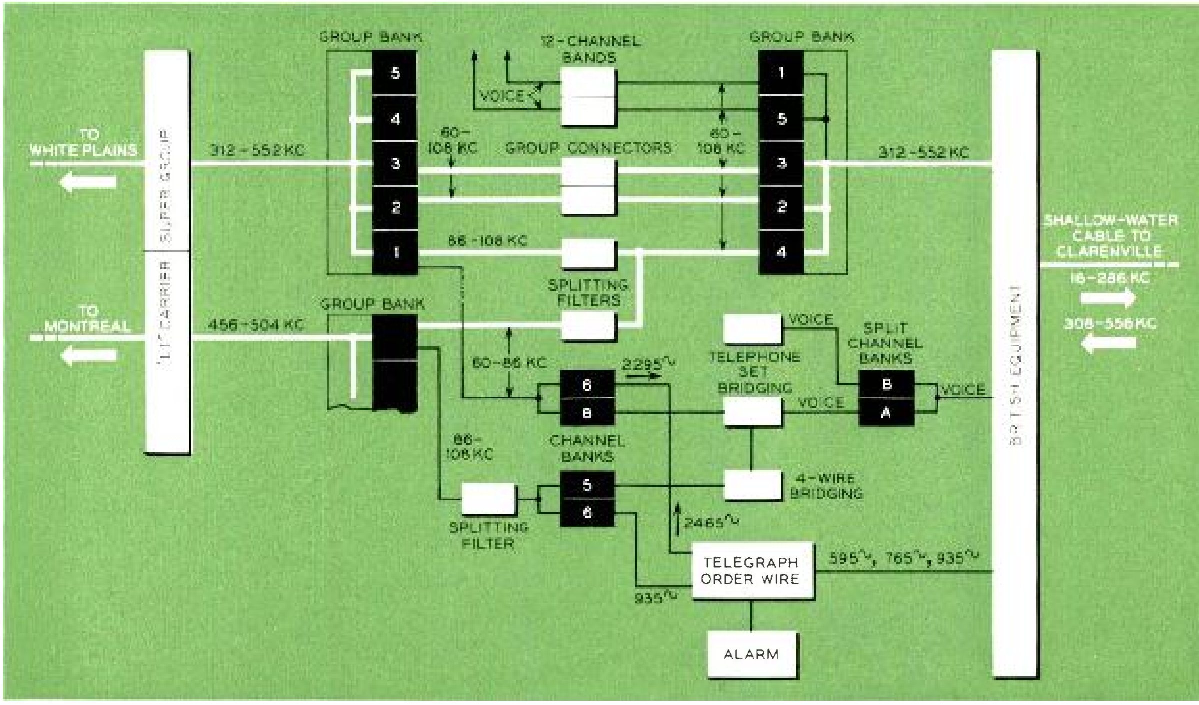
Some of the terminal equipment installed at Clarenville is seen in the photograph above. Arrangements of the terminal equipment supplied by the Bell System for use at Sydney Mines, Clarenville and Oban are also indicated by the simplified block diagrams shown below and on pages 463 and 464. The circuits shown on pages 463 and 464 are basically L1 Carrier Group Banks that have been modified to provide access for continuous monitoring of the system pilots — the continuously transmitted frequencies used to indicate system performance. These units efficiently translate super-group frequencies to group frequencies.

The thirty-six incoming transatlantic message channels are translated in the receiving group bank from their supergroup frequencies to three group frequency bands, each of which covers a range of 60- to 108-kc. The receiving group banks are cross-connected, through group connectors, to their respective transmitting group banks. Here the message channels are translated back to supergroup frequencies. This arrangement of equipment provides a supergroup connecting circuit, with facilities for breaking the through circuits and for connecting any twelve message channel group to standard channel bank equipment. Such connections are needed for emergency re-routing or maintenance at voice frequencies. Maintenance facilities for the Montreal circuits are provided in a separate enclosed area at both Sydney Mines and Clarenville.

A new design was required for the supergroup equipment associated with the deep-sea cable at Clarenville and Oban, as illustrated in the diagram below and on page 464. This equipment translates the 408- to 552-kc supergroup frequencies for the thirty-six channels to the submarine cable line frequencies — 20 to 164 kc — for transmission over the deep-sea cable at the proper levels. Protection is included to prevent overloading the submarine cable repeaters. In the design of this supergroup, standard, modified standard and new types of equipment were used. A new supergroup modulator-demodulator was designed. This circuit uses a carrier frequency of 572 kc from an L1 carrier supply circuit which was modified to select, amplify and distribute the carrier. The 408- to 552-kc frequency band from the L1 carrier group bank is translated in the supergroup modulator to the 20- to 164-kc band



Block diagram of terminal equipment at Oban, Scotland. This equipment is the actual connecting link between the British communication system and the deep-water Clarenville cable.



Block diagram of terminal equipment at Sydney Mines, Nova Scotia; this connects the microwave system to the shallow-water cable and forms the junction of Montreal and White Plains circuits.

(lower sideband). This band is selected by a low-pass filter and is amplified by an auxiliary amplifier of the type used in the Key West-Havana terminal.

A new transmitting amplifier was designed to amplify further this frequency band to the required level for transmission to the cable through the desired pre-equalization. Low modulation and a sharp overload characteristic are provided through the use of a large amount of negative feedback. This transmitting amplifier protects the repeaters from overload, since it is operated closer to its overload than are the under-sea repeaters in the over-all cable.

The 20- to 164-kc frequency band received from the deep-sea submarine cable is amplified by two auxiliary amplifiers (Key West-Havana type) and equalized. It is then translated to a 408- to 552-kc submarine cable supergroup band of frequencies in the submarine cable supergroup demodulator. These frequencies (lower sideband) are selected and amplified by a modified L1 carrier intermediate transmitting amplifier before they are transmitted to the modified L1 carrier group bank at Sydney Mines.

At Clarenville and Oban, the order-wire (speaker and printer)* channel equipment consists of Bell System split-channel banks, two channels of a modified C5 open-wire, carrier channel bank, and C5-carrier transmitting and receiving amplifiers with associated equipment. It also includes a newly designed telephone set bridging circuit, as well as a standard signaling supply, signal receiving equipment and telegraph equipment. The C5 channel bank was modified to provide carriers at 16 and 20 kc and channel bandwidths comparable with the message channels of standard Bell System A4 channel banks.

Channels 1 and 2 of the modified bank translate the audio frequencies to deep-sea cable frequencies of 16 to 20 kc and 12 to 16 kc respectively. Channel 2 is used for two telegraph order-wire channels, one direct from White Plains to London and the other with bridging facilities at specified points along the system. It also contains a third telegraph channel used at one cable terminal to indicate when transmission alarms occur at the distant terminal.

Channel 1, in conjunction with the split channel bank, is used for two-voice order-wire channels, one local between adjacent submarine cable terminals, and the other an over-all order wire with bridging facilities at specified points along the system. Each point on the system with bridging facilities can communicate with any other bridging point. Selective ringing is provided for calling in any one or all connected points. Provisions have also been made so that the split chan-

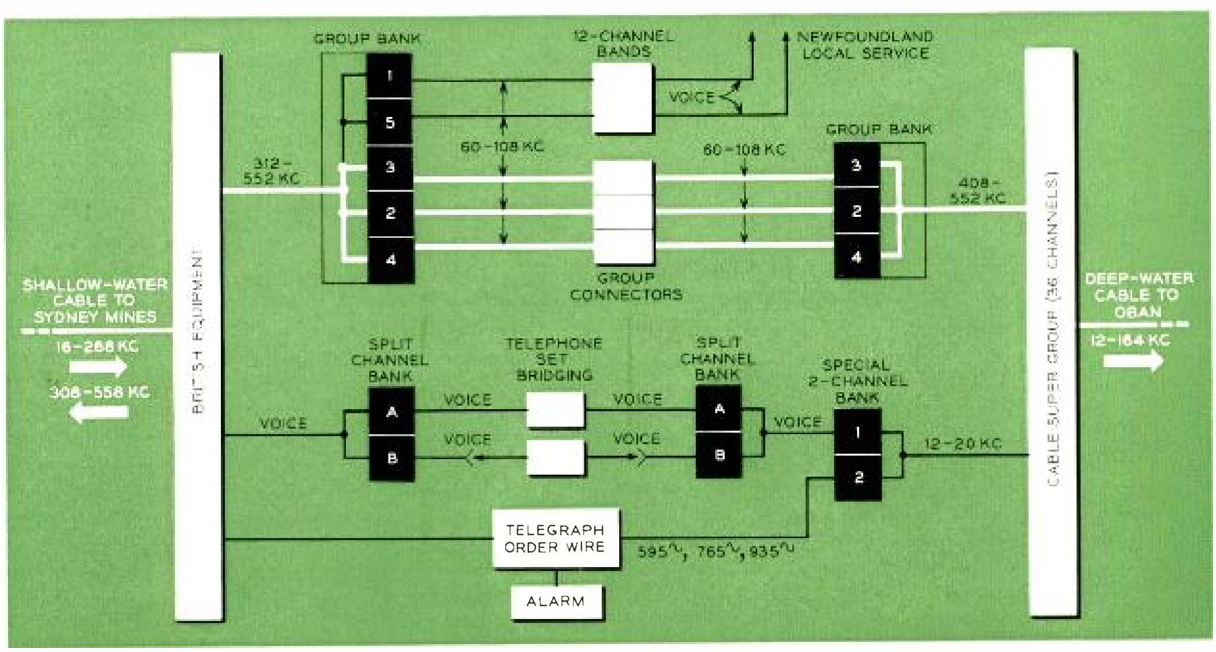
* For this project the term "speaker" was used for the voice order wire and "printer" for the telegraph order wire to avoid a misunderstanding in the meaning of the words "order wire" in the United Kingdom.

nel banks can be removed to eliminate the local order wire channels. This will provide a broad-band over-all voice order-wire channel when desired. The telephone bridging circuit was designed for an echo path loss of more than 60 db.

At Sydney Mines, the order-wire channel equipment consists of the new telephone set bridging circuit, standard signaling supply and signal receiving equipment, and telegraph equipment. The order-wire, four-wire bridging circuit, which was designed to provide a branch circuit to Montreal and to maintain the high-loss echo path, is also a part of the order-wire channel equipment at Sydney Mines.

Special equipment was required at Sydney Mines and Clarenville to supply a stabilized 92-kc pilot. This equipment was patterned after the 92-kc stabilized supply for the Bell System K2 carrier system. Special equipment was also required at Sydney Mines, Clarenville and Oban to check the 92-kc pilot levels continuously and to provide pilot-level alarms. The 92-kc pilots with their associated equipment provide continuous monitoring of the transmission in the sections of the submarine cable system that are located between cable terminals. The two bays on the left in the photograph on page 460 contain this new monitoring equipment.

The final design of the cable terminals, involving the intermixing and interconnection of Bell System and British Post Office equipment, was the result of close cooperation and the best judgment of personnel from the British Post Office Engineering Department, the Long Lines Department of the A.T.&T. Co., and Bell Telephone Laboratories. The successful completion of the over-all Transatlantic Telephone Cable system, in which the cable terminals are important links, is a good indication of the spirit of close cooperation that existed among the partners.



Block diagram of cable terminal equipment at Clarenville, Newfoundland; this arrangement connects the shallow-water cable to the deep-water cable and provides circuits for Newfoundland.

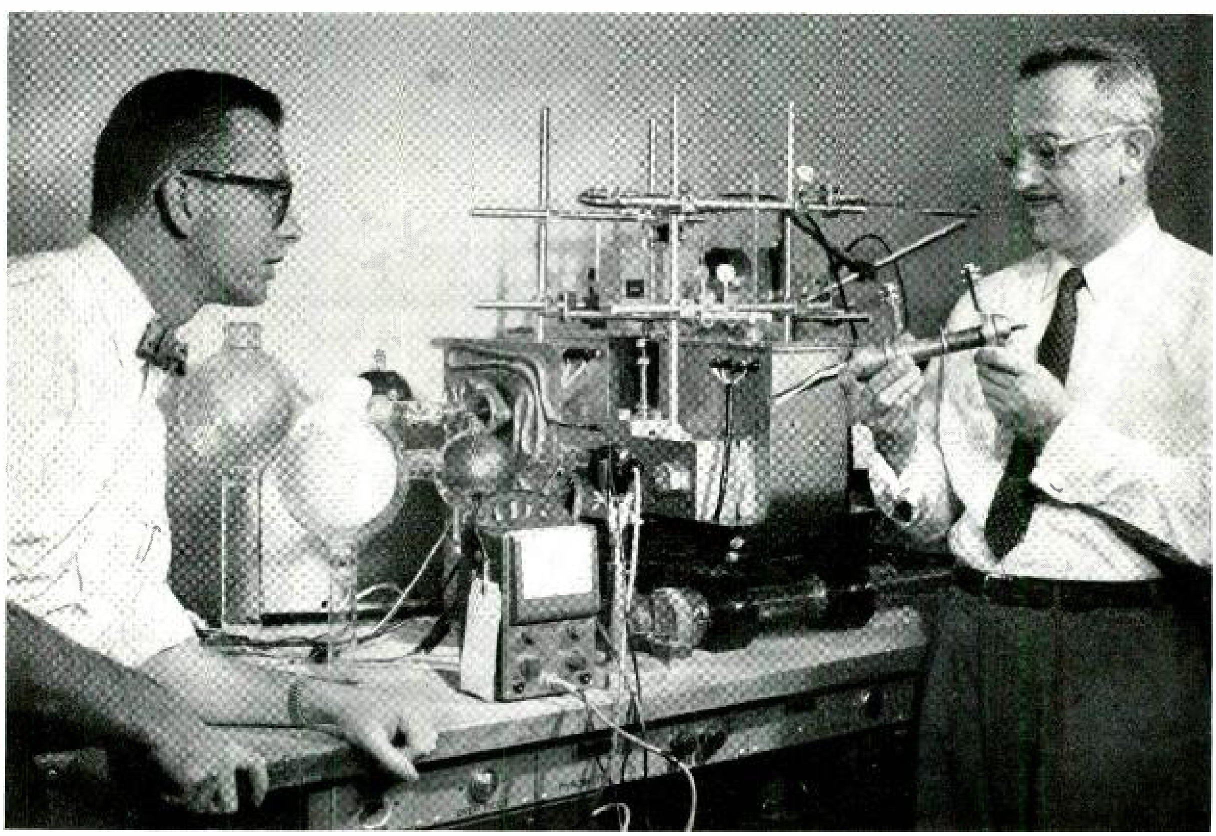
Six Papers Are Presented to the IRE Electron Devices Group

Scientists and engineers from Bell Laboratories recently acquainted the IRE Professional Group on Electron Devices with new developments at the Laboratories in the fields of modern amplifiers and techniques for connecting electronic components. The papers — presented at the Group's annual meeting in Washington, D. C., on October 31 — described new semiconductor devices, a new traveling-wave tube, and the latest developments in thermo-compression bonding.

A new traveling-wave tube in the early stages of development at Bell Laboratories was discussed by W. E. Danielson of the Military System Studies Department in a paper prepared by him and H. L. McDowell and E. D. Reed of the Electron Device Development Department. The importance of this device lies in its ability to put out 100 milliwatts of power or more at 55,000 megacycles, operating in a bandwidth of 10,000 megacycles.

Interest in frequencies in this high range has been sparked by the possibility of long-distance transmission of signals whose wavelength is measured in millimeters. These signals would be transmitted in a circular mode through round waveguide buried in the ground. The new tube could be used as a power amplifier for such a communication system; it has produced ten times more continuous wave power at this frequency than has been reported for any other amplifier.

In brief, the tube works as follows. A 7000-volt, 3-milliampere electron beam is projected through a helix four inches long and 15 mils in diameter. This helix is made of copper-plated molybdenum wire wound at the rate of 110 turns per inch. A magnetic focusing field of about 1500 gauss permits the beam to pass through the helix with 5 or less per cent of the beam current being intercepted. By means of a converging electron gun, the density of the cathode current is held to



H. L. McDowell, left, and L. J. Speck discuss the 55,000 megacycle traveling wave tube. At this frequency, the tube can put out 100 milliwatts of power in a bandwidth of 10,000 megacycles.

H. L. Mellor watches Miss Joyce Hoffmann attach lead to diode by thermocompression bonding.

about 1 ampere per square centimeter — a value which should make the cathode last several thousand hours.

Although similar in principle to helix-type traveling-wave tubes used at lower frequencies (see page 450), the millimeter-wave tube required a completely new design approach because of the small sizes involved. Manufacturers can obtain high precision by a combination of optical alignment techniques and special machining operations. The interesting result is the ability to obtain tolerances of about one-ten-thousandth of an inch for the tube as a whole, even though the parts that make up the tube can be less precise.

H. L. Mellor of the Device Development Department spoke on recent developments at Bell Laboratories in thermocompression bonding. He related that it is now possible to form large-area contacts between metallic leads and semiconductors. It is also now possible to attach leads to opposite sides of a semiconductor wafer simultaneously — thus making both anode and cathode contacts at one time.

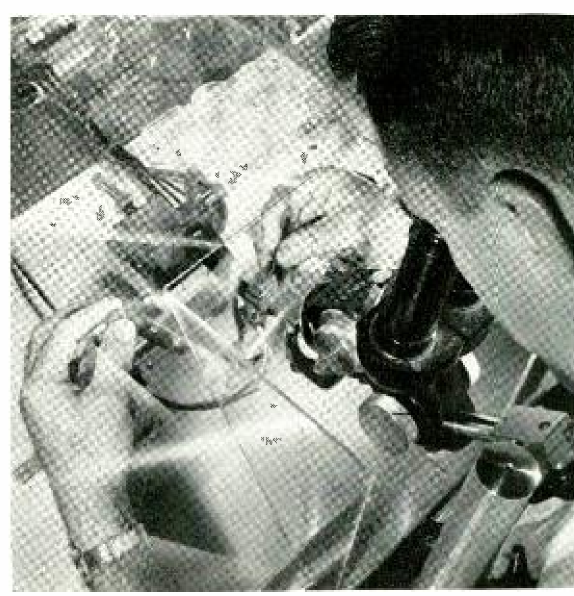
In thermocompression bonding, soldering and alloying techniques are eliminated, along with undesirable low melting materials and fluxes (RECORD, *September*, 1957; *November*, 1957). In a simplified form of the bonding process, the assembler presses a soft metal lead against the gold-plated surface of a semi-conductor. He then applies moderate heat, and adhesion generally takes place in a few seconds. Pressures required are from 12,000 to 20,000 psi and temperatures required range between 300 and 325°C. These temperatures are well below the melting point of either the metal lead or the semiconductor, and the pressures are below the deformation point of the semiconductor.

For large-area contacts, assemblers take gold or silver leads, from six to fifteen mils in diameter, and affix "heads" somewhat like tiny nails. These heads, commonly 30 mils in diameter, are fitted into a hollow jig in a ram and are pressed against the surface of a heated semiconductor. The assembler can also use wires with flattened ends in this manner when the diameter of the lead is too small to make "leading" practical. Laboratories engineers are presently using this bonding method to attach leads to diffused silicon diodes.

Another compression bonding technique, designed to make a bond stand extremely rough treatment, was outlined by T. B. Light of the Semiconductor Device Development Department. This technique fastens leads to the metalized surface of germanium in high-frequency transistors. The structure can handle a centrifugal force of 100,000 G's and very severe shocks.

To form the "rugged" bond, the assembler presses the wire on the desired area with a tool shaped as a half cylinder. He employs a force to deform the wire about 85 per cent, at a temperature of the annealing range of the lead material (about 300°C for gold). In a non-oxidizing atmosphere, a bond can thus be formed in one or two seconds which is stronger than the lead material itself.

A switching transistor developed for high-current, high-speed applications such as magnetic



Using a microscope, T. B. Light "compression bonds" gold leads to high-frequency transistor.

memories was described in a paper prepared by C. A. Bittmann, J. F. Aschner, J. J. Kleimack, W. F. J. Hare and N. J. Chaplin, all of the Semiconductor Device Development Department. The transitor is an n-p-n silicon unit with a diffused base and diffused emitter. This switch will control three-quarters of an ampere, with rise, storage and fall times of approximately one-tenth of a microsecond.

N. C. Vanderwal of the Allentown location of Bell Laboratories discussed the design and development of small, diffused germanium transistors to be used as millimicrosecond switches and also as oscillators and amplifiers in the frequency range of from 100 to 500 mc. He explained that objectives of the development program were to produce transistors having high gain at high frequencies. Furthermore, the devices, although small in size, were to be reliable and low in cost.

Another solid-state device designed at the Allentown location of the Laboratories is a diffused silicon diode to be used for moderately high speeds and high forward currents. As described in a paper prepared by P. Zuk, E. Lampi, and J. B. Singleton, this diode has a recovery time as short as 0.02 microsecond, making it particularly useful for switching applications. Some of its features include a forward voltage drop of 0.75 volt at 100 milliamps, a breakdown value greater than 100 volts, and a saturation current which at 40 volts is less than 0.1 microampere at room temperature. The authors also explained the diffusion techniques that form the junction and provide the proper distribution of recombination centers (RECORD, *February*, 1958) necessary to control recovery time in the reverse direction. To insure stability, the device is "baked" at high temperatures in vacuum.

The Professional Group on Electron Devices is a relative newcomer to the IRE. The October convention was only the fourth held since the group began. This group, however, is fast growing in importance, and is thus keeping pace with the field of electron devices in modern technology.

W. G. Pfann Receives Sauveur Award of ASM

W. G. Pfann of the Metallurgical Research Department has received the 1958 Albert Sauveur Achievement Award of the American Society for Metals. He thus joins a group of international metal scientists who since 1934 have been honored by the Society for their contributions to the science of metallurgy.

Mr. Pfann, inventor of the zone-melting process for producing ultra-pure germanium and silicon, received the Sauveur Plaque at the annual dinner of the Society in Cleveland on October 30. The ceremonies were held in conjunction with the 40th National Metals Exposition and Congress of the ASM. He was cited for his "contributions to the fields of metallurgy, semiconductors, chemistry and solid-state physics."

Mr. Pfann has published some 30 papers, including the book *Zone Melting*, and has over 40 patent applications. In 1955 he received the Mathewson Gold Medal of the American Institute of Mining and Petroleum Engineers for his papers on zone melting. Other citations include one from Cooper Union in 1956 and the 1957 Clamer Medal of the Franklin Institute.

The Albert Sauveur Achievement Plaque honors the memory of the "dean of American metallurgists," who, born in Belgium in 1863, won fame for his pioneering in metallography and for his work as a teacher.

W. G. Pfann, left, receives the Albert Sauveur Award of the American Society for Metals from G. MacDonald Young, president of the ASM.

news notes

W. C. Tinus Attends Army Advisory Talks

W. C. Tinus, Vice President of Bell Laboratories in charge of one of the areas devoted to military programs, attended the annual fall meeting of the Army Scientific Advisory Panel in Colorado Springs, Colo., October 26-29. Also attending this meeting of civilian scientists and industrialists was A.T.&T. Co. Vice President J. W. McRae, coordinator of defense activities for the Bell System.

D. E. Trucksess Named Fellow of A.I.E.E.

D. E. Trucksess, Power Development Engineer at Bell Laboratories, has been elevated to the grade of Fellow by the American Institute of Electrical Engineers. He was cited by the A.I.E.E. for his "contributions to power supplies for high-frequency communication systems."

Mr. Trucksess has been with the Laboratories since 1926 and since 1956 has been in charge of the design of power systems for switching, transmission and military equipment. During World War II, he was the supervisor of a group designing power supplies for military radar, sonar and radio equipment. He is a native of Philadelphia, Pa., and received a B.S. degree in electrical engineering from Pennsylvania State University in 1926.

Contents of the November, 1958, Bell System Technical Journal

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

Functional Design of a Stored-Program Electronic Switching System, by H. N. Seckler and J. J. Yostpille.

A High-Speed Line Scanner for Use in an Electronic Switching System, by A. Feiner and L. F. Goeller, Jr.

A Signal Distributor for Electronic Switching Systems, by L. Freimanis.

Application of Breakdown Devices to Large Multistage Switching Networks, by T. Feldman and J. W. Rieke.

The Timing of High-Speed Regenerative Repeaters, by O. E. De Lange.

Experiments on the Timing of Regenerative Repeaters, by O. E. DeLange and M. Pustelnyk.

Statistics of Regenerative Digital Transmission, by W. R. Bennett.

Timing in a Long Chain of Regenerative Binary Repeaters, by H. E. Rowe.

Helix Waveguide Theory and Application, by Hans-Georg Unger.

Attenuation of the TE_{01} Wave Within the Curved Helix Waveguide, by D. Marcuse.

J. E. May, Jr. Elected Chairman of IRE Group

J. E. May, Jr. of the Solid-State Device Development Department will be Chairman of the Professional Group on Ultrasonics Engineering of the Institute of Radio Engineers for the year 1958-59. The group is one of the I.R.E.'s 28 professional units.

Mr. May also received the group's "Best Paper" award for his paper, "Low Loss 1000 Microsecond Delay Lines," which appeared in the *Transactions* of the ultrasonics group.

Fortune Magazine Publishes Two Articles On Bell Laboratories

Two articles devoted to the history, organization and activities of Bell Laboratories appear in the latest issues (November and December) of *Fortune* magazine. The first installment, entitled "The World's Greatest Industrial Laboratory," deals mainly with research activities at the Laboratories and includes, along with the text, a seven-page portfolio of photographs, many of them in color. The second part, "Tomorrow's Telephone System," is devoted mostly to current development work and its possible impact on the Bell System, and is illustrated by numerous photographs and drawings.

Written by Francis Bello of the *Fortune* staff, these are the most comprehensive articles on Bell Laboratories ever published in a general magazine.

C. E. Shannon Appointed To M.I.T. Science Chair

C. E. Shannon, mathematical consultant to Bell Laboratories, has been appointed to the recently established Donner Chair of Science at the Massachusetts Institute of Technology. The new professorship was made possible by a $500,000 grant from the Donner Foundation of Philadelphia.

Mr. Shannon, formerly a mathematician at the Laboratories, is regarded throughout the world as the originator of, and a leader in, the vital new field of Information Theory. At the Laboratories, he specialized in research on communication theory, computing machines and automata.

In 1957, Mr. Shannon became Professor of Communications Sciences in the Department of Electrical Engineering at M.I.T., and also Professor of Mathematics. While holding the Donner Chair of Science, he also will have the rank of Professor in the two subjects.

Four New Books Written By Laboratories Authors

Four new books written by members of Bell Laboratories have been published recently.*

Two of these, Volumes II and III of *Transistor Technology*, complete a three-volume set on this subject, and depend on Volume I (see RECORD, *August*, 1958) for the development of fundamental concepts and descriptions of earlier techniques and processes. Edited by F. J. Biondi of the Semiconductor Device Development Department, Volumes II and III are devoted about equally to general information on transistors and specific information on germanium and silicon.

Volume III is in two divisions—the technology of materials with special emphasis on silicon, and principles of transistor design. The information on single-crystal materials was chosen to suit the needs of the technologist. The principles of design start with considerations of the diode and proceed to the more complex multiple-junction devices. Volume II also considers radiation-sensitive and field-effect devices, noise behavior, and the design implications of surface phenomena.

Volume II, shortest of the set, is in four major divisions — the preparation of junction structures, fabrication technology, measurements and characterizations, and reliability. All of the four divisions have an editorial introduction to provide continuity to the specific and detailed chapters.

Transistor Technology should be of interest to all of those who work in, or are interested in the rapidly expanding field of transistors and semiconductor devices.

Physical Acoustics and the Properties of Solids was written by W. P. Mason, head of the Mechanics Research Department. Mr. Mason's book is an introduction to the uses of wave transmission in solids, and describes both engineering applications and analytical uses. Chapters are divided into two parts, the first of which is devoted briefly to practical applications and methods of measurement. The second part is devoted to the analysis of the sources of dissipation and elastic dispersion in solids, and covers the effects of thermal conductivity, sound scattering, dislocations, lattice-electron interactions; and many other properties.

The underlying physics is presented as simply as possible with a minimum of mathematics, but an appendix rigorously develops the mathematics of stress-strain phenomena and other relationships. The book is expected to be of great aid to physicists, mechanical and electrical engineers, crystallographers, metal physicists, and both inorganic and physical chemists.

The fourth book, *Man's World of Sound* was written by J. R. Pierce, Director of Research — Communications Principles and E. E. David, Jr., Director of Visual and Acoustics Research. This book explores the science of human sound in its entirety. It synthesizes, for both the layman and the specialist, the recent discoveries and developments in acoustics, electronics and psychology that bear on man's use of sound.

The authors trace the history of experiments with sound from the Greeks to the modern scientist, and they show how sound waves behave in the throat, in the ear, and in electronic devices. They discuss hi-fidelity and appraise such modern refinements as binaural and stereophonic sound. *Man's World of Sound* should be valuable and interesting to anyone interested in the nature and uses of sound.

**Transistor Technology, Volume II* (Bell Laboratories Series), edited by F. J. Biondi. 701 pp., $17.50, D. Van Nostrand, Princeton, N. J.

Transistor Technology, Volume III (Bell Laboratories Series), edited by F. J. Biondi, 416 pp., $12.50, D. Van Nostrand, Princeton, N. J.

Physical Acoustics and the Properties of Solids (Bell Laboratories Series), Warren P. Mason, 414 pp., $9.00, D. Van Nostrand, Princeton, N. J.

Man's World of Sound, J. R. Pierce and E. E. David, Jr., 287 pp., $5.00, Doubleday, Garden City, N. Y.

Science and Research to Be Featured in 1959 "Telephone Almanac"

The 1959 *Telephone Almanac* will feature inventions and discoveries that have grown out of telephone research. The Murray Hill, N. J., location of Bell Laboratories is illustrated on the *Almanac* cover, and the 12 calendar pages depict outstanding scientific contributions made by the Bell System.

One of these is the science of radio astronomy, discovered in the early 1930's by Karl G. Jansky during the course of studies of static and noise that plagued early transatlantic radiotelephone service. Other scientific contributions by Bell Laboratories which are illustrated in the *Almanac* include the Bell solar battery, the transistor, sound motion pictures, television, over-the-horizon communications and the recently invented transistorized numeral reader.

C. R. Meissner Elected to Board of Directors of American Vacuum Society

C. R. Meissner of the Electrical Communications Research Department has recently been elected to the Board of Directors of the American Vacuum Society. He was also appointed Program Chairman for the organization's 1959 and 1960 Series of Vacuum Symposia.

The American Vacuum Society is an organization of engineers and scientists working with vacuum techniques and problems in the academic, research, engineering and production fields.

TALKS

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

SEMICONDUCTOR SYMPOSIUM, ELECTRO-CHEMICAL SOCIETY, Ottawa, Canada

Flaschen, S. S., see Pearson, A. D.

Kleinman, A. J., see Logan, R. A.

Logan, R. A., Kleinman, D. A., and Peters, A. J., *Electrical Properties of Dislocations in Silicon.*

Pearson, A. D., and Flaschen, S. D., *New Low-Melting Glasses Potentially Useful as Protective Coatings for Semiconductors.*

Peters, A. J., see Logan, R. A.

Silverman, S. J., *Precision Resistivity Measurements to Evaluate Silicon Single Crystals.*

Thomas, U. B., *The Oxides and Hydroxides of Nickel, Their Composition, Structure and Electrochemical Properties, A Review.*

Turner, D. R., *Junction Delineation on Silicon by Electrochemical Displacement of Metals.*

Turner, D. R., *Electroplating Metal Contacts on Semiconductors.*

FALL SYMPOSIUM, NORTH CAROLINA SECTION, I.R.E., Winston-Salem, N. C.

Elmendorf, C. H., III, *The Submarine Cable.*

Emling, J. W., *People, Too, Have a Place in the Future.*

Glaser, J. L., *Time Division Multiplex.*

Honaman, R. K., *Looking Ahead in Public Communications.*

Ketchledge, R. W., *Electronic Switching.*

Kostkos, H. J., *International Science at Brussels' World Fair.*

NATIONAL ELECTRONICS CONFERENCE, Chicago, Illinois

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

McDavid, W. J., and Tanner, T. L., *High-Voltage Magnetically Regulated DC Supply,* (Presented by Tanner, T. L.).

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

Mathews, M. V., see McDonald, H. S.

Renne, H. S., *How the Technical Publicity Department Views Your Technical Paper.*

Tanner, T. L., see McDavid, W. J.

WIRE & CABLE ASSOCIATION, Atlantic City, New Jersey

Bodle, D. W., *Tests to Evaluate Lightning Behavior of Telephone Wire and Cable Insulation.*

DeCoste, J. B., Howard, J. B., Wallder, V. T., and Zupko, H. M., *Plasticized Poly (Vinyl Chloride) for Retractile Cords.*

Howard, J. B., see DeCoste, J. B.

Jahn, A. P., and Vacca, G. N., *Accelerated Again Tests and Service Performance of Neoprene Jacketed Drop Wire.*

Lanza, V. L., *The Thermal Embrittlement of Stressed Polyethylene.*

Lechleider, J. W., *Preheating Conductors in Extrusion Insulating Processes by Copper Loss Method — Temperature as a Function of Current.*

Vacca, G. N., see Jahn, A. P.

Wallder, V. T., see DeCoste, J. B.

Zupko, H. M., see DeCoste, J. B.

AMERICAN CERAMIC SOCIETY, Asbury Park, New Jersey

Dillon, J. F., Jr., *Domain Structure and Optical Properties of Transparent Ferrimagnetic Crystals.*

Flaschen, S. S., and Pearson, A. D., *Low Temperature Sealing Glasses for the Protection of Electronic Components from Moisture.*

Gyorgy, E. M., *Flux Reversal in Square Loop Ferrites.*

Pearson, A. D., see Flaschen, S. S.

Scovil, H. E. D., *The Solid-State Maser.*

Van Uitert, L. G., *Line Width of Yttrium Iron Garnets as a Function of Sintering Treatment.*

ASTM SYMPOSIUM, CLEANING OF ELECTRONIC DEVICE COMPONENTS AND MATERIALS, Philadelphia, Pa.

Amron, I., see Koontz, D. D.

Amron, I., see Thomas, C. O.

Becker, E. J., *The Design and Use of a Mass Spectrometer to Study Gas Problems in Electron Device Development.*

Benn, D. R., see Elkind, M. J.

Craft, W. H., see Thomas, C. O.

Elkind, M. J., and Benn, D. R., *The Analysis and Control of Gas Atmospheres Used in Electronic Device Parts Treatment.*

Feder, D. O., and Koontz, D. E., *Detection, Removal and Control of Organic Contaminants in the Production of Electronic Devices.*

Graney, E. T., see Kern, H. E.

Helmke, G. E., see Pondy, P. R.

Kern, H. E., and Graney, E. T., *Thermionic Emission from Oxide Cathodes as Related to Glass Envelope Composition.*

Koontz, D. E., and Amron, I., *Use of Water, Detergents and Ultrasonics to Control Physical Contaminants.*

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

Koontz, D. E., see Sullivan, M. V.

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

Pondy, P. R., and Helmke, G. E., *Measuring and Controlling Dust.*

Slichter, W. P., *Nuclear Resonance Studies of Polymer Chain Flexibility.*

Sullivan, M. V., and Koontz, D. E., *Intrinsic Water for Processing Electron Device Parts.*

Thomas, C. O., Craft, W. H., Koontz, D. E., and Amron, I., *The Preparation of Ultra Clean Electron Tube Components by Chemical Etching.*

I.R.E. PROFESSIONAL GROUP, ELECTRON DEVICES MEETING, Washington, D. C.

Bartholomew, C. Y., *Impurities Introduced into Kovar-Envelope Electron Tubes by Atmospheric Corrosion.*

Danielson, W. E., McDowell, H. L., and Reed, E. D., *A CW Power Traveling-Wave Amplifier for 5-6 Millimeter Wavelength,* (Presented by McDowell, H. L.).

Ebers, J. J., *P-N Junctions-1958.*

Feder, D. O., see Kern, H. E.

Fox, W. M., *Transistors for Circuitry Exposed to Lightning.*

Graney, E. T., see Kern, H. E.

Kern, H. E., Graney, E. T., and Feder, D. O., *Glass Envelope Composition as a Factor in Oxide Cathode Poisoning.*

Leenov, D., *Generation of Harmonics and Subharmonics at Microwave Frequencies with P-N Junction Diodes.*

Light, T. B., *Compression Bonding Techniques for Lead Connections to Rugged High Frequency Transistors.*

McDowell, H. L., see Danielson, W. E.

Reed, E. D., see Danielson, W. E.

Reed, E. D., *A Review of Parametric Amplifiers.*

Rutter, V. E., *Some Measurements of the Ion Noise Phenomenon in a 6000-mc Traveling Wave Tube.*

Vanderwal, N. C., *Design and Fabrication of High Frequency Diffused Germanium Transistors.*

VonOhlsen, L. H., *Improved Formulas for the Calculation of Transconductance and Gain-Bandwidth Product of Close-Spaced Electron Tubes.*

OTHER TALKS

Anderson, O. L., *Adhesion of Metals in Air at Room Temperature,* A.S.M.E., New Haven Section, New Haven, Conn.

Anderson, P. W., *Collective Excitations in Superconductors,* Carnegie Institute of Technology, Pittsburgh, Pa.; Univ. of Illinois, Urbana, Ill.; and Rutgers, New Brunswick, N. J.

Beck, A. C., *A New Window in the Sky—How Radio Astronomy Began,* Atlantic Township Parent - Teacher's Association, Colts Neck, N. J.

Bemski, G., *Spin Resonance in Electron Irradiated Silicon, IBM,* Poughkeepsie, N. Y.

Berry, R. W., *Properties of Tantalum Oxide Formed on Sputtered Tantalum Films,* Conf. of Electrical Insulation, National Research Council, Pittsburgh, Pa.

Bobeck, A. H., *A New Solid State Memory Element—The Twistor,* Boston Section, I.R.E., Prof. Gr. on Electronic Computers, Boston, Mass.

Bömmel, H. E., *Application of Ultrasonic to Solid State Physics,* Physics Colloquium, Renesslaer Polytechnic Institute, Troy, N. Y.

Brown, W. L., *Electron Van de Graaff Techniques in Solid State Research,* Accelerator Conference, Cambridge, Mass.

Bullington, K., *Status of Tropospheric Extended Range Transmission,* National Symposium on Extended Range and Space Communications, Washington, D. C.

Calbick, C. J., *Energy of Particles Ejected during Evaporation of Carbon,* 4th International Conference on Electron Microscopy, Berlin, Germany.

Calbick, C. J., *Cathodic Etching in a Magnetic Field,* 4th International Conference on Electron Microscopy, Berlin, Germany.

Chapin, D. M., *Utilization of Solar Energy,* Conference on Science and Technology for the Peaceful Development of Israel and the Middle East, New York City.

Currie, A. A., *The SAGE Air Defense System,* West Street Auditorium, Murray Hill Auditorium and Whippany Auditorium.

Danielson, W. E., *Low Noise in Solid State Parametric Amplifiers at Microwave Frequencies,* Joint Meeting I.R.E. Professional Groups on Microwave Theory and Techniques and on Antennas and Propagation, Syracuse, N. Y

David, E. E., Jr., *Some Experiments in Pitch Perception and Binaural Interaction,* Psychology Colloquium, Harvard University, Cambridge, Mass.

Douglass, D. C., *The Use of Nuclear Magnetic Resonance to Measure Self-Diffusion Coefficients,* Chemistry Dept., NYU, New York City.

Early, J. M., *Introduction to Solid State Devices,* A.I.E.E.-I.R.E., New York City.

Geballe, T. H., *Some Thermal Conduction and Thermoelectric Processes in Diamond-lattice Semiconducors,* Westinghouse, Pittsburgh, Pa.

Geballe, T. H., *Thermomagnetic Effects in Germanium,* Carnegie Institute of Technology, Pittsburgh, Pa.

Geils, J. W., *Research and Development in Industry Today*, Newark College of Engineering, Newark, N. J.

Gibbons, D. F., *Effect of Dislocations in Crystals*, Lafayette College, Easton, Pa.

Gillette, D., see Ling, D. P.

Guttman, N., *Frequency Division of Speech in Real Time as a Means of Counteracting High-Frequency Hearing Loss*, 4th Congress of the International Audiological Society, Padua, Italy.

Hannay, N. B., *Mass Spectroscopy of Solids*, Spectroscopy Society, Pittsburgh, Pa.

Henneberger, T. C., *Planning and Programming in Bell Telephone Laboratories*, Wright-Patterson Air Force Base, Ohio.

Herriott, D. R., *Sinusoidal Sweep-Frequency Targets for Measurement of Transfer Function of Photographic Lenses*, 43rd Annual Meeting, Optical Society of America, Detroit, Mich.

Humphrey, F. B., *Introduction to Magnetic Properties of Thin Films*, 5th National Vacuum Symposium, San Francisco, Calif.

Israel, Joachim, *Self-evaluation and Goal-attractiveness*, Carnegie Institute of Technology, Pittsburgh, Pa.

Kellogg, L. H., *Project NIKE—A Guided Missile System for AA Defense*, Madison High School, Madison, N. J.

Keyser, C. J., *No Two Alike*, Pre-meeting Clinic of Am. Soc. for Quality Control, National Cash Register, New York City.

Ling, D. P., and Gillette, D., *Guidance System Engineering*, Missile and Rocket Course, University of Connecticut, Storrs, Conn.

Loomis, T. C., *Micro Applications of X-Ray Emission Analysis*, Stevens Institute of Technology, Hoboken, N. J.

McKay, K. G., *The Present Status of Solid-State Masers*, Meeting of the Verband Deutscher Electrotechniker, Stuttgart, Germany.

Murphy, R. B., *Some Aspects of Sampling Plans for Inspection*, 2nd All Day Forum, Montreal Section, Am. Soc. for Quality Control, Montreal, Canada.

Myers, G. H., *Capacity of Communications Channels with Memory*, Fall URSI-IRE Meeting, Pennsylvania State University, University Park, Pa.

Pearson, G. L., *Photoprocesses In Elemental Semiconductors*, Pacific Semiconductors, Inc., Culver City, Calif.

Pearson, G. L., *Silicon in Modern Communications*, Naval Reserve Research Company, 12th District, Palo Alto, Calif.

Pearson, G. L., *Variable Capacitance Semiconductor Diodes*, Physics Dept. Colloquium, Reed College, Portland, Oregon.

Pfann, W. G., *Recent Developments in Zone Melting*, Brookhaven National Laboratory, Upton, Long Island, N. Y.

Pierce, J. R., *Transoceanic Communication by Means of Space Satellites*, George Washington University, Washington, D. C.

Quate, C. F., *Recent Advances in Microwave Tubes*, Graduate Seminar, Polytechnic Institute of Brooklyn, N. Y.

Polkinghorn, F. A., *Value of Technical Societies to the Young Engineer*, Joint A.I.E.E.-I.R.E. Student Branch Section, Rutgers University, New Brunswick, N. J.

Raisbeck, Gordon, *Present Status of Solar Battery Research*, Headquarters Quartermaster Research and Development Command, Natick, Mass.

Read, W. T., *Imperfections in Semiconductors*, University of Warsaw, Poland.

Schawlow, A. L., *Penetration of Magnetic Fields into Superconductors*, IBM, Watson Laboratory, New York City.

Scheibner, E. J., *Stable Semiconductor Surfaces*, Physics Seminar, Engg. Equip. Station, Georgia Institute of Technology, Atlanta, Ga.

Schlabach, T. D., *Materials and Methods*, Institute of Printed Circuits, Chicago, Ill.

Schroeder, M. R., *Acoustics Research at Bell Telephone Laboratories*, Susquehanna Section, A.I.E.E., York, Pa.

Sherwood, R. C., see Williams.

Spencer, H. H., *Transatlantic Cable Power Supply*, National Association of Power Engineers, Morris Plains, N. J.

Terry, M. E., *Analysis of Planned Experiments*, Joint Meeting of Cleveland Section of Am. Statistical Assoc. and the Am. Society for Quality Control, Cleveland, Ohio.

van Bergeijk, W. A., *The Hydrostatic Balancing Mechanism of Xenopus Larvae*, Albert Einstein Medical College, N. Y. C.

Wehe, H. G., *Electron Beam Recording*, 5th National Vacuum Symposium, San Francisco, Calif.

Weinreich, G., *The Acoustolectric Effect*, *Physics Colloquium*, University of Pennsylvania, Philadelphia, Pa.

Williams, H. J., and Sherwood, R. C., *Magnetic Domain Structure*, A.S.M. Seminar on Magnetic Properties of Metals and Alloys, Cleveland, Ohio.

Willson, F. E., *Data Transmission Tests on Tropospheric Beyond-the-Horizon Radio Systems*, 4th National Aero-Com. Symp., I.R.E., Utica, N. Y.

PAPERS

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

Aaron, M. R., and Segers, R. G., *Necessary and Sufficient Conditions for Bounded Non-Decreasing Step Response*, I.R.E. Prof. Gr. on Ckt. Theory Trans., Letter to the Editor, CT-s, No. 3, pp. 226-227, Sept., 1958.

Ballhausen, C. J., *The Intensity of the "third" V (III) Absorption Band*, Z. für Physikalische Chemie, 17, pp. 246-248, Aug., 1958.

Batterman, B. W., *Effect of Chemical Impurities on X-Ray Integrated Intensities in Nearly Perfect Germanium*, Phys. Rev. Letters, 1, pp. 228-229, Oct. 1, 1958.

Bemski, G., and Struthers, J. D., *Gold in Silicon*, J. Electrochem. Soc., 105, pp. 588-591, Oct., 1958.

Bömmel, H. E., and Dransfeld, K., *Excitation of Very-High-Frequency Sound in Quartz*, Phys. Rev. Letters, 1, pp. 234-237, Oct. 1, 1958.

DeCoste, J. B., Howard, J. B., Wallder, V. T., and Zupko, H. M., *Plasticized Poly(Vinyl Chloride) for Retractile Cords*, Wire and Wire Prod., 33, pp. 1214-1217, and pp. 1263-1265, Oct., 1958.

Dillon, J. F., Jr., *Observation of Domains in the Ferrimagnetic Garnets by Transmitted Light*, J. Appl. Phys., 29, pp. 1286-1291, Sept., 1958.

Douglass, D. C., and McCall, D. W., *Diffusion in Paraffin Hydrocarbons*, J. Phys. Chem., 62, pp. 1102-1107, Sept., 1958.

Dransfeld, K., see Bömmel, H. E.

Engelbrecht, R. S., *A Low-Noise Nonlinear Reactance Traveling-Wave Amplifier*, Proc. I.R.E., Correspondence Section, 46, pp. 1655, Sept., 1958.

Fuller, C. S., Diffusion Techniques, *Transistor Technology*, Vol. III, D. Van Nostrand Co., Inc., pp. 64-89, 1958.

Gerber, E. A., see Koerner, L. F.

Goldey, J. M., Evaporation and Alloying to Silicon, *Transistor Technology*, Vol. III, D. Van Nostrand Co., Inc., pp. 231-244, 1958.

Heiss, J. H., and Lanza, V. L., *The Thermal Embrittlement of Stressed Polyethylene*, Wire and Wire Prod., 33, pp. 1182-1187, Oct., 1958.

Howard, J. B., see DeCoste, J. B.

Hrostowski, H. J., and Kaiser, R. H., *Infrared Spectra of Heat Treatment Centers*, Phys. Rev. Letters, 1, pp. 199-200, Sept. 15, 1958.

Jewett, W. E., and Schmidt, P. L., *A More Stable Three-Phase Transistor-Core Power Inverter*, Proc. Spec. Technical Conference, pp. 348-362, Aug. 6, 1958.

Kaiser, R. H., see Hrostowski, H. J.

Koerner, L. F., and Gerber, E. A., *Method of Measuring the Parameters of Piezoelectric Vibrators*, Proc. I.R.E., 46, pp. 1731-1737, Oct., 1958.

Lanza, V. L., see Heiss, H. H.

Lechleider, J. W., *Preheating Conductors in Extrusion Insulating Processes by Copper Loss Method — Temperature as a Function of Current*, Wire and Wire Prod., 33, pp. 1211-1213, Oct., 1958.

Mandell, Elaine, R., see Slichter, W. P.

Matthias, B. T., see Shulman, R. G.

Mayzner, M. S., and Tresselt, M. E. (NYU), *Anagram Solution Times: A Function of Letter Order and Word Frequency*, J. Experimental Psychology, 56, pp. 376-379, Oct., 1958.

McCall, D. W., see Douglass, D. C.

Pearson, A. D., *Studies on the Lower Oxides of Titanium*, J. of Phys. & Chem. of Solids, 5, pp. 316-327, 1958.

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

Segers, R. G., see Aaron, M. R.

Shulman, R. G., Wyluda, B. J., and Matthias, B. T., *Diamagnetic Nuclear Magnetic Resonance Shifts in Alloys*, Phys. Rev. Letters, 1, pp. 278-279, Oct. 15, 1958.

Slichter, W. P., *Characteristics of Rubber-Like Materials*, Lecture Notes for the Course on Advanced Elastomer Technology of the New York Rubber Group, pp. 1-53, 1958.

Slichter, W. P., and Mandell, Elaine R., *Molecular Motion in Polypropylene, Isotactic and Atactic*, J. Chem. Phys., Comm. to the Editor, 29, pp. 232-233, July, 1958.

Stadler, H. L., *Ferroelectric Switching Time of $BaTiO_3$ Crystals at High Voltages*, J. App. Phys., 29, pp. 1485-1487, Oct., 1958.

Struthers, J. D., see Bemski, G.

Vogel, F. L., Jr., *On The Orientation Effect in the Polygonization of Bent Silicon Crystals*, Acta Met., pp. 532-534, Aug., 1958.

Wallder, V. T., see DeCoste, J. B.

Weiss, M. T., *Microwave and Low Frequency Oscillations Due to Resonance Instabilities in Ferrites*, Phys. Rev. Letters, 1, pp. 239-241, Oct. 1, 1958.

Wyluda, B. J., see Shulman, R. G.

Zupko, H. M., see DeCoste, J. B.

PATENTS

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

Abbott, G. F. and Joel, A. E., Jr. — *Random Service Scanning System* — 2,853,555.

Almquist, M. L., Jr., Joel, A. E., Jr. and Posin, M. — *Line Scanner* — 2,853,553.

Baker, D., Carter, H. T. and Kelnhofer, S. A. — *Multistation Telephone Intercommunicating and Conference System* — 2,852,612.

Bishop, J. D. — *Current Supply Apparatus for Load Voltage Regulation* — 2,850,695.

Boysen, A. P., Jr. and Krebs, L. E. — *Vibratory Signaling Device* — 2,854,542.

Brooks, C. E., Joel, A. E., Jr. and Krom, M. E. — *Trunk Selection System* — 2,853,554.

Carter, H. T. — *Subscriber's Key Telephone Station and Signaling Circuit* — 2,850,579.

Carter, H. T., see Baker, D.

Collier, R. J. and Feinstein, J. — — *Magnetrons* — 2,854,603.

Cutler, C. C. — *Signal Storage Apparatus* — 2,850,677.

Feinstein, J., see Collier, R. J.

Felker, J. H. — *Regenerative Transistor Pulse Amplifier* — 2,853,-629.

Fox, A. G. — *Nonreciprocal Wave Transmission Component* — 2,850,701.

Gardner, L. A. — *Teletypewriter Switchboard Trunk Circuit* — 2,850,562.

Hamilton, B. H. — *Current Supply Apparatus for Load Voltage Regulation* — 2,850,694.

Howson, L. — *Phase Shifting Circuit* — 2,851,658.

Hussey, L. W. — *Serial Adder* — 2,851,219.

Irwin, G. C. — *Number Scanning Circuit* — 2,850,237.

Joel, A. E., Jr. and Krom, M. E. — *Service Observing Circuit* — 2,853,562.

Joel, A. E., Jr., see Abbott, G. F.

Joel, A. E., Jr., see Almquist, M. L., Jr.

Joel, A. E., Jr., see Brooks, C. E.

Kelnhofer, S. A., see Baker, D.

Kircher, R. J. — *Diode Circuits* — 2,854,651.

Kohs, D. W. — *Conversion of Two-Valued Codes* — 2,852,745.

Krebs, L. E., see Boysen, A. P., Jr.

Kretzmer, E. R. — *Apparatus for Compression of Television Bandwidth* — 2,850,574.

Krom, M. E., see Brooks, C. E.

Krom, M. E., see Joel, A. E., Jr.

Krom, M. E. and Posin, M. — *Line Concentrator System* — 2,850,-576.

Krom, M. E. and Posin, M. — *Line Concentrator System* — 2,850,-577.

Lundry, W. R. — *Delay Equalizer Network* — 2,852,751.

Meacham, L. A. — *Transistor Current Limiter* — 2,850,650.

Metzger, F. W. — *Electron Discharge Tube Circuit* — 2,853,-694.

Pfann, W. G. — *Continuous Zone-Refining* — 2,852,351.

Posin, M., see Almquist, M. L., Jr.

Posin, M., see Krom, M. E.

Raisbeck, G. — *Computation of Correlation* — 2,854,191.

Remeika, J. P. — *Barium Titanate as a Ferroelectric Material* — 2,852,400.

Shockley, W. — *High Frequency Negative Resistance Device* — 2,852,677.

Spahn, C. F., Jr. — *Relay Test Recorder* — 2,852,736.

Straube, H. M. — *Code Conversion* — 2,854,657.

Thurston, R. N. — *Apparatus for Eliminating Mechanical Vibrations in Aerial Cables* — 2,852,-595.

Vogelsong, J. H. — *Nonlinear Terminations for Delay Lines* — 2,850,703.

Wallace, R. L., Jr. — *Signal-Operated Switch* — 2,853,631.

West, F. — *Pulse Initiator* — 2,-851,635.

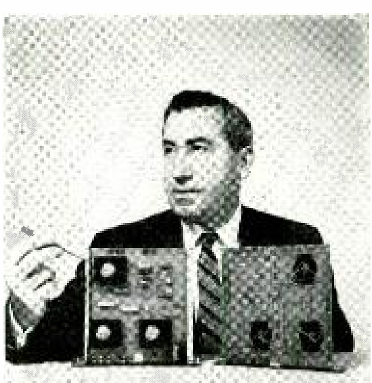
Wolfe, R. M. — *Counting Circuits Employing Ferroelectric Capacitors* — 2,854,590.

Young, W. R., Jr. — *Stabilized Positive Feedback* — 2,852,624.

THE AUTHORS

J. W. Gorgas

J. W. Gorgas, a native of Newark, N. J., began his Bell System service with the Bell Telephone Company of Pennsylvania in 1923. He worked on dial system maintenance, plant training, and maintenance engineering until he transferred to the Laboratories in 1946 to help in planning No. 5 crossbar training for the Operating Companies. Subsequently, he proposed and developed the detached - contact schematic and sequence chart method now widely used in the Bell System. Later, he was concerned with the design of 4A toll test circuits, and with formulating plans for the step-by-step CAMA system. Currently he is in charge of a group responsible for design requirements for No. 5 crossbar. In this issue, he is the author of the article concerning on-hook and off-hook signaling.



G. W. Meszaros

G. W. Meszaros, a native of New York City, started his Laboratories career in the Systems Drafting Department in 1926. Just prior to his receiving a B.E.E. degree from the College of the City of New York, he joined the trial installation group. After a short time in several engineering divisions of the Systems Department, he transferred to Power Development in 1941. Here he has specialized in electronically controlled power circuits, notably those for the Key West-Havana, Transatlantic, Hawaiian, and Alaskan undersea cables. Currently, he is in charge of a group designing transistorized power supplies for electronic switching and for several military projects. Mr. Meszaros is the author of the article on "Transistor Voltage Regulators," in this issue.

A. D. White

A. D. White received his B.A. from Rutgers University and his M.S. in physics from Syracuse University in 1951 after completing three years of military service in World War II. He joined the Laboratories in 1953 after two years with the I. T. & T. Research Laboratories in Nutley, N. J. where he was concerned principally with the investigation of gaseous electronic devices for microwave circuits. Since 1953 he has been associated with the development of talking-path gas diodes. Mr. White, a resident of Berkeley Heights, N. J., is a member of Sigma Xi and Phi Beta Kappa and is a member of the I.R.E. subcommittee on gas discharge tubes.

D. J. Brangaccio

D. J. Brangaccio, a native of New York City, joined the Laboratories in 1934 — eventually to become a technical assistant in the Television Research Department. In 1942 he received a B. of M.E. degree from New York University and in 1943 became a member of Technical Staff. In 1944 he joined the Transmission Research Department to engage in work on wide-band amplifiers. Another transfer in 1945 brought him to the new sub-department of Radio Research to work with the new traveling-wave tube. Here he contributed to studies on the output power and efficiency of these tubes. When, in 1952, Mr. Brangaccio's department became "Electronics Research," he was put in charge of a group making traveling-wave tubes. Upon completion of his work on the development of the broad - band oscilloscope tube — the subject of his article in this issue — he returned to work on traveling-wave tubes.

R. G. Ruwell was born in Philadelphia, Pa., and received the B.S. degree in Electrical Engineering in 1927 and the E.E. degree in 1940 from the University of Pa. In 1929, Mr. Ruwell joined the Pennsylvania Bell in the Execu-

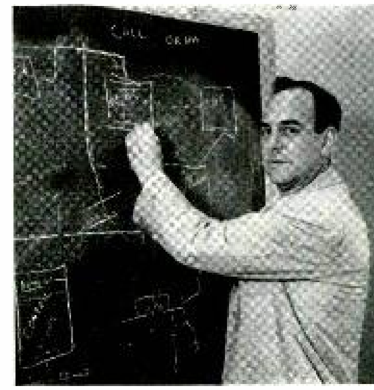
R. G. Ruwell

tive Operations Department, engaged in long-range planning. During World War II, he served as a Lieutenant Commander in the Naval Reserve, taught at the M.I.T. Radar School, and was connected with guided-missile research in the Bureau of Ordnance. He also served as technical observer for a U. S. Naval Mission in Europe. In 1946, he returned to Bell of Pa., and in 1951 was recalled to active duty to serve as Assistant Project Officer on the Terrier missile. In 1953, Mr. Ruwell transferred to the Laboratories, where he has been concerned with systems engineering of AMA, microimage information and electronic data processing. At present, he is responsible for systems engineering of CAMA for step-by-step intertoll. Mr. Ruwell, the author of "Ten Years of AMA" in this issue, is a member of Tau Beta Pi and Sigma Xi, a Commander in the Naval Reserve, and has served on several A.I.E.E. committees.

T. H. Guettich, a native of Brooklyn, N. Y., after graduation from Pratt Institute, spent many years in industry as a designer of automatic machinery, before joining the Laboratories in 1929. At that time he became associated with the design and development of sound picture reproducing apparatus which required the reproduction of vertical cut disc recordings. Subsequently he was concerned with the design of high and low power radio telephone and broadcast transmitters, speech input equipment for broadcasting studios and the engineering of Panel System apparatus. During World War II he was engaged in the design and development of apparatus for Underwater Sound Detection (Sonar), Rocket Firing Mechanisms and Rockets. Since that time he has been associated in the design of telephone relays, particularly those of the wire-spring type. Mr. Guettich is the author of the article on the "two-in-one" wire-spring relay in this issue.

T. H. Guettich

W. F. Miller, co-author of the article "Carrier Terminals for the Transatlantic Telephone Cable," joined the Laboratories as a messenger in 1934. He received the B.S. degree in E.E. from Newark College of Engineering in 1941 and an M.S. in E.E. from Stevens Institute of Technology in 1950. Prior to World War II he spent a few years in the development of carrier systems and during World War II he was engaged in the development of radar systems. He transferred to the Western Electric Co. during the later stages of the war to follow one of these systems into the Pacific War Area. Returning to the Laboratories in 1945, he worked with the development of carrier systems for the Bell System and military. Since 1955, he has been concerned with military weapons systems. He is a member of the I.R.E.



W. F. Miller

C. A. W. Grierson was born in Weymouth, Nova Scotia, Canada, and received a B.Sc. degree from Dalhousie University, Halifax, N. S. in 1925 and an S.B. and S.M. degree from M.I.T. in 1927 and 1928. He joined the Laboratories in 1928, where he worked on dial systems, and transferred to the Toll System Development Department in 1936, where he was associated with carrier systems and during World War II with various military projects. In 1954 Mr. Grierson transferred to Military Communication Systems Development, where he was associated with the development of the transatlantic cable terminals. He then worked in Military Communication Systems Engineering Development Department. He is a senior member of the I.R.E. In this issue he is a co-author of the article "Carrier Terminals for the Transatlantic Telephone Cable."

C. A. W. Grierson