Air Force Submarine Cable System

P. T. HAURY and **L. M. ILGENFRITZ** *Transmission Systems Development II*

The unique abilities of the Laboratories, Western Electric and the A.T.&T. Co. working together are often called upon to provide systems that may be critically important to the armed forces. One recent example of this cooperative effort resulted in a highly specialized submarine cable system for the USAF-MTC — United States Air Force Missile Test Center. This long-range missile proving ground extending southeastward from the coast of Florida required a combination of communication facilities that differed from any previously existing system.

Some years ago the United States Government undertook what has more recently been revealed to be a very ambitious program in the development of long-range guided missiles. Today, such cryptic abbreviations as IRBM and ICBM for intermediate range ballistic missile and inter-continental ballistic missile are regularly found in the news. There are also frequent articles concerning plans for man-made satellites, with those planned for the International Geophysical Year, 1957-58, now foremost in the news. Such satellites, like the death-dealing payloads of tactical weapons, will be delivered by guided-missile methods.

A part of the missile development program is a long range proving ground, originally undertaken as a joint venture by the Army, Navy and Air Force, and now known as the U. S. Air Force Missile Test Center. As shown in Figure 1, this range extends from Cape Canaveral on the coast of Florida to Puerto Rico, an airline distance of about 1,000 nautical miles.* Guided missiles are now being tested on the range and it is expected that its facilities will be used for launching earth satellites. Although plans are being considered for ex-

* The nautical mile for purposes of submarine cable work is defined as 6,087 feet or about 1.15 statute miles.

tending the testing range beyond Puerto Rico, this and succeeding related articles will be concerned with only the portion from Florida to Puerto Rico. Together, these articles will describe a submarine cable communication system designed by the Laboratories and installed by the Western Electric Company to serve this part of the range. This system was completed in the Fall of 1955 and is the longest submarine cable system of its kind in the world.

Cape Canaveral, the starting point of the test range, is located about mid-way between Jacksonville and Miami, and extends a few miles into the Gulf Stream. From this point missiles can be launched along a southeasterly flight line which passes over sparsely settled islands that are north of the Caribbean.

In addition to the Cape Canaveral launching area, eight "down-range" observation stations, including the Puerto Rico station, are provided at intervals of about 125 nautical miles. These are indicated in Figure 1 by the points marked with a star, and a typical station is illustrated in the headpiece of this article. As a missile traverses the range and enters the sphere of control of successive observation stations, they go into action to carry out their assigned tasks. These include radar tracking and optical observations as well as data recording and control procedures. Data, some of which are received from

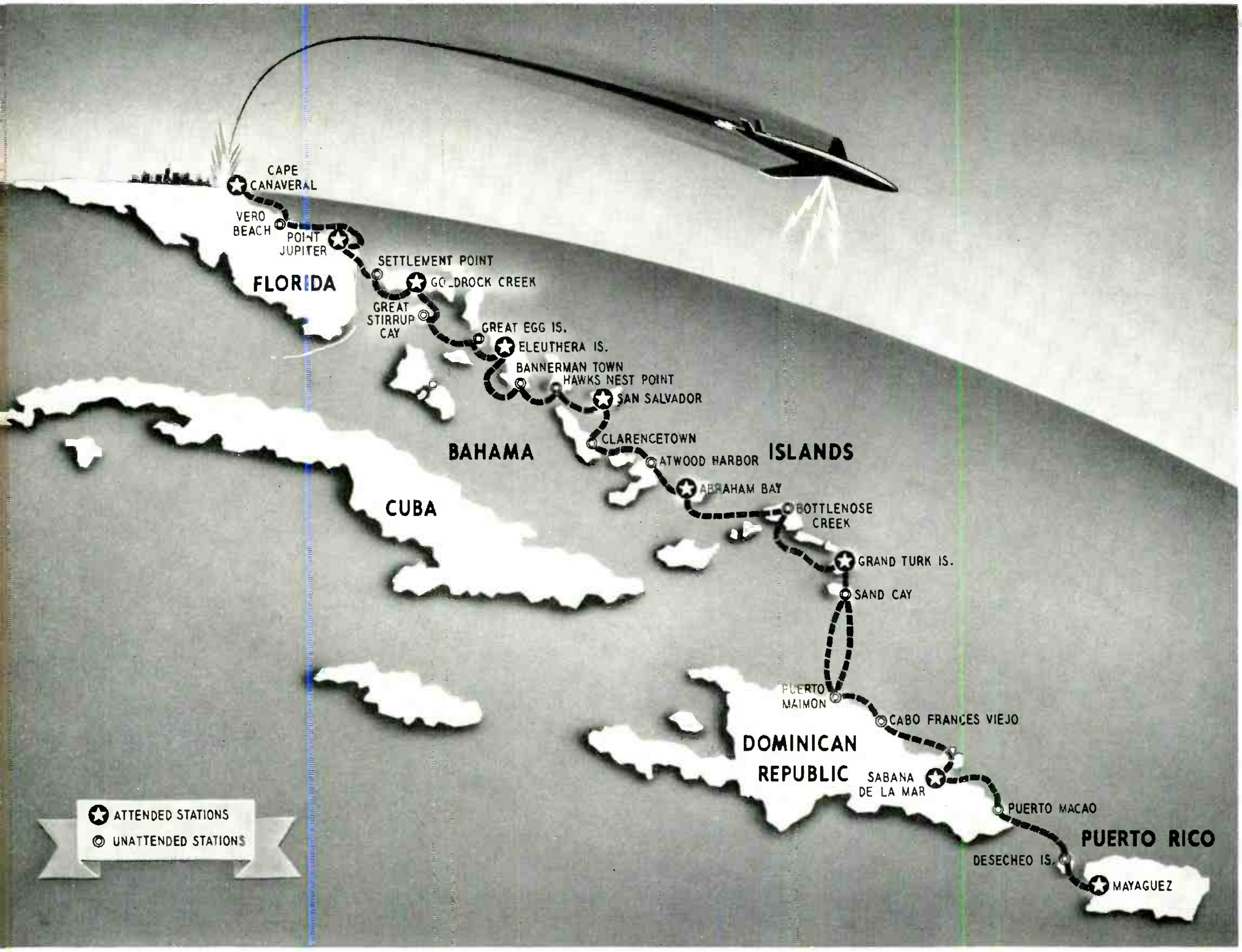


Fig. 1 — Route of the Air Force submarine cable from Cape Canaveral, Florida, to Mayaguez, Puerto Rico, an airline distance of about 1,000 nautical miles. This range is now being used for testing guided missiles and it is expected that its facilities will be used for launching earth satellites.

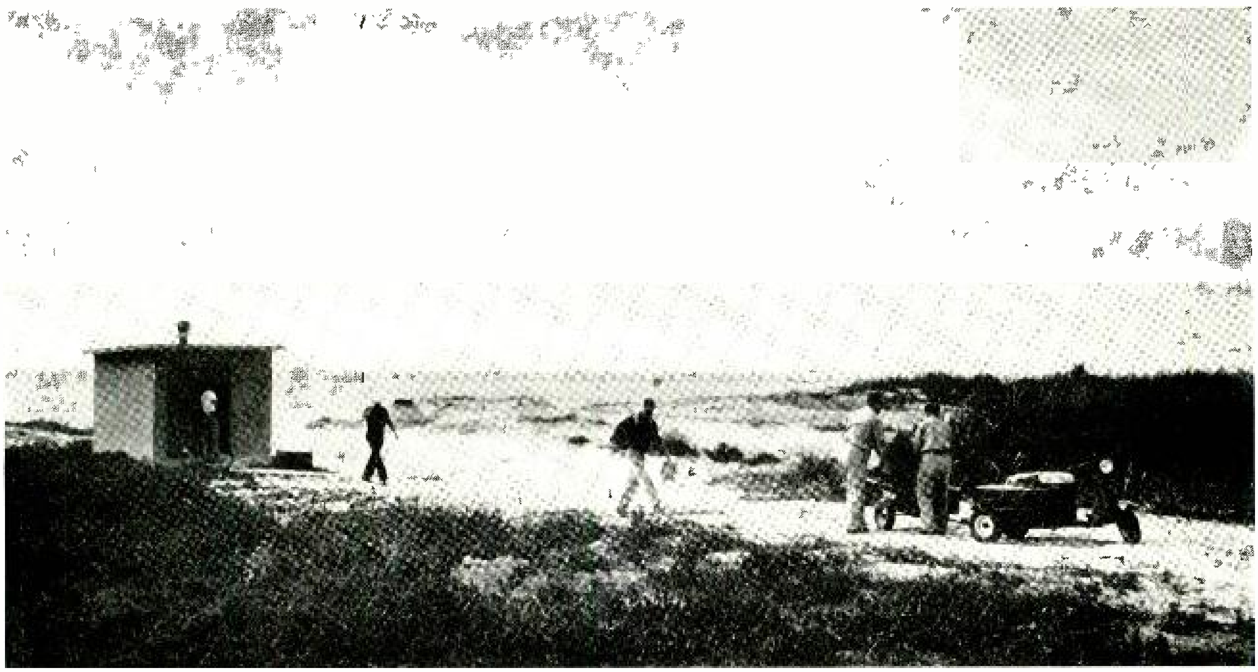


Fig. 2 — A filter hut, part of an unattended repeater, on one of the island sites.

the missile itself, in addition to being recorded at the observation station, must be transmitted to the reduction center at the launching site. Since a particular missile "shoot" occupies a continuous time period, and since the missiles travel at such high speeds, data records must be referred automatically to a common time base such as the instant the missile is launched. This requires the transmission of a succession of timing pulses from the launching site to the various observation stations.

Besides operations during the actual "shoot," there are a number of preliminary steps that must be completed. These include frequent weather reports, range clearance checks, and presumably "dry-run" tests to insure that all is in readiness. These preliminary operations and the operation during the actual tests require close coordination of the sort that can be provided only with the aid of a reliable communication system. This system must also provide special facilities for such items as data and timing pulse transmission. In the early stages of the missile test center operation, short-wave radio communication was used as a temporary measure to permit restricted operations until more permanent arrangements could be provided.

Early in the planning stages of the range, the communications problem was referred to the Laboratories for study and recommendations. This study was carried out under the first of a series of contracts and resulted in the choice of the submarine cable system. Further work covered specific recommendations for the transmission features of the system, physical problems such as buildings and land cables, choice of cable routes and landing sites, and ocean bottom surveys of these cable routes. The survey of cable routes was undertaken with the aid of the U. S. Hydrographic Office.

From these studies, definite plans were made for the cable system. It appeared that the necessary communication channels could be provided for both directions of transmission on a single cable, using frequencies up to about 150 kc. The single cable was chosen in the interest of economy since a large share of the cost of such a system is in the cable itself. It was known, however, that it would be impossible to span the distances from one observation station to another without intermediate repeaters, even using powerful transmitting equipment and the largest deep sea cable with which there had been any previous experience. Plans were therefore made to locate one or two unattended repeaters, such as illustrated in Figure 2, between adjacent observation stations. Fourteen such repeaters, which could be powered over the cable from the nearest observation stations, were required.

Since cable production facilities were limited, it was important that manufacture be started as soon as survey data permitted. A separate contract was negotiated for purchase of the cable, and manufacture was begun by the Simplex Wire and Cable Company in 1951. The first cable sections were laid in 1952 by the British cable ship "Monarch" under Laboratories charter. Final sections, bringing the total to about 1370 nautical miles, were laid in 1954.

Because of the extensive amount of surveying, construction and other outside plant work involved in placing the submarine cable and associated land cable extensions, it was essential that an experienced field crew be obtained. This need was ably filled by a group of engineers and cable splicers transferred temporarily from the Long Lines Department of the A.T.&T. Co. to the Western Electric Company. Meanwhile, the Laboratories was designing the repeaters, terminal equipment and special power plants, and preparing manufacturing specifications for the Western Electric Company.

The facilities provided by the system include telephone circuits, some of which are arranged for conference networks, a channel for transmission of timing pulses, a wide-band program transmission circuit for either direction, and a still wider band for telemetering signals being sent from any observation station back to the launching area. Also, a single telemetering channel is provided for transmission from the launching area to any observation station, and an order circuit links all attended and unattended stations. These features will be described more fully in subsequent articles.

One departure from the single cable transmission system was required in the section from Sand Cay in the Turks Island group to the Dominican Republic. Here, it was necessary to use two parallel cables because the distance exceeded the limit for satisfactory single cable transmission. This required repeater designs somewhat different from those at other unattended points and introduced additional problems which resulted in the decision to split the project into two parts. The portion from Florida to Grand Turk Island was placed in service in April of 1954, and the entire system to Puerto Rico was completed in September, 1955.

THE AUTHORS

P. T. Haury received a B.E. degree from Vanderbilt University in 1941, and after a year of graduate study at Rutgers University he joined the staff of Bell Telephone Laboratories. Following a short period in the trial installation group, Mr. Haury was engaged in the design of military radio and radar equipment. In 1946, he transferred to a group working on carrier telephone systems including K and L carrier, and the initial phases of Type-O carrier. Mr. Haury began work in 1951 on the submarine cable project for the Air Force Missile Test Center. He is currently engaged in work on the Ketchikan-Skagway submarine cable system, and is supervisor of a group responsible for developing entrance links and terminals for the TH Radio system.

L. M. Ilgenfritz received a B.S. degree in electrical engineering from the University of Michigan in 1920, and joined the Development and Research Department of the A.T.&T. Co. in that same year. He transferred with that department to Bell Telephone Laboratories in 1934. Mr. Ilgenfritz's work has been concerned with transmission development of carrier systems except during World War II when his effort was concentrated on defense. Since the war he has supervised the transmission design of the submarine repeaters and terminals for the No. 5 and 6 Key West-Havana cable systems, and subsequently, the transmission designs of the Air Force Florida-Puerto Rico and Alaska Communication System Ketchikan-Skagway submarine cables. He is currently engaged in the completion of the latter project.

Point-Contact Transistor Action

A. UHLIR, JR. *Transistor Development*

Detailed studies of point-contact transistor action have been carried out since this device was first announced by the Laboratories, and additional investigations are still in progress. From knowledge gained in this way may come other useful devices and significant improvements in existing models. In this field, as in most others, the work of the Laboratories does not end with an initial discovery or development, but goes on to search for ways of improving performance and lowering costs.

The transistor first announced by Bell Telephone Laboratories was of the point-contact type. Since its inception, this transistor has been developed to fill several applications in the Bell System. N-type germanium units, for example, are used in the tone generator for extended-area dialing and in the amplifier for the 4A crossbar card translator. Many of these transistors are also employed in the TRADIC computer developed by the Laboratories for the Air Force.

As illustrated in Figure 1, a point-contact transistor may be made by mounting two sharpened wires of appropriate metals so that their points press against the chemically etched surface of a piece of n-type germanium. For good performance, these points – the "emitter" and the "collector" – must be placed within a few thousandths of an inch of each other. A "base" contact is soldered to a relatively large abraded area on the opposite side of the germanium crystal. Electrical processes occurring at the two point contacts interact in such a way that the current and voltage at the collector may be controlled by the current and voltage at the emitter. The result of this interaction is useful power gain.

The operation of any transistor depends on the ability of a semiconductor to carry current by the motion of both positive "holes" and free electrons.* A positive hole is a place in the electronic structure of a semiconductor from which an electron is missing. This vacancy behaves much like an electron but with the opposite, or positive charge.

A pure specimen of a semiconductor contains equal numbers of free electrons and positive holes. This balance, however, may be overpowered by the presence in the crystal lattice of various impurities. Impurities called "donors" produce an excess of electrons in the crystal, resulting in an n-type semiconductor. "Acceptor" impurities produce an excess of positive holes, resulting in a p-type semiconductor. Also, the surface of germanium tends to have a charge that makes a thin surface layer act like a p-type semiconductor, regardless of the conductivity type in the bulk of the germanium that is involved.

When the emitter wire, shown in Figure 1, is made positive with respect to the base, current flows in the emitter circuit. Within the semicon-

* RECORD, *August*, 1954, *page* 285.

ductor, this current consists of a flow of positive holes which originate in the p-type surface layer under the emitter contact. If this contact is located sufficiently close to the collector contact, the positive holes will be attracted by the electric field of the negatively charged collector, and most of them will be transported to the collector and there discharged. This action causes an increment of current to flow in the collector circuit. As a result, the magnitude of the collector current may be controlled by controlling the emitter current.

Another way of looking at transistor action is to recognize that, although the emitter point is small, the resistance to the flow of emitter current is low. One reason for this is that the injected holes greatly decrease the effective resistivity of the germanium near the contact by increasing the local density of both holes and conduction electrons. The effect of hole injection upon the resistivity of the germanium is substantial at distances measured in thousandths of an inch. From the point of view of a solid-state physicist, these distances are remarkably large. This decrease in effective resistivity requires that the germanium have a nearly perfect crystal structure; otherwise the holes would recombine with electrons and would not affect the resistivity at any distance away from the emitter contact.

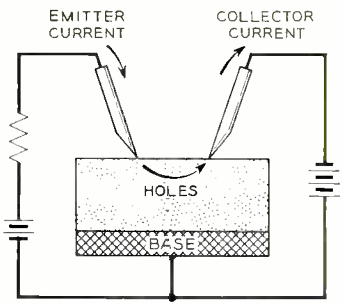


Fig. 1 — Diagram of n-type, point-contact transistor in a simple circuit (normal bias).

The collector of a point contact transistor is placed well within the region where the resistivity can be lowered by the holes injected at the emitter. Collector current and voltage are therefore controlled by the emitter. This control is similar to the control of plate current by the grid of a tube.

The action just described can be illustrated quantitatively by the family of collector voltage versus current characteristics shown in Figure 2. If the emitter circuit is left open, and the collector voltage versus current characteristic is measured in the absence of emitter current flow, the particular curve labeled Ie = 0 will result. This curve is simply the rectifier reverse characteristic of the collector point contact. If the emitter circuit is closed and one milliampere of emitter current is caused to flow, the collector voltage versus current characteristic will be displaced to a new position labeled Ie = 1 ma. This displacement in the direction of larger collector current is the result of the collection of positive holes which are injected into the semiconductor at the emitter. The other members of this family of characteristics can be determined by repeating this measurement using successively higher values of emitter current.

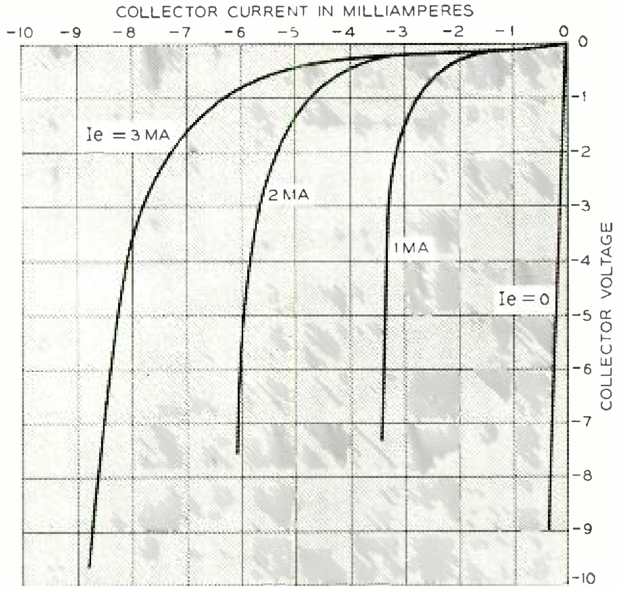


Fig. 2 — Collector voltage-current characteristics of a point-contact transistor.

How the transistor action just described results in power gain can be seen from the following argument. The emitter contact has a low resistance because of hole injection, and because the applied voltage is in such a direction that the emitter behaves like a diode operating in the forward or low-resistance direction. On the other hand, the collector is biased in the reverse or high-resistance direction. Whenever a current is introduced into a device at low resistance and substantially the same current is withdrawn from the device at higher resistance, power gain results. A typical point contact emitter may have a resistance of 200 ohms and a typical collector may have a resistance of 10,000 ohms. The corresponding power gain would then be about 50 times. In this sense, the transistor acts like an impedance step-up transformer in which the current is not correspondingly stepped down, as is the case in an ordinary passive transformer.

Examination of the family of characteristics in Figure 2 shows that, in addition to behaving as described, the point-contact transistor also acts as a current amplifier. For example, the separation between two adjacent curves in this family resulting from a difference of one milliampere of emitter current corresponds to a change of two or three milliamperes of collector current. The physics of the transistor action previously described could not result in a current gain greater than one. Therefore, some other process must also be taking place.

The physics of this current amplification can be described with the aid of Figure 3. The collector current of a point-contact transistor may be regarded as the algebraic sum of three individual components. First, there is the "reverse leakage current" of the collector diode which flows even in the absence of emitter current. This current is represented by the characteristic $Ie = 0$ on Figure 2. It consists of a flow of electrons which are introduced at the collector contact and which flow out at the base contact as shown in Figure 3. Because electrons have a negative charge, the electric current they carry is opposite to the direction of their flow. Second, there is the current of positive holes being collected, which has been described earlier. Third, there is an additional electron current component originating at the collector contact and resulting from the act of hole collection. As the positive holes approach the collector, they attract additional electrons from the collector, many of which escape recombination and survive to flow out of the semiconductor at the base contact. It is

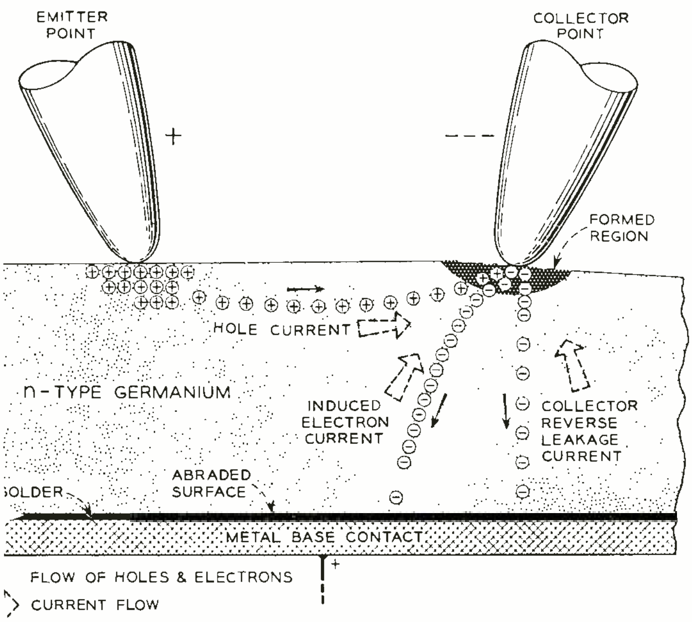


Fig. 3 — An illustration of hole and electron flow in a point-contact transistor.

this third current component, which is represented in Figure 3 by the flow labeled "induced electron current," which is responsible for the current amplification.

In a typical point-contact transistor, the induced current may be about twice as large as the hole current which causes it. As a result, the total cur-

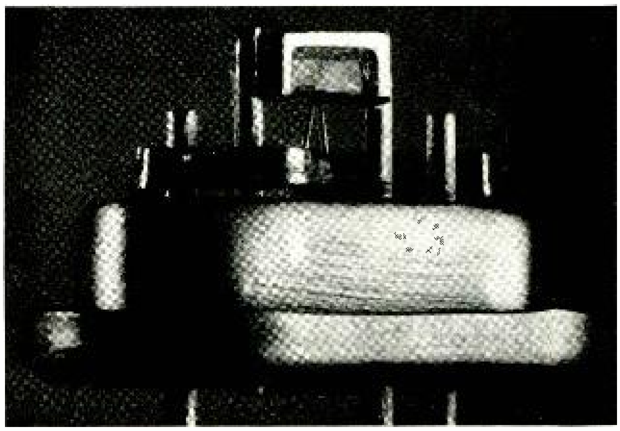


Fig. 4 — Point-contact transistor developed at Allentown. Unit will be hermetically sealed.

rent increment appearing in the collector circuit may be about three times as large as the increment of emitter current responsible.

Some of this extra collector current can be fed back to the emitter through simple circuit elements such as resistors and capacitors. This is positive feedback, since the signal fed back from collector to emitter is in phase with the exciting signal already present at the emitter. Positive feedback can be used to make the transistor oscillate, or to build regenerative computer-type circuits.

For comparison, in the ordinary junction transistor, the changes in the current *out* of the collector are slightly less than the changes in the current *into* the emitter. A junction transistor can be connected in ways that make it an amplifier of currents, but the amplified currents are in such a direction that only negative feedback can be obtained with simple circuits. On the other hand, the point-contact transistor with its positive feedback capabilities is a basic computing element which can, in a certain sense, do a job which requires two junction transistors. Point-contact transistors are also comparatively fast; they can operate at megacycle repetition rates.

An electrical treatment known as "forming" is required to make the collector a satisfactory source of electrons for the third collector-current com-

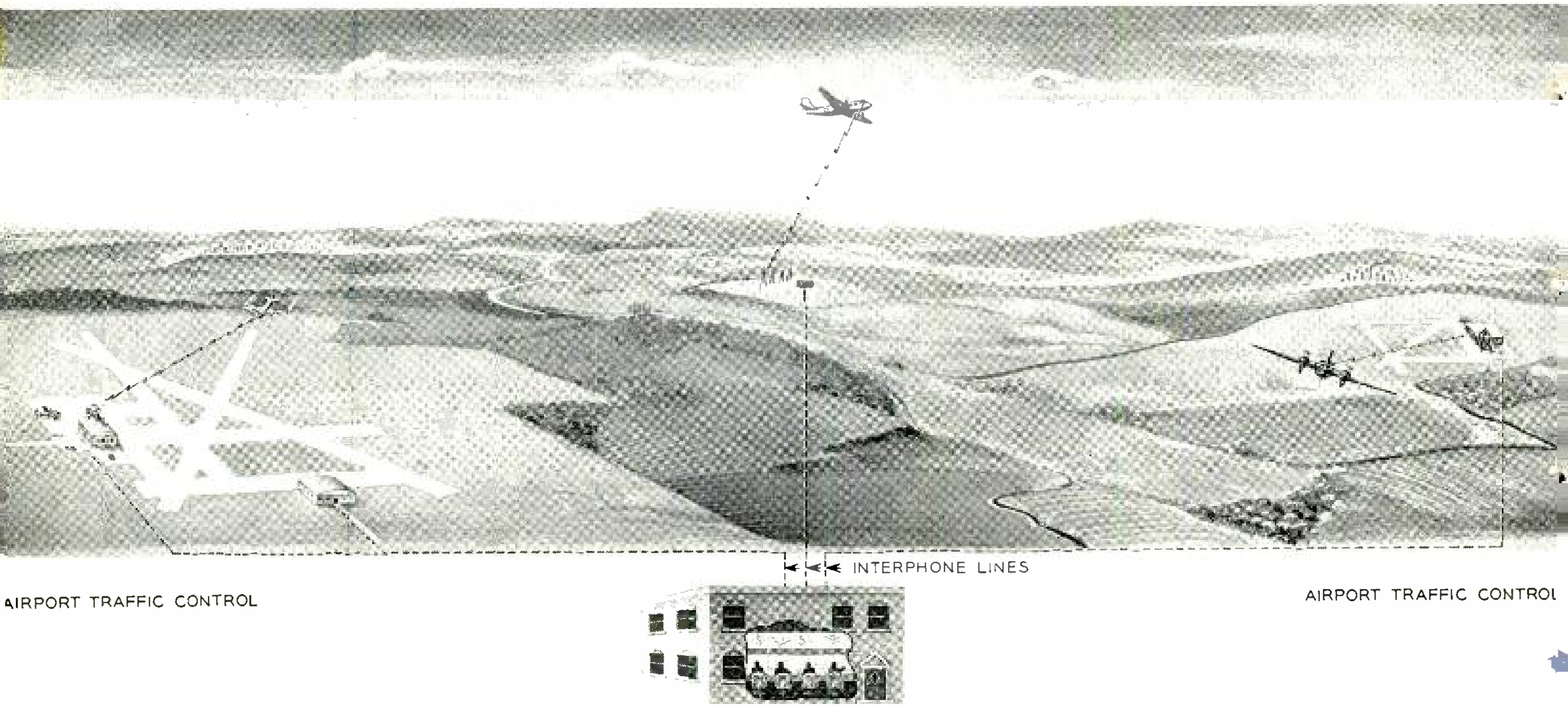


Fig. 1 — Communication arrangements for the Air Route Traffic Control Center. The communications network of both wire and radio facilities enables the controller to keep in touch with the actual situation in his sector through reports often relayed to him by telephone.

After the plane is airborne, a report of its position is sent to the ARTCC each time it passes over a "compulsory reporting point." In many areas, however, the controller cannot speak directly to pilots in the air via radio. Position reports from a commercial airliner are usually picked up by the airline company's radio stations. Military and itinerant flight reports are usually picked up by radio at Interstate Airways Communications Stations (INSACS), operated by CAA. Both types of radio stations relay reports to the ARTCC over telephone lines, and receive instructions and information the same way for relay by radio to pilots.

The question was raised, "Could delays to aircraft be reduced by more efficient use of the communication facilities?" To help answer this question, the Laboratories undertook a study of information flow in the ARTC system. This study, sponsored jointly by the Bell System and the Air Navigation Development Board, focused its attention on the Hartford Sector of the Boston ARTCC, a fairly busy area with a number of airports and a complicated orientation of airways, Figure 2.

Questions asked during the studies included: (1) how frequently do calls reach the controller over each of the various lines; (2) how long are they delayed because he is busy talking to someone else; (3) how long do calls last after they reach him; and (4) what are the calls about? Similarly, how frequently does the controller originate a call; how long does he talk; and what does he talk about? The controller's conversations are very definitely stylized because they concern specific aspects of the control of aircraft. To better understand the control system and its special jargon, Laboratories engineers and technicians spent considerable time at control centers, in airport towers, and flying "jump seat" in aircraft.

The Hartford controller has fifteen telephone lines connecting him to airport towers, airline offices and radio stations, INSAC radio stations, military air services, and air search and rescue. Nine of these lines were observed during the studies. Most of the lines are direct-wire service, but some are arranged as party lines, with several stations on the same line. Outward calls from the controller on these party lines use voice paging over loudspeakers at each station so that all stations will know that a call is being made. The controller has access to all lines through 102A key equipment at his control board.

During the study period, arrangements were made with the CAA so that all telephone conversations of the Hartford controller and his assistant could be recorded, and the Franklin Institute of Philadelphia, under sub-contract to the Laboratories, recorded all air-ground radio conversations in the area. Special circuit appliques and isolation networks were provided to insure that pen registers and voice recorders could be connected with the control center without affecting normal communications. In addition to voice recordings, all telephone calls were counted and timed, hourly teletypewriter aviation weather reports were collected, and flight strips from the controller's flight progress board were obtained.

The first recording was made on October 5, 1953. Identification of lines and all functional operations such as signaling were recorded on twenty-pen Esterline-Angus recorders. All conversations were taken down on tape recorders and later transcribed onto other tape and disc recorders for later reference. Silent periods greater than one minute were removed during the transcribing process. The Hartford study included data taken during twenty-two

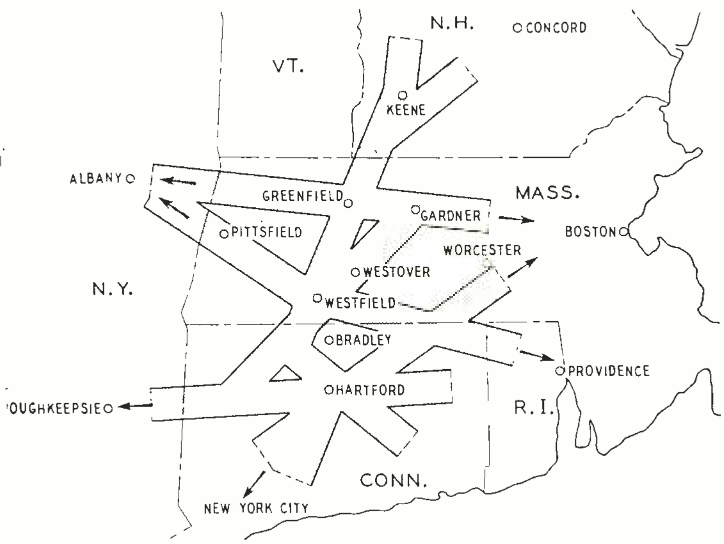


Fig. 2 — Map of the airways involved in the studies.

study sessions, each 100 minutes in duration. It was followed by a three-sector study of the Hartford, Salem, and Boston sectors comprising 900 minutes of recording during three different days. In the three-sector study, cameras were mounted above each flight progress board and arranged to take pictures at thirty-second intervals. Changes that took place from picture to picture gave a measure of over-all activity.

The recorded information was not in a form suitable for immediate analysis, so the first step was processing. Calls were sorted out and then subdivided into messages. Messages were transcribed onto 5- by 8-inch Keysort cards and numbered consecutively. Major data was recorded by punching numbered fields around the periphery of each card, facilitating classification and sorting.

With the study data condensed and classified in this manner, it was possible to seek answers to

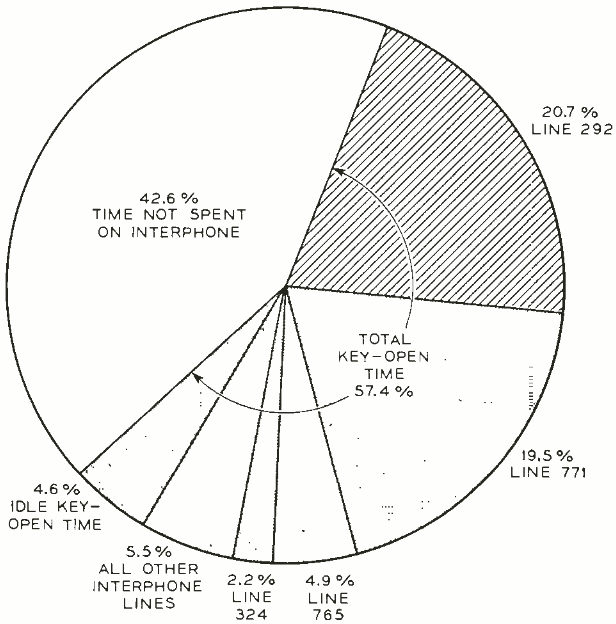


Fig. 3 — Chart of Hartford controller's time.

the principal questions. Figure 3, for example, shows the way in which the Hartford controller divides his time. About 57.4 per cent of his working time is spent communicating by voice over interphone lines, the remaining 42.6 per cent being used in performing clerical tasks on his flight progress board, talking to other controllers, and reaching

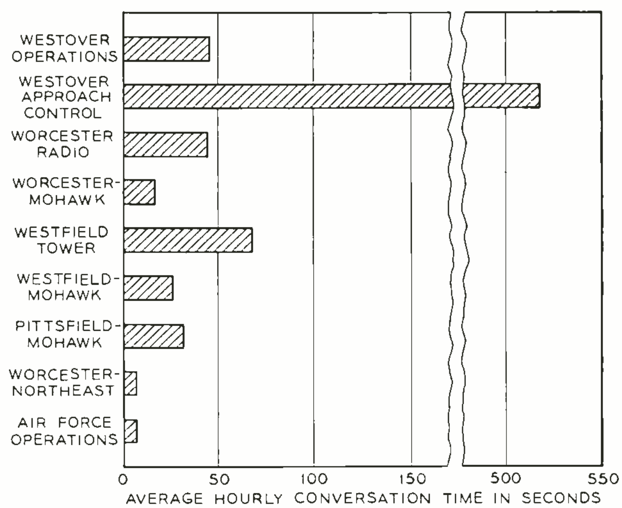


Fig. 4 — Breakdown of conversation time on line 292 between controller and the remote stations.

decisions. Most of the time spent on telephone conversations is divided between two lines. Line 292, with eight stations along its route, accounts for 20.7 per cent of his time; line 771, with seven stations, accounts for 19.5 percent. Another 4.6 per cent is "idle key-open time," when his line key is operated but no conversation is taking place because he must study and record information that is related to his problem.

Table I gives a breakdown of conditions on the nine lines used during the studies. The calling rate and holding time for lines 292 and 771 are practically the same; with the large number of stations on these two lines and the fact that the controllers involved are occupied in duties other than conversation, information is frequently delayed in reaching them. This tends to increase the "age" of information reaching the controller, making it more difficult for him to maintain an orderly flow of aircraft and avoid imposing delays. Another factor that increases the age of information is the relaying of messages to and from aircraft. In the studies, the average age of a relayed message was 3.1 minutes, whereas the average age for direct air-ground radio contact was 1.4 minutes. The CAA is well aware of this fact and, at heavy traffic centers, is providing controllers with various direct air-ground radio arrangements.

Table I

Line No.	*No. of Stations Per Line*	*Calls Per Hour Incoming and Outgoing*	*Seconds of Conversation Per Hour*	*Average Holding Time, Sec.*
292	8	24.4	729	29.5
771	7	23.9	672	29.4
765	1	3 6	156	43.4
324	2	5.2	73	14.0
1710	1	2.1	55	26.2
280	1	3.2	54	16.9
1761	1	1.0	31	31.0
331	1	1.7	27	15.9
307	1	0.8	13	16.2

Another factor that determines the age of information is the length of time an incoming call must wait for the controller because he is already busy. It was found that the median delay was 14 seconds and the average was 25 seconds. Ten per cent of the delays exceeded 70 seconds. Both the length and frequency of delays increased rapidly as the controller spent more time communicating. Thus, only a small amount of extra communicating time could result in a large number of additional delays.

THE AUTHORS

D. K. White joined Bell Telephone Laboratories in 1945 after serving with the United States Army Signal Corps in the European Theater during World War II. Prior to this work on the CAA air route traffic control study at the Laboratories, he had been engaged in work on radio-telephone systems and over-the-horizon propagation studies. At present, he is concerned with broadband transmission systems. Mr. White attended the Brooklyn Polytechnic Institute.

L. A. Yost, after receiving the degree of B.S. in E.E. from Purdue University, joined the Western Electric Company Hawthorne Works where he took the long-term student course. In 1927, he transferred to the Kearny works, and in 1931 to the Department of Development and Research of the A.T.&T. Company. He was chiefly concerned with manual central-office switchboards, and continued similar work after the transfer of the D & R to the Laboratories in 1934. After Pearl Harbor, Mr. Yost engaged in developing equipment for information centers for the Armed Services. Since the war, he has been concerned with facilities engineering of new dial equipment.

A complete conversation between the controller and a remote station is defined as a call. Such a call may include several messages, each containing a unit of information related to one particular subject. Eleven classifications were assigned in the studies to cover all possible messages. These are indicated in Table II. Clearances, which represent control decisions, use 30.4 per cent of the controller's communicating time. However, position reports and estimates, which require only clerical action, take up 25.5 per cent of his communicating time.

The controller's work load is determined in large measure by the number of aircraft under his control, but these planes fly many different routes, on different schedules, and for various reasons; they therefore generate varying amounts of communications. What improvements could be made in reducing the controller's communicating load, with the resultant possibility of reducing the lengths of delays? One improvement would be to relieve the controller from the necessity of handling progress reports and possibly other types of messages requiring only clerical handling. The 25.5 per cent of his time represented by these messages would then be available for other purposes. This suggestion is cited only as an illustration of some of the typical applications of the results of such studies. Information gleaned from this and subsequent studies is being coordinated to provide a comprehensive plan for over-all improvements in communications for air traffic control.

TABLE II

Message Classification Number	*Type of Information*	*Average Percent of Interphone Time*
1	Flight plan	4.70
2	Clearances	30.40
3	Forwarding estimates to other centers	6.10
4	Coordination	14.60
5	Forwarding estimates to tower or approach control	7.40
6	Cancellation of flight plan	2.00
7	Position reports and estimates	25.50
8	Weather information	1.60
9	Receiving estimates from other centers	0.66
10	Flow control	0.04
11	Miscellaneous	7.00
		100.00

W. D. Bulloch Named Editor of The RECORD

William D. Bulloch, Associate Editor of the RECORD, has been named Editor, effective with this issue. J. D. Tebo, Editor of the RECORD and the Bell System Technical Journal since 1953, continues as Editor of the latter publication. George E. Schindler, Assistant Editor of the RECORD, succeeds Mr. Bulloch as Associate Editor.

A graduate of Dartmouth College, with his master's degree in physics from the University of North Carolina, Mr. Bulloch taught courses in physics, mathematics and astronomy at the latter institution for a number of years. He was also Assistant to the Director of the Morehead Planetarium at Chapel Hill, North Carolina.

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

An Experimental Picture-phone

H. L. Barney, at the left, demonstrates how one experimental model of a Picture-phone would be used. Camera lens is mounted above picture.

R. L. Miller examines picture strip from facsimile-type recorder being investigated at the Laboratories for possible use in receiver.

A telephone that transmits pictures along with sound is being developed toward commercial feasibility, Bell Telephone Laboratories announced recently at a joint meeting in Los Angeles of the Institute of Radio Engineers and the West Coast Electronic Manufacturers' Association. An experimental "Picture-phone" system has been used to transmit recognizable pictures over various distances including transmission from New York to Los Angeles.

Experimental pictures vary in size from one by one and a half inches to two by three inches, and are viewed from one to two feet away. Unlike television, a new picture is displayed every two seconds. It has good black-and-white contrast and the person at the other end of the line is recognizable. Head and shoulders can be seen and facial expressions are readily apparent.

It will be possible for a caller's picture to be "dialed" like an ordinary telephone call, provided the switch on the picture equipment is turned on at both ends of the line. If the switches are off, the telephone call will be completed without pictures. The picture can also be turned on after a conversation is underway. It would be impossible for a customer to be seen by the caller unless his switch was turned on.

Operation of the Bell Telephone Laboratories Picture-phone system has been made possible by slowing down the rate of transmission of picture information to such an extent that the required bandwidth can easily be handled by conventional telephone circuits. The raster is made up of 60 lines, each of which may have a maximum of 40 dots. Thus, each complete frame may be thought of as being made up of 2,400 dots. If a single frame were transmitted each second, an over-all bandwidth of 1,200 cycles per second would be necessary. With the present system, one complete picture is transmitted every two seconds, requiring a bandwidth of 600 cycles per second.

This 600-cycle "video" band contains very low frequency components which might suffer undue attenuation during transmission over phone lines. Therefore, a carrier scheme is employed in which the "video" signal amplitude-modulates a 1,200-cycle carrier. The transmitted intelligence is then a conventional amplitude-modulated double-side-band signal with a frequency range of 600 to 1,800 cps. This signal lies within the range of optimum transmission of telephone lines, and so can be treated exactly like a voice signal. It can be passed through repeaters, and transmitted via microwaves, coaxial cable, twisted pair, or open wire lines.

One possible line-up of components, which has been tested experimentally, uses a conventional TV camera of the type employed in industrial TV systems. This camera contains a Vidicon tube and the necessary horizontal and vertical sweep circuits for producing a raster. These circuits are so adjusted that the 60-line raster is obtained with one complete scan occurring every 1/20 second.

Since the transmitted picture repetition rate is only one every two seconds, a total of 40 scans is available in the two-second interval. One of these scans is arbitrarily selected and the remaining 39 are unused. The information in this scan is recorded on a magnetic drum which is rotating at a speed of 20 revolutions per second. All of the picture information for a single frame is thus recorded on a single rotation of the drum.

By means of suitable gating and timing circuits, this stored information is then picked off the drum at 1/40 the rate at which it was recorded. Thus, by the time it has turned 40 revolutions (an interval of two seconds), all the information from a single scan has been passed on to the modulator, and the drum is erased and made ready for the next picture. At this point, timing and synchronizing data are combined with the signal to be transmitted. Such data are added in much the same manner as synchronizing information is combined with a conventional TV signal.

Left to right, R. L. Miller, H. L. Barney and F. K. Becker discuss tests on an experimental viewing unit.

F. K. Becker demonstrates the use of another experimental Picture-phone arrangement being studied for possible further development.

It is possible to take advantage of the storage properties of the camera tube itself, and thus eliminate the magnetic drum memory system. By means of a suitable shutter arrangement, the image tube can be made to receive a momentary image once every two seconds, and then the whole two seconds used for the scanning procedure. The signal thus derived can be sent directly to the modulator. Sufficient experience has been gained with this technique to indicate that it is feasible.

A number of other possible transmitting and receiving systems are being investigated, and some of these are indicated in the accompanying photographs. Exploratory work is also under way to determine the combination of picture repetition rate and resolution which will make best use of the available bandwidth. In its present form, equipment for the Picture-phone is rather bulky and expensive, but avenues are being explored for reducing the size, complexity and cost.

The picture equipment is still being developed and evaluated, and is not ready for manufacture or commercial use. After further development, it could be offered as a separate, optional telephone service. The system was devised at the Laboratories by W. E. Kock, F. K. Becker, R. L. Miller and others.

Electron Microscopy of Ceramics

MISS S. E. KOONCE
MISS F. M. BERTING
Analytical Chemistry

Because of its great depth of focus and high magnification, the electron microscope is able to "see" submicroscopic features of surfaces in great detail. Recently it has been used in the investigation of a porcelain and of a multicrystalline barium titanate — two ceramic materials whose surface characteristics vary with production methods, which in turn affect ultimate electrical properties. These studies have aided scientists and engineers in tailoring ceramics to a wide variety of experimental applications.

In many research projects, a complete chemical analysis is often necessary, but often too it is not sufficient. In addition to knowing *what* is in a material, we frequently need to know *how* certain constituents have crystallized or otherwise distributed themselves and how manufacturing processes have affected structural properties.

For these problems, the electron microscope has proved to be an invaluable analytical instrument. Its high magnification and great depth of focus have permitted detailed observation of grain growth, development of crystal planes, and changes of physical structure. In the work described here, it was used to gain a better understanding of two ceramic materials of interest to the communications industry. One of these is a porcelain type of ceramic used in the fabrication of deposited-carbon resistors, and the other is a barium titanate ceramic used as a transducer for conversion between electrical and mechanical energy.

The instrument used in this work is an RCA EUM-1 electron microscope. This is a transmission-type instrument — one in which the image is formed as a result of electrons passing through the sample being observed. Since the ceramics were too thick for direct examination, it was necessary to prepare very thin replicas of the surfaces. No polishing or etching was employed; replicas were made of the natural surfaces as developed in the sintering process. During sintering, the raw constituents fuse and react at an elevated temperature to produce a microstructure of glassy and crystalline phases. The amounts of the various phases depend upon composition, distribution, temperature and time.

Replicas are made in several ways, but the following method proved most satisfactory. The surface was first coated with a layer of plastic (collodion in amyl acetate). This film, when thoroughly dry, was strong enough to be handled easily. It was stripped from the sample and then mounted in a vacuum-evaporator for application of two layers: one of silica and one of germanium. First, a film was applied by allowing vaporized silica to travel in a direction normal to the surface of the plastic impression. This forms a continuous base film of uniform thickness. Second, a "shadow" layer was formed by tilting the impression so that vaporized germanium traveled at an angle toward the surface. Germanium thus builds up on one side of a "peak" or high portion of the impression, and a partial or total shadow is cast on the other side. Such shadow-casting greatly increases the contrast in the final image. Finally, the impression was supported on a fine-mesh screen, and the plastic was dissolved, leaving a thin, shadowed replica only about 10^{-6} to 10^{-5} cm thick.

Surface characteristics were of interest because very accurate and stable resistors can be made by depositing carbon onto a ceramic core. The carbon forms a thin film whose resistance can be more precisely specified than with the usual types of resistors. To fabricate such components successfully, the surface of the ceramic rod must be rough enough to hold the film, yet not so rough as to impair it. For very high resistances, an extremely thin film is deposited, which requires an exceptionally fine surface. Electron microscopy was called into use for investigating the submicroscopic characteristics that influence the adherence of the carbon.

Ceramic rods were supplied by three manufacturers, whose products are here labeled A, B and C. All products were made according to the same general specification, but processing variations were great enough to necessitate this study. Concurrent with the electron microscope investigation, an X-ray diffraction analysis was conducted to check crystalline compositions. The ceramics were alkaline earth porcelains, that is, porcelains in which all but traces of the sodium and potassium of ordinary porcelains had been replaced by barium, calcium, strontium or magnesium. Diffraction analysis showed crystallographic differences in the three products, and the electron microscope made possible the identification of the surface characteristics of several of the crystal structures. Differences between the surfaces were revealed, and some of these could be traced to variations in production methods.

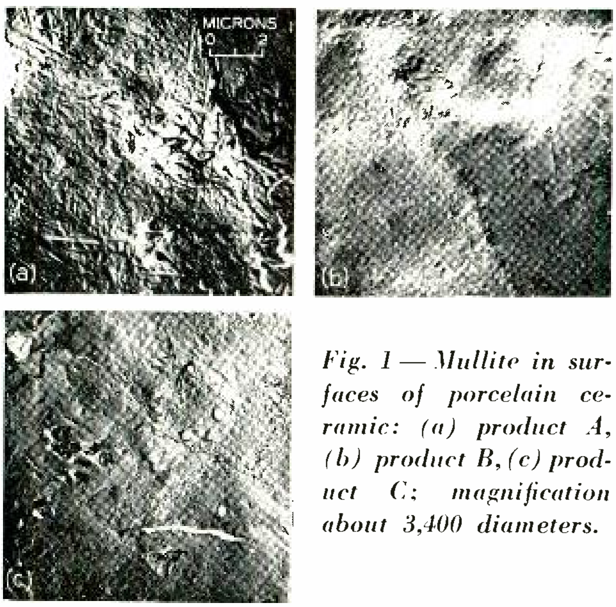


Fig. 1 — Mullite in surfaces of porcelain ceramic: (a) product A, (b) product B, (c) product C: magnification about 3,400 diameters.

Most readily identified in the electron microscope was mullite, a crystalline substance with the chemical formula ($3Al_2O_3 \cdot 2SiO_2$). It is observed on the ceramic surface as characteristic masses of needle-shaped crystals embedded in and projecting from a glassy matrix. Mullite apparently increases the mechanical strength of the ceramic core and provides good adherence of the carbon film. Mullite was present in all three products, but was more prominent in product A. As evident in Figure 1(a), the needles stood out clearly from their glassy matrix. Needles in product B, seen in Figure 1(b), were about the same length as in product A, but were much narrower, did not form so tight a mesh, and were surrounded by considerably more glass. Mullite in product C, Figure 1(c), formed needles in only a few places, for example amid the tiny pits of a rough portion of the surface.

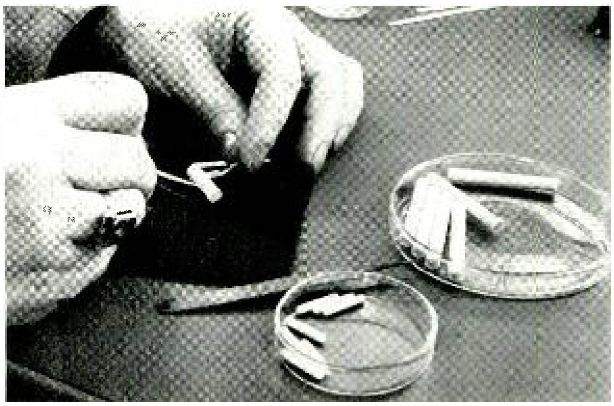


Fig. 2 — Applying collodion to resistor core surface; two sizes of cores can be seen in foreground.

An interesting observation was that these cores, when refired for two hours at 1350°C, showed a marked increase in surface mullite; in product A the needles became larger, increasing particularly in width. In product B, they spread over greater areas, and in product C, where almost no mullite was evident before refiring, crystals formed in large areas, covering most of the surface with a network much like that found in the original product A.

The three products were also examined after fracturing; that is, the samples were broken and new replicas made so that an end view or cross-section of the surface could be observed. On the fractured surfaces of the three products, mullite appeared almost exclusively in pits and irregularities, rather than in smooth extensive deposits as on the outer surfaces. In fact, mullite was the only crystalline substance identified microscopically on

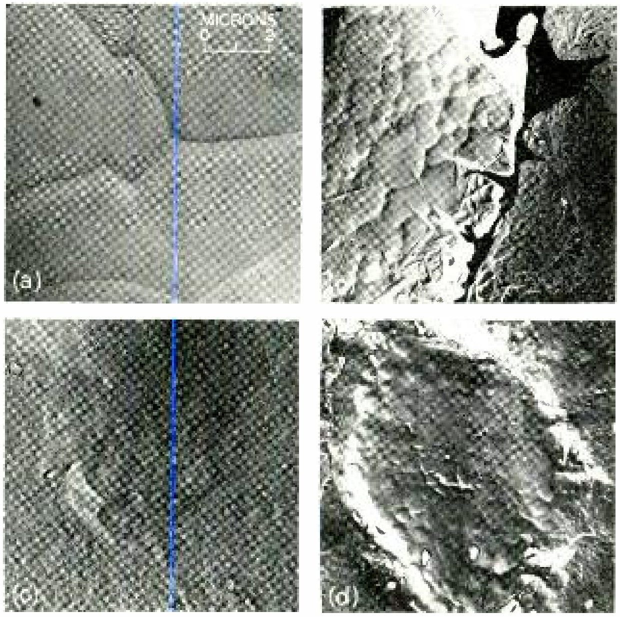


Fig. 3 — Cristobalite on porcelain ceramic: (a) surface of pure cristobalite, (b) product A, (c) product B (d) product C; magnification 4,200 diameters.

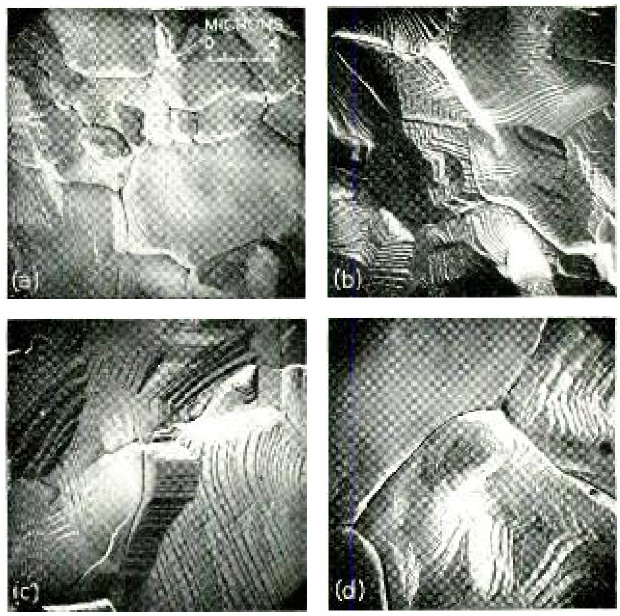


Fig. 5 — Barium titanate samples after different firing times and temperatures: sizes of grains get progressively larger; magnification 2,000 diameters.

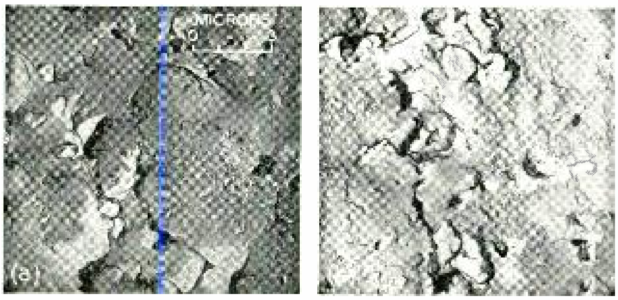


Fig. 4 — Barium cordierite on porcelain ceramic surfaces: (a) surface of pure barium cordierite, (b) product C; magnification about 3,400 diameters.

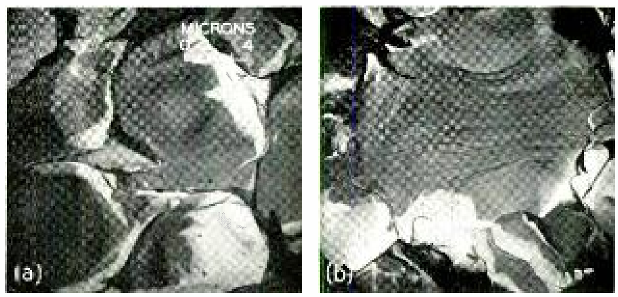


Fig. 6 — Barium titanate with 4 per cent glass, fired for (a) 1 hour, and (b) 4 hours; magnification in these micrographs is approximately 2,000 diameters.

the fractured surfaces, and it could be observed only on the surfaces of voids or bubbles.

A second component of interest was cristobalite, a crystalline material with the composition (SiO_2). In the ceramic, this material appears as slightly rounded surface irregularities that probably reduce the thermal shock resistance of the ceramic. Regions of cristobalite are often bounded by large ridges or cracks, which are detrimental to the uniformity of the film.

Cristobalite was identified on the surfaces of all three products by correlation with X-ray diffraction data, and by comparison of electron microscope images with those of surfaces of pure cristobalite. A typical surface of the pure material, as seen in Figure 3(a), has well defined crystals that are the prototype of those seen in clusters on the ceramic cores. As with mullite, cristobalite developed differentially on the three products. On product A, Figure 3(b), they are well formed and distinct. On product B, Figure 3(c), they are rather scattered and incompletely developed, while product C, Figure 3(d), has both well formed and undeveloped crystals.

On the surface of product C there appeared a structure that did not look crystalline, but it had certain definite characteristics that could be traced to one specific crystalline material — barium cordierite. This is a crystal with the approximate composition ($BaO \cdot 2MgO \cdot 3Al_2O_3 \cdot 9SiO_2$). The barium form of cordierite had been studied extensively at the Ceramic Research Station of Rutgers University by Mrs. Harriet Wisely, who recognized the

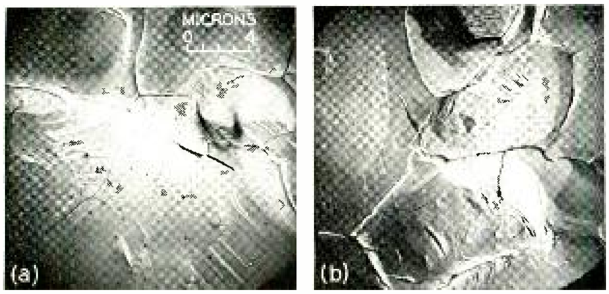


Fig. 7 — Barium titanate with lead titanate added: (a) 1 hour, (b) 4 hours; magnification 2,000 diameters.

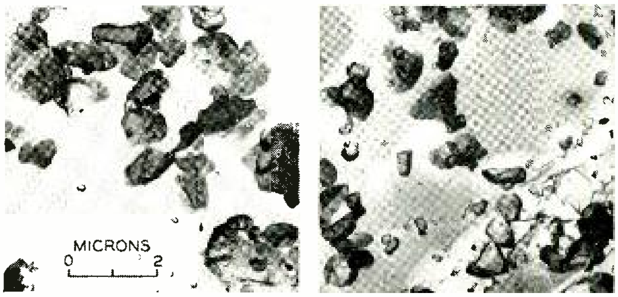


Fig. 8. — Original particles of barium titanate before firing; magnification about 5,600 diameters.

resemblance between the X-ray diffraction pattern of an unknown phase of our ceramics and a cordierite material.

Barium cordierite, in addition to mounds and valleys, has certain surface characteristics — small pits and many cracks or pores — which may be undesirable because the carbon deposited in pores and cracks is usually of the sooty type which absorbs considerable quantities of gaseous impurities and which may therefore impair the stability of the resistor. Barium cordierite was not detected in product A, but appeared in closely similar form on the surfaces of products B and C. A surface of pure barium cordierite seen in Figure 4(a) is quite similar in structure to a portion of the surface of product C seen in Figure 4(b).

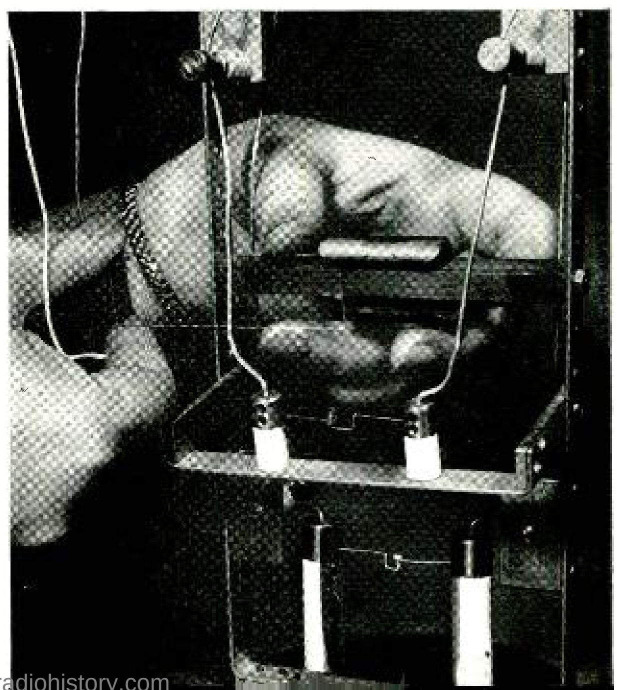
These studies of porcelain ceramics demonstrated some of the effects of different methods of processing and provided additional means of selecting ceramics for particular applications. In consequence, the knowledge derived from the investigations has contributed to the manufacture of better resistors.

The second type of ceramic studied in these investigations was barium titanate. This is a very useful material because it has the property of converting electrical energy into sound energy and vice versa, and thus is incorporated into devices such as delay lines* and apparatus for the generation of ultrasonic acoustic waves. It has the advantage over other electromechanical transducer materials (quartz, for example) that it is easily fabricated by casting, pressing, or extruding into shapes and sizes desired for specific applications. Its characteristics vary, however, with differences in fabrication procedure, and the electron microscope studies were concerned principally with three of the factors important to the performance of the material — grain sizes, compactness of grain boundaries, and crystal structure. The preparation of the best barium titanate ceramic for a particular application depends upon a delicate balance between these and other variables. Broadly speaking, it is desirable to obtain as dense and compact a grain-boundary structure as is possible without impairing the transducing or power-handling capabilities.

A commercial grade of barium titanate was formed into a ceramic by firing at a temperature of 1,300°C or greater. Below 1,300°C the ceramic is too porous to be useful. Four groups of samples were made: one was fired at 1,300°C for 1 hour, a second at 1,300°C for 4 hours, a third at 1,300°C for 16 hours, and a fourth at 1,425°C for 4 hours. Typical electron micrographs from each of these four groups can be seen, in order, in Figure 5.

In the first group, grain sizes were small and the boundaries were rather deep valleys with some holes or voids where the boundaries intersect. In Figure 5(a), the grain boundaries are the solid

Fig. 9 — Plastic replica on microscope slide being positioned prior to vacuum evaporation. Small "baskets" for silica and germanium can be seen between the two sets of binding posts at bottom.



* Record, *June*, 1956, *page* 212; *August*, 1949, *page* 285.

lines enclosing areas that show a terrace-like structure. As we go through groups 2, 3, and 4, as shown in Figure 5(b), (c), and (d), we note that the grains get larger. In group 4, many grains were larger than 20 microns. Also, the grain boundaries become increasingly compact through groups 1, 2, and 3, but the boundaries in group 4, fired at 1,425°C for four hours, are somewhat less compact than in group 2. The boundaries in group 4 showed, in addition, a tendency toward rounding at the boundary edges, and there were some holes or voids. Such facts can be correlated with the firing procedure and with the electrical characteristics of the barium titanate, so that these characteristics can be accurately controlled and altered as desired.

Besides these investigations, several other associated studies were carried out in connection with barium titanate. In one of these, it was thought that the addition of a small amount of glass might aid in achieving more compact grain boundaries. Two groups of samples containing 4 per cent glass were made; both were fired at 1,300°C, one for 1 hour and the other for 4 hours. As illustrated in Figure 6, grain sizes were much larger than in the plain barium titanate, but the boundary conditions were actually much worse. In another study, the effect of adding lead titanate was investigated. The firing times and temperature were the same as above, namely one and four hours at 1,300°C. Electron micrographs, Figure 7, showed that the lead titanate increased the average grain sizes, but had little effect on the compactness of the grain boundaries.

Some attention was also given to original particles of barium titanate as they exist before being fired. Direct examination of particles dispersed on a plastic film proved unsatisfactory, so another replica procedure was used. In this case, silica was evaporated onto the particles, and then the particles were dissolved, leaving only the silica shells. These were thin enough to transmit electrons. Figure 8 shows two micrographs of such particles. The sizes of these particles (about 0.1 to 0.8 micron) are another factor that can be correlated with the sizes of the grains after firing.

The electron microscope study showed that firing procedures could be varied to produce different degrees of compactness and of crystallite or grain size. The dense structures composed of smaller crystals well bonded together proved best for most experimental transducer applications where stability was of major importance, while dense structures with large crystals exhibited slightly better piezoelectric characteristics. Thus, the changes in electrical characteristics and certain other physical properties were found to be closely associated with, and presumably determined by, the micrographically observed grain size and compactness of the sintered barium titanate.

THE AUTHORS

Miss F. M. Berting received the B.A. degree in Physics from Oberlin College in 1950 and the MA degree, also in Physics, from Smith College in 1952. After joining the Laboratories in September, 1952, Miss Berting worked in the instrumental analysis group of the Chemical Research Department, where she engaged in X-ray diffraction studies and electron microscopy of ceramics. In September, 1954, Miss Berting left the Laboratories for additional studies at the Massachusetts Institute of Technology, and in October, 1955, she accepted a position as chemist with the Radiation Laboratory of the University of California, where she is engaged in general analytical work using emission spectroscopy.

Miss S. E. Koonce attended Louisberg College in North Carolina and joined the Laboratories in 1942. She was early engaged in the development of precision carbon resistors, and later was concerned with microphone carbon produced from polymers. In 1951, Miss Koonce transferred to the analytical chemistry group to work on an investigation of the growth of filamentary metal "whiskers." Later she conducted electron microscope studies of the surface characteristics of porcelain-type and barium titanate ceramics and of various semiconductor crystals, and more recently has been concerned with a continuation of the "whiskers" studies, with nickel cathodes, and with ferrites and other magnetic materials. Miss Koonce is a member of the New York Society of Electron Microscopists and of the Electron Microscope Society of America.

Systems Testing in the Switching Laboratory

E. J. FOGARTY *Switching Systems Development II*

It is not sufficient that a switching circuit or system be designed and tested as a single development. Each circuit must fit into the Bell System switching network, and how it will affect and be affected by other parts of the network must be considered. Over-all laboratory testing thus requires that each new circuit be tested, not only as a unit, but in conjunction with many other circuits. In any switching development, many departments of the Laboratories cooperate, among themselves and with other parts of the Bell System.

With the gradual introduction of Direct Distance Dialing throughout the country, the switching network of the Bell System and the independent telephone companies is evolving into one vast integrated machine. The lines of demarcation between local and toll systems are rapidly fading, and constantly larger areas of the network are being made accessible to the individual customer's dial.

When, for example, a customer in Englewood, New Jersey, dials 415-AN9-1234, a multiplicity of relays, switches, electron tubes and transistors in various types of offices in Englewood, Newark, Sacramento, and San Jose respond to the dialed instructions and establish a connection over the most economical route to the desired line in San Jose. If the circuits of the most economical route are busy, other circuits through other cities are automatically substituted. In this and other similar cases, large groups of electrical equipment located in cities that are often hundreds of miles apart interact as a coherent whole.

One effect of this integration is that new switching developments often overlay the boundaries between systems, requiring new circuits or modifications of existing circuits in two or more systems. As a result, the fabric of the switching network becomes more closely interwoven, providing constantly greater flexibility in the routing of calls.

The fact that the customer directly controls extensive long-distance connections makes it more important than ever before to test new developments thoroughly before they are placed in service. While long-distance calls were all controlled by operators, the operators could maintain service under equipment difficulties and report symptoms of operating troubles to the maintenance forces for corrective action. The customer who is dialing long-distance calls directly has neither the information nor the facilities to by-pass equipment difficulties, and cannot be relied upon for prompt and accurate information on operating troubles. Therefore, to maintain satisfactory service with customer distance dialing instead of operator dialing, the equipment must be extremely reliable and troublefree.

A major switching development is a cooperative endeavor of all branches of the Bell System. The A.T.&T. Co. gathers information from the Operating Telephone Companies as to services required by customers, and from this information lays broad plans for developments that will be uniformly applicable throughout the system. These broad requirements are submitted to the Systems Engineering Department of the Laboratories, which analyzes them from a technical and economic standpoint and produces a master plan for the development. This master plan is turned over to the Switching Development Department, which designs the necessary circuits and equipment, tests the circuits for proper operation, and provides the drawings and specifications from which the Western Electric Company manufactures and the Telephone Companies maintain the equipment. During the course of the development, Western Electric and the Telephone Companies are informed of the services to

New Equalizers for Local TV Circuits

H. M. THOMSON *Apparatus Development*

In the band of frequencies used for transmission of television signals, the higher frequencies lose strength much more rapidly than the lower frequencies over a given length of transmission cable. Equalization circuits are therefore introduced to compensate for this characteristic and to provide faithful reproduction of signals at the receiving end. The new A2A local video system uses a combination of "coarse" and precisely adjustable equalizers to meet the loss characteristics of a wide variety of cable lengths.

Behind the scenes of action of live television programs and TV transmitters are the connecting circuits provided by the Bell System. Coaxial cables and radio circuits take care of the long-distance network links, but locally there are many short cable links, the median length being about a mile and a half. Right after World War II, the rising demand for television service was responsible for the modification and manufacture of the A2 video transmission system, which was developed before the war to provide short-link TV circuits. Now the A2A video transmission system* is available to provide the broader band and higher quality transmission required by color TV standards. Indispensable to the achievement of high quality transmission in the new system is the development of the new attenuation-correcting equalizers.

Attenuation in the network cables increases rapidly at the higher signal frequencies and causes distortion in the delivered TV signals; additional distortion is contributed by the line and terminal equipment. The longer the link, the worse the distortion becomes. The function of the equalizers is to compensate for distortion arising from all causes by introducing into the circuit, at repeaters and terminals, an attenuation which is complementary to the attentuation of the rest of the circuit. As a result, the TV signals are restored to their original relationships with a high degree of fidelity.

In a field trial, it was found that an A2A system, when equalized, can provide equal transmission for all frequencies from about 100 cycles per second to 4.5 mc per second, even with lengths of cable having attenuations as high as 100 db. This system consists of various circuits that are used between studios, network control points, operating centers of

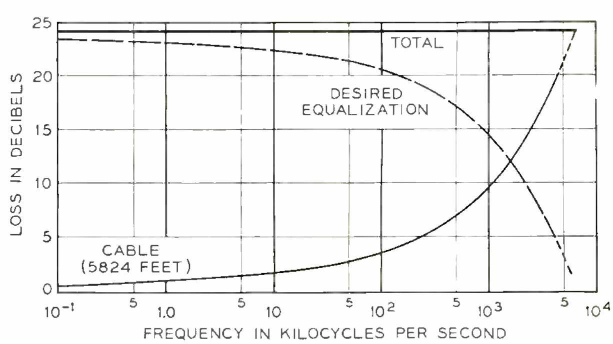


Fig. 1 — Solid curve: cable loss versus frequency; dashed curve: desired equalization characteristic; when added to cable loss, it gives flat line at top.

* RECORD, *April,* 1956, *page* 126.

Associated Telephone Companies, and television broadcast transmitters.

The cable portions of the local video links already in service consist of low-loss, 16-gauge polyethylene-insulated balanced pairs of copper wire incorporated in underground cable. Since the cables may be any length from a fraction of a mile upwards, and since a large part of the signal distortion is a function of transmission distance, the equalizers must be applicable to any expected circuit length. This flexibility is accomplished by providing eight fixed equalizers for approximate equalization in large steps, and three adjustable equalizers to compensate for the residual distortion.

For the large steps, the fixed equalizers were designed to equalize lengths of cable on the basis of the difference between the attenuation at 30 cps and 4.5 mc. This difference in attenuation increases at a rate of about 18 db per mile.

Figure 1 illustrates the desired equalization characteristics for a length of cable (here 5,824 feet) in an A2A link. The solid curve is the cable's attenuation characteristic, which shows the increased losses at the higher end of the frequency band. The dashed curve is the desired complementary attentuation, and the sum of the two curves is the flat line at the top. The closer the fixed equalizers can come to the desired attenuation curve, the less residual distortion will have to be "mopped up" by the adjustable equalizers.

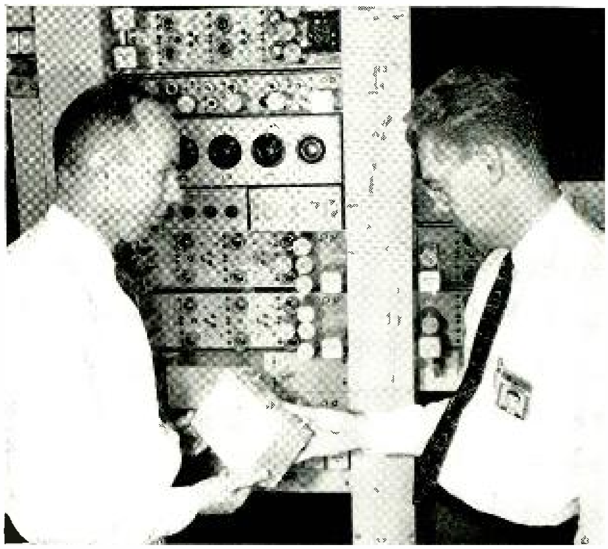


Fig. 3 — C. L. Semmelman (right) inspecting a fixed equalizer that the author has just removed from an A2A transmission-system frame.

A close approximation to the required equalization characteristic can be obtained from several different simple equalizer sections connected in tandem. A more efficient circuit is used, however — the "bridged-T" network shown in Figure 2. The bridged-T network minimizes or avoids troubles due to parasitic elements and impedance mismatches. A simple all-pass "phase-equalizer" section is included in tandem to correct for delay distortion of the cable, repeaters and terminals.

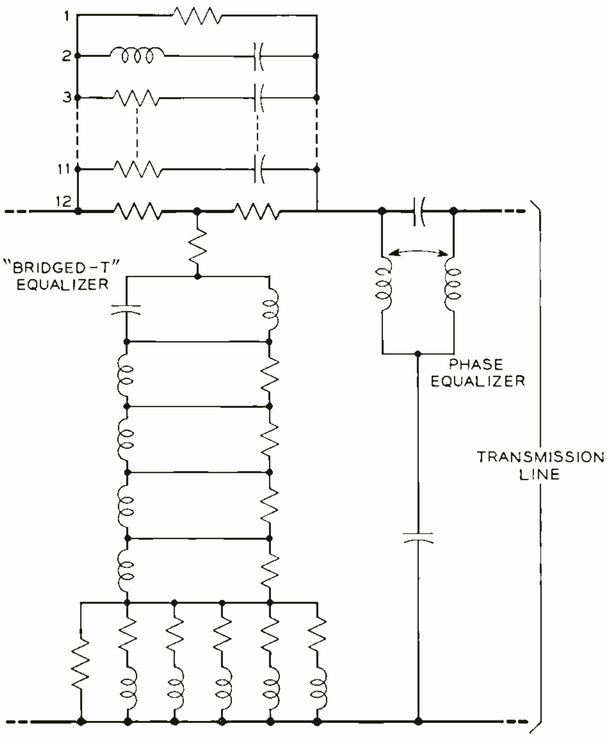


Fig. 2 — "Bridged-T" circuit of fixed equalizers (left) and phase equalizer circuit (right).

To be adaptable to any particular installation, the basic terminal equipment layout must provide for a wide range of total equalization. To meet this requirement, the fixed equalizers are designed as plug-in units, all mechanically interchangeable (see Figure 3). Internally, the structure is simple and easily assembled (Figure 4).

This design accommodates a large variety of components for which the size and mounting arrangements differ widely. The largest capacitor is over forty times the volume of the smallest. Two of the three types of inductor used are air-core types having core-slug tuning; the third is a new ferrite type that was in process of development simultaneously with the equalizers.

Capacitor lead lengths are kept short because many of them are critical for electrical performance. Parasitic inductances in connection paths are absorbed in most instances by the inductors. Orientation and spacing of the inductors are arranged for negligible parasitic effects, and coaxial jacks are used to provide uniform impedances at the terminal connections and to facilitate plug-in.

Since hardly any two cable links are of equal length, the fixed equalizers contribute only a first

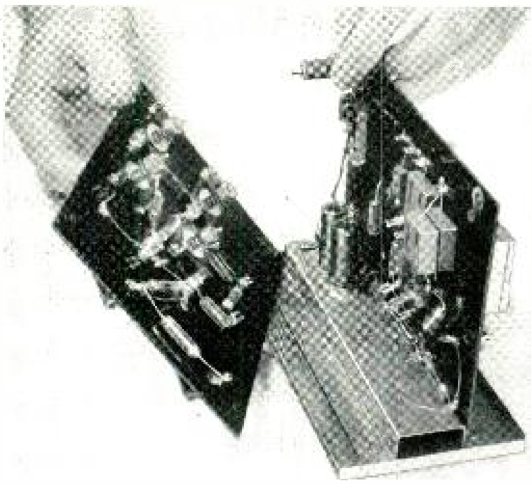


Fig. 4 — Fixed equalizer showing compactness of components and ease of assembly.

approximation to the total equalization required for any particular link. Adjustable equalizers are therefore provided for "mopping-up" the residual cable distortion as well as the additional distortion introduced by network amplifiers, short lengths of other types of cable, misterminations, temperature changes, and manufacturing deviations in the cable.

Most residual distortion of the A2A links can be "mopped up" by five equalizers whose characteristics are separately adjustable. The loss shapes of these equalizers are shown by the first five curves in Figure 5. Indicated here are the maximum positive characteristics, but each equalizer is continuously adjustable to produce a negative value below the reference "flat" position, plus many intermediate values. A combination of these five shapes, when added in tandem to the "coarse" values of the fixed equalizers, will result in a good approximation to almost any required shape over the 100-cycle to 4.5-mc band.

Physically, the basic structure of the five equalizers is similar to that of the fixed equalizers (see illustration at head of article). Specially constructed rheostats, mounted on extensions of U-shaped channel brackets, contain precision resistors and include design features required to minimize parasitic capacitance and inductance. The different types of capacitors and inductors, as well as the resistors and rheostat, can be seen in the closer view of one of the equalizers, Figure 6. All five equalizers are combined in one unit termed the 331A equalizer, shown in Figure 7.

Final "mopping up" equalization is provided by two adjustable-type, plug-in equalizers, the 330M and 330S. Each has four controls and four adjustable attentuation characteristics. The maximum positive characteristics of the 330M are indicated in the lowest part of Figure 5. Like the curves of the other adjustable equalizers, each can provide proportional characteristics between those shown and others opposite in sign. The curves of the 330S equalizer are similar but have peaks at other frequencies; this unit is used only in the relatively few cases where the video circuit contains a network amplifier.

The new equalizers meet inherently stringent electrical requirements over more than seventeen octaves in the frequency spectrum for the A2A sys-

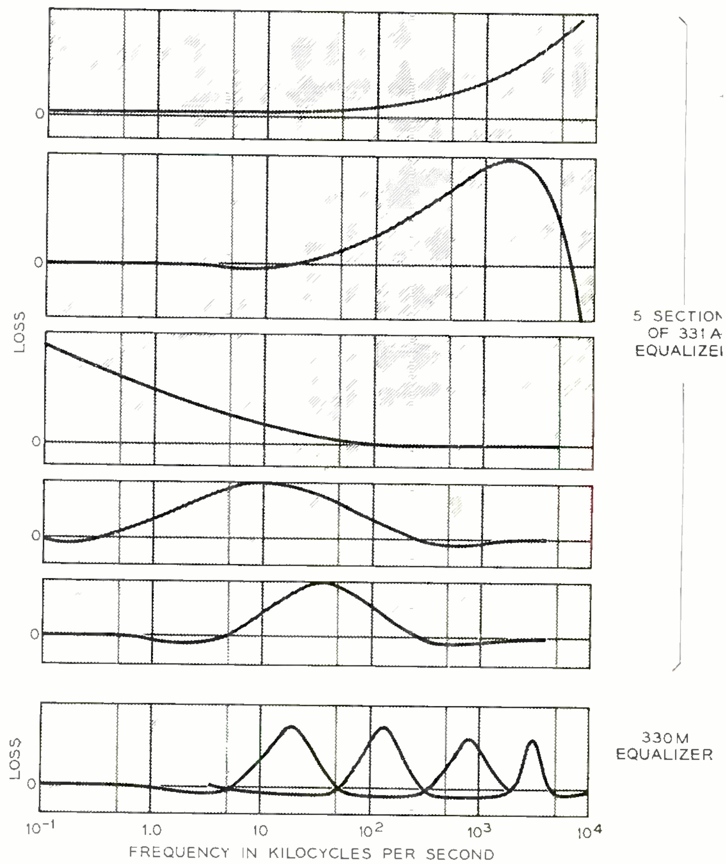
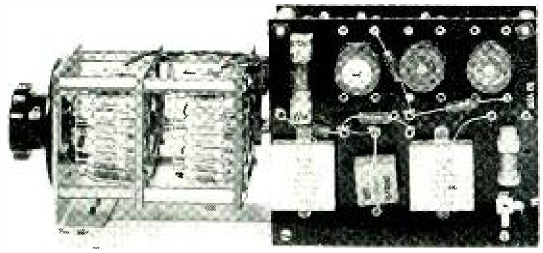


Fig. 5 — The five curves of the 331A adjustable equalizer sections, and (bottom) curves of the 330M equalizer.



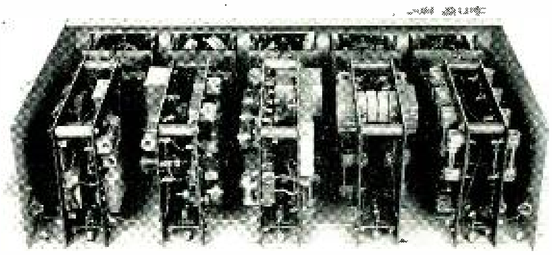


Fig. 6 (left) — One section of the 331A equalizer: the rheostat at left controls the loss shape of the equalizer at right. Fig. 7 (right) — Complete 331A equalizer with the five adjustable sections.

tem. The equalizers meet close tolerance limits in regular production, and residual distortion of the system is well below the acceptable norms.

Mechanically, the equalizers achieve high efficiency in space utilization and provide easy wiring, assembly and inspection. The piece parts are simple and are based on preferred apparatus dimensions. Such features have helped materially in meeting the low cost objectives. Development of these equalizers and of the over-all A2A system enables the Bell System to provide the high quality transmission facilities necessary for good color television.

THE AUTHOR

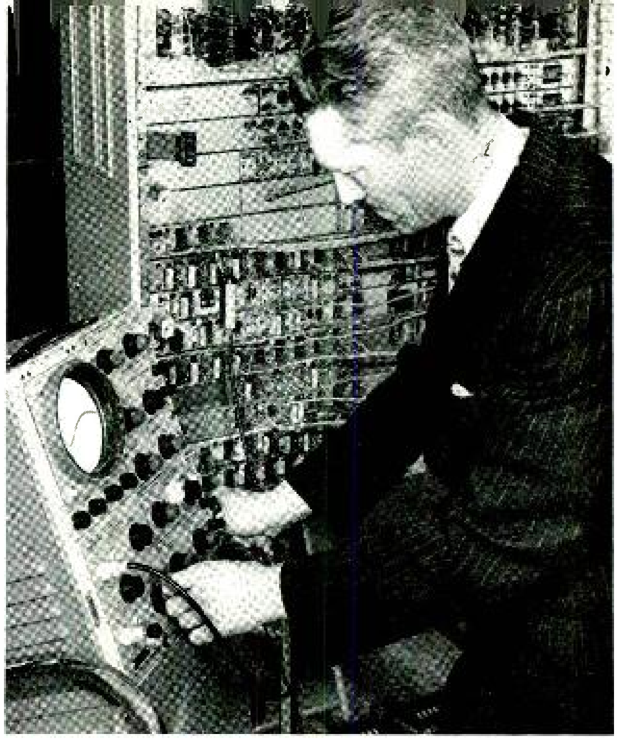
H. M. THOMSON received the B.S. degree in Electrical Engineering from the University of Washington in 1930, and in the same year joined the Radio Research Department of the Laboratories. For a time, he assisted in field tests of an experimental transmitting wave antenna for the A.T.&T. Co., and later took part in other long-wave radio transmission studies. In 1937, Mr. Thomson transferred to the Apparatus Development Department, where he engaged in work on filters and equalizers. Later he was concerned with equalizers for the L1 coaxial system and then with the mechanical design of microwave networks. More recently he has been engaged in the design of filters and networks for the P-carrier system and of equalizers for the A2A local video system. Presently Mr. Thomson is at the Merrimack Valley location, where he is concerned with the electrical and mechanical design of equalizers and networks for the TD2 and TE transmission systems and of filters for the A5 channel bank.

Laboratories Offer New Graduate Study Plan

The Laboratories has announced the initiation of a new Graduate Study Plan, designed to aid employees in pursuing graduate study along lines relating to the individual's work in the company. Under the new plan the Laboratories will provide reimbursement of one half of the tuition fee upon registration for a graduate course and the balance upon certification by the school that the course has been satisfactorily completed. Regular employees who hold a bachelor's degree in arts, sciences or engineering are eligible for enrollment under this Graduate Study Plan.

The new plan includes the previous arrangement whereby employees may secure a reduction in working time of not more than seven and one-half hours per week where necessary. It is expected that prior to application for a course involving reduced working time, consideration will be given to equivalent instruction not requiring a reduction in working hours; that is, Laboratories Out-of-Hours Courses, evening or extension courses in local colleges, in-hours courses offered by the Communications Development Training Program, and courses offered on other than scheduled working days.

Relay Contact Protection



R. H. GUMLEY *Switching Apparatus Development*

Relay contacts that make and break current through magnets or other relays are subject to electrical erosion resulting from sparking and arcing as the contacts open or close. This erosion is not too serious for contacts expected to operate only a few million times in an anticipated forty-year life. Where contacts must operate many millions or even billions of times, erosion would be a serious factor in relay life and circuit reliability if some form of protection were not used. Application of a few simple rules permits the design of relatively inexpensive resistor-capacitor protection networks, and these are widely used in the Bell System.

In a typical No. 5 crossbar dial telephone office, about 60,000 relays are used for each 10,000 lines of central-office equipment. Many of these relays – about 40 per cent – are in circuits that are held for the duration of a conversation. These relays therefore operate infrequently – less than about 2 million times in an expected life of 40 years. Another 20 per cent of the relays are in circuits that are held only until signaling and dialing are completed. Some of these relays operate as many as 100 million times or more. The remaining 40 per cent are in high-speed, short-holding-time circuits, and some of these relays may operate as many as one billion times.

Relay contacts also operate under widely varying load conditions. Whenever a contact controls the current in a circuit by opening or closing, sparking or arcing will take place and contact erosion will occur. About one-fourth of all relay contacts control other magnets or relays and are therefore subject to electrical erosion. The other three-fourths of the relay contacts prepare or maintain a circuit path where another relay contact controls the current. Such non-sparking, or "non-working," contacts are subject to only an insignificant amount of erosion, mostly due to mechanical wear. However, for standardization of apparatus and equipment design, the contacts on each relay type are generally made uniform in shape and size regardless of contact load. In the Bell System today, relay contacts are commonly of palladium or silver except for those with a gold overlay on palladium now used on the new wire-spring family of relays.

Each contact metal has a characteristic value of current below which arcs will not occur. To obtain a long contact life, the circuit designer restricts the steady-state current to a value below the minimum arcing current for the particular metal. Palladium contacts are limited to 1.0 ampere and silver contacts to 0.5 ampere. With these current limitations, a contact life of 2 to 50 million operations is obtained in 50-volt circuits, depending on the magnitude of the current and the inductive energy in the load circuit. Where longer life is required or where erosion may cause contacts to snag or bridge, contact protection is used.

In the Bell System, contact protection almost universally consists of a capacitor in series with a resistor since this offers the best compromise between cost and performance. In the newer switching systems, the resistor and capacitor are assembled into units called contact protection networks. For example, the 185A network consisting of a 0.1-mfd. capacitor and a 470-ohm resistor and the 186A network with a 0.3-mfd. capacitor and a 120-ohm resistor, are of the pigtail type. The capacitor is wound over a metal tube that serves as a housing for the resistor and also as a connection between one end of the capacitor and one end of the resistor. The 180A network, with 0.3 mfd. and 150 ohms, is a molded unit designed particularly for use with multicontact relays.

To understand the function of the contact protection network, it is helpful to review the effect of a load circuit on an unprotected contact. The conventional relay circuit of Figure 2(a) can be represented as an inductance in series with a resistance as shown in the approximate equivalent circuit of Figure 2(b). A more accurate approximation is shown in Figure 2(c). The inductance L is the inductance of the relay winding. Eddy-current losses in the relay structure can be simulated by resistance R_E, and a copper sleeve, if provided, can be shown as resistance R_S in parallel with R_E. Since relays have pole-face and hinge gaps and are subject to heavy flux saturations, a series inductance L_L must also be included to represent the leakage inductance of the relay winding. The winding re-

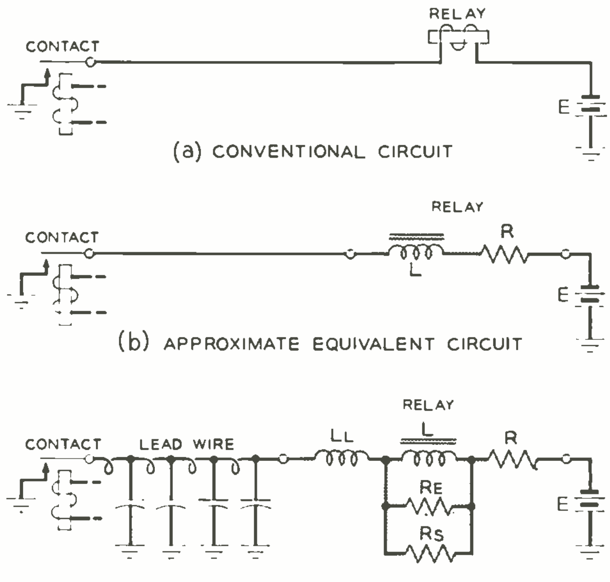


Fig. 2 — The simple circuit of (a) can be approximated for some purposes by (b). For analytical purposes, (c) is a better equivalent circuit.

sistance is shown as R. The lead wire between the relay and the contact has a distributed inductance *l* and a distributed capacitance c per unit of length. This gives the lead wire a surge or "characteristic" impedance of the square root of *l*/c ohms; in switchboard cables, it amounts to about 100 ohms.

Assume that current is flowing in the circuit of Figure 2(a). If, now, the contact opens, the circuit is broken and the current must drop to zero. However, the collapsing magnetic field in the inductance tends to keep the current flowing at the steady-state value. Since it cannot flow through the contacts, it flows to ground through the distributed capacitance of the lead wire, producing a transient voltage across the capacitance and thus across the open contacts. At the first instant of contact opening, the voltage will rise at a rate of I/C volts per second, where I is the steady-state current in amperes in the relay winding and C is the total capacitance of the lead wire in farads. When the contact voltage reaches the minimum sparking potential of air at about 300 volts, a spark occurs and the gap breaks down. A 15-volt arc discharge then takes place across the gap with a peak current

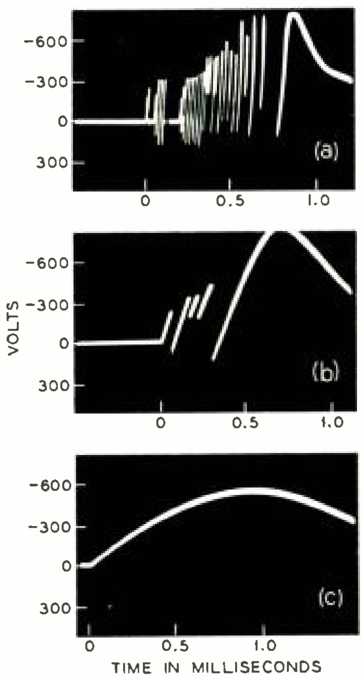


Fig. 1 — Oscillograms of transient voltages across an unprotected contact when the lead length is (a) 20 feet, (b) 60 feet, and (c) when it is 400 feet.

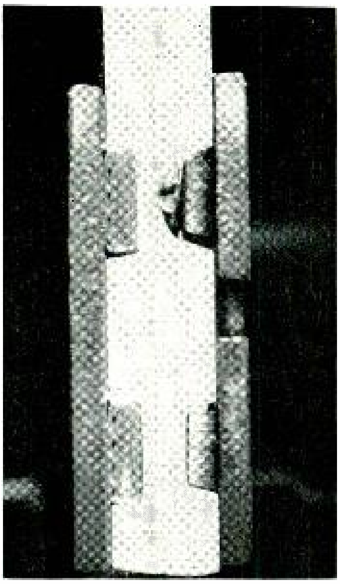


Fig. 3 — Unprotected palladium contacts after several million operations carried on with an inductive load.

limited only by the surge impedance of the cable and having a peak value of approximately

$$\frac{300 \text{ volts} - 15 \text{ volts}}{100 \text{ ohms}} = 2.85 \text{ amperes}$$

The arc will persist only for the fraction of a microsecond required to discharge the capacitance and then the process will repeat. The contacts at this instant still have only a minute separation. As they continue to separate, the voltage required to produce breakdown of the contact gap goes to higher and higher value, approaching 1,000 volts or more. The current in each arc discharge then has a peak value of 10 amperes or more. In Figures 1(a) and 1(b), each charging of the capacitance appears as a line sloping upward to the right, but the discharges take place so quickly that no downward trace is evident. These high-current arc discharges, lasting for only a fraction of a microsecond, cause heavy contact erosion as the contacts open. Twin contacts eroded for several million operations by such an inductive load are shown in Figure 3.

The oscillogram of Figure 1(a) was taken with a 20-foot cable between the contact and a 2,500-ohm relay. In Figure 1(b), with the higher capacitance of a 60-foot cable, the rate of voltage rise I/C has been decreased, reducing the number of breakdowns that can take place during the contact opening. In Figure 1(c), with a 400-foot cable, the rate of voltage rise has been reduced so much that the voltage at any instant is always less than the breakdown threshold value for air at that separation and no breakdowns occur. The large cable capacitance now provides contact protection and the life of the relay contacts is therefore considerably prolonged.

Wires and cables in a telephone office may range from only a few inches to hundreds of feet in length, but a few feet would be typical. Where contact protection is needed, the wiring usually will not provide enough capacitance, so a capacitive protective network is commonly connected into the circuit. In designing a contact protection network, it is important that the network cost, size and required mounting space be as small as possible, consistent with providing adequate protection. Since cost, size and mounting space are closely dependent on the size of the capacitor required, the problem is mainly to determine the minimum value of capacitance that will adequately protect the contacts.

The protective capacitance must be large enough to prevent the contact voltage from rising to a value greater than the air breakdown value at any instant. This value depends on the contact separation but is never less than 300 volts. Consequently, the capacitance should be large enough to hold the peak voltage to less than 300 volts, particularly if the contacts open slowly. With few exceptions, a 0.1 mfd. capacitor is satisfactory for U- and AF-type relays.

Limiting the voltage rise across the contacts to less than 300 volts peak will not necessarily prevent all breakdowns of the gap. At the very first instant of contact opening, the contact separation is so

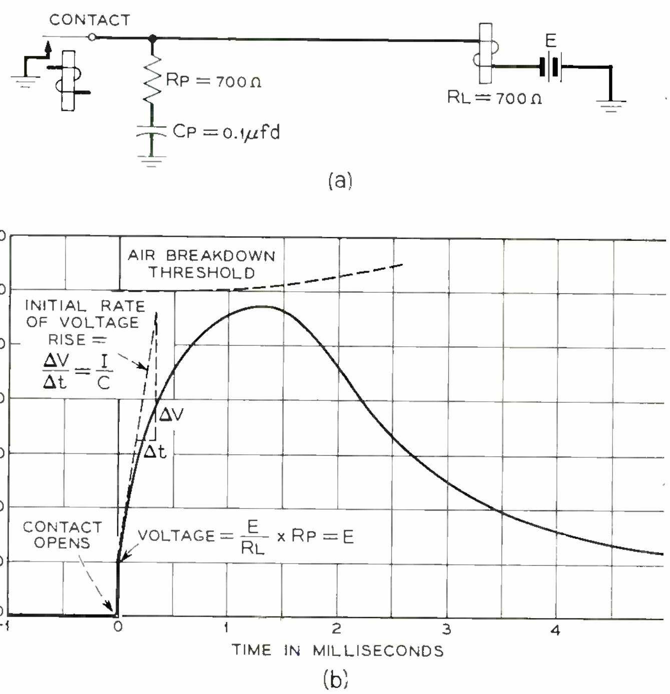


Fig. 4 — Contact protection circuit and resulting voltage.

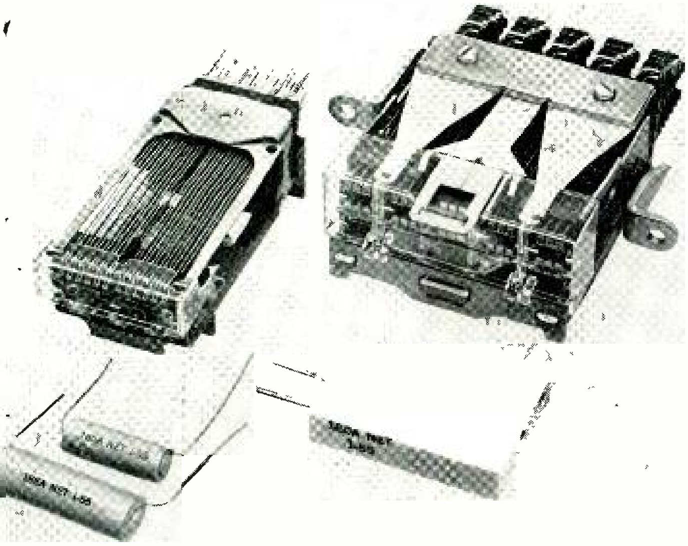


Fig. 5 — Pigtail-type protection networks used with general-purpose wire-spring relay (left) and molded network used with wire-spring multicontact relay (right).

minute that low-voltage breakdowns of the gap may occur. To minimize this possibility, it is the practice on the U-type relay to impose the additional requirement that the contact protection capacitor shall limit the rate of voltage rise immediately after the contact opens to one volt per microsecond. This requirement will be met if the ratio I/C is less than unity where I is in amperes and C is in microfarads. For slow-moving contacts with very small restoring forces, such as on 280-type polar relays, even larger capacitors are used. On the other hand, for wire-spring relays such as the AF-type, having higher contact velocities and larger restoring forces than the U-type relay, adequate contact protection is obtained if the rate of voltage rise is held to two volts per microsecond. Wire-spring relays therefore require only about half the capacitance used to protect a contact on a U-type general-purpose relay.

With sufficient capacitance in the circuit for protection when the contact opens, a resistance is needed for protection when the contact closes. The network capacitor is charged to the full battery voltage when the circuit is open. Closing the contacts effectively short-circuits this voltage, so a resistance is connected in series with the network capacitor to limit the current through the contact. The resistor thus reduces erosion as the contact closes, but also tends to increase it as the contact opens. The sudden diversion of the steady-state current into the protection network on contact opening immediately produces a voltage across the contacts due to the current flowing through the protection resistance. A compromise value is therefore necessary, and it is general practice to make the protection resistance approximately equal to the load resistance. Consequently, the instantaneous voltage rise as the contact opens is limited to approximately the normal operating voltage — 50 volts in a 50-volt circuit. Figure 4 shows a typical relay circuit protected by a contact protection network selected according to these rules, and the voltage transient that ensues as the contact opens.

The values of capacitance so derived are not too critical. Greater capacitance than necessary is often specified so that available or standard sizes of capacitors can be used. For standardization, 0.1 mfd is used wherever possible since reducing the capacitance below this value will give insignificant reductions in network costs. The resistance requirement is closely followed for currents approaching the arcing limits of 0.5 ampere for silver and 1.0 ampere for palladium or platinum. For currents in the order of 0.1 ampere or less, erosion is reduced so much that the resistance is standardized at 470 ohms. A typical circuit of a 2,500-ohm relay with the 185A network, 0.1 mfd and 470 ohms, connected for contact protection is shown in Figure 6a.

Contact protection can increase the life of palladium contacts with inductive loads by a factor of about 100, and the life of silver contacts by about

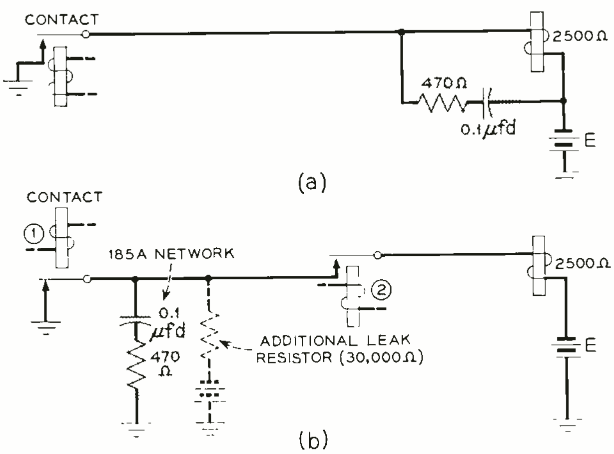


Fig. 6 — Typical circuit using 185A network (a), and addition of a leak resistance to prevent trapped charges from discharging on next closure (b).

10 provided the atmosphere is relatively free of organic vapors.* However, under heavy vapor concentrations, such as occur when relays with organic

* RECORD, *June*, 1954, *page* 226.

insulation are enclosed, the contacts become seriously activated and the improvement in life from protection may be small or non-existent. Under such conditions, different contact metals or more elaborate contact protection schemes may be needed to obtain adequate contact life.

In crossbar senders and registers, it is common to find relay contacts that will close the circuit but will not open it because the circuit will be broken by other contacts. It might be expected that no protection would be needed for such "make only" contacts but, with the U-type relay, contact chatter on make is sufficient to cause significant erosion with an inductive load. This is particularly serious because mechanical locking of the contacts may result where the restoring forces are not large. With wire-spring relays, contact protection is not needed for such "make-only" conditions because the extremely small chatter reduces the erosion correspondingly and the large restoring forces prevent contact locking.

Since only transient voltages are of interest, no distinction is made between connecting a contact protection network to ground or to battery, across the contact or across the load relay. Also, where the cable length is appreciable, the network can be mounted near the contact or near the load. These choices do not significantly affect the contact life and are usually decided by equipment considerations.

In applying contact protection to a circuit, it is important to insure that trapped charges are not left for the next contact closure to discharge. In Figure 6(b), if contact 2 released a few milliseconds after contact 1 opened the circuit, a charge would be trapped on the capacitor since there is no dc discharge path to ground. Suppose this happened at the peak of the transient in Figure 4. On the next closure of contact 1, several hundred volts across the capacitor would be discharged through the contact, shortening the contact life. Where this arrangement is unavoidable, it is the practice to provide an additional leak resistor of 30,000 ohms or so to keep the capacitor from holding such a large trapped charge. The resistance must be low enough to discharge the capacitor before the next circuit usage. It is connected to battery so as not to delay release of the load relay unnecessarily.

From time to time, suggestions for better or cheaper protections are made. A cold-cathode gas tube across the load has too long an ionization time to prevent contact damage, and will also delay release of the magnet or relay. Silicon-carbide rectifiers provide a low resistance while the transient voltage is high, but are somewhat less effective than a resistor-capacitor network and they also delay relay release. Other more elaborate designs involving a germanium rectifier in combination with a capacitor and a resistor have been tried under difficult contact conditions where the contact is activated by organic vapors or oil. Such networks are found to be no better than the simple resistor-capacitor network unless the contact to be protected can be made essentially chatter-free during closure. With the small values of capacitance now used and the low cost of modern networks, the resistor-capacitor type of contact protection continues to be preferred in the Bell System.

THE AUTHOR

ROBERT H. GUMLEY joined the Laboratories in 1930, and spent the next seven years on apparatus adjusting and wiring including work on the No. 1 crossbar system. In 1937 he transferred to work on relay requirements and testing and the application of relays to circuits. During World War II he worked on the design and testing of operation flight trainers for the Navy. He has since been engaged in studies of relay performance and relay engineering. Currently he heads a group studying systems requirements and testing. Mr. Gumley received the B.E.E. degree from New York University in 1939.

The Splicer's Scissors Become More Versatile

One of the simplest yet most important and widely used tools employed by Bell System craftsmen is the splicer's scissors. These small sturdy scissors are used not only by the splicing forces but also by installers, repairmen and many of the other crafts. Some idea of their importance and popularity can be gained from the fact that about 55,000 pairs are supplied annually.

In splicing operations on paper- or pulp-insulated cable conductors, the scissors are used for a variety of purposes, including wire cutting and insulation skinning. In the latter use, the insulated conductor is grasped between the back of the scissors blade and the splicer's thumb. The splicer removes the insulation by drawing the scissors toward him, breaking the insulation and pulling it from the wire to get a stripped length of conductor.

With the introduction of polyethylene insulation, a new problem of skinning was encountered, since the higher tensile strength and toughness of this plastic prevented its removal by the simple techniques used with paper. It is not that the matter of removing plastic insulation is anything new. Plastics are now used to insulate many kinds of wire, and the market carries numerous tools and gadgets for stripping such material from conductors. The problem was one of providing easy and effective means of removal of the insulation without adding to the already extensive tool kits that are normally carried by craftsmen.

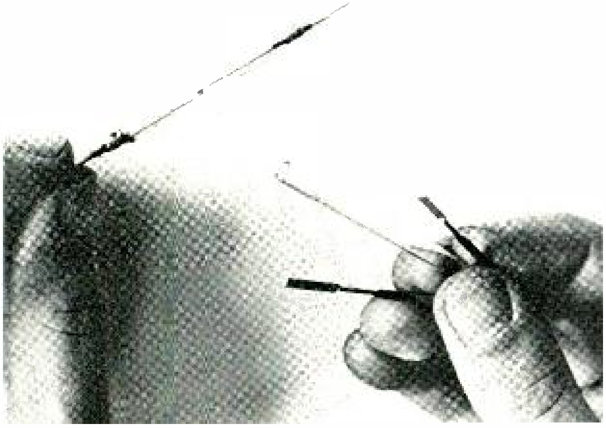
Fortunately a simple solution was found. By experiment it was determined that two properly shaped and dimensioned notches in the back of one blade of the splicer's scissors would permit a very quick and easy removal of the insulation. These notches have V-shaped entrances for guiding the insulated wires into parallel-sided, round-bottom skinning sections which are slightly wider than the conductor diameters. The larger notch accommodates 19-gauge conductors, and the smaller is for use with 22, 24 and 26-gauge wires.

In use, the scissors are held as shown, and the insulated conductor is forced into the appropriate notch by thumb pressure to effect a partial circumferential break in the insulation by the edges of the V-opening. A pull on the scissors completes the insulation break and, with the conductor held in the skinning section of the notch, the separated portion of insulation is removed by sliding it along the conductor under slight thumb pressure. Thus, by a simple modification of the scissors, the craftsman can easily skin plastic insulation from cable conductors using the same tool and essentially the same motions that he employs in removing paper or pulp insulation.

Notches in blade of scissors permit quick removal of plastic insulation.

H. G. Geetlein
Outside Plant Development

Dry-Reed Switches Manufactured by Automation



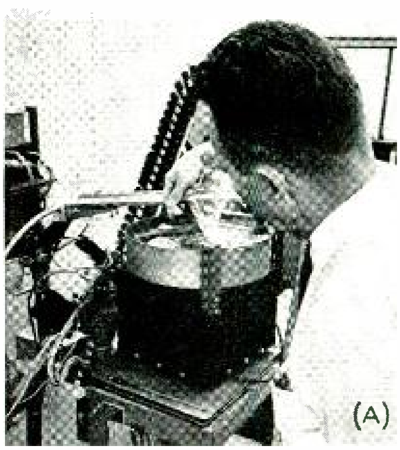
A dry-reed switch and its components.

A "dry-reed" switch developed by the Laboratories was potentially important for use in No. 1 and No. 5 crossbar and AMA equipment if it could be produced in volume economically. This has been made possible through automation at the Western Electric Allentown Plant.

Four machines turn out the switches automatically. Each performs a complete manufacturing cycle of several different operations, and each detects and corrects its own errors in the process. Together, they turn out about 3 million completed dry-reed switches a year. This automated process not only produces the switches ten times faster than would be possible otherwise, but it also does it at less than one-twentieth of the cost to turn out the same switch on a manual production line.

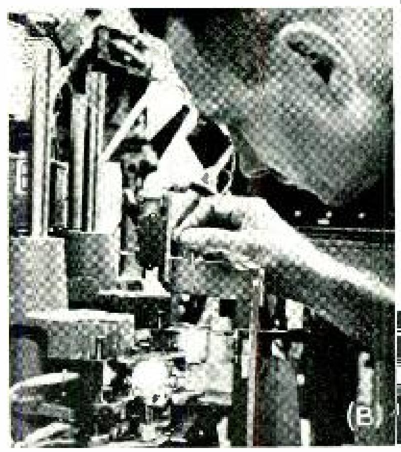
The dry-reed switch consists of a 2-inch glass tube and two flat metal "reeds" of magnetic material each about one inch and a half long. By means of the automated manufacturing process, a reed is inserted into each end of the glass tube and sealed into position so that the opposing reeds overlap.

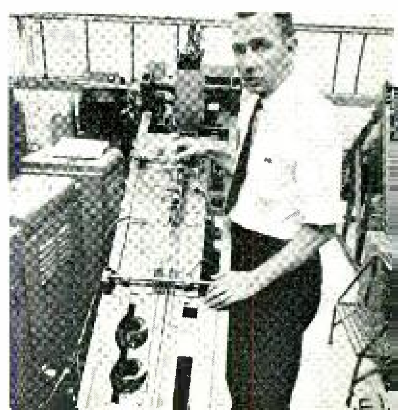
In use, from one to twelve switches are placed inside an electromagnetic coil and the assembly constitutes a relay. As a relay component, the dry-reed switch has a number of advantages. First, its unique design makes it impervious to dust, moisture and other airborne foreign matter that sometimes



Automated machine being demonstrated by A. L. House, Western Electric engineer.

A — Reeds are dropped into a vibrating hopper at the beginning of the manufacturing process.
B — Metal jaws hold elements of switch. Glow indicates that the top end of the glass tube is being heated and sealed.
C — Servomechanism receives error information and makes necessary adjustment.
D — Completed switches are released by the assembly head and deposited in a numbered holder.
E — Switches are subjected to a number of electrical and mechanical tests. Acceptable units pass through "good" hole, others are shunted off.





interferes with the operation of conventional open-contact relays. In addition, relays using this switch are compact and will operate faster with less power than conventional relays. These features, combined with increased reliability and freedom from maintenance, make them desirable components for modern switching systems.

Western Electric engineers began studying the problem of manufacturing these switches economically several years ago. Automatic machinery then used in the glass industry was studied, but these machines could not approach the required precision. The reeds within the switch must be positioned so that the gap between them does not vary more than five ten-thousandths of an inch from the established value. The alignment of the reeds must also be carefully controlled. Since these switches cannot be adjusted or repaired once they have been sealed, the necessary precision must be built into the manufacturing process.

To solve these problems, Western Electric engineers at the Allentown Plant developed the rotary assembly machine shown in the accompanying photographs. The rotary part of the machine has eighteen "heads." Each head automatically receives the elements of one switch – the glass tube and two reeds – and holds them during the various steps of manufacture. Three minutes are required from the time the metal jaws of the head pick up the parts until the completed switch is released into a container that carries it to the apparatus where electrical and mechanical tests are performed.

True automation is used beginning about midway in the process – at the point at which the gap is set. Since accuracy at this point determines how well the switch will operate in use, it is important to know whether the gap-setting mechanism is performing within specifications at all times. To do this, the "feedback" principle is employed. If a test indicates that the space between reeds is not exact, this information is fed back by means of an electronic circuit to the gap-setting part of the machine, and a correction is made automatically. Thus, the machine keeps a constant check on itself, detects its own errors, and makes whatever adjustment is necessary to turn out an acceptable product.

Earth Furnishes Variety of Bell System Materials

Vast quantities of raw materials from many parts of the earth go into building and operating the Bell Telephone System. Each year some $250,000,000 worth of raw materials are used by the Western Electric Company to manufacture the many thousands of items that are needed by the Bell System. Some raw materials are used at Western Electric just as they are taken from the earth's crust – in the form of native ores or minerals; others pass through refineries and processing plants where primal material is changed into another form.

The materials most used in the making of telephone equipment are copper, lead, steel, aluminum, palladium, cotton, polyvinlchloride, polyethylene and Neoprene. Also used in great quantities are gold, silver, platinum, germanium dioxide, nickel. cobalt, zinc, wood pulp and synthetics like acetate rayon and Nylon. Western Electric obtains most of these essential materials from the mines, smelters, refineries and basic producers in the United States. Often, however, certain materials can be found only in other countries: South Africa, Australia, Spain, Mexico, Canada, Belgian Congo, Chile, are only some of the countries from which materials are currently obtained.

Today, with chronic shortages in the world, vast economic expansion, and heavy competition, Western Electric purchasing men find that the problems of developing adequate, economical and reliable sources of supply are multiplied. An example is copper; Western Electric consumes about 10 per-cent of the domestic supply of this metal, making it one of the biggest purchasers of copper in this country. Last year, a record-breaking exchange-area cable program pushed copper purchasing to over 100,000 tons of wire bar alone – the highest in the Company's history. This record high demand was met despite a copper shortage created by work stoppages in the mining industry, and in the face of an intense demand for copper throughout the world. To do so called for careful, thorough and often ingenious measures on the part of Western Electric's purchasing men.

Scarcity is not the only problem that besets Western Electric purchasers. Rare, precious and unusual raw materials also present problems. Western Electric uses carbon made from a special coal for telephone transmitters – a special coal that meets exacting Bell Laboratories specifications. Some 25 years ago a world-wide search was conducted to locate a supply of this special coal. When a supply was found, Western purchased 1,000 tons, enough to last

Phototransistors developed at the Laboratories are now being used to check the quality of varistors on a production line at the Western Electric Company Allentown Plant. As shown in the upper right portion of the illustration, the phototransistor and its light source, a switchboard lamp, are mounted on a double arm that is attached to the outer case of a meter and set to any desired reading. When the meter needle, moving between the phototransistor and the light source, breaks the light beam, an electrical circuit is energized that either accepts the varistor and records its test, or rejects it, all automatically.

many years. The remainder of the original tonnage is now stored in special concrete enclosures at the Hawthorne and Indianapolis Works. The mine from which it was taken has been closed and cannot be reopened, so this careful, long-range procurement by Western Purchasing men has paid off, and will continue to pay off, many times over.

One precious material is palladium for electrical contacts in wire spring relays used in crossbar equipment. Western Electric is the largest consumer of this precious metal in the country, using upwards of 60 per cent of the total U. S. consumption. Palladium, however, is produced in only three regions of the world – the Sudbury Basin of Canada, the South African gold fields and somewhere in Russia.

Another problem material is germanium dioxide – the precious material used in transistors and diodes. Germanium is not easy to process; one ton of ore yields only a few ounces of germanium dioxide. Therefore, Western Electric Purchasing and Bell Laboratories encouraged and assisted potential producers, thereby increasing sources of this material in recent years from two to seven.

R. M. Burns Honored by Electrochemical Society

R. M. Burns, Chemical Director at the Laboratories prior to his retirement in 1955, has been selected to receive the Edward Goodrich Acheson Gold Medal of the Electrochemical Society. Presentation of the medal and a prize of $1,000 will be made at a convention dinner of the society, to be held in Cleveland, Ohio, on October 2, 1956. The Acheson award is made once every two years for conspicuous "contribution to the advancement of the objects, purposes, or activities of the society."

Dr. Burns received the Perkin Medal of the Society of Chemical Industry in 1952, and the Willis Rodney Whitney award of the National Association of Corrosion Engineers in 1953. He is a member of a number of technical societies and has served in various official capacities in several of them. Dr. Burns is also a member of the Technical Advisory Panel on Biological and Chemical Warfare to the Assistant Secretary of Defense for Research and Development. He is a member of the Advisory Committee to the Department of Chemistry at Princeton University, and the Advisory Committee to the Research Division of the College of Engineering at New York University.

Fine copper lines — 0.0017 to 0.005 inch thick — printed on boards provide "printed-wire" circuits that greatly reduce the effort required to assemble many telephone components. One such circuit is being inspected above at the Western Electric Company Hawthorne Works.

Western Electric Building New Plant at Omaha

Ground-breaking ceremonies took place recently for Western Electric's new 1,700,000 square-foot plant at Omaha. Scheduled to be in partial operation by 1958, this location will be devoted chiefly to the manufacturing of No. 5 crossbar and exchange cable. The new plant will require some 4,000 to 5,000 employees. The Western Electric Company's newest location will occupy a 390-acre tract eleven miles west of Omaha that was formerly devoted to field crops and pasture land.

The three main buildings will extend nearly half a mile over what is now open country. All together, some 40 acres will be under roof. Dominating the new plant will be an administration building of three floors having a frontage of 600 feet. The single story cable building will measure 680 feet by 700 feet, and dimensions of the crossbar-merchandise building will be 1,000 feet by 880 feet.

The schedule calls for grading work to be done during the latter part of this year. Foundations will be placed next Spring, and soon thereafter structural steel erection should start. The cable building, first of the three, will be ready for occupancy in 1958 and the entire plant will be complete and in production by the end of the following year or early in 1960. When completed, and operating at full efficiency, the plant will be capable of producing 24 billion conductor feet of cable a year and over 600,000 lines of No. 5 crossbar equipment.

A. T. & T. Co. Calls Special Meeting of Share Owners

The American Telephone and Telegraph Company recently announced that a special meeting of its share owners will be held on September 5, 1956 to vote on an increase in the amount of authorized stock of the company from 60,000,000 shares to 100,000,000 shares. If the increase in authorized stock is approved, the company plans to mail to share owners on October 1, 1956 "rights" to purchase additional stock at par, $100 per share, on the basis of one new share for each ten shares outstanding. About 5,750,000 shares will be involved in the offering and therefore about $575,000,000 will be made available to meet the requirements of the Bell System companies for new capital.

The company pointed out that although the new stock issue is the largest direct offering of stock ever made by an American corporation, it is in line with the requirements of the Bell System for new capital. To meet the public's growing need for telephone service, expenditures for new construction in 1956 will amount to more than $2,000,000,000 and it is expected that expenditures in 1957 will be fully as large as this amount. This compares with expenditures of $1,643,000,000 in 1955, which in itself was a record year. After utilizing funds from internal sources such as depreciation, the Bell System companies must continue to raise on the average about $100,000,000 of new money each month by the sale of securities.

Patents Issued to Members of Bell Telephone Laboratories During June

Barlow, D. S., and Crofutt, G. B., Jr. – *Translating System* – 2,749,387.

Blair, R. R. – *Ohmmeter* – 2,749,512. *Apparatus for Testing Nonlinear Resistors* – 2,749,517.

Chase, F. H. – *Transistor Circuits* – 2,751,545. *Current Supply Apparatus* – 2,751,549. *Current Supply Apparatus* – 2,751,550.

Crofutt, G. B., Jr., see Barlow, D. S.

Duncan, R. S. *Superregenerative Transistor Broadcast Receiver* – 2,751,497.

Glass, M. S. – *Tuning and Frequency Stabilizing Arrangement* – 2,751,499.

Hewitt, H. W., Jr. – *Measuring Apparatus for Wave Guides* – 2,749,507.

Ketchledge, R. W. – *Distortionless Feedback Amplifier* – 2,751,442.

King, A. P. – *Apparatus for Joining Lengths of Wave Guide or the Like* – 2,750,912. *Wave-Guide Mode Discriminators* – 2,751,561.

Nyquist, H. – *Measurement of Transmission Time* – 2,749,-508.

Ohl, R. S. – *Semiconductor Translating Devices* – 2,750,541.

Pfann, W. G. – *Process for Separating Components of a Fusible Material* – 2,750,262. *Silicon Translating Devices and Methods of Manufacture* – 2,750,544.

Pierce, J. R. – *Solid State Television Pick-up Tube* – 2,749,-463. *Frequency Stabilized Oscillator* – 2,751,518.

Robertson, G. H., and Walsh, E. J. – *Electron Discharge Device* – 2,750,529.

Walsh, E. J., see Robertson, G. H.

Papers Published 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.

Anderson, P. W., see Holden, A. N.

Bridgers, H. E., *The Formation of p-n Junctions in Semiconductors by the Variation of Crystal Growth Parameters,* J. Appl. Phys., **27**, pp. 746-751, July, 1956.

Cook, R. K., and Wasilik, J. H., *Anelasticity and Dielectric Loss of Quartz.* J. Appl. Phys., **27**, pp. 836-837, July, 1956.

David, E. E., and McDonald, H. S., *A Bit-Squeezing Technique Applied to Speech Signals,* I.R.E. Convention Record, **4**, Part 4, pp. 148-153, July, 1956.

Dewald, J. F., and Lepoutre, G., *The Thermoelectric Properties of Metal-Ammonia,* J. Am. Chem. Soc., **78**, p. 2956, July 5, 1956.

Feher, G., *Method of Polarizing Nuclei in Paramagnetic Substances,* Phys. Rev., Letter to the Editor, **103,** pp. 500-501, July 15, 1956.

Feher, G., and Gere, E., *Polarization of Phosphorus Nuclei in Silicon,* Phys. Rev., Letter to the Editor, **103**, pp. 501-503, July 15, 1956.

Geller, S., and Wood, E. A., Mrs., *Crystallographic Studies of Perovskite-Like Compounds I. Rare Earth Orthoferrites and $YFeO_3$, $YCrO_3$, $YAlO_3$,* Acta Crys., **9**, pp. 563-568, July 10, 1956.

Gere, E., see Feher, G.

Gianola, U. F., and James, D. B., *Ferromagnetic Coupling Between Crossed Coils,* J. Appl. Phys., **27**, pp. 608-609, June, 1956.

Gilbert, E. D., *Enumeration of Labelled Graphs,* Canadian J. Math., **8**, pp. 405-411, 1956.

Hannay, N. B., *Recent Advances in Silicon. Progress in Semiconductors, Book* 1, pp. 1-35, 1956. (Published by Heywood & Co., Ltd., London).

Holden, A. N., Matthias, B. T., Anderson, P. W., and Lewis, H. W., *New Low-Temperature Ferromagnets,* Phys. Rev., **102,** p. 1463, June 15, 1956.

James, D. B., see Gianola, U. F.

Kaminow, I. P., see Kircher, R. J.

Kircher, R. J., and Kaminow, I. P., *Super-Regenerative Transistor Oscillator,* Electronics, **29**, pp. 166-167, July, 1956.

Kretzmer, E. R., *Reduced-Alphabet Representation of TV Signals,* I.R.E. Convention Record **4**, Part 4, pp. 140-147, 1956.

Lee, C. Y., and Chen, W. H., *Several-Valued Combinational Switching Circuits,* Commu. and Elec., **25**, pp. 278-283, July, 1956.

Lepoutre, G., see Dewald, J. F.

Lewis, H. W., see Holden A. N.

Manley, J. M., and Rowe, H. E., *Some General Properties of Non-Linear Elements – Part I. General Energy Relations,* Proc. I.R.E., **44,** pp. 904-913, July, 1956.

Matthias, B. T., see Holden, A. N.; Wood, E. A.

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

McLean, D. A., and Power, F. S., *Tantalum Solid Electrolytic Capacitors,* Proc. I.R.E., **44,** pp. 872-878, July, 1956.

Power, F. S., see McLean, D. A.

Riney, T. D., *On the Coefficients in Asymptotic Factorial Expansions,* Proc. of Am. Math. Soc., **7**, pp. 245-249, Apr., 1956.

Rowe, H. E., see Manley, J. M.

Shulman, R. G., *Hole Trapping in Germanium Bombarded by High-Energy Electrons,* Phys. Rev., **102,** pp. 1451-1455, June 15, 1956.

Shulman, R. G., and Wyluda, B. J., *Copper in Germanium – Recombination Center and Trapping Center,* Phys. Rev., **102,** pp. 1455-1457, June 15, 1956.

Tien, P. K., *A Dip in the Minimum Noise Figure of Beam-Type Microwave Amplifiers,* Proc. I.R.E., Correspondence Sect., **44,** p. 938, July, 1956.

Wasilik, J. H., see Cook, R. K.

Wernick, J. H., *Determination of Diffusivities in Liquid Metals by Means of Temperature-Gradient Zone-Melting,* J. Chem. Phys., **25**, pp. 47-49, July, 1956.

Wood, E. A., Mrs., and Matthias, B. T., *Crystal Structures of Nb_3Au and V_3Au.* Acta Crys., **9**, pp. 534, June 10, 1956.

Wood, E. A., see Geller, S.

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

Talks by Members of the Laboratories

During June, a number of Laboratories people gave talks before professional and educational groups. Following is a list of speakers, titles, and places of presentation.

Ahearn, A. J., *Mass Spectrographic Analysis of Solids,* Westinghouse Research Laboratory, East Pittsburgh, Pa.

Anderson, O. L., *The Kinetics of Structural Rearrangement in Glass Under Pressure,* Fourth International Congress on Glass, Paris, France.

Fletcher, R. C., *Microwave Applications of Ferrites,* University of Michigan Summer Symposium, Ann Arbor.

Fuller, C. S., Morin, F. J., and Reiss, H., Three talks on the general subject *Interactions Among Defects in Germanium and Silicon,* Conference on Physics and Chemistry of Metals, Gordon Conferences, New Hampton, N. H.

Lince, A. H., *Transatlantic Telephone Cable,* Naval Reserve Unit, New York City.

Morin, F. J., see Fuller, C. S.

Morrison, L. W., *Nike I – A Guided Missile System for Anti-aircraft Defense,* Kiwanis Club, Madison, N. J.

Read, W. T., Jr., *The Dislocation Theory of Grain Boundaries,* Gordon Conferences, Meriden, N. H.

Reiss, H., see Fuller, C. S.