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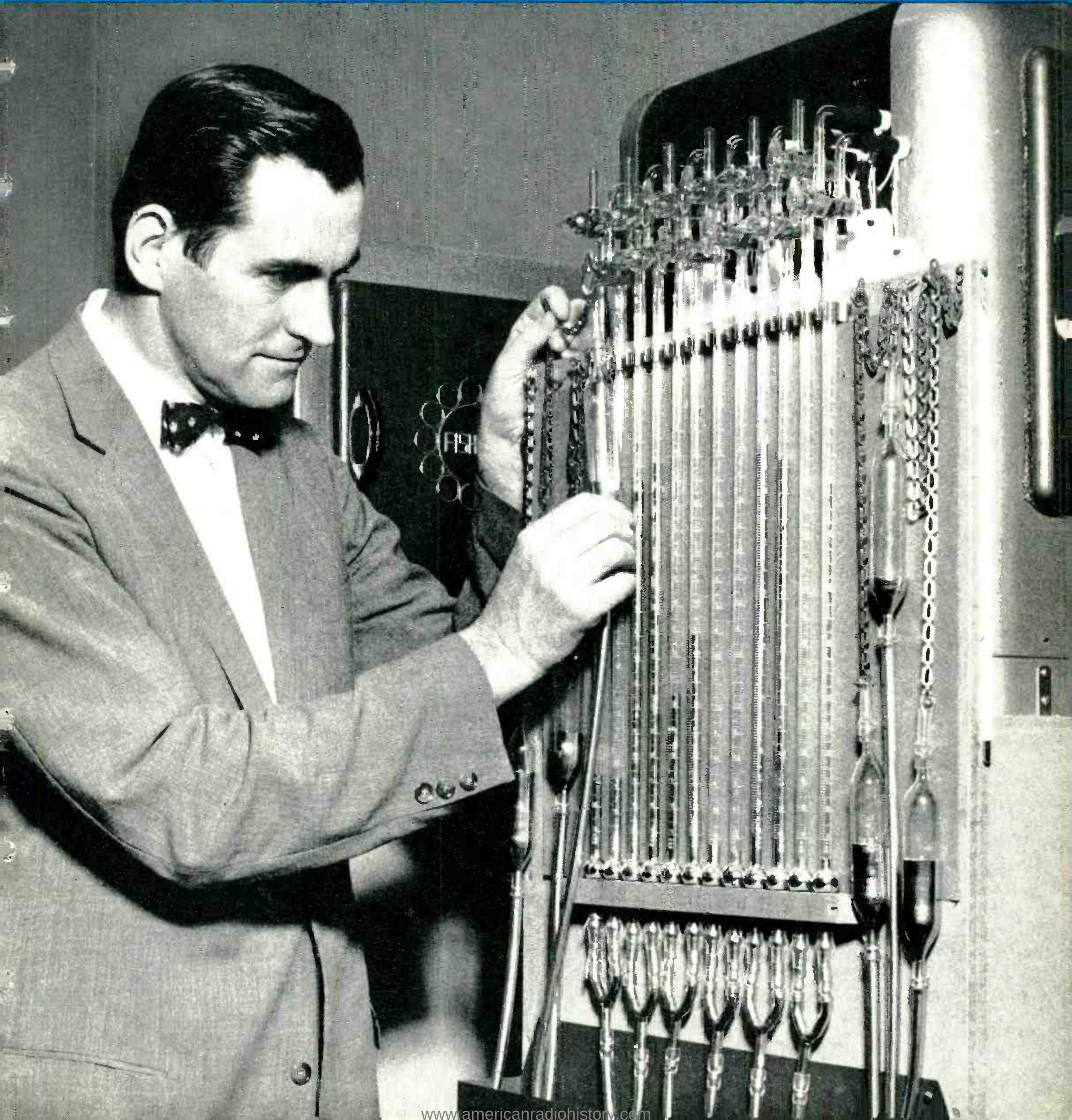

Bell Laboratories RECORD

CONTENTS

THE COVER: F. H. Winslow of the Chemical Research Department conducting accelerated oxidation tests on polyethylene to determine effectiveness of various thermal antioxidants (see page 78).

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An Experimental Signature-Verification System

F. K. BECKER and J. R. HEFELE

Transmission Research

One of the results of advanced study and experiment at Bell Laboratories is an experimental system for transmitting small, still pictures — adequate for such closed-circuit television applications as signature verification. This system, recently demonstrated, uses transmission circuits having a 5,000-cycle bandwidth instead of the circuits of multi-megacycle bandwidth required for standard television transmission.

In describing some remote object or action, visual messages – pictures – often convey more meaning than spoken communications. This fact was undoubtedly responsible for man's first attempts at picture-making. From these first crude images, man has progressed to television – a method of seeing some remote scene instantaneously. Today, this latest of the picture-making arts is being adapted to the same sort of practical uses which motivated primitive man in his crude attempts at visual reproduction – making work easier.

The possible applications of television to everyday tasks are almost numberless, and hundreds of very useful installations have already been made. Perhaps the best-known examples of "industrial" or "closed-circuit" television are highway-traffic observation, freight-car identification, railway and airline accommodation reservations, and bank-balance and signature verification. These uses of television save both time and money compared to previous ways of doing the job, but for many other possible applications, the use of television is frequently prevented by the cost of the transmission facilities.

Television is by far our most expensive communication medium. Specifically, the wire lines used for transmitting television are nearly ten times as costly as those used for transmitting sound. Television is expensive because it is designed primarily to send a faithful reproduction of a moving image. In many applications of closed-loop television, however, the image to be transmitted is a still picture – for example, written material. The standard television rate of thirty complete pictures per second therefore is unnecessary, since the image only has to be reproduced once to serve its purpose. Likewise, in most still-picture applications, a transmission time of several seconds would be entirely adequate.

Transmission problems of this kind have been a concern of the Bell Laboratories for over thirty years.* To give substance to some of the current studies of video transmission techniques, the Transmission Research Department undertook the design and construction of an experimental system for transmitting signatures. This experimental system incorporates some of the tentative results of recent research into a low-cost transmission scheme for still pictures. The physical requirements of a typical signature-verification system were supplied by the New York Savings Bank of New York City.

Very briefly, the experimental equipment works

* RECORD, *May*, 1927, *page* 298; *April*, 1957, *page* 150.

Fig. 1 — Miss P. A. Kerrigan of the Laboratories puts a card holder on the scanning carriage.

as follows. A teller at a branch bank telephones a request for verification of a signature and a bank balance. The transmitter operator in the central record-depository puts the pertinent information — written on two cards slipped into a special holder — on the scanning carriage of the transmitter. Each teller's display unit has an "address" button on the transmitter, and when the operator presses one of these address buttons, transmission starts. At the end of a five-second transmission period, another card holder may be immediately placed on the scanning carriage. A photograph of the transmitter in use is shown in Figure 1.

A single, common receiver at the branch bank distributes the received signals to one of several display units. Once displayed, the image remains on the screen for as long as two minutes, or it can be wiped off immediately. As Figure 1 shows, the system has been temporarily packaged in a form suitable for demonstration.

Like any other communication device, the signature-verification system is made up of three essential parts — a transmitter, a receiver, and a transmission link. In selecting a transmission channel, bandwidth was the important consideration, since it is related to both picture quality and transmission cost. A study of the bandwidths of readily available Bell System circuits indicated that 5,000-cps "program circuits" should be used if at all possible. Program circuits have a virtually flat amplitude-response from 100 to 5,000 cps, and were designed primarily to furnish sound transmission of broadcast quality. For local transmission, these circuits are physically identical to standard telephone circuits except for special equalizer networks and amplifiers inserted to maintain bandwidth and preserve signal level.

The basic problem, therefore, was to investigate various transmitters and receivers which could operate satisfactorily over program channels.

Transmitting a picture electrically begins with scanning — the process of systematically exploring the image through an aperture. The product of scanning is a voltage that varies with time in accordance with the luminance (photometric brightness) of successive areas of the picture. The scanner moves along successive parallel paths the width of the aperture apart, producing a series of contiguous "lines". These lines are in turn made up of picture "elements", which are the very small areas of the picture being scanned at any instant.

The amount of detail in, or resolution of, a picture is directly related to the number and size of these picture elements. Lines and elements, and the scanning that produces them, are also intimately related to transmission bandwidth, because two picture elements — actually, alternations of light — correspond to only one alternation of current. The required signal frequency, therefore, need be only one-half the number of picture elements scanned per second. The scanning process, then, produces

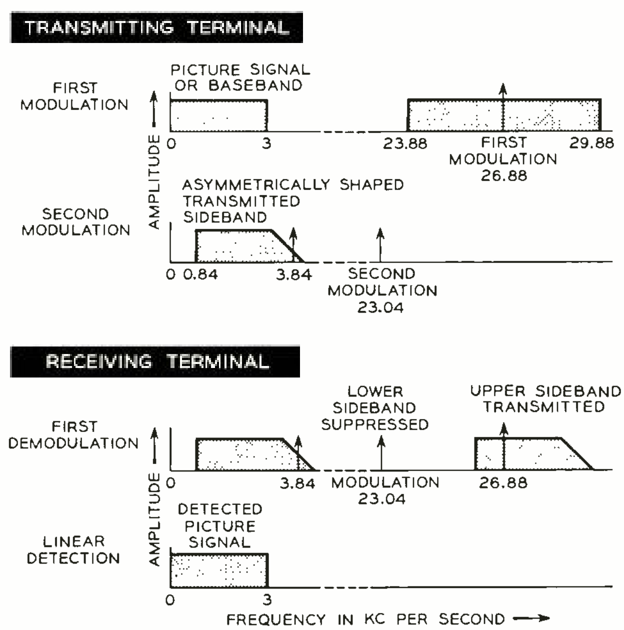


Fig. 2 — Diagram showing vestigial-sideband frequency translations at both transmitter and receiver.

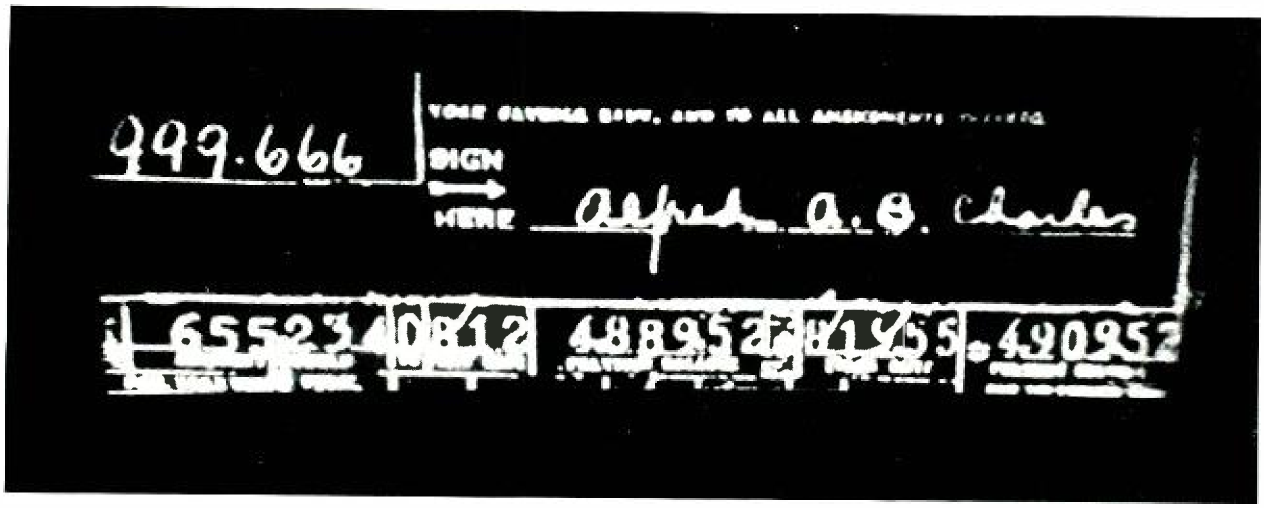


Fig. 3 — Verification image as received on tellers' display unit shown slightly larger than actual size.

a signal with a bandwidth that extends from dc to a frequency equal to one-half the number of picture elements scanned per second.

Program circuits, however, will not pass dc and they produce distortion in visual signals near both the top and bottom of the band. Carrier transmission — a familiar communication technique — was therefore the most logical means of using transmission circuits having limited bandwidth. By modulating a carrier frequency with the signal frequencies derived from scanning (the baseband frequencies), the baseband can be moved into the most desirable transmission band of the program circuits. The most efficient system available for doing this is asymmetric- or vestigial-sideband transmission, used in both facsimile and broadcast television. Vestigial-sideband systems transmit one sideband and a portion, or vestige, of the other sideband, as shown in Figure 2. Except in the restricted region around the carrier frequency, these systems are similar to single-sideband arrangements. A signal-frequency sideband of 3,000 cps, with the carrier located at 3.84 kc, allows the vestigial sideband to extend to the top edge of the 5,000-cps channel. The lower portion of the channel is used for signaling, with the lowest extreme of the channel providing a guard band to reject 60- and 120-cycle harmonics injected in the transmission line.

To meet these transmission requirements, the system requires a scanning device capable of producing electrical signals that can be transmitted over a 3,000-cps band. The scanner must produce this electrical signal from the signature and bank-balance information contained on two cards arranged to occupy an area five by 1¼ inches. An experimental card-holder can be seen in Figure 1. A signal composed of only two amplitude levels need be used since all of the intelligence consists of inked lines on white or light-colored cards. The machine-printed numerals are from 0.0075- to 0.01-inch wide, while the lines of some handwriting specimens measure only 0.005-inch wide.

Satisfactory electrical signals can only be derived from such fine lines by a scanner that will resolve 1,000 picture elements across the card, and a possible 250 picture elements (lines) vertically. Resolving power of this quality is not required at the receiver, however. Two signatures and a line of account numerals can be recognized by the viewer — with little masking of their essential characteristics — on a 100-line system resolving 300 elements across each line. A 100-line by 300-element system may contain 30,000 picture elements. Based on the one-to-two ratio of modulating frequency to picture-element frequency mentioned previously, a picture signal containing 30,000 elements can be transmitted over a 3,000-cps channel in five seconds. This method of transmission means that each line must be scanned in 1/20 of a second.

In the experimental system, three steps are taken to make the resolution of fine detail necessary in the scanner compatible with the resolving power of the eyes of the viewer. First, a high-resolution scanner is used because of the fine detail and low contrast ratios of the signatures. Second, a special circuit processes the scanning signals so that they instantaneously have either of two values, corresponding to "background" or to "inked line." Third, a unique arrangement lengthens the fine-line signals to a value satisfactory for transmission over a channel which is limited in bandwidth to only 3,000 cps.

Since commercial cathode-ray-tube scanners fail to meet the 1,000-element resolution capability by a factor of nearly two, the low line-scan rate of the

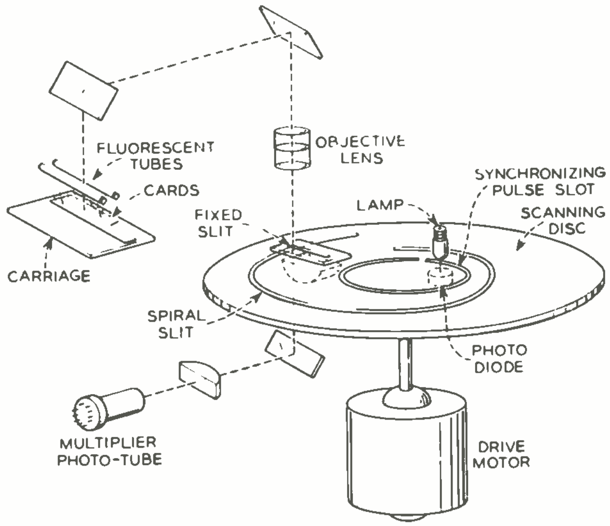


Fig. 4 — Schematic diagram of the high-resolution mechanical scanner used in the transmitter unit.

system indicated the use of a precision mechanical scanner. Hogan Laboratories, Inc., built to Laboratories' specifications a scanning mechanism which met the resolution requirement. A schematic of this scanner is shown in Figure 4. Optically, a series of mirrors and lenses forms a reduced image of the card at the intersection of a spiral slit on the scanning disc and a straight slit fixed parallel to the image. When the disc is rotated, this intersection forms the aperture which scans the image horizontally. The size of the aperture gives a horizontal resolution of 1,000 elements per line. The card-holder carriage moves the image on the cards across the fixed linear slit in five seconds, thus producing the vertical scan. The light from each successive point of the image, as determined by the scanning aperture, is then converted by a multiplier phototube to a proportional electrical signal.

This signal must now be processed so that it will be suitable for transmission. The first step in this process is to apply the baseband frequencies to a processing circuit, where the analog signals derived from scanning are limited to levels corresponding to either black or white. This circuit likewise stretches the duration of fine-line signals to a value satisfactory for transmission. The rectangular output pulses of this special circuit pass through a low-pass filter, and then modulate a 26.88-kc carrier frequency. A second stage of modulation and filtering produces a vestigial-sideband carrier of 3.84 kc suitable for transmission over a program circuit. These two steps in the modulation process are shown in the upper portion of Figure 2.

The unique feature of the circuit which processes the baseband signal is its nonlinear, pulse-stretching operation. Variable-duration pulses with a minimum length of 160 microseconds can be transmitted through a band-limited system of three kilocycles. The scanner, however, may generate signal pulses as short as fifty microseconds when scanning signatures written with a very fine pen. The combination limiter and pulse-stretcher circuit first recognizes the presence of a signal pulse, and then isolates it as a two-level signal free of background noise. Next, signal pulses less than 160 microseconds long are lengthened and appear at the output as clipped, rectangular pulses lasting 160 microseconds. Longer signal pulses appear with their original durations. The output signal of this circuit is a series of rectangular pulses corresponding to the inked lines of figures on the scanned image.

By scanning, special electrical processing and modulation, the transmitting system has essentially encoded the information printed on the signature and bank-balance cards. To make use of this encoded information, the display system must also receive the key to the code – a synchronizing pulse. As shown on the scanner diagram, Figure 4, a synchronizing signal is generated during scanning. This synchronizing pulse indicates the start of each scanned line. The other special signals of the system, which are also part of the transmitted information, are a tone burst to indicate the start of a message, and the "address" frequency of one of the several display tubes.

This four-part signal is transmitted over the pro-

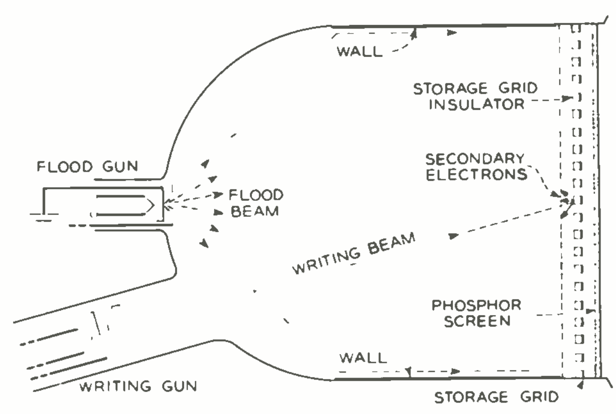


Fig. 5 — Sketch showing important elements of direct-view storage tube and writing beam path.

gram lines to the receiving equipment at the branch bank. The receiving equipment is separated into three natural divisions – a single, common distribution-amplifier, individual control units, and individual display units at each teller position.

The signal comes first to the distribution amplifier. The leased program circuit terminates here. Primarily, this unit contains filters that pass the four-part signal and eliminate harmonics caused by power frequencies in the line.

The individual control units process the distributed signal in three branches. The first branch includes an amplifier for selecting the proper receiver. An address frequency passed by this amplifier starts the vertical sweep in the display tube and also actuates a "gate" for signal processing. This gate also insures no response in the other receivers.

The second branch processes the signal so that it will provide a continuous horizontal sweep that is highly stable. The signal first goes through a "detection" process to regain baseband – the frequencies derived from scanning. Subsequently, the horizontal synchronizing pulses, also generated during scanning, are separated and stabilized.

The third branch processes the picture signal. The received signal is first translated to a higher frequency for more accurate envelope-detection. After suitable amplification, the signal is restricted to levels representing "black" or "white" and is then impressed on the grid of the display tube. The restriction to two levels gives maximum immunity from transmission-line noise.

The third division of the receiver equipment – the tellers' display equipment – is made up of a direct-view storage tube and the required circuitry. Direct-view storage tubes were used because, unlike the standard television picture tube, they can store an image for some time. The direct-view storage tubes used in this system were built for the Laboratories by the Farnsworth Electronics Company and the Radio Corporation of America. The external appearance of a seven-inch storage tube is shown in the photograph above (Figure 6).

These tubes, as Figure 5 shows, have a writing section and a viewing section. The essential parts of the viewing section are an aluminized phosphor screen, a storage grid, a collector screen, and a divergent-beam flood gun. The operation of the viewing section is analogous to the operation of a negative-grid triode: large negative charges on the storage grid will prevent flood-gun electrons from reaching the phosphor screen.

If an electron beam from the writing gun is

Fig. 6 — J. R. Hefele (left) and F. K. Becker inspecting direct-view storage tube used in signature-verification system for transmitting still pictures.

also directed onto the storage-grid dielectric, however, secondary electrons will cause the potential on the dielectric to rise. The storage grid, now less negatively charged, will allow flood-gun electrons to pass through and strike the screen. In other words, by varying the current of the writing beam, different charges are put on the storage grid, and the pattern stored there will control the amount of flood current reaching various areas of the screen.

In an actual signature-verification display, the writing gun – the control element in the tube – is activated by the picture signal from the control unit. The areas of the storage grid made less negative by the action of the writing gun appear as bright elements on the viewing screen. Hence, the transmitted information is presented as white writing on a black background. This image, shown in Figure 3, is sharper than a positive (black on white) image would be because the visual resolution of positive images is considerably reduced by halation.

To remove the stored pattern from the grid, a positive pulse is applied to the backing electrode. The capacitively-coupled dielectric then becomes positive and attracts large numbers of flood-gun electrons. Removal of the potential supplied by this pulse returns the storage-grid dielectric to its original negative potential.

In a typical operating cycle of the teller's display equipment, vertical run-down is started by a tone burst from the transmitter, and the ever-present horizontal sweeps deflect the writing beam over the screen of the display tube. The writing-gun control grid is then modulated "on" by the processed signal from the control unit, and wherever the writing beam strikes the storage grid, the grid assumes a less-negative potential. Following the five-second writing cycle, the screen high-voltage is applied, and the stored image appears on the viewing screen. When transmission is completed, the circuit is free to send signature and bank-balance information to other tellers.

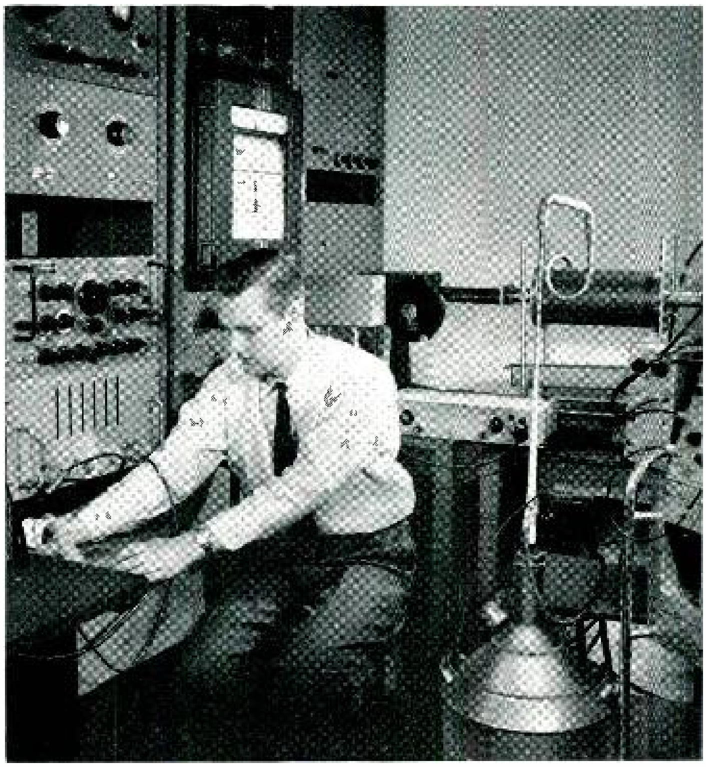
In trials of this equipment, high-quality verification images have been sent over inexpensive, narrow-band wire loops of 48 miles. These were standard Bell System program circuits supplied by the New Jersey Bell Telephone Company.

THE AUTHORS

F. K. BECKER, a native of Denver, Colorado, received the B.S. (E.E.) degree from the University of Colorado in 1945, and after a tour of duty as an electronics officer in the Navy, he received the M.S. (E.E.) degree from the California Institute of Technology in 1947. He then joined the Mountain States Telephone and Telegraph Company in Denver, Colorado, where he worked as a dial-equipment engineer. He transferred to the Laboratories in 1951 and after a short stay was recalled by the Navy for a two-year tour of duty at the Office of Naval Research in Washington, D. C. He rejoined the Laboratories in 1954 as a member of the Transmission Research Department assigned to acoustics and underwater sound projects. More recently, he has been concerned with the development of experimental, picture-transmission systems using narrow bandwidth circuits.

J. R. HEFELE, a native of Yonkers, N. Y., joined the Western Electric Engineering Department in 1923. When the Laboratories was formed, he transferred to the electro-optical research group and began his lifetime work in television systems research. He has participated in all of the television developments and demonstrations of Bell Laboratories including the first television show in 1927. During World War II he was engaged in the investigation and development of airplane detection and automatic-following radar devices. In 1956 he transferred to the visual systems group in the Transmission Research Department, where he is currently concerned with special problems of visual transmission over restricted bandwidth channels. He obtained the B.S. degree in 1929, and the E.E. degree in 1932 from Cooper Union while attending postgraduate classes at Fordham and Columbia Universities. He is an active member of several technical committees of the Electronic Industries Association and the I.R.E.

Electrical Breakdown in p-n Junctions



A. G. CHYNOWETH

Research in Physical Sciences

In semiconductor devices, p-n junctions can "break down," or permit a sudden flow of electricity in the direction that normally shows high resistance. For some time a puzzle to physicists, the mechanism of this phenomenon can now be described as a result of recent research studies carried out at Bell Telephone Laboratories.

Pure crystals of silicon or germanium are relatively poor electrical conductors at room temperature, but their conductivity can be increased by deliberately adding certain impurities to them. Impurities with an excess of electrons (donors) result in n-type conductivity – current carried by free electrons. Impurities deficient in electrons (acceptors) capture other electrons and leave free positive holes that cause p-type conductivity. The junction between two parts of a single crystal, one of which is n-type and the other p-type, behaves as a rectifier. That is, if the current is plotted against the voltage across the junction, then for one polarity of the voltage (forward direction) the junction exhibits a low resistance. For the opposite polarity of the voltage (reverse direction), the junction exhibits a high resistance.

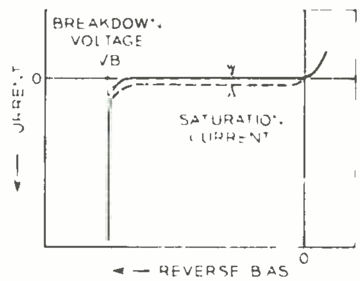
Figure 1 shows a typical plot of current versus voltage through a crystal junction. In the reverse direction, the current varies only slightly with the voltage until the latter approaches a critical value; the current then increases rapidly. The voltage at which the current tends to become infinite is called the breakdown voltage, and in general, it is quite sharply defined. Much effort has been devoted to determining the basic processes responsible for this phenomenon of electrical breakdown.

This article outlines the experiments, and their results, that have led to our present knowledge about breakdown in p-n junctions and its associated phenomena. This discussion is confined to breakdown processes occurring at the p-n junction within the body of the crystal, and thus excludes surface effects. Although many of the basic processes are no doubt common to p-n junctions in general, this account is concerned with p-n junctions in silicon, the material for which the most comprehensive data exist.

To describe the behavior of a p-n junction in terms of electronic processes, it is convenient to use the energy diagram shown in Figure 2. In this diagram the potential energy for electrons is plotted as ordinate, against distance through the crystal as abscissa. The diagram can be more easily interpreted if electrons are pictured as trying always to "drop down" (holes try to "climb up" because of different sign) to minimize their potential energy.

The energy diagram consists of three parts. The lowest region of the diagram — the valence band —

Fig. 1 — A typical plot of current versus reverse bias through a semiconductor junction.



represents a set of allowed energy levels which normally are almost fully occupied by electrons. The top region of the diagram — the conduction band — represents a set of allowed energy levels which are almost empty. (Energy *bands* in crystals can be regarded to some extent as the solid-state equivalent of energy *levels* in single atoms.) Between the two bands is the "forbidden region" where electrons cannot reside except at localized energy levels associated with the impurities (for example, with the donors and acceptors).

As a result of thermal agitation, electrons (from the donors) are always present in the conduction band of the n-type material. These free electrons cause n-type conductivity. Also, in the p-type material electrons from the valence band are captured by the acceptors, and leave free positive holes that cause p-type conductivity. Imagine the two regions as two separate crystals (n-type and p-type) electrostatically neutral and in perfect contact. The free electrons from the n-side tend to spill over into the p-side, thus making the p-side negative with respect to the n-side. A similar process works for the holes — holes spilling over from the p-side to the n-side also will aid in making the p-side negative with respect to the n-side. In the energy diagram, this charging effect is indicated by the p-side being raised relative to the n-side.

The electrons that reach the p-side combine there with the holes. At the same time, thermal agitation excites a small but steady supply of electrons, raising them from the valence band to the conduction band. On the p-side, these thermally-generated electrons (on the p-side free electrons are termed minority carriers) can diffuse to the junction and be swept to the n-side. In equilibrium, the rate at which electrons leave the n-side for the p-side and recombine is equal to the rate at which the electrons thermally generated on the p-side diffuse to the junction, and so reach the n-side. A similar situation also applies to the positive holes in the valence band. These equilibrium conditions determine the height of the potential barrier between the n- and the p-sides when no external voltage is applied to the crystal.

When a reverse bias is applied to the junction, the p-side of the energy diagram is raised still further relative to the n-side. Thus, electrons can no longer go from the n-side to the p-side, nor can holes go from the p-side to the n-side, because of the high potential barrier. The only current flowing across the junction is a constant one due to those carriers thermally generated on either side of the junction (electrons on the p-side and holes on the n-side) that manage to diffuse to the junction. This current, therefore, depends only on the rate of generation of the carriers which, in turn, is independent of the voltage across the crystal. The constant current is called the "saturation" current; it is usually too small to show up on oscillograph traces of the rectifier characteristic. A specific objective of the research described in this article was to determine why, at higher biases, the reverse current departed from the saturation value and eventually led to the unexplained breakdown.

More than twenty years ago, the American physicist Clarence Zener made theoretical investigations of the problem of electrical breakdown in insulators.

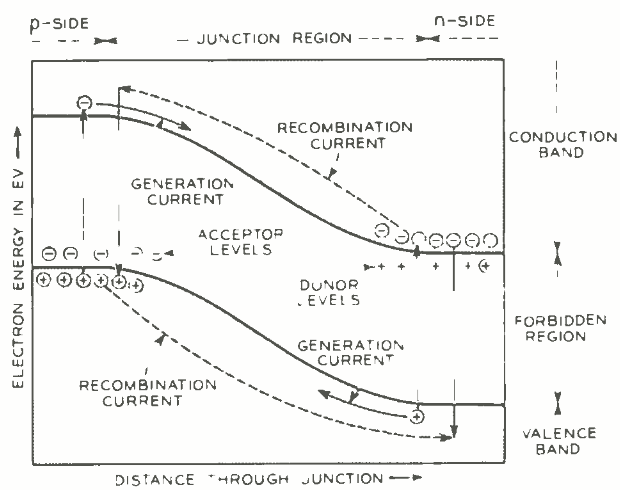


Fig. 2 — The energy diagram of a p-n junction: potential energy of an electron versus its distance through the crystal showing the "forbidden region."

He concluded that at high but experimentally realizable fields, electrons could be torn from the valence band and raised to the conduction band at a rate sufficient to account for large breakdown currents; this process is called "internal field emission." When breakdown was first observed in p-n junctions, scientists thought it was caused by internal field emission, because very high field-strengths could be produced in narrow junctions. In fact, the breakdown voltage of junctions was often called the Zener voltage. This misnomer has persisted even though subsequent work has shown that, in general, another process is responsible for breakdown.

When an extra number of minority carriers are freed close to the junction (for example, by means of an externally-applied flash of light) some will diffuse into the high-field region and produce a pulse of current. The magnitude of this current is determined by the number of carriers crossing the junction per second. The amplitude of the current pulse, measured as a function of the low reverse bias applied, is found to be constant. At a certain "threshold" bias, however, the current starts to increase. This current grows rapidly as the bias continues to increase until, close to the breakdown voltage, it is very many times its original value.

Evidently at higher biases, more carriers cross the junction than are injected by the light. This condition is called "charge multiplication," and it provides the clue to the cause of breakdown. Consider an electron entering the junction at the p-side, as indicated in Figure 3(a). Its passage through the junction (the region that encompasses the high field and is finite in width) is decided by a competition between two processes: (1) the high field tries to accelerate the electron, but (2) during its journey, the electron interacts with other electrons bound to the crystal lattice and tends to lose the kinetic energy it gains from the field. In Figure 3(a), the horizontal portions of the zig-zag line depicting the electron path represent the first process. The vertical portions represent the energy losses resulting from the second process.

If the field is sufficiently high, the electron will gain energy faster than it loses it. It may even reach an energy state (found experimentally to be 2.3 electron volts for silicon) where, in a subsequent collision, it can knock a valence electron up to the conduction band. This energy is called the "threshold for pair-production" since the original electron has created two new carriers — the new electron in the conduction band and the positive hole it leaves behind in the valence band.

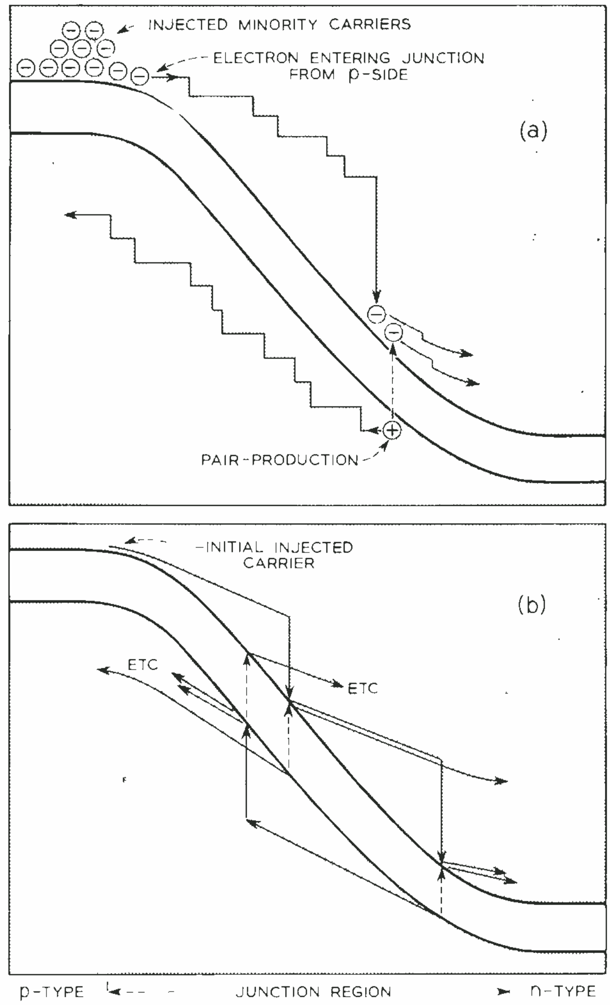


Fig. 3 — Charge multiplication at (a) moderate reverse bias, and (b) high reverse bias. The zig-zag lines of (a) are drawn as straight lines in (b) to simplify the representation of this latter process.

Each of the two free electrons can now repeat the pair-production process if there is, in the high-field region, sufficient travel left to them. The hole (which will move in the opposite direction) likewise can gain energy from the field and furnish pair-production. This mechanism may be pictured as providing positive feedback; the two carriers produced by the energetic hole can, in their turn, go on to produce more free carriers, and so on. In a high enough field, the processes initiated by the entry of one free carrier into the junction will build up to an "avalanche" with correspondingly high currents, see Figure 3(b). Investigation of the multiplication behavior has shown that breakdown occurs by this avalanche mechanism in all but the narrowest of germanium and silicon p-n junctions.

Several decades ago the English physicist J. S.

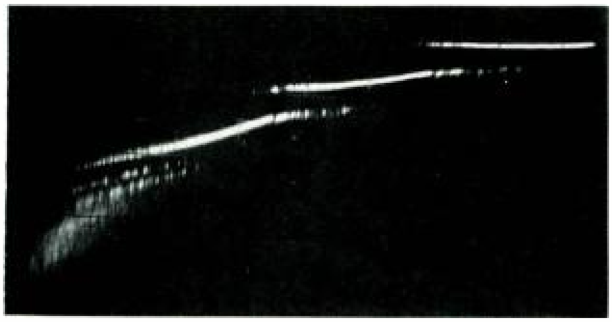


Fig. 4 — Each step in the curve represents the onset of the unstable breakdown condition that is associated with a particular light spot.

Townsend proposed that an avalanche mechanism was the reason for electrical breakdown in gases. Some of the equations he developed are identical in form to the ones now used to express the amount of charge multiplication as a function of the reverse bias applied to the semiconductor junction. As a further analogy, the most significant result obtained from measurements of the charge multiplication is the dependence of the ionization rate on the electric field. Ionization rate can be defined as the number of electron-hole pairs produced per centimeter of path by a carrier traveling in a uniform field. Recent accurate measurements of the amount of charge multiplication as a function of the bias show that the ionization rate in semiconductors varies with the field in a way very similar to its behavior in gases.

Visible radiation is emitted during breakdown — another feature in common with gases. This is best observed in a silicon p-n junction designed like that of the Bell Solar Battery;* that is, the junction must lie parallel and very close to the polished surface of the crystal. Light originating at the junction thus is not absorbed too greatly within the crystal; rather it emerges through the top layer. Contrary to what one might expect, the light emission does not appear as a uniform glow extending over the whole area of the junction. Instead, it appears as many very small, intense spots distributed in a random fashion. Tests have shown that all the breakdown current streams through these spots — each spot carries about 100 microamperes. These light-emission patterns provide direct evidence that breakdown is a body property and is not confined to the surface.

Recourse can be made to the methods of gas discharge analysis to explain why spots of light, rather than a uniform glow, appear on the crystal surface. Analysis of the p-n junction has shown that it is quite feasible for a highly localized (a few hundred angstroms in each direction), quasi-stable avalanche condition to be created, and that this condition is self-limiting in regard to current. The local region of breakdown has been named a "microplasma" by analogy with the terminology of gas-discharge physics.

Another feature of p-n junction rectifiers has been related to these light spots. At a bias just below breakdown, the junction is observed to become very noisy. This noise consists of short, square pulses of current, of about 100 microamperes each. A pulse, which switches on and off very suddenly, may last from less than a few tenths of a microsecond to several microseconds. If the breakdown current is increased slowly and continuously from a low value, definite sets of noise pulses appear at certain biases. In some junctions it has been possible to distinguish up to twenty sets of noise pulses. A typical display of these pulses is shown in Figure 4.

A set of noise pulses can be correlated with the appearance of a new light-emitting spot. The intermittent nature of the avalanche breakdown of one of these spots can perhaps be explained by the possibility that occasionally a sufficient number of carriers fail to produce multiplication when they cross the junction. This would terminate the avalanche until another statistical fluctuation of pair-production in the other direction turns it on again.

Spectrum measurements suggest two possible mechanisms for the origin of the light emission: (1) recombination radiation — where an electron in the conduction band falls into a positive hole in the valence band; (2) de-excitation radiation — where an energetic carrier suddenly loses some of its energy but remains in the same energy band. The former mechanism must account for the most ener-

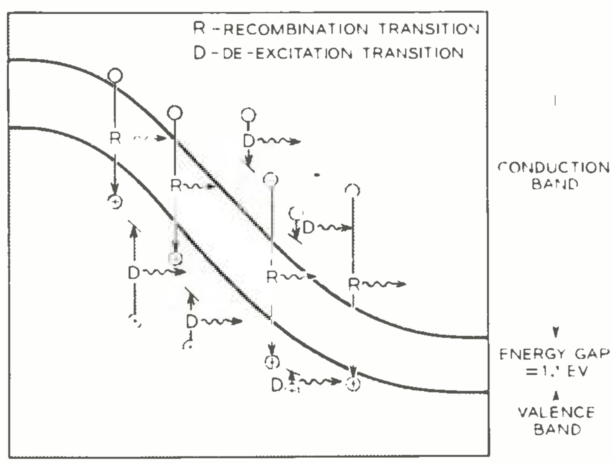


Fig. 5 — Theory of production of light by recombination "R" and de-excitation "D" transistions.

* Record, *July*, 1955, *page* 241.

getic photons emitted; photons up to 3.2 electron volts of energy (blue wavelengths) have been observed. Since the energy gap between the conduction and valence bands corresponds to 1.1 electron volts in silicon, the existence of 3.2-electron volts photons requires recombination between electrons and holes where at least one of these possesses high kinetic energy. Very few electrons can exist in an energy state greater than about 2.3 electron volts, the energy found to be necessary for pair production. It is much more probable that the electron will lose such energy by the pair-production process rather than by processes of the emission of light.

At the other end of the energy scale (infra-red wavelengths), photons with energies considerably less than the band gap (1.1 electron volts) have been detected. Obviously, these cannot be produced by recombination. They are suspected to result when energetic carriers suffer a sudden loss of energy but remain within the same energy band. Such a process could account for photons with energies ranging from very small values up to about 2.3 electron volts. Figure 5 depicts the two types of processes responsible for the light emission. It is interesting to note that avalanche breakdown constitutes one of the best understood ways of producing electro-luminescence.

The behavior of very narrow junctions (those a few hundred angstroms in width) has been found to differ in several respects from that of the wider junctions exhibiting avalanche breakdown. In wide junctions the breakdown voltage increases with temperatures; in narrow junctions it decreases. Also, narrow junctions exhibit extremely high reverse currents which are relatively insensitive to temperature. In fact, experiments have shown that the high reverse currents in narrow junctions are produced by the internal field emission, originally thought to be responsible for breakdown in all p-n junctions.

The study of basic breakdown processes in p-n junctions is leading us to a more detailed understanding of the behavior of electrons and holes in crystals. Furthermore, out of such studies comes much of the information required for the design of many semiconductor junction devices. The article which follows, for example, includes a discussion of the breakdown characteristics of transistors used in a rural carrier telephone system.

THE AUTHOR

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Transistors for Rural Telephone Systems

I. C. SAVADELIS *Allentown Laboratory*

Even the best theoretical and experimental designs require considerable development before reaching the stage of manufacture. With future automation in mind, Laboratories engineers have created voice-frequency and carrier-frequency n-p-n transistors to a very exacting set of requirements for trials of rural-carrier telephone equipment.

One of the principal problems in supplying rural telephone service is the relatively high investment cost per telephone that results from the need for many miles of wire line through sparsely populated areas. Over long-distance routes that carry heavy telephone traffic, it is common practice to conserve wire lines by using a carrier system for placing several conversations on a single pair of wires – a procedure that has generally proved too expensive for rural routes. Because of the transistor's small physical size and low power requirements, however, it may now be possible to develop simple and relatively inexpensive circuits to bring cost levels below those required for more conventional equipment.

The rural carrier system, now being manufactured by the Western Electric Company, is termed the P1 carrier system. It is the first complete system of telephone equipment to be transistorized. Although a few transistors in this system are of the alloy type,* the great majority are of the grown-junction type.† Grown-junction transistors are fabricated from germanium material which is "grown" by "pulling" the crystal out of a melt. The various conductivity layers are formed by the introduction of impurities or "dope" at specific times during the pulling operation. In P1 carrier, two types of germanium grown-junction transistors are used – one (the 4B) in voice-frequency circuits, and the second (the 4C) in carrier-frequency circuits. These two codes are final designs that evolved from models used in earlier stages of development.

(Above) The author (right) and R. W. Eckert of the Western Electric Company discuss production of transistors at the Allentown, Pa., Plant.

Early exploratory work was done with a transistor bearing the Laboratories designation 1752. The 1752 grown-junction transistor was encapsulated in plastic, and although it was very useful for circuit design, its reliability and stability left much to be desired. In addition, it was known that improvements in the gain-frequency characteristics of the unit would simplify the carrier-frequency circuits of the rural system.

A second transistor, the 1858, was therefore developed to overcome these disadvantages. This is the type used in the field trial of the system in Americus, Georgia, during 1954-55‡ The 1858 transistor was enclosed in a hermetically sealed container to protect it from moisture and contaminants. Further, the crystal bar in the transistor was covered with a compound (red-lead polyethylene-polyisobutylene) to reduce some of the detrimental surface effects that can seriously impair performance unless special precautions are taken.

The model 1858 transistors performed well in the Americus trial, during which they were used for over four million transistor-hours. In one respect, however, performance fell below expectation – during the short-term or initial aging period (about six months) the current-gain (alpha) decreased more than was desirable. Consequently, a laboratory investigation was undertaken which disclosed that the red-lead compound was responsible for this ini-

* RECORD, *January*, 1956, *page* 8. † RECORD, *October*, 1955, *page* 374. ‡ RECORD, *April*, 1954, *page* 158.

tial aging and that it could be arrested by substituting a dry oxygen atmosphere.

This solved an important performance problem of the rural-carrier transistors, but there remained the problem of design for manufacture. To take full advantage of the transistor's potential economy, the Western Electric Company determined that at some future date, automatic manufacturing methods were to be used both in the assembly of components into circuits and in the manufacture of the transistor itself. Automatic assembly techniques therefore dictated the transistor's external shape, dimensions, lead configuration and lead size. Anticipation of automatic manufacture also determined the transistor's internal structure, assembly and dimensions.

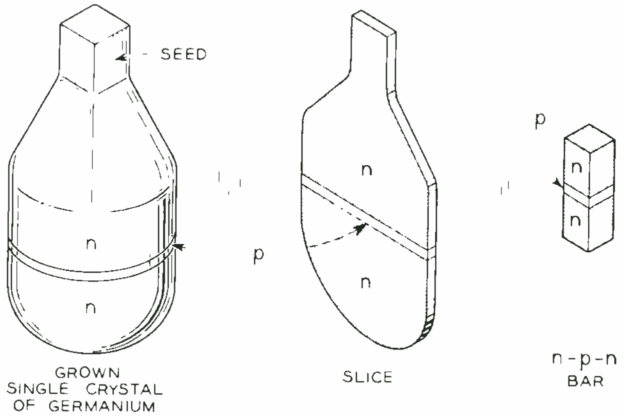


Fig. 1 — Formation of the n-p-n bar: germanium is grown from a seed crystal and is then cut and sliced to the required dimensions of the element.

The 4B and 4C transistors are both of the n-p-n type. Each has a p-conductivity layer (current carriers are *p*ositively charged holes) between two n-conductivity layers (current carriers are *n*egatively charged electrons). In addition to the design problems already mentioned, their development involved the successful tailoring of three of a transistor's most fundamental electrical properties. One of these is the current-gain (alpha) discussed earlier in connection with the problem of aging; the second is the "alpha-cutoff frequency" or the frequency at which alpha drops to 70.7 per cent of its low-frequency value; and the third is the collector reverse-breakdown voltage, or the maximum voltage that can be applied in the direction of difficult current flow in the collector junction. These properties are determined primarily during the growing of the n-p-n crystal.

Current-gain or alpha is more accurately defined as the fraction of emitter current that flows across the collector junction. It is the principal quantity that determines how good an amplifier the transistor will be. Ideally, for junction transistors, it should approach a value of unity, and in the specified operating range it should not vary greatly with temperature or frequency. When alpha is unity, all of the electrons that the emitter injects into the base region diffuse through the base region into the collector. Inefficiencies are, however, inevitable. The requirement for the rural carrier system was that alpha should not be less than 0.96. In other words, a minimum of 96 per cent of the electrons injected into the base region must appear in the collector.

Keeping alpha close to unity is a matter of studying, and controlling in a satisfactory manner, the processes by which electrons are injected by the emitter, diffuse through the base region, and are collected. To treat such processes quantitatively, however, it is necessary to identify three types of efficiency involved in the mechanism by which the electrons travel through the crystal. These are (1) the emitter efficiency, or ratio of electron current at the emitter to the total emitter current, (2) the transport efficiency, or ratio of electron current at the collector to the electron current at the emitter, and (3) the collection efficiency, or incremental ratio of total collector current to electron current reaching the collector. Since alpha is the product of the three, all must be near unity.

To a certain extent, these requirements conflict

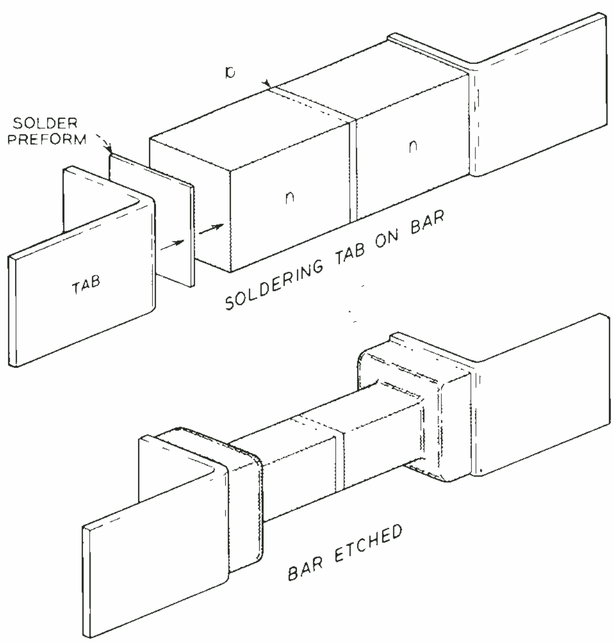


Fig. 2 — Assembly of the transistor: tabs are soldered to germanium bar, which is later etched to remove disturbed material from the surfaces.

with other desirable electrical characteristics, so compromises are necessary to achieve an optimum set of properties. For example, very high emitter efficiency can be achieved by doping the emitter very negatively and the base only slightly positively, but this could result in an undesirable high value of input impedance. In the 4B and 4C transistors, the emitter is doped negatively to a fairly high extent (resistivity about 0.001 ohm-cm) and the positive doping of the base is held to a low value (resistivity about 1 ohm-cm). This helps to ensure that the short-circuit input impedance does not exceed an established upper limit of 50 ohms.

The second requirement, high transport efficiency, is achieved principally by using a thin base region. If electrons have only a short distance to travel to reach the collector, there is less chance for them to be neutralized by recombining with holes. The thickness of the p-layer, however, is governed primarily by another consideration – alpha-cutoff frequency. Frequency cutoff of alpha depends upon the dispersion in transit times of the electrons as they traverse the base region. The wider the base region, the longer the transit time; the longer the transit time, the greater the dispersion in transit times (following the diffusion law). Thus, the greater the dispersion in transit times the lower the frequency cutoff, and for this reason the p-layer must be kept thin. Manufacturing controls become more difficult as p-layer thickness decreases, and an economic design is one which compromises correctly between circuit need and the degree of manufacturing complexity.

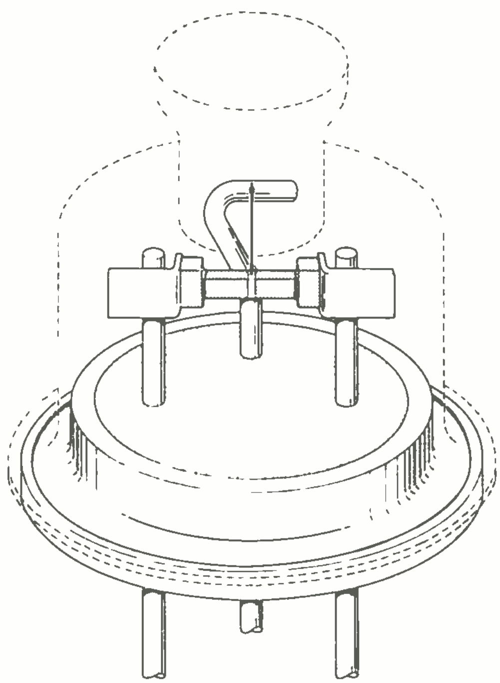


Fig. 3 — Internal structure showing mounting of junction bar and positioning of base lead.

For a median alpha-cutoff frequency of about 3 megacycles, the p-layer thickness of the 4C transistors is about 1/1000 of an inch. The 4B transistor uses a thicker p-layer of about 1/700 of an inch to produce a median alpha-cutoff frequency of about 1.5 megacycles. Each of these thicknesses is well within that required to give a transport efficiency of very nearly unity.

The third requirement, high collector efficiency, is a problem only because the nature of the collector junction may be such that the efficiency can become greater than unity. Injected electrons that arrive at the junction are attracted into the collector region by the high electric field existing at a reverse-biased p-n junction. Once the electrons enter the collector region, however, appreciable electric field is required to move them away from the junction. This field accelerates minority holes in the collector region toward the junction, and these holes are then attracted back through the barrier region and into the base. Thus, an extra current, in addition to the electron current, flows across the junction. As the temperature increases, more holes are generated in the collector, which results in a greater hole current across the junction.

For this reason, the collector efficiency can be greater than unity. In this case, the total alpha of the transistor may also be greater than unity, and in addition will vary appreciably with temperature. This effect can be minimized by keeping the resistivity of the collector region low, thereby suppressing the generation of the minority carriers in the collector. For the 4B and 4C transistors, the collection efficiency is reflected in the requirement that alpha, at 60°C and with 50 milliwatts power dissipation, be less than unity.

The collector resistivity is also important in determining the collector voltage breakdown. Voltage breakdown is the result of a multiplicative or avalanche process analogous to the Townsend discharge in a gas tube. (See discussion of the physics of the breakdown process in the preceding article by A. G. Chynoweth.) High breakdown voltage may be achieved by having a wide transition layer separating the p and n region at the collector. The techniques here are to use high resistivity material for either the base or collector, or both, or to use a gradual transition from n- to p-type germanium. A compromise is necessary because low resistivity is needed in the base for low input impedance and in the collector for control of collection efficiency.

In the 4B and 4C transistors, keeping the collector resistivity in the range of 0.5 to 1 ohm-cm makes it possible to keep the collector efficiency below unity and to meet the voltage-breakdown requirement. This requirement is that the reverse collector current with zero emitter current be less than 15 microamperes when 30 volts is applied between collector and base.

As mentioned, automatic assembly techniques dictated the external shape, dimensions, lead configuration and lead size. A round enclosure is used with the three 0.025-inch diameter leads spaced 90° apart on a 0.100-inch radius. The height is limited to 0.550 inch and the diameter to 0.500 inch.

The internal assembly steps are shown in the accompanying drawings. Assembly of the transistor starts with germanium bars (0.032 by 0.032 by 0.125-inch) cut from the grown n-p-n junction ingot. Next, nickel-iron alloy tabs, which have nearly the same coefficient of expansion as germanium, are soldered to the ends of the bar. This is done with solder preforms doped with arsenic to insure an ohmic contact to the n-type germanium. This assembly is then placed in a fixture, and the surface of the bar is electrolytically etched by a stream of an 0.1 per cent solution of potassium hydroxide. This solution flows over the surface but is confined to the vicinity of the junctions. The purpose of the etching is to remove the superficial layer of disturbed material left by the mechanical preparation and to expose the undisturbed body of the crystal beneath. After etching and washing in deionized water, the assembly is mounted on a round header by spot welding the tabs to two diametrically opposite leads: emitter and collector.

The mounted bar-header assembly is now ready for attachment of the base lead. Gold wire is used, 0.002-inch in diameter and doped with two per cent gallium. The gallium ensures an ohmic contact to the p-layer. One end of the wire is flattened in the form of a spade with a thickness of 0.0004 inch. This thin section is used as a probe and is dragged along the surface of the bar until the pattern on an oscilloscope indicates that the p-layer has been found. A pulse of current is then passed through the wire and the germanium bar, which bonds the probe to the p-layer. The other end is welded to a third header lead, which is called the base terminal.

A steel can with a copper tubulation brazed to the top is next welded to the header assembly. With the exception of the opening in the tubulation, this operation seals the unit. It is then heated to a temperature of 130°C and evacuated to a pressure of less than 1 micron of mercury. After evacuation, the unit is backfilled with dry, clean oxygen to a pressure of 1½ atmospheres. Pinching-off the tubulation completes the sealing. Finally, the unit is oven-aged at a temperature of 100°C for four hours.

The practicability of producing high quality transistors for carrier systems has been demonstrated by experience with the grown-junction transistor, and the P1 carrier field trials helped in evaluating their performance. Subsequent improvements in design and processing have resulted in close control of electrical characteristics and greater reliability.

The performance of a similar grown-junction transistor (the 4D) in the handset for the hard of hearing offers an example of the degree of reliability which may be expected.* Results from the field to date indicate only one known transistor failure in the approximately 100,000 handsets put into Bell System service over the past two years.

* RECORD, *October*, 1955, *page* 361.

THE AUTHOR

I. C. SAVADELIS, a native of Arlington, N. J., received the B.E.E. degree from Rensselaer Polytechnic Institute in 1942. After serving in the Armed Services during World War II, he was employed for several years in industry. In 1952 he received the M.S. degree in Electrical Engineering from Pennsylvania State University and joined the transistor development group of the Laboratories at Allentown. Initially he was engaged in designing transistor circuit packages and has since worked on the final development of germanium grown junction transistors. At present he is concerned with final development of the diffused base germanium transistor. Mr. Savadelis is a member of the A.I.E.E. and the I.R.E.

Traffic Studies of Line Concentration

W. S. HAYWARD, JR. *Traffic Studies*

To ensure that telephone equipment is planned and designed on sound engineering principles, extensive mathematical analysis typically precedes a Bell Laboratories development. This is nicely illustrated by recent work on line concentration. To aid in systems planning, large amounts of special traffic data were collected from central offices; then, further information was obtained from field trials of actual line concentrators. Analysis revealed traffic characteristics important to the use and design of such equipment.

Line concentration is an attractive way of increasing the efficiency of telephone cables that connect residential telephones to central offices. For example, 50 telephones in a particular geographical area ordinarily require 50 cable pairs to the central office. Calls on these lines, however, might be switched locally, or "concentrated," into only ten pairs or concentrator trunks, which in turn would carry the calls to the office, a saving of 40 cable pairs. Such concentration of lines into trunks is a standard procedure within a central-office, and in certain respects, remote concentration is a logical extension of central-office switching to a location near the customer's premises.*

In effect, what was formerly the first stage of switching at the central office is moved as close as possible to the customer. At first glance, therefore, this move would not seem to have any effect on the manner in which the switching system handles telephone calls. In practice, however, there are certain differences in both the method of switching and in the properties of the telephone traffic. As a result, concentrators present several unprecedented traffic problems. First, because the concentrator serves lines selected from customers in a relatively small geographical area, the characteristics of the telephone-call traffic from this area will usually differ from the office average. Second, the use of remote concentrators introduces a new objective in traffic administration – to assign concentrated and unconcentrated lines for maximum savings of cable. And third, the use of concentrators requires measurement of the usage of individual lines to achieve the desired efficiency ("line fill") while maintaining on concentrated lines the same traffic service given to non-concentrated lines. These new problems have been studied extensively at Bell Laboratories.

The evolution of a switching arrangement for concentrated lines is a typical example of how traffic theory can be applied to the design of tele-

* Record, *May,* 1957, *page* 168.

phone switching circuits. As shown in Figure 1(a), the first stage of switching within a No. 5 crossbar central office connects as many as 59 lines by line switches to line links which terminate on junctor switches. The No. 5 crossbar remote concentrator, as originally conceived, was to perform the function of the line switch, so that the concentrator trunks would in reality be line links associated with the junctor switches in the central office. This early concept is indicated in Figure 1(b). With a design of this type, however, each customer line must be capable of being connected to any of ten concentrator trunks, which would have required ten crosspoint connections for each customer line.

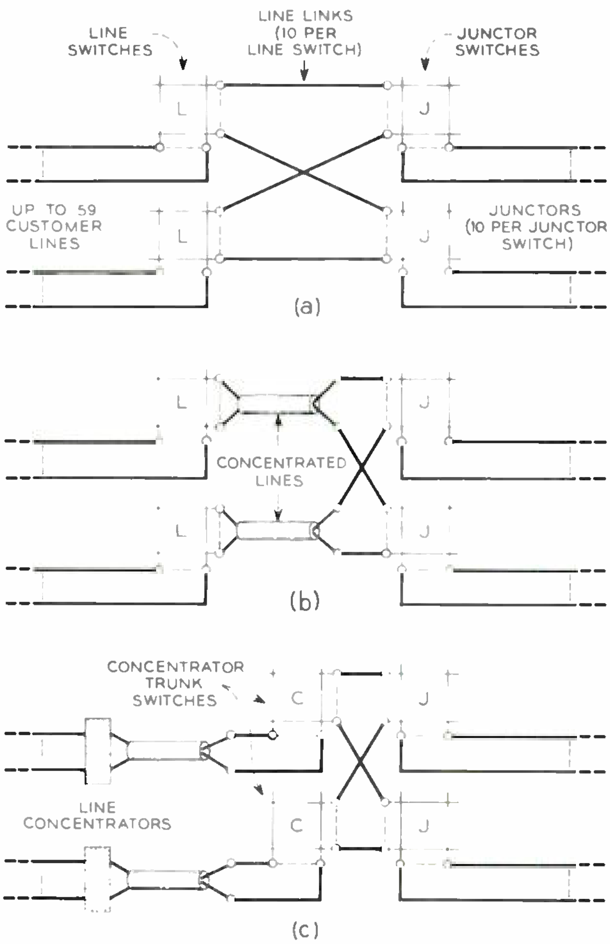


Fig. 1 — (a) Regular No. 5 central-office switching, where customers' lines appear on line switches; (b) initial plan to use line switches as concentrator equipment; (c) eventual scheme leaving line links in the telephone central office.

A major part of the cost of concentrators lies in the line crosspoints. To reduce this cost, therefore, a new scheme was invented whereby each line can be connected to only a certain fraction of the total number of concentrator trunks. This arrangement, indicated in Figure 1(c), permits the trunks to be switched to line links by relatively inexpensive crosspoints in the central office. With this design, the ten concentrator trunks are thus made part of a separate stage of switching ahead of the line links. If every line could reach every trunk, the potential traffic capacity of the concentrator trunk group would be almost 20 per cent higher than the capacity of the ten line links in the central office. It is therefore possible to give each customer line access to only six of the ten concentrator trunks without materially reducing total traffic capacity.

The arrangement, a modified "graded multiple," is illustrated by the diagram shown as Figure 2, which indicates how customer lines have access to concentrator trunks. Along the bottom of the diagram are indicated ten groups of customer lines, each group consisting of up to five individual lines. The vertical row of numbers at the left identifies the ten concentrator trunks. To interpret this graded multiple, we follow a customer line through a vertical column from bottom to top. For example, suppose that the line for one customer appears in group number 7. When the customer places a call, the concentrator will first attempt to establish a connection to the central office over trunk number 1, as indicated by the "one" (first choice) at the intersection of line group 7 and trunk 1. If trunk 1 is busy, an idle trunk is sought in the indicated order of preference: trunks 5, 0, 4, 8, and 9. Notice that

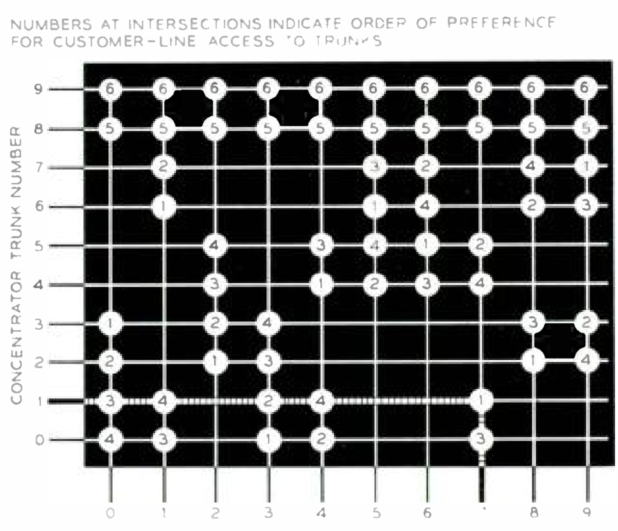


Fig. 2 — The modified "graded multiple" giving customer lines access to six out of ten trunks, with trunks 8 and 9 as the last choices for all lines.

trunks 8 and 9 are the last two choices for all lines; otherwise, lines have access only to patterns of four trunks out of the series 0 to 7.

Purely from the point of view of maximum traffic capacity, it would have been better to arrange the multiple so that each line could have access to an entirely independent combination of six trunks (the "full random slip" condition). To meet other service requirements, however, the two trunks 8 and 9 must be accessible to all lines, and to reduce manufacturing costs, the patterns should be as regular as possible. In spite of this departure from the ideal, a theoretical solution of traffic capacity based on the fully random condition is sufficient for estimating the chances that calls may encounter "all-trunks-busy" at a concentrator. This probability must of course be kept very small; the theoretical values were verified by manual and computer traffic-simulation studies in the laboratory and by data taken in field trials of a concentrator. The probability that all concentrator trunks will be busy to a telephone call, combined with the probability that no path can be found through the central-office switching network, determines the maximum traffic capacity of the concentrator. That is, capacity cannot be increased beyond the point at which service to customers is impaired.

As mentioned earlier in this article, the characteristics of traffic offered to a concentrator will differ from the broad "cross-section" type of traffic handled by the central office. The prime cause of such differences appears to be that people living in the same area will generally have similar calling habits. Although traffic rates vary widely from group to group, a fair correlation between housing costs and concentrator group usage has been observed. Comparisons shown in Figure 3 illustrate that, roughly speaking, the higher the housing cost the greater the usage of telephone lines. For the data collected, this graph shows on the ordinate the per cent of fifty-line groups with traffic usage higher than the per cent of average central-office usage indicated on the abscissa. For example, note the vertical line drawn at 120 per cent — that is, 20 per cent greater than the office average. If we choose a sufficient number of fifty-line groups *at random* from the lines served by a central office, we notice that only about 13 per cent of these groups may be expected to have a traffic rate 20 per cent higher than average. If, however, instead of selecting groups of lines at random we select them from medium-cost housing areas, 31 per cent of these groups may be expected to have a traffic rate 20 per cent higher than average. For a high-cost housing area, the figure increases to about 41 per cent. Such data are of considerable use to planners of installations in estimating how many concentrators can be placed in a given geographical area.

Another difference between concentrator traffic and regular central-office traffic is a higher likelihood of "intra-group" calls. That is, a customer is more likely to place a call to his own concentrator

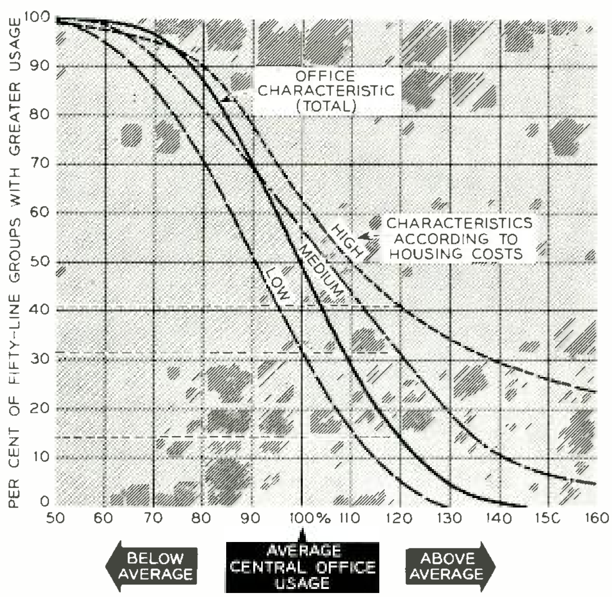


Fig. 3 — A special study of traffic data indicates relationship between line usage and cost of housing.

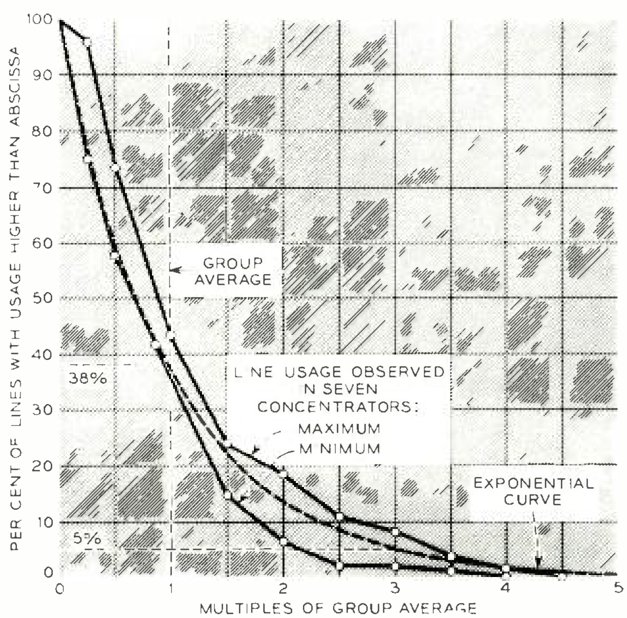


Fig. 4 — Individual telephone lines vary widely in their contributions to total central-office traffic.

area than another customer is to place a non-concentrated call to a number served by the same line switch in the central office. An intra-group concentrator call causes a double usage — two concentrator trunks, two line links, and two junctors in the same group. This double usage results in a higher probability of a failure to set up a connection than is observed for normal traffic at the same load. However, even if 50 per cent of concentrator traffic consists of intra-group calls, the probability of finding all trunks busy is not greatly changed. Since an intra-group calling rate as high as 10 per cent is unusual, only a minor adjustment in rated capacity of the concentrator is required.

To this point, we have dealt mainly in terms of rather broad averages calculated from groups of lines. But it should be noted that individual lines vary widely in their contributions to the traffic load of concentrators. Figure 4 shows, on the basis of measurements of individual lines in seven concentrators, the extent of this variation. In the two examples indicated in Figure 4, we see that only 38 per cent of the lines are used more than the office average, while about 5 per cent of the lines are used as much as three times the office average. The dashed curve drawn between the minimum and maximum values shows that the distribution is approximately exponential in nature.

Knowledge of this variation can be put to use in assigning lines. In the distribution plotted in Figure 4, 5 per cent of the lines generate a fifth of the total concentrator traffic, and 10 per cent of the lines generate a third of the total. Knowing this, the traffic engineer can assign high-usage lines to non-concentrated conductor pairs, and can place a greater number of low-usage lines on the concentrator. Combined with data on the broader aspects of traffic usage, the more detailed measurements will result in greater economy of installation.

It is evident that such planning calls strongly for measurement of the usage on each line. For concentration systems which do not provide a separate line appearance in the central office, a special line usage recorder is needed. If a central office appearance is available, however, the Traffic-Usage Recorder has been designed so that it be used to collect line usage data. The Recorder uses a switch-counting technique for treasuring usage with a scan rate of one scan or "look" at a group of lines per hundred seconds. Studies have shown that lines must be measured for a period of at least two weeks to achieve the good estimate of traffic load needed to assign the proper lines to concentrators.

Fig. 5 — The author (left) and J. W. Gibson discuss data from studies of line concentration.

Much of the theoretical work described here was undertaken before any concentrator equipment was built. The construction on paper of mathematical models, and the analysis of actual field data from central offices, permitted the rapid evaluation of various proposals made during development. Working solutions to the several new traffic problems were reached well in advance of wide-scale use of remote line concentrators.

THE AUTHOR

W. S. Hayward, Jr. received his A.B. degree from Harvard University in 1943 and subsequently served in the U. S. Navy from 1944 to 1946. He then returned to Harvard, where he received the S.M. degree in 1947. He joined Bell Laboratories in this same year, and after two years in switching systems development, he joined the Traffic Studies Department, where his prime concerns were traffic measurements and the traffic capacity of crossbar switching systems. Mr. Hayward is presently engaged in long-range planning of transmission systems. He is a member of the A.S.A. and an associate member of the I.R.E.

Voltage Conversion with Transistor Switches

P. L. SCHMIDT
Military Apparatus Development

Modern magnetic-core components are powerful new running mates for semiconductor devices. In many areas of electronics, this combination has greatly improved the reliability, efficiency and ruggedness of existing apparatus. In some cases, such as the conversion of a dc voltage to ac, the combination of transistors and magnetic-core components has provided an entirely new approach to the problem.

In ac power circuits, one voltage is generally converted to another with a transformer. When only dc power is available, however, as in many types of portable equipment, the conversion from the primary power voltage to other required voltages is a more difficult problem. Voltage changes of this type are usually accomplished by a time-honored, multistep procedure.

In this method, mechanical vibrators change the dc to ac by simply interrupting the current mechanically at a desired frequency. The ac output is then fed into a transformer, changed to the desired output voltage, and finally, rectified back to dc. This conversion method is still widely used in automobile radios and in many military applications such as power supplies for missiles and portable electronic equipment. Its principal disadvantages, however, are inefficiency and the short, uncertain life of mechanical vibrators, some of which make and break current-carrying contacts up to several hundred times per second.

A new approach to the problem of voltage conversion has been made possible by the recent development and availability of alloy-junction power transistors. With these new transistors in conjunction with a special transformer, a circuit has been developed which converts dc to ac with efficiencies up to 90 per cent. This circuit, called an inverter, is shown in Figure 1(a), and it operates as follows: the two transistors, T_1 and T_2, conduct alternately and apply the dc input voltage to windings 2 and 3 of the transformer while two other windings, 1 and 4, control the switching of the transistors. This produces a nearly square-wave ac output at winding 5.

The operation of the circuit depends primarily on the properties of the transformer core material. For example, the saturation flux-density of the core is a factor in determining the frequency of oscillation of the circuit. Also, the abrupt saturation of the rectangular-hysteresis-loop material produces changes in the feedback voltages which force the transistors to switch instantly when the transformer voltages become negligible. Because this circuit operates at much higher frequencies than conventional vibrators and dynamotors, it has the important advantage of using much smaller transformer and filter components.

Before we examine in any detail the operation of the circuit, it should be emphasized that the transistors in this arrangement operate as switches and not as linear control devices. While one transistor is conducting, the other is essentially an open circuit. The principal advantage of operating a transistor as a switch is that power dissipated as heat in the transistor is only a small fraction of the usable power controlled. On the other hand, when the transistor is operated in the linear region of its characteristics, the dissipation is equal to or greater than the usable power.

The characteristic curves of a p-n-p alloy-junction power transistor, shown in Figure 2(a), help to illustrate this difference in transistor-power dissipation and also help to show how the transistor operates as a switch. These curves show the relationship of collector voltage, V_c, to collector current, I_c, for the simple circuit of Figure 2(b). If a 28-volt source of dc and a four-ohm load are connected in series with the collector and emitter, the voltage across the transistor can be varied from essentially the entire source voltage to zero by varying the base current, I_B. The four-ohm "load-line" from point a to point b in Figure 2(a) shows these conditions. Even for zero base current, a very small load current will flow because of reverse leakage in the collector junction. The load current can be reduced almost to zero if the base is made positive with respect to the emitter and collector. The transistor is then "cut-off" and may be likened to an open switch.

The positive base voltage required for cut-off is less than one volt, and the base current in this case is very small. If the base is made increasingly more negative with respect to the emitter, however, the voltage drop across the transistor decreases and the load current increases until the base current reaches a value of about 300 milliamperes. At this value (point b), the voltage across the transistor is less than 0.5 volt, so that almost all the source voltage is across the load, and the load current cannot increase. In this state, the transistor is "saturated" and may be thought of as a closed switch with a resistance as low as 0.05 ohm.

If the base voltage, V_b, is switched suddenly from a positive value to a negative value sufficient to produce saturation, the load current will likewise be switched from essentially zero to approximately seven amperes, just as though a switch were suddenly closed. Conversely, if the base voltage is instantaneously made positive, the transistor will cut-off, and the current in the load will return to zero as though a switch were opened. The power dissipated by such a transistor switch is very small because when it is saturated (closed switch) the current is high, but the voltage across it is small. Similarly, when it is cut off (open switch), the voltage across the transistor is high, but the current is essentially zero.

A power-dissipation line is shown in Figure 2(a) for twenty watts, the assumed dissipation rating of this power transistor. Although the load-line passes through the high-dissipation region when the transistor switch opens (point a) or closes (point b), the switching time can be made small enough to maintain a *low average* dissipation. Consequently, the power that can be controlled by the transistor is much greater (a factor of over ten, usually) than the dissipation rating of the transistor.

With these two points in mind – operation as a switch, and low average-power dissipation – perhaps the clearest way to explain the transistor volt-

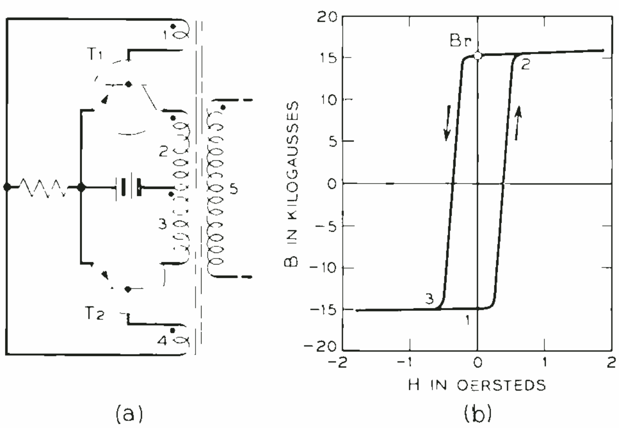


Fig. 1 — Basic circuit (a) of the transistor-core inverter, and dynamic hysteresis loop (b) of the core.

age-inverter would be to describe first, in some detail, the action of the circuit of Figure 1(a). Suppose that the circuit is energized, and a slight unbalance exists in the arrangement of the transistors so that more current flows through winding 2 than winding 3 of the transformer. Assume also that the magnetic state of the core is at point 1 on the rectangular hysteresis loop, Figure 1(b). The flux in the transformer core now begins to change toward positive saturation, inducing a voltage in windings 1 and 4. This voltage then makes the windings positive at the dots shown.

With the windings polarized thus, the base of transistor T_1 becomes negative and the base of transistor T_2 becomes positive, causing T_1 to saturate and T_2 to cut-off. The total energizing voltage, except for the small voltage drop across transistor T_1, will then appear across winding 2, and the flux in the core will change at a constant rate determined by the voltage, number of turns and area of the core. This constant rate change will continue until positive saturation of the core is reached at point 2 on the hysteresis loop. At this point, the current in winding 2 increases sharply, driving the core far out into saturation. The induced voltages in the windings, however, quickly fall to approximately zero, so that transistor T_1 cuts-off and checks the current flow in winding 2.

As a result of this cut-off, the flux in the core returns toward its B_r, or residual, value. This induces a voltage of the opposite polarity in windings 1 and 4 so that the base of T_1 becomes positive and the base of T_2 negative. This forces T_1 to cut-off completely and T_2 to conduct. Conduction in T_2 applies the source voltage to winding 3, and the flux in the core begins to change toward negative saturation. During the period the flux is changing from positive to negative saturation, the induced voltages are sufficient to keep T_1 cut-off and to saturate T_2. When negative saturation is reached, at point 3 on the hysteresis loop, the switching process again occurs, so that transistor T_1 conducts, T_2 cuts off, and the core flux changes toward positive saturation.

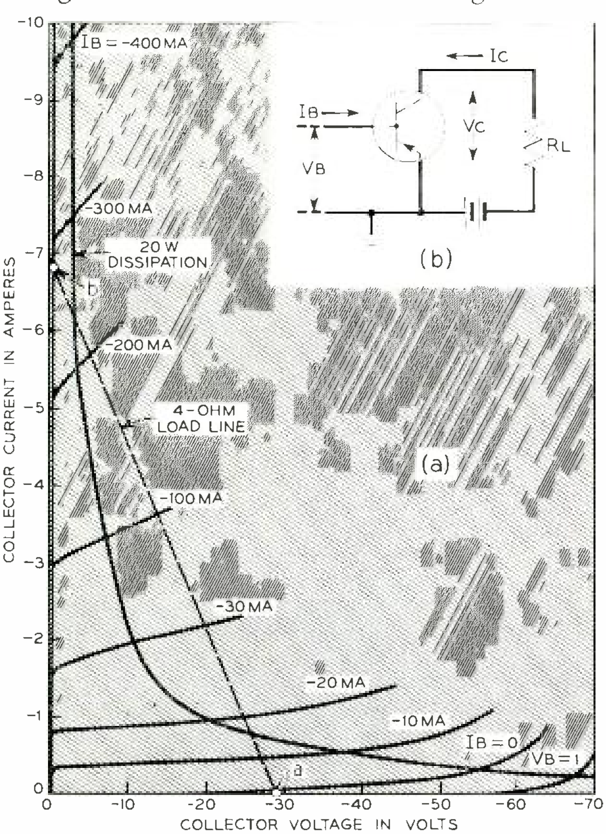


Fig. 2 — Grounded emitter-collector characteristics of an alloy-junction transistor (a), for the common-emitter circuit arrangement shown in (b).

This cycle continues to repeat itself, and the repeated switching action of the transistors is mani-

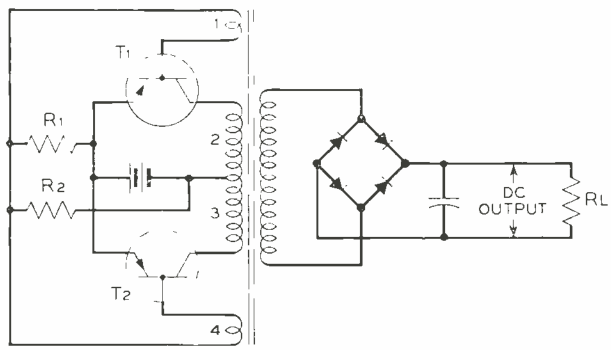


Fig. 3 — The dc-to-dc converter circuit with the self-starting feature incorporated.

fested by a square-wave ac output at winding 5. The frequency of this ac output can be mathematically determined from the basic design equation: for a core of given saturation flux-density, cross-sectional area and number of turns in the windings, the frequency is directly proportional to the dc voltage applied.

Applications for the transistor-core inverter fall into two general classes – conversion from one dc voltage to another, and conversion from dc to ac. The former application may best be illustrated by considering a frequently encountered engineering problem. An engineer must design a power supply for a portable receiver or transmitter, or for airborne missile equipment, knowing that the prime source of power is a low-voltage dc battery and that both higher and lower dc voltages will be required for various electronic circuits in the equipment. He knows from past experience that dynamotors are bulky and electrically noisy; that vibrators as normally used in power supplies have limited life; and that the circuits require special treatment to avoid the effects of noise. Also, efficiencies of these mechanical devices are rarely as high as 65 per cent and the vibrator is limited in frequency to about 250 cycles. With presently available transistors, however, the transistor inverter circuit may be operated up to nearly 2000 cps for power in the order of 100 watts, and up to twenty kilocycles where power in the order of ten watts is required. Operation at these higher frequencies also makes possible the use of miniature transformers, inductors and magnetic components.

A typical transistor circuit for converting from one dc voltage to another is represented schematically in Figure 3. The three essential elements of the circuit are a transistor-core inverter, a rectifier for converting back to dc, and a filter. Generally, the filter need only be a small capacitor, since the output is basically dc with very little ripple. This inverter circuit differs slightly from the basic circuit, Figure 1(a), in that resistor R_2 has been added. The basic circuit is usually not self-starting under heavy loads, but the addition of this resistor biases the transistors into action when the circuit is energized, and oscillation starts immediately because of the increased unbalance in the circuit.

The dc-to-dc conversion circuit of Figure 3 has been incorporated into the design of power supplies for various military projects covering a wide range of input and output voltages and power ratings. To give some idea of the size of this type of power supply, Figure 4 shows one recently designed for thirty-watts output and 24-volts input, packaged in a hermetically-sealed can having outside dimensions of 2 x 3 x 4 inches.

Aside from the size and weight considerations, apparent from the display board shown in the photograph on page 62, this power supply offers many electrical advantages over the conventional mechanical-vibrator power supply. Since there are no contacts to wear or pit, the transistor converter offers increased reliability. The average life of some mechanical vibrators is less than forty hours. Some of the transistor circuits, however, have operated for more than 5,000 hours without transistor failure. The transistor inverter is also more efficient — as high as 85 per cent compared to about 65 per cent for vibrator inverters. Further, the transistor is a much more rugged and noise-free device than a mechanical vibrator — a component sensitive to shock and vibration and frequently productive of spurious electrical noise due to contact arcing.

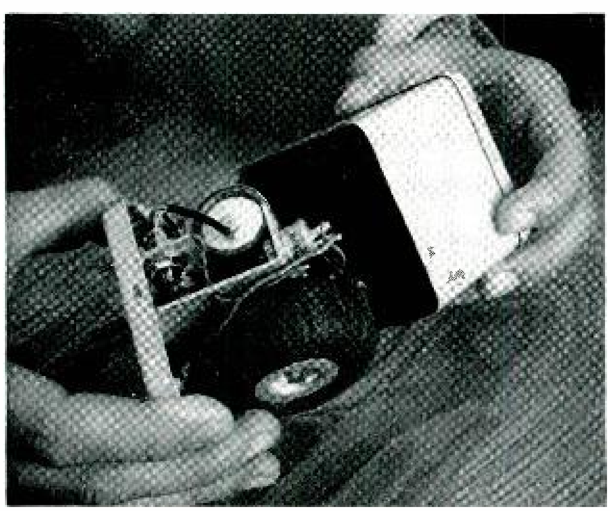


Fig. 4 — Thirty-watt power supply showing packaged arrangement of the various components.

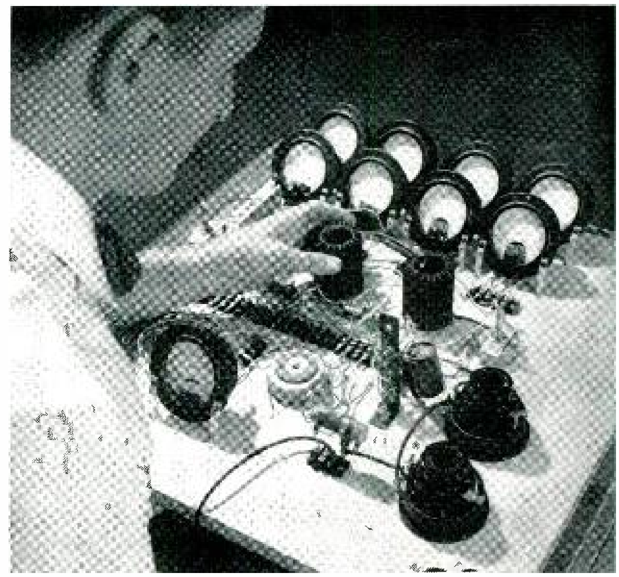


Fig. 5 — F. Kadri checks temperature of heat-sink designed to conduct heat away from transistors.

The apparent disadvantage of the transistor inverter is the operational ceiling of the germanium transistor imposed by the ambient temperature. Environmental tests, however, have shown that missile power supplies operate reliably at a chassis temperature of 85°C, and in addition, the detrimental effect of high temperature on transistors operating as switches is much less than on transistors operating as linear amplifiers. This maximum operating temperature will in all probability be raised considerably when silicon power-transistors with characteristics suitable for this circuit become available. The breadboard arrangement in Figure 5 shows how "heat sinks" for the transistors may be used to maintain a safe operating temperature.

The second broad area of application for the transistor-core inverter — conversion from dc to ac — assumes one of its most interesting and urgently needed roles as a high-frequency carrier supply for magnetic amplifiers.* One of the disadvantages of the magnetic amplifier is that it has a slow response when operated from the usual 60- or 400-cycle

* RECORD, *January*, 1958, *page* 16.

power source. Since the response time of a magnetic amplifier depends on the supply frequency, it is often desirable to operate well above the available supply frequency to get faster response. In the past, there has been no efficient method of converting the supply frequency to higher frequencies for magnetic amplifier operation. The transistor-core inverter can be readily adapted for this purpose, and offers the added advantages of small size and high efficiency. To cite an example, the transistor voltage-conversion circuit makes possible an audio-frequency magnetic amplifier with a self-contained, twenty-kc supply which would have a bandwidth of at least 2,000 cycles.

Other ac applications of this inverter are currently being investigated. In the field of power, for example, ac is frequently required where only dc power is available. This dc to ac inverter also makes an excellent telemetering device, since its output frequency is proportional to the applied voltage.

This circuit, or more accurately, this unique application of the transistor, has been treated in some detail because of its broad field of application in modern electronics. The transistor, discovered about ten years ago at the Laboratories, is constantly being re-discovered through its varied and almost universal applications. This voltage-conversion circuit is but one of the many advances in transistor circuitry made possible by the great advances in transistor technology.

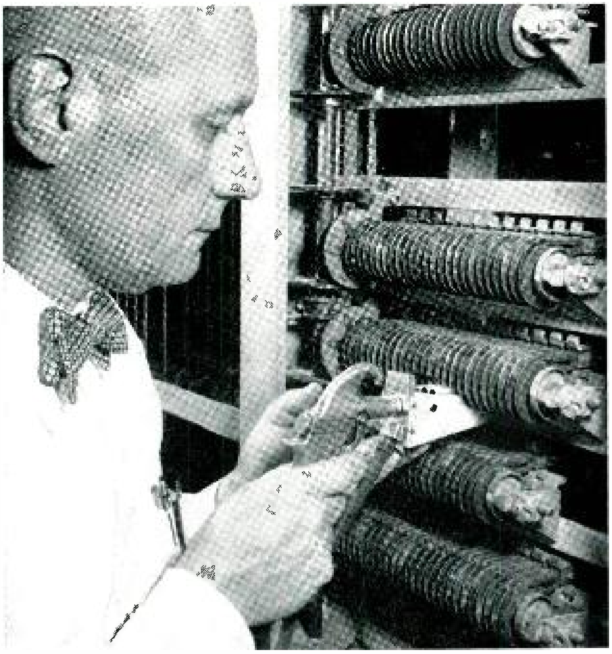
THE AUTHOR

P. L. Schmidt, whose home town is Pittsburgh, Pa., received an A.B. degree from Capital University, Columbus, Ohio, in 1939 and an M.S. degree in Physics from Ohio University in 1941. After teaching for several years in the Pittsburgh Public Schools, he joined the Westinghouse Electric Corporation, where he engaged in development work in magnetic materials, magnetic amplifiers and semiconductor rectifiers. Mr. Schmidt joined the Laboratories in 1954, and since that time has been associated with the power apparatus development group. He has been responsible for the development of a wide range of magnetic devices, including transformers, inductors, power supplies, magnetic amplifiers and regulated rectifiers for both Bell System and military uses. Mr. Schmidt is a member of the A.I.E.E., active in the program of the Magnetic Amplifiers Committee.

Western Electric Company Organizational Changes

Several changes in the organization of the Western Electric Company have recently been announced. Paul R. Brousse, formerly Vice President-Finance, has been appointed Vice President-Manufacturing, to succeed Paul A. Gorman who resigned to join the New Jersey Bell Telephone Company as Vice President-Operations. Mr. Brousse was succeeded as Western Electric's chief financial officer by Charles D. Dugan, formerly Vice President-Comptroller. Frank J. Hammel, formerly Assistant Vice President, was elected a Vice President of Western to fill the post Mr. Dugan leaves. These changes became effective January 1 of this year.

In additional changes effective December 15, 1957, Harvey G. Mehlhouse, former Manager, Merrimack Valley Works, was elected Vice President of Western in charge of Manufacturing Area "A" with headquarters in New York. Mr. Mehlhouse replaces A. Pope Lancaster, Vice President, who has taken charge of Manufacturing Area "B" with headquarters in Chicago. W. Clare Brooks, Personnel Director of the Company, succeeds Mr. Mehlhouse as Manager of the Merrimack Valley Western Electric Works.



A New Method for Cleaning Sequence Switches

B. B. MANN *Switching Apparatus Development*
H. W. HERMANCE *Chemical Research*

Maintenance of equipment is essential to dependable service in the Bell System. In the search for more efficient cleaning methods to help reduce switching troubles, the Laboratories has evolved a practical device which more efficiently removes foreign matter from sequence-switch cams in panel-type telephone switching offices.

When the panel dial system was first installed in 1921, it was expected to have a service life of twenty years. Today, however, a number of large cities are still using successfully the original panel installation. This extension of service life can be credited in some cases to modifications and additions to the system. But the main factor in keeping a system operable is the use of proper maintenance procedures. Reduction of noise and removal of surface contaminants and corrosion have, for example, been continual problems in switching offices. This paper describes a new method of cleaning the sequence switches of the panel system. The method not only reduces switching troubles, but also reduces maintenance time and maintenance frequency.

In the panel dial system a series of small, vertically-stacked terminals are connected in parallel (multipled horizontally) to form a bank. Selector frames are composed of five of these banks mounted one above the other. At the top of each frame is placed a "commutator" – a series of contact plates that act mainly as sequence counters. Multiple brushes – rigidly fixed on a vertical selector rod that is movable – travel over the selector-bank terminals. These brushes have contacting fingers composed of "sleeve" contacts to select the circuit path, and "tip and ring" contacts to complete the supervisory and talking circuits. Each rod carries six brushes so that contact can be made with the commutator and any one of the five selector banks.

Mounted at the side of each selector frame are a series of sequence switches; each switch is associated with a vertical rod. A sequence switch is made up of a number of cams mounted on a rotatable shaft, and each cam consists of two metal discs separated by a phenol-fiber insulator. Two metal contact springs press against each side of a cam. Portions of the metal cams are cut away so that, in certain positions, a spring will rest on the fiber and thus open a part of the circuit.

Panel offices carry a considerable part of Bell System traffic, often in the critical areas where high standards of performance must be maintained. Troubles, in the form of noise and electrical resistance, develop on sliding base-metal (non-precious metal) contacts. These troubles affect the quality of transmission and, in turn, the performance standards. Base-metal contacts are found on selector-bank terminals, brushes, commutators, and sequence-switch cams and springs. The latter present a particularly important cleaning problem. As a result of Bell Laboratories research, a new and improved method of cleaning the sequence switches is now employed to reduce greatly noise-causing films and deposits. On the more recent installations and on replacements, silver-surfaced cams and multiple brushes equipped with contact shoes of solid silver have been provided.

Atmospheric agents deteriorate brass, bronze, silver, and nickle-silver surfaces by forming oxide and sulphide films that adversely affect electrical contact. One typical problem is the switching failure or objectionable noise that results from the inability of a brush or sequence-switch spring to break through these films. Another problem arises when sliding action compacts loosened wear deposits and, by heat of friction, generates oxide films in the track. Also, the breaking of a highly inductive circuit causes erosion and oxidation and results in an oxide-filled "pit" in the cam surface. These pits have high resistance, and they also tend to fill with various dusts and the products of corrosion and wear.

On the panel-bank terminals a specially-developed semi-solid mixture is applied to reduce the tarnish and corrosion. Unfortunately, however, this treatment cannot be used on sequence switches because many of the cams make and break heavy switching currents, and electrical erosion of the metal is accelerated in the presence of copious oils or greases. Use of a silver overlay on the more critical cams has reduced pitting and improved signaling performance, but the noise problem has remained because of the formation of silver-sulphide films.

Previous methods used in sequence-switch maintenance included dry wiping and dry brushing of the cams – methods that gave poor results. Dry wiping smears wear and dust deposits between the wiping and wiped surfaces, and packs these deposits into the pits and other surface irregularities. Dry wiping also piles up deposits to form ramps on the insulator at the cam edge. Dry rotary-brushing showed some improvement over dry wiping, but the advantage was limited by the brush construction. The coarse, sparsely distributed bristles neither covered the surfaces completely, nor were able to reach into the pits. To overcome these disadvantages, engineers substituted a brush moistened with petroleum spirits – a solvent whose action improved the removal of loose deposits.

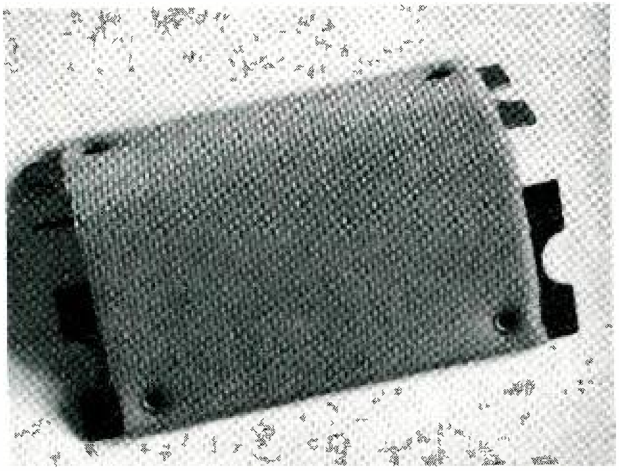


Fig. 1 — Front view of the scrubbing pad unit shows the dense velvet pile material.

To obtain full advantage of this washing method, however, a more efficient scrubber than the wire-bound bristle brush was obviously needed. Also needed was a device to control the feed of fluid to the scrubber and collect the washings from the cams. A search was therefore undertaken for a scrubbing material capable of reaching into the corners formed between the fiber insulator and the cutaway portions of the cams, as well as into the pits and irregularities in the brush-spring tracks. Further requirements included good capillary capacity and good wearing properties.

Research indicated that a velvet-pile material would most nearly meet these requirements. Such a material provides thousands of tiny erect scrubbers per square inch of surface, and their dense packing affords excellent capillary properties. Numerous fabrics were tested, and eventually a nylon velvet was chosen. To render the material suitable for washing cams, the back of the velvet was coated with a solvent-resistant synthetic rubber. This treatment bonds, erects, and stiffens the pile and gives it the desired body and resilience for the fabrication of the scrubber pads. Features of the scrubbing pad can be seen in Figure 1.

The washing tool consists essentially of a rectangular basin mounted on a pistol-type handle. The basin holds three replaceable pads – each formed in an inverted "U" – allowing six cam sides to be scrubbed at one time. Flexible leaf springs inside each "U" press the pad against the cam surface. Normal rotation of the sequence switch and the scrubbing motion of the tool produce the cleaning action. Above each pad is a small nozzle which feeds wash fluid, the flow of which is controlled by a trigger valve in the handle of the tool. A drain at the bottom of the basin leads away the spent fluid.

The washing tool is connected, through flexible hoses, to a combination unit that contains a pres-

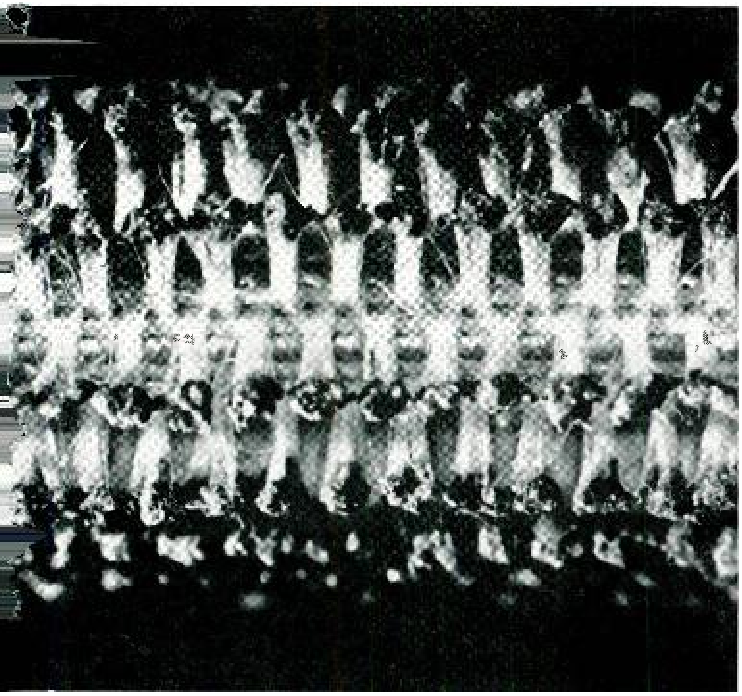


Fig. 2 — An enlarged photograph (magnified 16 times) of the pile tufts after application of abrasive mixture.

surized fluid supply reservoir and a receptacle for collecting the washings drained from the tool basin. The washing fluid is a special petroleum fraction with a high flash point, containing a small quantity of lubricant. The upper chamber of the unit serves as a reservoir for the fluid. In this chamber a small hand pump provides air pressure sufficient to raise the fluid and flush the scrubber pads. A second tank, comprising the lower part of the unit, receives the washings and is detachable for emptying. Proper insertion of the washing tool is shown in the illustration on page 65.

Sequence-switch washing removes atmospheric dust deposits, loosely adherent corrosion products, and the products of wear and erosion produced in the operation of the switch. Such treatment, however, does not remove the more adherent tarnish and corrosion. Particularly tenacious are the heavy sulphide deposits often found on silver cams and the dense oxide deposits found in the pits of bronze cams. For these a more drastic cleaning is necessary.

Formerly, pitted areas were ground smooth by a stone rotating on a power-driven flexible shaft. This required individual treatment for each pit – a tedious and expensive operation. Also, the frictional heat generated by the stone left a thin oxide film on the cam. No standard method for removing sulphide from silver cams existed. With better control of noise on panel banks afforded by the use of petrolatum-base protectant, noise from sulphided silver cams became the controlling factor affecting the quality of transmission.

A single, economical treatment was sought which would remove the tenacious films from all areas of both silver and bronze cams, including the bottoms of any pits occurring on the latter. Experiments with conventional materials, such as abrasive coated papers or fabrics, were unsuccessful. It became evident that the material needed must have the same characteristics as those of the pile washing pads; but in addition, the pile ends would have to be tipped with an abrasive. Such abrasive action simulates that of a micro scratch-brush instead of the hard shearing action of the abrasive particles cemented to papers or cloths. The abrasive tips follow the surface, reaching into pits and other low areas with just enough pressure to flex the pile tuft. Thus, the abrasive material can clean with a minimum removal of metal; the action is somewhat selective for the softer oxides and sulphides.

After considerable experimentation, a technique was developed for capping the pile tufts with a mixture of fine carborundum and an adhesive. A precision printing method during manufacture applies the abrasive-adhesive mixture to the same rubber-backed nylon velvet already described for washer-pad use. Figure 2 is an enlarged photograph of the treated pad.

To remove films from the sequence-switch cams, a rectangular reservoir, into which a single cam dips,

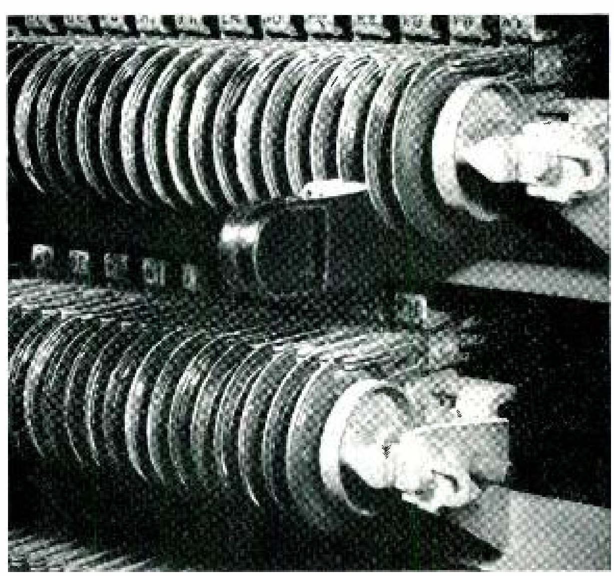


Fig. 3 — The scouring reservoir is positioned so that the abrasive pads contact both sides of an individual cam in a panel-system sequence switch.

was designed for cam scouring. This well hangs from the switch by hornlike extensions of its sides which curve over the collars that separate the cams on the center of the switch (see Figure 3). Within the well are two abrasive pile pads pressed against each other by thin phosphor-bronze springs. The cam is slipped between these pads; normal rotation of the switch is employed for scouring.

The well is partially filled with high flash point petroleum spirits. The fluid serves several purposes. First, it lubricates the cam and thus reduces the tendency to snag and tear the pile or the abrasive caps as the cam rotates. It also quickly disperses the abrasion products, cleaning the surface for efficient action of the abrasive scrubbers. Finally, it reduces the temperature generated at the points of abrasion and excludes air so that a minimum of oxidation accompanies the film removing process.

Because of the amount of drag applied by the scouring surface, generally only one cam on each switch is scoured at a time. After several cams have been scoured, the tool and pads are flushed and the well is refilled with clean washing fluid. About one minute of scouring suffices to remove the worst silver sulphide films; the amount of metal removed during this time is less than ½ of one per cent of the overlay thickness. In treating pitted bronze cams, about four minutes of scouring are recommended for the deepest pits. While this type of scrubbing does not eliminate the pit, the oxide is removed and the sharp sides are rounded so that chatter is minimized as the pit passes the contact spring. Upon completion of scouring, the cams are washed in the manner previously discussed.

THE AUTHORS

B. B. Mann, a native of Liverpool, England, joined the New York Telephone Company in 1929. He was temporarily assigned to the Laboratories during World War II where he engaged in a program to reduce noise in panel type switching offices and also a program to develop facilities for applying and removing contact protectant in this system. In 1947 he transferred permanently to the Laboratories and has since engaged in providing tools and gauges for central-office maintenance. He has also participated in instrumentation for recording missile data in the NIKE system and is currently engaged in a program for treatment and cleaning of bank terminals in step-by-step switching systems.

H. W. Hermance, a native of New York City, joined the Laboratories in 1927 after two years with the Western Electric Company where he worked on the analytical control of materials. Previously he had worked with the Crucible Steel Company and Procter and Gamble in this same field. During this period, he carried on part-time study at Newark Technical School and at Columbia University. His experience also includes chemical analysis in toxicological and criminological work. Since coming to the Laboratories, he has specialized in micro-analytical methods and has had a prominent part in developing analytical techniques and laboratory facilities. Since 1945 he has been in charge of a group specializing in the diagnosis of chemical and related problems as they affect switching apparatus in the field.

An Improved Multiple-Contact Connector

W. H. WALKER
Switching Apparatus Development

Multiple-contact connectors (groups of plugs and jacks in common assemblies) offer great convenience to the equipment designer and to maintenance people because they permit quick interchange of circuit connections and rapid substitution for faulty units. A new 20-point connector recently designed at Bell Telephone Laboratories lessens the chance of damage to the contacting members when such plugs and jacks are aligned.

In most switching and other electrical equipment, it is frequently necessary to make circuit connections between various units or subassemblies. One of the two basic methods of making such circuit connections is to solder conductors permanently in place in the equipment; the second is to use any of a wide variety of plug-and-jack arrangements so that connections can be conveniently made or broken. To avoid using great numbers of individual plugs and jacks, it is common practice to group many conductors together and establish multiple electrical paths with a single connector.

The 20-point connector is used heavily in the Bell System – over a million are currently installed in many types of communication equipment. Also, the demand for this type of connector is expected to rise sharply because of the introduction of equipment that uses connectors for rapid installation, maintenance and repair on customers' premises. For example, the newly designed 756A PBX* incorporates about one hundred 20-point connectors. In addition, the trend toward plug-in equipment units for rapid insertion into circuits has further extended the usage of such connectors. Typical of this second type of application are the plug-in assemblies used on Type-O and Type-N carrier systems so that defective units can easily be replaced.

Connectors of this type were primarily intended for connecting an indvidual cable, whereby the plugs and jacks are brought into alignment with a single guide pin incorporated into the connector structure. In this operation, the visual control of the mating parts and the "feel" of the guide pin, plugs, and jacks under relatively light pressures greatly minimize the possibility of damage to the jack contact. If any tendency to snag is encountered, the insertion is not completed until proper alignment is achieved.

When the use of this style of connector is extended to projects where such sensitive control of insertion is less ideal, the hazard of snagging is increased. For instance, control is lost or considerably reduced when a connector is mounted on a rather heavy and sizable common package, the alignment of which is guided by some part of the unit other than the connector guide pin. Under these and

* RECORD, *December*, 1957, *page* 485.

similar conditions, damaged contacts have occurred in the field. Inasmuch as a damaged (snagged) contact may result in a contact failure which could cause a serious service interruption, it was readily apparent that a connecting device should be made available that would eliminate this difficulty.

The redesigned 20-point connector is shown in Figure 1. It is similar in general appearance to the earlier connector, but it will be noted in Figure 2 that the jack arrangements are quite different.

Fig. 1 — New multiple-contact connector employing "two-petal" contacts and longer guide pin.

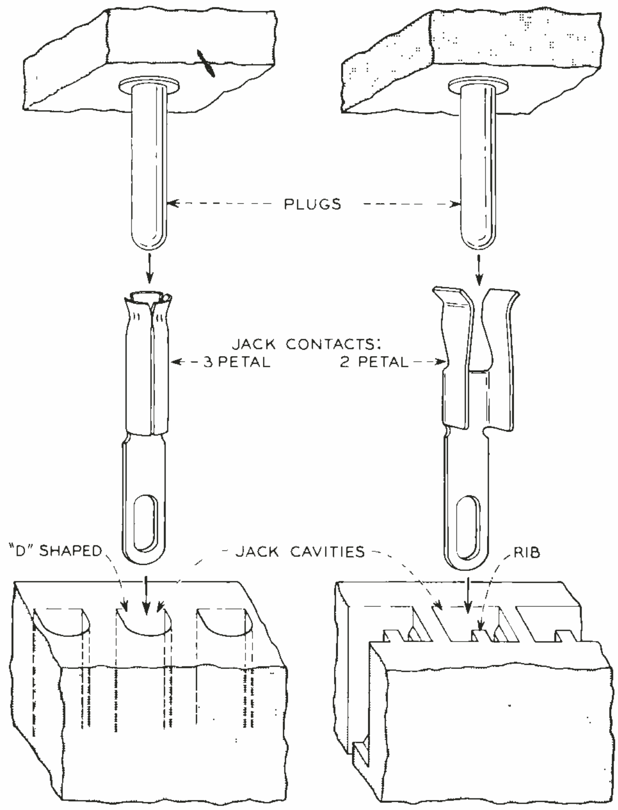


Fig. 2 — Large-scale drawing showing details of jack contacts and jack cavity structures for old and new types of multiple-contact connectors.

Heretofore, as shown in the left part of Figure 2, 20-point connectors have employed jack contacts made of a piece of sheet metal cut and formed into the so-called "three-petal" construction. These contacts are located in the "D"-shaped cavity seen in the illustration. In this design, a jack contact can "float" to one side of its cavity, and the associated plug pin can move toward the opposite side of the cavity because of rotation about the guide pin. Occasionally, these misalignments may be large enough that the pin could snag or butt against a petal edge of the jack contact. Therefore, upon insertion, the plug pin would bend or collapse the petal. Furthermore, a taut connecting wire at the terminal end frequently prevents the jack contact from assuming a favorable registration with the plug pin.

Perhaps the most challenging factor in the redesign of the connector was the requirement that the new design must be interchangeable with the large number of connectors currently in service. The problem thus resolved itself into designing a connector which has a single guide pin and which insures trouble-free engagement of mating parts. In addition, there had to be sufficient contact pressure to produce low, stable contact resistance. Combined with these features, the connector had to meet satisfactory insertion and withdrawal forces.

In general, a connecting device of this type features one-piece blocks molded of a phenolic molding compound, gold-plated brass plug pins molded into the plug assembly, and jack contacts which are punched and formed of a phosphor bronze strip and which also receive a gold-plated finish.

As shown in the right part of Figure 2, the newly designed jack employs a "two-petal" contact. This contact is oriented so that the plug pins move in a

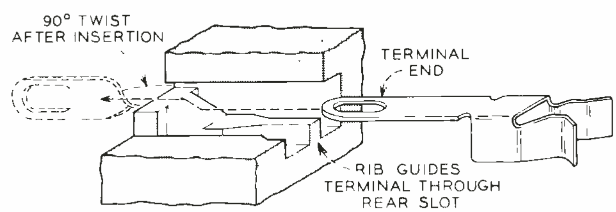


Fig. 3 — Sloped rib in jack cavity guides terminal during automatic insertion process of manufacture.

sidewise direction approximately parallel to the petals. Thus, no petal edge falls within the path of the pins. The slight sidewise motion of the plug pins, resulting from rotation about the guide pin, is restricted by the introduction of a rib in the jack cavity and by the off-center location of the cavity with respect to the plug pins. In addition, the rib restricts the float of the jack contact, but allows sufficient movement to absorb the maximum possible misalignment between the plug pin and the jack cavity in the longitudinal axis of the connector. This structure assures the same deflection in each petal (with allowance for commercial tolerances) during insertion of the plug pin. Restriction of the float also made it possible to increase the flare of the contact petals and subsequently to widen the open end of the cavity parallel to the contact petals. Thus, a more favorable funneling engagement of pin and contact is possible.

This rib in the contact cavity has another advantage. When the connectors are manufactured, the two-petal contacts are automatically inserted into the cavities of the connector block. The innermost portion of the rib is sloped to act as a guide so that the terminal or soldering end of each contact slides easily through a slot at the rear of the block.

After the contact is inserted into the cavity, the rearward-projecting terminal is twisted. The twist serves to retain the contact in its proper position in the cavity, and it also prevents damage to the contact if a force is applied to the terminal that would otherwise tend to deform the contact petals. If there is an excessive sidewise pull on the wires soldered to the terminals, the terminal ends will deflect without impairing the action of the contacts.

W. E. Asbell (left) and N. Wasserman making contact resistance measurements of connector.

As an added precaution against mishandling – such as extreme angular engagement by hand – the single guide pin in the jack was increased in length. This prevents insertion of the contact pins until the plug and jack are angled into a position that assures satisfactory registration between the pins and their associated contacts.

The 20-point connector is but one of a family of connectors having considerable output. Other types employing 21, 35 or 50 contacts are similar in design and will ultimately be considered for modification to incorporate the features described herein.

THE AUTHOR

W. H. Walker, a native of Philadelphia, started his Bell Laboratories career in 1930 when he entered the Apparatus Drafting Department. His work with this group included projects such as sonar equipment for the U. S. Navy during World War II, AMA apparatus, crossbar switch development and the card translator. Subsequently he transferred to the switching apparatus development group, where he has been concerned with connecting devices and more recently with the design and development of the new wire-spring key. He attended the evening division of the Polytechnic Institute of Brooklyn.

An Automatic Machine for Temperature Cycling

In the traditional method of joining, or splicing, conductors in telephone cables, a cable splicer has to perform a series of manual operations that are intricate and time consuming. The joints produced by this method sometimes develop high electrical resistance, which impedes the flow of current and introduces noise in the telephone circuit. For this reason, Bell Laboratories' engineers recently developed a "punched-sleeve" method for splicing cable conductors that greatly simplifies the splicing operation and produces joints of better electrical quality than those produced by the older method.*

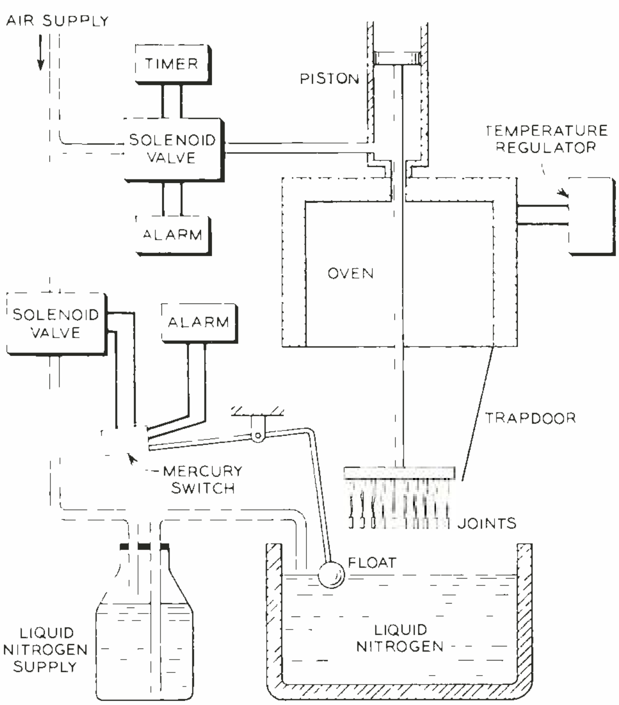


Fig. 1 — Schematic diagram of automatic temperature-cycling apparatus for testing cable splices.

The development of the punched-sleeve method of conductor joining involved measurement of the electrical resistance of the joints as one of several criteria of electrical quality. Telephone cables, during their normal life as part of the outside plant, are subjected to seasonal atmospheric temperatures that may range from —40°F to +150°F. These temperature changes may cause displacements within the joints unless the joints are held together by stresses sufficient to prevent motion. To evaluate the electrical and mechanical characteristics of the joints, they must, therefore, be repeatedly subjected to at least this temperature range.

Exposure to cycles of temperature has been an important tool in the field of physical measurement for many years. To save time in such tests, the effects of these daily or annual temperature changes can be duplicated by relatively short repetitive cycles in the normal range and can be greatly accelerated by increasing the range.

The establishment of an accelerated temperature cycle for evaluating experimental cable conductor joints followed this general approach. Exposure to 100 cycles between an oven at 150°F and liquid nitrogen at —324°F produces resistance changes in joints made by the old twisting method that can be correlated with those occurring under natural aging conditions in the field. For the latter type of joint we have a long and well-documented background of practical plant experience.

* Record, *December*, 1957, *page* 499.

Fig. 2 — J. A. Brower checking resistance of experimental joints after temperature-cyling tests.

Fig. 3 — L. W. Faulkner loading racks of experimental cable-splice joints for automatic cycling.

The test specimens are mounted on racks to make them easier to handle when making electrical measurements or when introducing them to the high- and low-temperature environments. Manually placing the racks in and removing them from the high-temperature and low-temperature environments, however, became an undue burden in the course of an extensive experimental program. Hence, the possibility of obtaining an automatic temperature-cycling machine was investigated. Since a survey of existing commercial testing equipment revealed no unit that satisfied the requirements, a suitable automatic temperature-cycling device was constructed in the laboratory. This mechanism lifts a test rack of joints into an oven for a specified length of time, then lowers it into a liquid nitrogen bath, and repeats this cycle continuously.

The racks of joints to be exposed to temperature cycling are mounted on the lower end of a pneumatically powered piston and rod arrangement as shown in Figure 3. Up to five racks may be mounted for cycling at one time. The thermostatically controlled oven has an outward-opening trapdoor in the bottom that opens and closes as the test samples enter or leave the oven. Compressed air powers the piston for the lifting stroke, and gravity provides the necessary force for the downstroke. A timer controls the operation of a 3-way solenoid valve that feeds air to the cylinder for the upstroke and allows the cylinder to bleed air for the downstroke. Compressed air is used to pressurize the liquid-nitrogen supply under the control of a valve that is operated by a float in the liquid-nitrogen bath — thus automatically maintaining the level of the liquid-nitrogen bath.

Alarms are provided for the air pressure and for the level of the liquid-nitrogen bath. The air-pressure alarm sounds if the air pressure falls below the operating requirements, and the low-level alarm sounds if the liquid-nitrogen bath falls below a preset level. A mechanical counter registers each time a new temperature cycle begins.

In the development of the punched-sleeve method of conductor joining, this apparatus has proven very useful for evaluating thousands of laboratory-made wire joints. It is also continuing to be of use in exploratory studies of other wire-joining methods.

T. C. Ewoups
Military Systems Development

W. C. TOOLE

G. B. SMALL

W. C. Toole Elected Secretary, G. B. Small, Treasurer, by Laboratories Board of Directors

The Board of Directors of Bell Laboratories on December 23 elected W. C. Toole, Secretary, and G. B. Small, Treasurer. The changes became effective on January 1, in anticipation of the retirement of M. B. Long, Secretary and Treasurer of the Laboratories. Mr. Toole and Mr. Small report to Mr. R. L. Helmreich, Vice President and General Manager. Mr. Toole will also continue as General Attorney of the Laboratories.

Mr. Toole has been with the Laboratories since 1926. He was graduated from the College of the City of New York in 1920 with a Bachelor of Science degree. In 1926 he received the Bachelor of Laws degree from Brooklyn Law School, St. Lawrence University. The following year he received the Doctor of Jurisprudence degree, also from St. Lawrence. He served as an attorney in the Laboratories Legal Department and in 1938 was named Assistant Secretary. In 1949 he was named Assistant Treasurer. He has continued in these positions and in addition has served as General Attorney since August, 1952.

Mr. Small was born in Kearny, N. J., and following graduation from Kearny High School in 1914 joined the Western Electric Company's Engineering Department, which was later incorporated as Bell Laboratories. Throughout his telephone career he has been a member of the accounting staff, and in 1942 was named Auditor of Disbursement. Since 1956 he has held the position of General Accounting Manager.

Myron C. Taylor Resigns from A.T.&T. Board; Henry T. Heald Elected

The Board of Directors of the American Telephone and Telegraph Company on December 18 accepted with regret the resignation of Myron C. Taylor, who served on the Board for over 28 years. He has the longest service of any member of the present Board, it being one of the longest in the history of the company. At the same time, Henry T. Heald, president of the Ford Foundation, was elected to the Board.

In expressing its appreciation of Mr. Taylor's contributions, the A.T.&T. Board said "his service in the fields of education, philanthropy, and culture as well as his wide and active participation in industry and world affairs gave his counsel and advice a long-range perspective and deep insight which were of inestimable value to the telephone business."

Mr. Heald was graduated from Washington State College and received a master's degree in civil engineering from the University of Illinois. He has received honorary degrees from many colleges and universities and a number of other awards, including the Navy Award for Distinguished Civilian Service.

Before joining the Ford Foundation in 1956 Mr. Heald's career was in higher education. In addition to service with many civic and professional groups, he was president of the Armour Institute of Technology in Chicago, president of Illinois Institute of Technology, and chancellor and later president of New York University. He is a trustee of the Teachers Insurance Annuity Association Stock, a member of the College Retirement Equities Fund, and is a director of Equitable Life Assurance Society of the United States, Stewart-Warner Corporation, and Swift and Company.

B. S. Biggs Accepts Post with Sandia Corporation

B. S. Biggs, Assistant Chemical Director-Development of the Laboratories, has been granted a leave of absence to accept a position with the Sandia Corporation as Director of Materials and Standards Engineering.

In his new capacity, Mr. Biggs reports to R. W. Henderson, Vice President-Development at Sandia. The change became effective January 15, 1958.

F. R. Kappel Reports Bell System Growth in 1957

Sees Long-Term Need for Continued Expansion

"Growth of the Bell System in 1957 was very large although the rate of growth was not as fast as in 1956," Frederick R. Kappel, president of American Telephone and Telegraph Company said in a year-end statement released on December 26. "Earnings for the year are about $13 per share of A.T.&T. stock, or approximately the same as in the two previous years. The average number of shares outstanding in 1957, however, is more than 6 million larger than in 1956 and some 13 million more than in 1955.

SERVICE INCREASES

"The System added nearly 3 million telephones in 1957 and more than 52 million are now in service. Long distance conversations were up 7 per cent over 1956. Today 91 per cent of all our telephones are dial-operated and the dialing of long distance as well as local calls is growing rapidly. Some 5 million customers can now dial directly to many far-away points without the assistance of an operator, and 15 million can dial directly to nearby points.

"To provide the new facilities needed for growth and modernization the Bell companies in 1957 expended some $2.5 billion for construction. One of the important events of the year was the inauguration of service between Hawaii and the mainland over a 2,400-mile submarine telephone cable. This triples the number of voiceways previously available by radio and greatly increases the dependability and ease of service. The first transatlantic telephone cable, opened about 15 months ago, is already so heavily used that we are going ahead with a second one to be ready in 1959.

"To help finance construction the System obtained about $1,150,000,000 of new capital in the past year. Most of this was raised through the sale of debt issues, and was, of course, in addition to the more than $500 million obtained in the fall of 1956 through the offering of A.T.&T. stock to share owners.

NEED FOR NEW CAPITAL

"Looking ahead, although 1958 growth and construction may be somewhat below 1957, we expect they will still be very large and that much new capital will be required. Accordingly, at a special meeting to be held January 15, A.T.&T. share owners will be asked to authorize a $718 million issue of convertible debentures, and to authorize also a new employees' stock plan under which 7 million shares of A.T.&T. stock would be available for offering to Bell System employees during the next several years.

"The long-term outlook is that telephone services must be widely expanded to meet all the needs of our fast-growing country. Under these circumstances we foresee the need for continuing heavy construction which will require new capital in the range from a billion to a billion and a half dollars a year. The first and clear necessity is to have earnings that will assure the success of such a program. Only on that foundation can the needs of the nation be met as they should be. Bell System earnings, which are currently at the rate of 6.7 per cent on capital, in our judgment definitely should be higher and we shall vigorously pursue our efforts to convince regulatory commissions that the level of earnings should be raised."

"The Unchained Goddess" on TV February 12

Dr. Frank Baxter (right), playing the role of Dr. Research, points out a feature of a weather map to Richard Carlson, who plays the role of the Fiction Writer in "The Unchained Goddess" TV show.

"The Unchained Goddess," a new program in the Bell System Science Series, will be presented in compatible color over the NBC television network on Wednesday, February 12, at 9 PM, EST. It shows that, contrary to Mark Twain's classic remark, quite a number of people are doing something about the weather.

Produced by Academy Award winner Frank Capra, who also collaborated with Jonathan Latimer on the screenplay, "The Unchained Goddess" explains what makes weather and then shows what scientists are doing to predict it and to attempt the control if it. As in earlier Science Series programs, Richard Carlson and Dr. Frank Baxter are starred as Fiction Writer and Dr. Research. Carlson also directed "The Unchained Goddess."

STORY OF THE WEATHER

The fictional animated characters to whom Carlson and Baxter tell their story are Meteora, the Goddess of Weather, and her court. These include Boreas, the god of wind; Cirrus, the cloud god; Thor, the god of thunder; and the three Marutas, the Vedic gods of snow, rain, and hail. Shamus Culhane Productions provided the animation for "The Unchained Goddess."

The first half of the program details what science has learned about winds, clouds, precipitation, and lightning. The second half shows how these combine to make weather and what science has been able to do in the field of weather forecasting and weather control.

"The Unchained Goddess" was made with the co-operation of the United States Weather Bureau, the Department of Defense, the University of California at Los Angeles, Witwatersrand University in South Africa, and a number of individuals interested in weather.

Dr. Bernhard Haurwitz, New York University meteorologist, served as principal advisor in the production of the program, and Dr. Morris Neiburger of the University of California at Los Angeles served as consultant. Like other Science Series programs, this was produced under the general supervision of a board of 10 leading American scientists, including Dr. Ralph Bown, former Vice President in charge of research at Bell Laboratories, chairman, and Dr. J. R. Pierce, Director of Research in Electrical Communications at the Laboratories.

Dr. Research opens "The Unchained Goddess" with the explanation of what makes wind. According to scientists, the basic cause of wind is the sun. As air is heated it rises, and cooler air moves in to take its place. This becomes heated in its turn, creating a persistent circulation.

CIRCULATION PATTERNS

This circulation shows three loops between the equator and each pole, formed as the heated air over the equator rises and is replaced by cooler air from the higher latitudes. These prevailing winds are deflected by what is known as the Coriolis effect. Although they try to move straight north or south, the turning of the earth under them in its daily revolution makes them curve to the right in the northern hemisphere and to the left in the southern hemisphere. Thus, there are the northeast trade winds just above the equator and the southeast trade just below it, and the polar easterlies at each pole.

The third wind pattern in each hemisphere, in the middle latitudes, is a reverse loop. Here we have the prevailing westerlies that blow the year around over North America, Europe and Asia in the northern hemisphere. This explains why our weather comes mostly from the west.

In addition to descriptions of many of the other mechanisms of weather phenomena, the program includes actual weather scenes and explanations of the work of forecasters and others concerned with the field of meteorology. High-speed cameras have caught pictures of multiple lightning flashes, for example, and some unusual views of tornadoes are shown. "The Unchained Goddess" also tells of the work of Air Force and Navy fliers in tracking hurricanes, of the U. S. Weather Bureau in gathering data and preparing weather maps, and of the National Weather Analysis Center in making long-range weather predictions using a huge electronic computer.

As with the earlier Science Series programs — "Our Mr. Sun," "Hemo the Magnificent" and "The Strange Case of the Cosmic Rays" — the Bell Telephone Companies will make 16-mm color prints of "The Unchained Goddess" available for showings in schools soon after the telecast. Present plans call for a subsequent program on the human senses and another on man's use of language to be telecast during the 1958-59 television series. One or two earlier programs may be repeated.

Scene from the new Bell System Science Series program: a meteorologist using radar to track a hurricane which may be situated many miles away.

Telephone Statistics Show World Trends

"The World's Telephones," the annual compilation of telephone facts and figures, was released by the A.T.&T. Co. on December 19. The information relates to the beginning of 1957, since it takes nearly a year to gather statistics from more than 200 countries.

A feature of each edition is a ranking of countries and areas according to number of telephone conversations per person for the year. The new edition shows that during 1956, Alaskans were the most talkative people on the globe so far as the telephone is concerned. With an average of 630 conversations per capita, Alaska topped Hawaii, the leader for 1955. This time Hawaii came in second with an average of 531 conversations per inhabitant; Canada reported 481; Sweden 455; and the United States 426. The world average was 51 conversations per person.

The annual survey also shows that throughout the world, more telephones were added during 1956 than ever before. A gain of 7½ million telephones brought the total in use at the start of 1957 to 110 million. With 60,190,000 telephones, the United States had 55 per cent of the world's total. New York was the leader among the world's cities. Except for the United States itself, only three *countries* (the United Kingdom, Canada and West Germany) had more than New York's 4,077,000 telephones. London was the leader among the foreign cities with 2,140,000.

The United States had 35 telephones per 100 persons, and Sweden ranked second with 32. The world figure increased from 3.8 per 100 in the previous survey to 4.0 per 100. In this grouping according to telephone density, Washington, D. C., was first among all the cities of the world with 65 telephones for every hundred persons, while Stockholm outranked other foreign cities with 56.

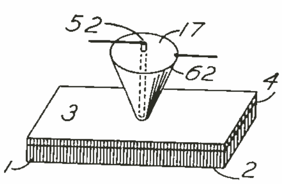
Thermal Antioxidants for Polyethylene

A number of new additive combinations which are exceptionally effective in inhibiting the oxidation of polyethylene, the most widely used of all plastic materials, have been discovered at Bell Telephone Laboratories. These protectants are up to ten times as effective as presently-used antioxidants. (See cover photograph.)

Certain substituted thioethers, when used in conjunction with carbon black, have been found to gain exceptional antioxidant activity over their use in clear polyethylene. Conventional protectants tend to lose their effectiveness in the presence of carbon black. The substituted thioethers are formed by the condensation of conventional thermal antioxidants, such as aromatic amines or phenols, with sulfur dichloride. Alkyl, aryl and heterocyclic thiols and disulfides without amine or phenolic substituents are also effective antioxidants when used with polyethylene containing carbon black. About 0.1 per cent of the sulfur compound with 3 per cent carbon black is highly effective in reducing both thermal and photo-oxidation. The carbon black, added to cut down photo-oxidation, accounts for the fact that much polyethylene in use today is black in color.

The best conventional antioxidants protect carbon black – polyethylene formulations for less than 200 hours under accelerated test conditions of 140°C in an atmosphere of oxygen. Furthermore, the oxidation process becomes autocatalytic – that is, it reaches a point at which it "runs away" – under such test conditions. With several of the new protectants, however, oxidation proceeds at a slow, even rate and does not become autocatalytic even after 2000 hours at 140°C. This is equivalent to much more than 20 years of normal service life.

Some of the new additives, such as polymeric organo-sulfur compounds including thiols and the polymer from 1, 10-decamethylenedithiol, offer possible other advantages. By control of the molecular weight of the antioxidant, its diffusion rate in polyethylene can be varied. Also, by varying the size of the repeating unit in the antioxidant, the concentration of the active groups can be changed without necessarily affecting their diffusion rates. A high concentration of functional groups in comparatively high molecular weight additives allows maximum protection over longer periods of time. Finally, high molecular weight antioxidants can possibly be added in large enough amount to act as plasticizers for polyethylene.



Patents Issued to Members of Bell Telephone Laboratories During November

Anderson, A. E. – *Transistor Trigger Circuit* – 2,812,445.
Carter, H. T. – *Interrupter Circuit* – 2,812,386.
Cook, J. S., Poole, K. M., and Sullivan, J. W. – *Periodic Focusing in Traveling Wave Tubes* – 2,812,470.
Cory, S. I. – *Telegraph Transmission Error Register* – 2,813,149.
Doba, S., Jr – *Single Frequency Transmission Lineup for Amplifiers* – 2,813,157.
Doherty, W. H. – *Transposed Coaxial Conductor System* – 2,812,502.
Egan, T. F. – *Electrical Contact* – 2,812,406.
Heber, E. – *Harmonic Generator Apparatus* – 2,813,200.
Hewitt, W. H., Jr. – *Magnetically Controllable Transmission System* – 2,814,783.
Joel, A. E., Jr., Krom, M. E., and Posin, M. – *Line Concentrator System* – 2,812,385.
Kock, W. E. – *Doubly Resonant Filter* – 2,812,032.
Kompfner, R. – *Electron Beam System* – 2,812,467.
Krom, M. E., see Joel, A. E., Jr.
Kummer, O. – *Frequency Setting and Measuring System* – 2,814,775.
McMillan, B. – *Electronic Computing Device* – 2,812,133.
Mendel, J. T. – *Microwave Detector* – 2,814,779.
Ostendorf, B., Jr., and Rea, W. T. – *Impulse Signal Distortion Circuit* – 2,813,151.
Pearson, G. L. – *Photo-Resistance Device* – 2,812,446.
Pfann, W. G. – *Temperature Gradient Zone-Melting* – 2,813,048.
Pfleger, K. W. – *Differential Loss Measuring System* – 2,812,492.
Poole, K. M., see Cook, J. S.
Posin, M., see Joel, A. E., Jr.
Rea, W. T., see Ostendorf, B., Jr.
Robertson, G. H. – *Helix Assembly for Traveling Wave Tube* – 2,812,499.
Roberston, G. H. – *Electron Beam Discharge Device* – 2,813,990.
Roberston, S. D. – *Spatial Harmonic Traveling Wave Tube* – 2,812,468.
Shockley, W. – *Semiconductive Device* – 2,813,233.
Sullivan, J. W., see Cook, J. S.
Waltz, M. C. – *Method of Plating Silicon* – 2,814,589.
Winslow, F. H. – *Method of Purifying Volatile Compounds of Germanium and Silicon* – 2,812,235.
Woodbury, J. R. – *Binary Decoder* – 2,814,437.

R. L. Shepherd Retires; C. Pologe Production Editor

R. Linsley Shepherd retired from the Laboratories on January 31 after 28 years of Bell System service, including 11 years as Production Editor of the RECORD. Succeeding Mr. Shepherd in this position, Conrad Pologe becomes responsible for the design and printing of the RECORD, effective this issue. Mr. Pologe is also in charge of the production group responsible for military reports and other printed material issued by the Laboratories, and in addition becomes production editor of the *Bell System Technical Journal.*

Mr. Shepherd was graduated from Yale University in 1919 with the degree of Ph.B. After several years with the McGraw-Hill Publishing Company, he joined the Laboratories in 1929, where he was for a time Assistant Editor of the RECORD until becoming Production Editor in 1947.

Mr. Pologe was graduated from Brooklyn College in 1942 with an A.B. degree. Before joining the Laboratories in 1956 he was associated with the William Byrd Press of Richmond, Va.

Contents of the January Bell System Technical Journal

The January, 1958, issue of THE BELL SYSTEM TECHNICAL JOURNAL contains the following articles:

Nature and Origin of Standards of Quality, by W. A. Shewhart.

Contribution of Statistics to the Development Program of a Transformer for the L3 Carrier System, by G. J. Levenbach.

Runs Determined in a Sample by an Arbitrary Cut, by Paul S. Olmstead.

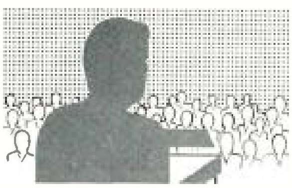
Properties of Control Chart Zone Test, by S. W. Roberts.

A Criterion of Limit Inspection Effort in Continuous Sampling Plans, by R. B. Murphy.

Nonparametric Definition of the Representativeness of a Sample – with Tables, by Milton Sobel and Marilyn J. Huyett.

Fluctuations of Random Noise Power, by D. Slepian.

The Measurement of Power Spectra from the Point of View of Communications Engineering – Part I, by R. B. Blackman and J. W. Tukey.



Talks by Members of the Laboratories

Following is a list of talks given before professional and educational groups by Laboratories people during December.

Bader, J. A., *Traffic Aspects of Communication Switching Systems*, Eastern Joint Computer Conference, Washington, D. C.

Bozorth, R. M., *Magnetic Materials*, A.S.M., New York City and Maryland Institute of Metals, Baltimore, Md.

Brattain, W. H., *Semiconductor Surfaces*, Northwestern University, Evanston, Ill.

Depp, W. A., *Data Transmission*, Graduate School Seminar, University of Illinois, Urbana, Ill.

Devereux, R. A., *The Evolution of Strategic Bombing*, New York Medical-Surgical Society, N. Y. C.

Dimond, T. L., *Devices for Reading Handwritten Characters*, Eastern Joint Computer Conference, Washington, D. C.

Drenick, R. F., *A Possible Approach to the Synthesis of Information Processing Systems*, Human Factors Symposium, Philadelphia, Pa.

Fullerton, W. O., see Sproul, P. T.

Feher, G., *Donor Wave Functions in Silicon by the "ENDOR" Technique*, RCA Laboratories, Princeton, N. J.

Geballe, T. H., *Thermomagnetic Effects in Germanium*, I.B.M. Watson Laboratory, N. Y. C.

Geller, S., *Rare Earth Perovskites and Garnets*, Chemistry Seminar, Rutgers University, New Brunswick, N. J.

Hagstrum, H. D., *The Surface Auger Effect*, Physics Colloquium, University of Chicago, Chicago, Ill.

Harvey, F. K., *The Physics of Hearing and Music*, Eastern Shore Section of A.I.E.E., Salisbury, Md.

Joel, A. E., *Communication Switching Systems as Real Time Computers*, Eastern Joint Computer Conference, Washington, D. C.

Jutson, R. P., *Solid State Electronics*, Armed Forces Communications and Electronics Association, N. Y. C.

Katz, D., *Introduction to Magnetic Amplifiers*, Student Branch A.I.E.E., Newark College of Engineering, Newark, N. J.

Ketchledge, R. W., *An Introduction to the Bell System's First Electronic Switching Office*, Eastern Joint Computer Conference, Washington, D. C.

Kleinfelder, W. C., *Cable Splicing Goes Modern*, 6th Annual Signal Corps Symposium on Wire and Cable, Asbury Park, N. J.

Lewis, W. D., *Industrial Organizations and Creative Output*, Am. Management Association, N. Y. C.

Pollak, H. O., *The Problem of Minimal Connecting Networks*, Princeton University, New Jersey.

Rongved, L., *Displacement Discontinuity in the Elastic Half-Space*, Applied Mechanical Division, A.S.M.E., N. Y. C.

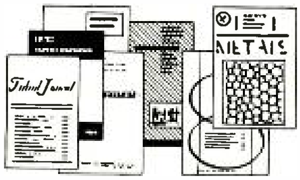
Sproul, P. T., and Fullerton, W. O., *The TH Microwave Radio System*, New Jersey Divisions, New York Section, A.I.E.E., Murray Hill, N. J.

Thomas, D. G., *Recent Work on Surface Properties of Zinc Oxide*, Division of Electron Physics, Stanford University, Palo Alto, Calif.

Troussoff, G. B., *Maintainability of NIKE-AJAX Ground Equipment*, EIA Maintainability Symposium, Los Angeles, Calif.

Weinreich, G., *The Acoustoelectric Effect*, Physics Colloquium, Princeton University, New Jersey.

Weiss, M. T., *The MAVAR–A Ferrite Microwave Amplifier*, Northern New Jersey I.R.E. Section, Montclair, N. J., and Long Island I.R.E., P.G.M.T.T. and P.G.E.D. Meeting, Garden City, L. I.



Papers by Members of the Laboratories

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

Baker, W. O., *The Small Forces of Nature,* Proceedings of the Symposium on Science, Industry and Education, pp. 28-49, 1957.

Barney, H. L., and Dunn, H. K., *Speech Analysis* and *Speech Synthesis* "Manual of Phonetics" (North-Holland Publishing Co., Amsterdam), Chapters 12 and 13, 1957.

Bemski, G., see Bittman, C. A.

Bittman, C. A., and Bemski, G., *Lifetime in Pulled Silicon Crystals,* J. Appl. Phys., **28**, pp. 1423-1426, Dec. 1957.

Burrus, C. A., *Millimicrosecond Pulses in the Millimeter Wave Region*, Rev. Sc., Inst., **28**, pp. 1062-1065, Dec. 1957.

Dunn, H. K., see Barney, H. L.

French, N. R., *Auditory Considerations,* "Manual of Phonetics" (North-Holland Publishing Co., Amsterdam), Chapter 4, 1957.

Fuller, C. S., and Logan, R. A., *The Effect of Heat Treatment upon the Electrical Properties of Silicon Crystals,* J. Appl. Phys., **28**, pp. 1427-1436, Dec., 1957.

Iwersen, J. E., see Nelson, J. T.

Keywell, F., see Nelson, J. T.

Kiersky, L. J., *General and Special Aspects of Photoreproduction,* Special Libraries, **48**, pp. 401-413, Nov., 1957.

Lander, J. J., see Thomas, D. G.

Logan, R. A., and Peters, A. J., *Effect of Oxygen on Etch-Pit Formation in Silicon,* J. Appl. Phys., **28**, pp. 1419-1423, Dec., 1957.

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