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An L3 auxiliary repeater hut at Scotch Plains, New Jersey.

The L3 Coaxial Carrier System

R. H. KLIE *Transmission Systems Development II*

Beginning in 1918 with the four-channel type-A carrier system on open wire, the Bell System has continually investigated means of increasing the number of messages that can be transmitted simultaneously. The type-K cable system provided twelve message channels, and, with the development of coaxial cable, the L1 system increased this number to 600. Recently, the new L3 system has made it possible to transmit more than 1,800 simultaneous messages over a pair of coaxial conductors. Alternatively, this system can be used to transmit as many as 600 telephone messages and a television signal at the same time.

A new, improved member has been added to the family of Bell System carrier facilities. In February, 1953, the first installation of the new L3 coaxial carrier system was put into commercial service between Newark and Philadelphia. Initially, this installation provided for the transmission of about 100 message signals, but ultimately it will provide for simultaneous two-way transmission of about 1,800 message signals. The L3 system has been designed to transmit a maximum of 1,860 high-quality telephone message signals or one broadcast television signal and 600 message signals in each direction over a pair of coaxials. This marks the first time that a system has been so arranged that television signals and telephone messages can be transmitted over the same pair of coaxials at the same time.

The L3 system is a direct development from the L1 coaxial system put into service prior to World War II. At the conclusion of hostilities in 1945, it was apparent that the demands for long distance service would require the full development of all possible transmission media. In addition to this high demand for new telephone circuits, rapid expansion of the television industry in the immediate postwar period also created a demand for high-quality broadband systems capable of providing network service.

To help satisfy these great demands, between 1945 and 1950, thousands of miles of coaxial cable were installed and equipped with the L1 system. Since it was designed, however, significant advances in the development of new electron tubes and other important components have made it possible to extend the transmission frequency band and thereby provide far more efficient use of coaxial cables.

To take advantage of these new components and to make the most efficient possible use of coaxial cable, the L3 system, with three times the message-carrying capacity of the L1, was developed. Since it was highly desirable to be able to convert existing coaxial installations from L1 to L3, this new system was designed to re-use as much of the L1 plant as possible. Telephone terminal equipment, the location of repeaters, and re-use of the cable itself are examples of how the L3 design was influenced by existing L1 installations.

Functionally, the L3 system is similar to other broadband transmission systems. Each new system, however, includes novel features that are a result of either advances in the design art, or that are brought about by changing conditions in the telephone plant. Detailed descriptions of many of these new features will be given in articles that are to be published in subsequent issues of the RECORD.

Primary design objectives of the L3 system were to provide one television channel at least four megacycles wide simultaneously with 600 four-kilocycle telephone message channels. Alternatively, the new system was to provide as many additional message channels as possible when television was not required. As shown in Figure 1, the final frequency allocations provide for transmitting 1,800 telephone messages in three master groups occupying the frequency band between 0.564 and 8.284 mc. If television is required, the 1,200 channels in master groups 2 and 3, as shown in Figure 1, are replaced by one television signal with an upper sideband about 4.2 mc wide. The 600 telephone channels in master group 1 are transmitted simultaneously with the television signal. In the all-telephone application, 60 additional channels in the 0.312 - 0.552-mc band may be used for high quality, long-haul service. With the combined telephone and television application, however, these channels are restricted to routes that are less than 200 miles long.

Transmission objectives for the L3 demanded that all telephone message channels (except the 60 described above) be transmitted over 4,000 miles without exceeding prescribed signal-to-noise ratios. For television service many new transmission objectives were established which the L3 system was designed to meet for 4,000-mile transmission paths.

TABLE I — REPEATER SPACING FOR L1 AND L3

CABLE TYPE	REPEATER SPACING IN MILES L1	L3
0.375 inch polyethylene insulated	7.90 ± 0.30	4.00 ± 0.20
0.27 inch polyethylene insulated	5.45 ± 0.30	2.88 ± 0.20
0.27 inch rubber insulated	5.25 ± 0.30	2.80 ± 0.20

The L3 system, with nearly three times the bandwidth of its predecessor, the L1, requires twice as many amplifiers along the coaxial route as the older system. These are required to compensate for the increased cable losses associated with the transmission of the broader frequency band. When a coaxial system is converted from L1 to L3, the L1 repeater locations are therefore re-used, and new repeater huts are established along the cable at points midway between the original installations. One of these repeater huts is shown at the beginning of this article. The actual repeater spacing in both L1 and L3 depends on the type of coaxial cable in use. Nominal repeater spacings for the two systems as used with the most important types of cable are given in Table I.

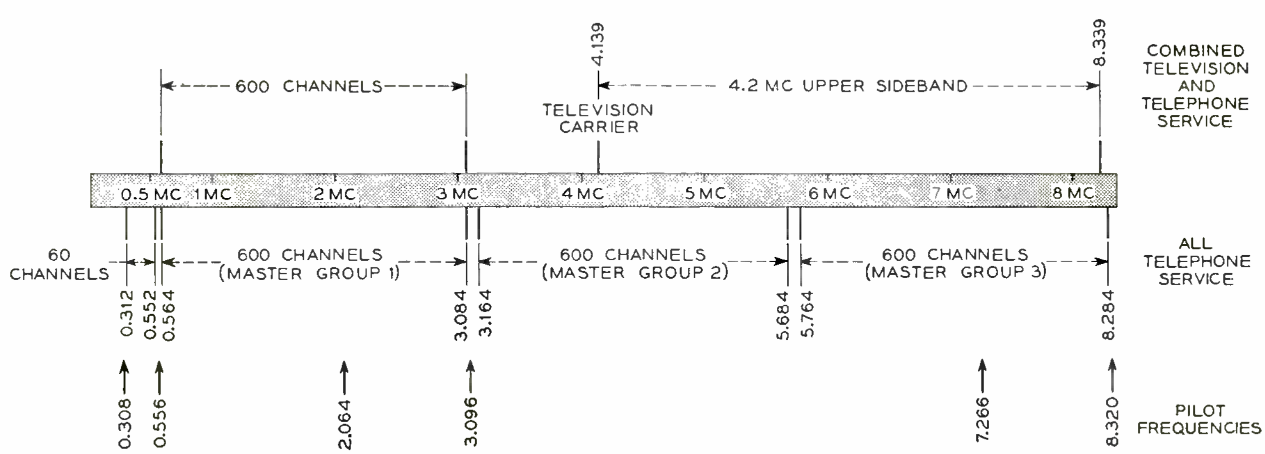


Fig. 1 — Frequency allocations in the L3 system.

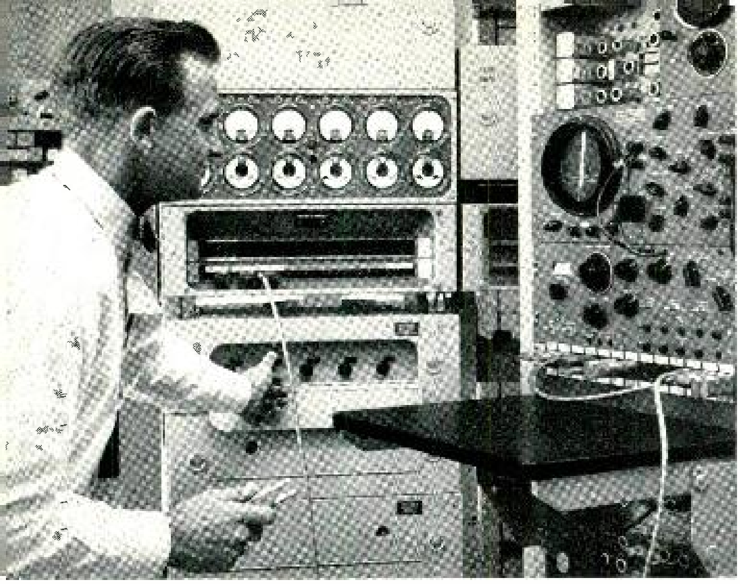


Fig. 2 — C. G. Arnold observing pilot indicators at an L3 terminal to test the effect of an overload on regulator action.

Two types of newly designed amplifiers are required in the L3 system: line amplifiers and office amplifiers. Both types are similar in general configuration, use of components, and mechanical arrangements. The principal differences between the two are in their gain characteristics, and in the gain adjustment possible with each. The line amplifier has a gain characteristic which is designed to compensate for the loss in four miles of 0.375-inch polyethylene insulated cable plus the losses introduced by the filters and equalizers associated with each amplifier. Two gain controls which change the gain-frequency characteristic are used on these amplifiers; one is a manual adjustment used only at the time of installation and at subsequent maintenance visits to the repeater huts. The second gain adjustment is automatically controlled by a single-frequency 7.266-mc pilot which acts through a regular circuit to vary the impedance of an interstate network between the two units which form each amplifier. This automatic gain control compensates for changes in cable attenuation caused by changes in temperature.

The terminal amplifier, on the other hand, has a flat gain characteristic and is used to compensate for the losses introduced by equalizers and office equipment. The amplifier has a single, manually-operated gain control which varies the gain without changing the gain-frequency characteristic.

Both types of L3 amplifiers consist of two units connected in tandem with a two-terminal network acting as an interstage between them. Each of these two units, in turn, consists of a two-stage amplifier using vacuum tubes designed specifically for the L3 system.

The amplifiers are connected to the coaxial line, or to office equipment, through input and output coupling networks which contain a number of novel features. New manufacturing methods were developed, for example, to achieve the precision required in the transformers used in these networks, and several new materials, including ferrites for the transformer cores and Vycor glass for the forms, were used to provide the required electrical characteristics.

In any broadband transmission system, such as the L3, that employs many amplifiers connected in tandem, it is necessary to maintain accurate and continuous control of the over-all gain characteristic. Changes associated with aging and temperature variations would otherwise accumulate and make the system inoperative. To provide this control, single-frequency pilot tones with carefully controlled amplitudes are transmitted over the system. The frequencies of the pilots used in L3 are indicated on Figure 1. Any changes in the amplitudes of these pilots are measured by regulators, and when changes are detected, the regulators introduce compensating changes in the system characteristic.

Three types of regulators are used in the L3 system. First, the line regulator detects changes in the 7.266-mc pilot and adjusts the gain of the line amplifiers accordingly. The second type, called office regulators, are similar to the line regulators except that higher feedback is used to stabilize their operation. To reduce the cost of regulation in the L3 system, a third type of regulator is used to supplement the line regulators. This type, called a thermometer regulator, measures the temperature of the ground near the amplifier with which each is associated, and adjusts

Fig. 3 — The author (left) and O. D. Grismore observing line current at the power control bays in an L3 terminal.

the gain of the amplifier to compensate for the changes. By using these relatively inexpensive regulators, it is expected that only one-third to one-half the line amplifiers will have to be equipped with pilot-operated line regulators.

Some small transmission deviations occurring at each amplifier location in the L3 system would be increased by a factor of 1,000 if they were allowed to accumulate over a 4,000-mile route. A deviation as small as 0.1 db per repeater, for example, would amount to an over-all deviation of 100 db on a 4,000-mile route. To make control of the L3 transmission characteristic feasible, deviations are allowed to accumulate through a number of amplifiers and then they are corrected by equalizers having the necessary compensating characteristics. These equalizers are located at approximately 100-mile intervals along the transmission line.

A total of five types of equalizers are used in the L3 system. The first type consists of fixed equalizers used to compensate for deviations introduced because amplifiers do not exactly compensate for cable loss. A second type, called "cause associated shape" equalizers, introduce gain-frequency characteristics which correspond to system deviations caused by such factors as temperature variations and vacuum tube aging. The loss characteristics of these equalizers are continuously varied under the control of the pilot-operated regulators previously described.

Manually operated equalizers form the third type used in the L3 system. These are adjusted when changes in the system make it necessary. For example, amplifiers must be replaced from time to time, and these equalizers are adjusted to compensate for any differences between the gain characteristics of the old and new units. The fourth and fifth types used in L3 consist of fixed and manually adjustable delay equalizers which, when the system is used for television transmission, correct for the delay distortion characteristics. These equalizers are not required for telephone message service.

Fig. 4 — J. J. Jansen measuring gain characteristics of an L3 amplifier in Bell Telephone Laboratories.

Tests of the L3 system and its components have been underway for some time on a trial installation between New York City and Philadelphia. In February of last year, the trial system was cut over to partial commercial operation. The results of the trial system tests and early commercial operation have been gratifying. In addition, signals for color as well as standard black and white television have been successfully transmitted.

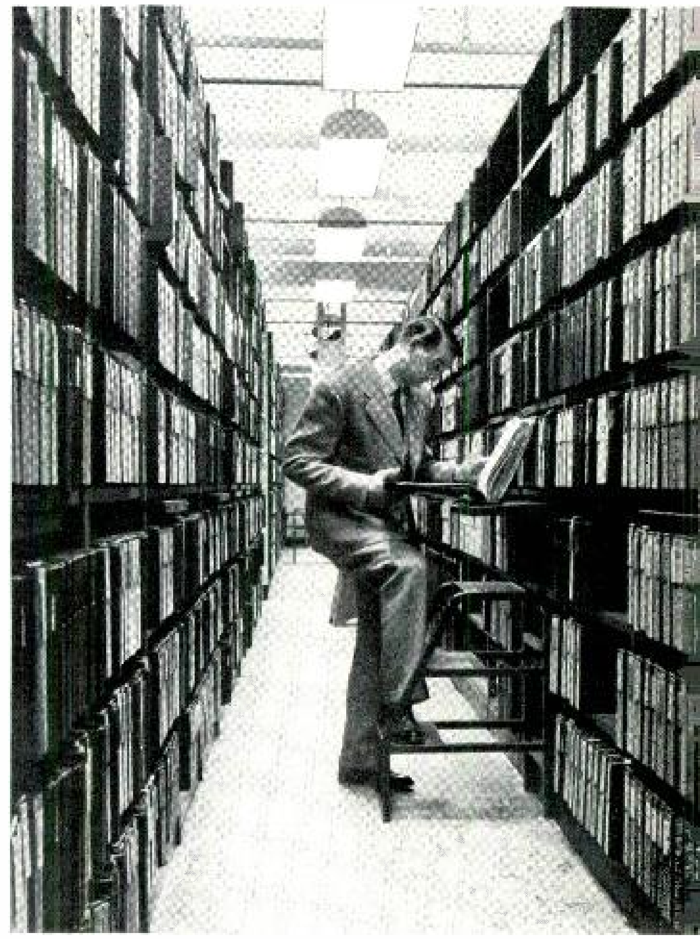
THE AUTHOR

ROBERT H. KLIE spent twelve years at the New York Telephone Company before transferring to the Laboratories in 1942. For the next two years he was a member of the Commercial Relations Department, and then entered a group working on the development of radar systems. Since 1946 he has been concerned with systems analyses on coaxial systems development. He is currently dividing his attention between the development of equalization plans for long L3 television circuits, and long-range submarine cable systems development. Mr. Klie received his B.E.E. degree from Polytechnic Institute of Brooklyn in 1945. He is a member of Tau Beta Pi and Eta Kappa Nu.

Inventing and Patenting At Bell Laboratories

RALPH BOWN *Vice President — Research*

The primary responsibility of the Laboratories is to furnish the Bell System with new developments and improvements throughout the broad field of communications. As a result, the making of inventions — and protecting the System's rights by appropriate patents — is an important part of our daily work. At the same time, our new knowledge is made available to society. The Laboratories' Vice President in charge of research recently discussed these concepts and their underlying philosophy, with some newer members of his department. Because of the fundamental place which these ideas hold, not only in the Bell System but indeed, in our system of private enterprise, the RECORD is publishing the essence of his remarks.



More than 350,000 different patents are kept on file in the Laboratories Patent Department. At the right H. V. Harsha is shown in the West Street Patent Library.

What are patents? Why are they necessary? These look like simple questions, but to answer them requires a deep penetration into the nature and origins of present day civilization.

In layman's language a patent is a certificate of ownership of an invention, a certificate given by Society to the originator of a useful idea. In return the originator—the inventor—describes and discloses the idea publicly for all to know, and agrees that his ownership will terminate at the end of seventeen years. It is a free and voluntary bargain. Each party gains. Nobody loses. Society gains the knowledge and the inventor gains the exclusive control of its use.

The right conferred upon the inventor by his patent is the right to exclude all others from using his invention *directly without his consent*. Of course, in a sense he already has such a right in that he can keep the whole thing a secret if he wishes. But then he would have difficulty in getting any value from the invention himself and would have no recourse against anyone else who learned of the idea by accident or discovered it himself later and independently. I have used the words "exclude all others from using his invention *directly* without his consent," emphasizing the word *directly*, because obviously there may be indirect effects of the disclosure, such as the stimula-

Patenting an invention involves the joint efforts of Patent Attorney and inventor. S. E. Hollander of the Patent Staff discusses a patent application with W. Ulrich, inventor.

tion of alternative ideas, over which the inventor may have no control. But essentially a patent is like a deed to a piece of land in that it is the legal instrument by which the inventor can prove ownership.

From this analogy one can see that the idea of a patent is as fundamental to our mode of life as is the concept of private property itself. In this respect it is antithetic to communism or other community property systems and is one of the foundation stones of a free society. Recognizing this, the founders of our government wrote into the Constitution in Article I, Section 8, the following words which underlie our entire patent system:

"The Congress shall have power to promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive rights to their respective writings and discoveries."

A student of history could trace the evolution of the idea of patents from the Middle Ages when secret processes and the Closed Shop Guild were the ways used to guard technical ideas. He could show how the advance of science, at least in recent times, has been supported by the advance of technology, which in turn has been fostered by the protection of property rights given by patents. In the present era, complete secrecy of all technical advances is unthinkable, and therefore we all have a tremendous stake in the patent system.

Now coming closer home, what do patents do for the Bell System? We are a service industry. The ultimate consumer gets no material thing from us. He gets only service. In many cases, the Bell System provides the only way he has of getting that service.

This places an obligation on us to see that he gets the most for his money that a sound business is able to give him. It means among other things that in designing the equipment we employ we should be able to take advantage of the best ideas and knowledge that man has produced. Freedom to use the best technical means is a key objective in our patent policy.

How can we achieve this end? One way is to invent as many of the good novel things as we can ourselves. Then we can patent them. Another way is to buy patent rights or licenses from other inventors when we wish to use their contributions, and a third way is by exchanging patent rights with others.

Our desire to have access to the best ideas of others must, in the long run, be matched with a willingness to make our ideas available to others. And so we are led to a fundamental policy of the Bell System which was enunciated by Keith McHugh, now President of the New York Telephone Company when, as a Vice President of the American Telephone and Telegraph Company in 1949, he wrote the following words in the Bell Telephone Magazine:

"It is the Bell System's policy to make available upon reasonable terms to all who desire them non-exclusive licenses under its patents for any use."

Note the ideas – non-exclusive licenses, reasonable terms, anybody, any use. It is a frank offering to do honest business with anyone.

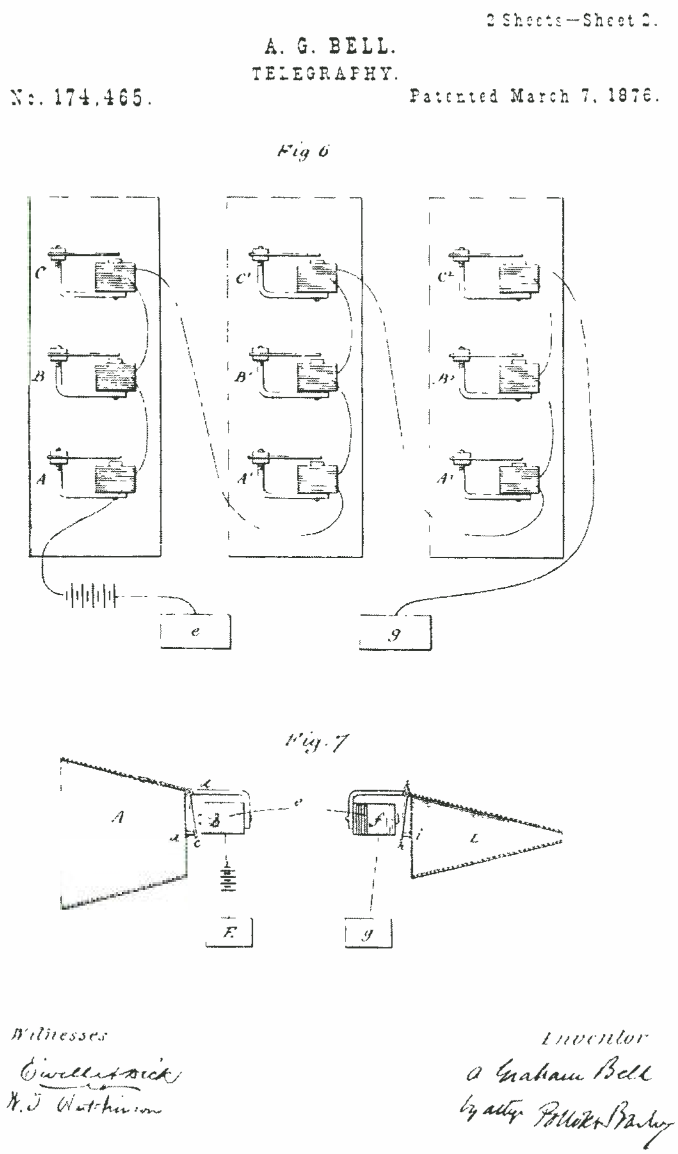
If the patent owner has patent rights which are of interest to the Bell System, an exchange of licenses may be effected with the terms adjusted to reflect the differences in the value exchanged.

Many members of the Laboratories who publish papers no doubt tend to think of the Patent Department release only as one of those annoying hurdles which impede scientific freedom. Perhaps they have never stopped to figure out what makes it possible for their general department head to give them a green light on publishing a paper anyway. Perhaps they have never really run down the thing which enables us to have a liberal publication policy. If they do, they will find that the principal reason is patents. By filing applications for patents on any inventions which may be disclosed in or suggested by the publication, we can protect our rights in the results of the work. That is the thing which enables us to share our knowledge freely with others without loss to ourselves.

Although our patent system may make it possible for a successful industrial research laboratory to follow a publication policy nearly as free as that of an individual worker in pure science, it is not the only thing necessary. The patent system is available to all, but not all companies permit easy publication. There is always a temptation to hold a new invention back until a pattern of related ideas and alternative inventions can be embroidered about it and all the easy smart alternatives it suggests are covered. Also the advantage of hitting the market with a new product fully developed and ready to deliver in advance of any competition is a powerful motive. A publication policy is a judicious mixture of these influences together with the desire for the reputation which flows from scientific leadership, and with a realization that submission of new ideas to other minds will result in faster over-all progress. The fact that the Bell System wants only freedom to use the best ideas man can produce, and is willing to buy or trade for these when necessary, is a powerful factor in our publication-policy thinking.

We can continue this freedom of publication and build it still further only if it succeeds. If it leads to better work on our part, to more and better inventions and an enhanced position in the world for our endeavor, we will succeed. We will pay our way and the rest of the Bell System will value our services highly as well as be proud of the scientific reputation we bring them.

I believe that at the present time we are in a sound



Having described my invention, what I claim, and desire to secure by Letters Patent is as follows:

1. A system of telegraphy in which the receiver is set in vibration by the employment of undulatory currents of electricity, substantially as set forth.

2. The combination, substantially as set forth, of a permanent magnet or other body capable of inductive action, with a closed circuit, so that the vibration of the one shall occasion electrical undulations in the other, or in itself, and this I claim, whether the permanent magnet be set in vibration in the neighborhood of the conducting-wire forming the circuit, or whether the conducting-wire be set in vibration in the neighborhood of the permanent magnet, or whether the conducting-wire and the permanent magnet both simultaneously be set in vibration in each other's neighborhood.

3. The method of producing undulations in a continuous voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration or motion of the conducting-wire itself, in the neighborhood of such bodies, as set forth.

4. The method of producing undulations in a continuous voltaic circuit by gradually increasing and diminishing the resistance of the circuit, or by gradually increasing and diminishing the power of the battery, as set forth.

5. The method of, and apparatus for, transmitting vocal or other sounds telegraphically, as herein described, by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sound, substantially as set forth.

In testimony whereof I have hereunto signed my name this 20th day of January, A. D. 1876.

ALEX. GRAHAM BELL.

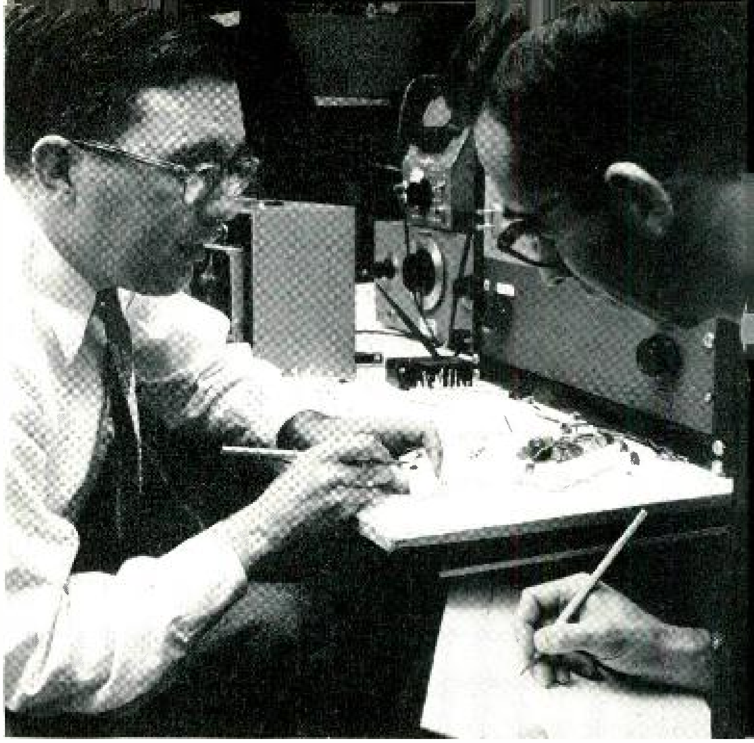
Witnesses:
THOMAS E. BARRY,
P. D. RICHARDS.

A reproduction of part of the original telephone patent entitled "Improvement in Telephony" granted to A. Graham Bell on March 7, 1876. The second of two sheets of diagrams is shown at the left, and the five broad claims are shown above.

position. What we publish we decide in the interest of the System as a whole. The Bell System has delegated to its Laboratories the job of watching out for its technical future. We are expected to be a part of the advancing front of scientific and engineering knowledge and to overlook no possibilities in bringing applicable knowledge to the service of the Operating Companies. Making and patenting the right inventions is one way we do this. If our score is good, our methods will be admired and approved. Our score has been good. We have a wide range of freedom. We expect to keep it that way.

One subject related to patents on which different companies have widely differing policies is the reward for invention. In some companies special rewards or prizes are offered for inventions which are appraised to have special value or merit. In other companies any and every application for or issuance of a patent is given a monetary recognition. In Bell Laboratories we do none of these things. We have come to our present ideas on this matter through long experience. Perhaps the best way to state our practice is to say that we class the production of inventions as a meritorious performance to be thrown into the scale along with all other merits in appraising the present and potential value of the individual to the organization, and thereby in awarding to him his fair share of our salary budget.

We know that the conceiving of an invention does not occur in a vacuum. It is inevitably influenced and fertilized by environment. It is fostered by the accessibility of information and skill necessary to putting the inventor on a platform of knowledge which enables his inventive faculty to reach that height of creative insight which is invention. Our patent law does not permit application for patent by the organization because the law recognizes only individuals, or individuals jointly, as inventors. There is a false doctrine which attempts to say that true inventions cannot be made in an industrial laboratory environment because it is too much of a partnership or teamwork activity, and therefore that patents should not be granted to cover such creations. We know that this is not true and that the first to reach the creative concept can be identified. We know also that all inventing is a competitive race among individuals all over the world. It is this competitive element which leads to the danger in special awards or rewards to inventors when taken outside the framework of their total contribution as compared with the total contributions of their co-workers. Each man for himself and the devil take the hindmost may be a good motto for stimulating



J. M. Early (left) reviews the various techniques for electrolytically etching semiconductor blanks with patent attorney D. H. Wilson, Jr.

some kinds of effort but it has no place in the joint endeavor of a technical group of individuals pooling matched and interlocking talents and skills. It is an interesting and perhaps significant fact that approximately one out of every four (23.3 per cent) of the inventions made at Laboratories during the past twenty-five years involved two or more inventors.

The relation between the Patent Department and the technical departments includes a form of joint responsibility which should lie between the attorney or his supervisor and the group supervisor or work planner, at whatever level he may be, in the technical department.

The technical department is charged with accomplishing the work, whether it be research or development, and delivering a notification of inventions or probable inventions to the Patent Department. The Patent Department identifies and files on the inventions. This kind of business can be done by mail, and in fact to a regrettable degree was so conducted when the Patent Department was isolated in the Davis Building in New York. That mode of operation leaves much room for the missing of valuable subject matter because the parties do not sufficiently feel a joint responsibility for the scope and character of the protection secured. When the relation is close enough so that the attorney and the inventor can discuss and plan their work jointly, there is a performance which creates values superior to those which accrue when the whole thing is left to chance.

Our success in this regard is sometimes good and sometimes not so good. It depends more upon the technical people than upon the attorney. He is already interested in patents. If the inventor and his supervisor are also interested, we have a good team and a strong coverage of a new field will result. The first good job of this kind which I had opportunity to observe personally was done by George Southworth in his early waveguide work. In it he was fortunate to have the understanding cooperation of Carl A. Richmond, an attorney of the American Telephone and Telegraph Company Patent Department. We have done well in our work on the transistor. Here the number of inventors and attorneys has been greater and they spread into several departments, but the common objective of getting wide and thorough coverage of a new field has given us a very satisfactory position in this newest of communications arts. It appears beyond question that our good inventing job on transistors accompanied by early publication has enhanced the professional standing of our laboratory and its members more than would either inventing without publishing or publishing without inventing.

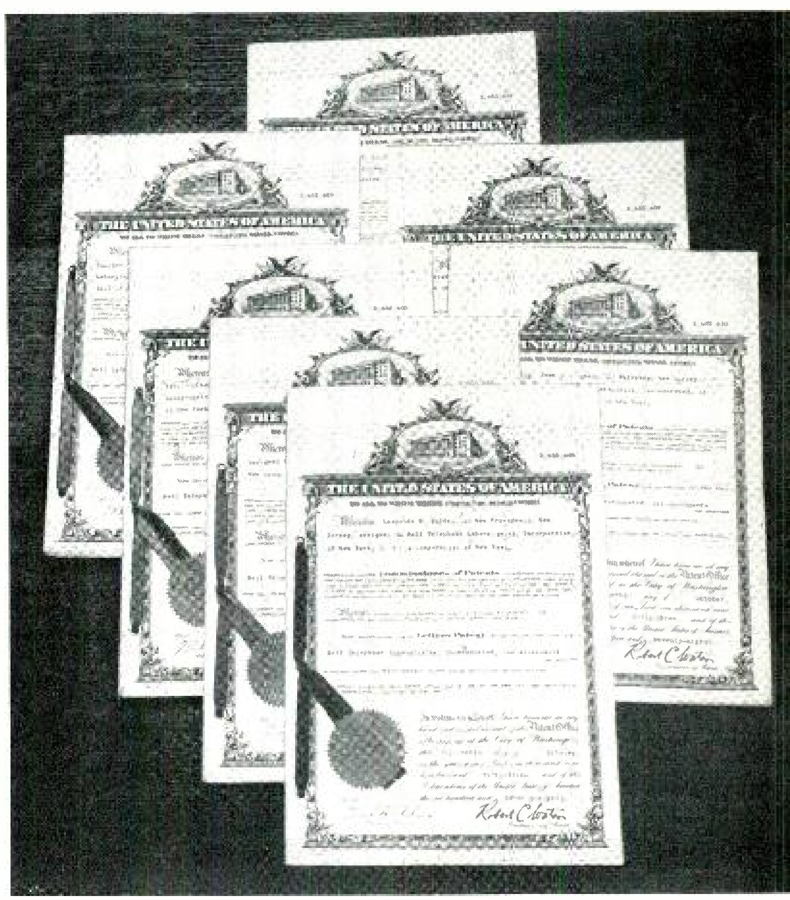
This sort of surveying and planning of a field to lay down needed inventions is not only the duty of a good workman in research and development, but it is fun. Seeking out the new and useful embodiments of a principle to discover the desirable ways of achieving the result is an intellectual exercise comparable with bridge or chess. It is a form of intellectual development and self-training of no mean value in the evolution of the productive faculty of a person having creative instincts.

I do not hold that inventing can be learned in the sense that arithmetic can be learned by anyone above the moron level, but I do believe that enhancement of creative capacity through thinking about inventions is very real. The essential characteristic of the inventor is that he has naturally or by development a quality of what I choose to call uninhibited insight. Inventions exist first in the mind before there is any move to give them physical embodiment. In a certain sense the next group of inventions for which our technical advances have prepared us may be said to be now in being. We do not see them because they are unfamiliar and we do not know they are there. It is as though we were viewing a tangle of woodland and did not see the wild creatures there because they hold themselves immobile and because they have protective coloring. It is only the uninhibited penetrating eye which can pick them out of the familiar scene. So it is in the realm of the inventor. His mental vision is not satisfied or inhibited by the familiar. His questioning mind analyzes the familiar into new patterns which reveal the strange faces hidden among the outlines of the leaves.

This quality of looking at things as though for the first time and giving all things equal and searching scrutiny even though some are all too familiar is a quality which can be learned in some degree by practice. Whether it can be taught is another matter. The only way I have ever seen it learned is by example. My advice to anyone who wants to become a better inventor is to study the mental habits of some people who have themselves demonstrated a capability for invention.

Being an inventor is apparently something that is not learned overnight. On the average, inventors require several years to reach a level of maximum output. In the Laboratories on the average, this level is reached at age thirty-five. There is ample evidence, however, that many individuals can and do continue at their maximum creative levels throughout their entire careers. The invention rates of other individuals decrease for many reasons, the foremost factor being

Patents issued to Bell Telephone Laboratories inventors during the week of October 12, 1953.



the assumption of administrative responsibility.

It is generally thought that the individual who is destined to be a prolific inventor will begin to invent in the early part of his career. The records of eighty-four inventors who are presently with the Laboratories and for whom twenty-five or more applications have been filed reveal that only fourteen disclosed an invention during the first year they were here. Twenty-five were with the Laboratories more than four years before disclosing their first invention. Two were here more than ten years before this took place.

To round out the subject of inventing and patenting, something ought to be said about Patent Department work of other kinds than just getting patents. Freedom to use the best art, which is our object, implies that we know when we are free, that is to say when we are not infringing somebody else's patent. A very important part of the Patent Department's work is making "freedom-to-use" studies and searches. Each new development, before it goes into use, requires a scrutiny of the applicable patents to be sure either that we have rights or that we do not need them.

Inventors are continually sending us suggestions they think we ought to want to use in the business. Sometimes these are already patented, sometimes they have no protection, and sometimes they are proposed as a lever to get a job. Dealing with these in a way both to protect the company and to preserve good public relations is not always an easy task but it is one the Patent Department does. Evaluating patents and groups of patents under which we desire rights to be obtained by purchase or trade is also an important and time-consuming matter. Our Patent Department does a great deal of this work in collaboration with Western Electric and American Telephone and Telegraph Patent Departments as a part of the patent licensing work handled by the Western Electric Company.

In closing, here are some of the important points which make up our patent philosophy:

A patent is a statement of ownership of an invention. Patents are as real and valuable as land and buildings or flocks and herds and are a vital element in our system of private ownership and private enterprise.

In the Bell System, patents are the means by which we acquire freedom to use the best technical art in giving service.

In Bell Telephone Laboratories they protect our ownership of our own new advances and thereby they permit a liberal publication policy.

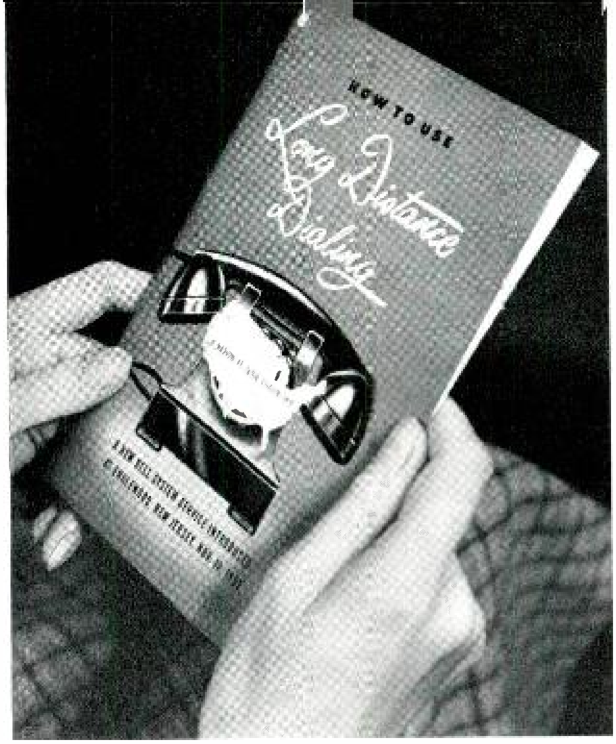
Although inventing is a very important part of our work and some inventions may be of great value, the inventor must be integrated with his environment in evaluation of his contribution.

Planning work with an eye to good protection by patents is an interesting challenge which in no sense stultifies the scientific or technical merit of the work.

Natural talent for invention, like any other talent, may be enhanced by conscious study and practice.

THE AUTHOR

Ralph Bown, vice president in charge of research and patents, joined the A. T. & T. Co. in 1919 with M.E. (1913), M.E.E. (1915) and Ph.D. (1917) degrees from Cornell University. In 1934 he transferred to the Laboratories as Associate Radio Research Director and after several technical and executive appointments in radio and television research became vice president in 1951. Much of his work has been concerned with the transmission aspects of radio engineering and ship-to-shore and overseas telephony. During World War II he was responsible for all phases of radio and television research at the Laboratories, and served as a division member and consultant of the National Defense Research Committee, specializing in radar. He also served as an expert consultant to the Secretary of War. Recipient of the I.R.E.'s Morris Liebmann Memorial Prize and Medal of Honor, Dr. Bown is a Fellow and also a past president of the Institute, and a member and past chairman of the Joint Technical Advisory Committee of the I.R.E. and the Radio-Television Manufacturers Association. He is a Fellow of the A.I.E.E., the American Association for the Advancement of Science, the Acoustical Society of America and the American Physical Society, and a member of Sigma Xi, Eta Kappa Nu and Gamma Alpha.



The Englewood Story

E. L. GETZ *Switching Engineering*

In the latter part of 1951, nationwide dialing was made available to thousands of telephone users in Englewood, New Jersey, who can now dial their own calls to customers in central offices stretching from New York to the West Coast. This initial installation was at first an experiment, but Englewood customers have since proved that Foreign Area Customer Dialing is highly acceptable to most telephone users. The Bell System plans to extend this service to other areas throughout the country, but the speed of applying the service will be governed by economic considerations and by the availability of adequate facilities.

November 10, 1951, is an important date in the history of the Bell System, for it marked the introduction of nationwide or Foreign Area Customer Dialing (FACD) in the United States. The event took place in the Englewood, New Jersey, No. 5 crossbar office where the Mayor of Englewood, in the presence of special guests, dialed the ten-digit number 415-LA-3 (Lakehurst 3)- 9727. The call was to the Mayor of Alameda, California, and was answered by the mayor seventeen seconds after dialing had been completed.

Prior to the introduction of FACD, the individual and two-party line Englewood customers could reach by direct dialing some 1,100,000 telephones in New Jersey and 3,100,000 telephones in New York City. With FACD these same customers could dial an additional 7,100,000 telephones, or a total of 11,300,000. The service was not made available and is still not available to coin customers and four-party customers because message charges cannot yet be handled automatically in these cases.

Although this new service has been widely publicized, it will be of interest to discuss some of the details concerning the planning and preparation required to introduce FACD, to present an analysis of customer and service performance, and to summarize briefly the future of this service.

First of all, the idea of permitting customers to dial nationwide calls is not new. It has been done in Europe for years in countries where distances are not so vast as in the United States. In Belgium and Switzerland, for example, this type of dialing has been available for at least fifteen years and extends for 150 miles or more within the respective countries. Introduction of the service in this country, where the design and charging problems are more complex, had been a Bell System objective for some years, but several problems had to be solved before it could be attained.

One very important problem was to obtain a dialing arrangement which could locate the telephone address of the particular destination wanted. Remembering that FACD will ultimately embrace Canada

Fig. 1 — With his own telephone, a customer in Englewood can dial a long distance call, perhaps to a friend or relative in San Francisco, California. Fig. 2 — Mrs. J. C. McCartney at the Service Observing desk in Englewood. Data gathered here proved that customers liked nationwide dialing.

as well as the United States, there are many thousand central office names which must be reached, and the office code digits are repeated many times. For example, consider the office code digits 426. In Baltimore these stand for HAmilton 6, in Newark for HArrison 6, in Philadelphia for GArfield 6, and so on. The same is true for other combinations of digits.

The answer to this problem had to be found even before nationwide dialing by toll operators could be inaugurated, and the solution has equal application for FACD. The solution[1] was to divide the United States and Canada into zones or numbering plan areas and to give each area a distinct three-digit code. This division is illustrated in Figure 3, and at the present time consists of about 85 areas within the United States and 9 areas in Canada. By prefixing the area code ahead of the directory number, a call is given a routing to the desired destination.

The introduction of nationwide dialing by toll operators carried with it the necessity of mechanizing the handling of toll traffic. Such mechanization is being introduced as rapidly as possible by installing toll crossbar[2] and crossbar tandem[3] switching systems to provide a switching network covering the entire country. This network is being used for both customer- and operator-dialed toll calls.

Another major barrier was that of automatically recording the charges for which the customer is billed. Although the message register is a recording device that has been used for many years, it is inadequate as a charging instrument for FACD calls. Within recent years, however, two new methods for full automatic recording of charges have been made available, namely local automatic message accounting (AMA or LAMA)[4] and automatic ticketing (AT).[5] Either of the two methods automatically identifies and records the calling customer's directory number, and automatically records the called customer's number as dialed by the originating customer.

A third major barrier, and one which is still very real for all local dial systems, with the exception of the No. 5 crossbar system, is the arranging of new and existing offices for ten-digit dialing in the most economical manner. This is not a problem in the No. 5 crossbar, however, because provision was made for ten-digit operator and customer dialing in the initial design of this system.

The decision to proceed with nationwide customer dialing on a trial basis was made in the early part of 1950. It was to be on a trial basis because the introduction of a new service such as this presented new dialing requirements to the customer and new operation problems to the telephone companies. These conditions therefore had to be appraised before a

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[1] Record, *October*, 1945, *page* 368. [2] Record, *April*, 1944, *page* 355, and *October*, 1953, *page* 369. [3] Record, *August*, 1942, *page* 286. [4] Record, *November*, 1952, *page* 428; an AMA Bibliograph appears with this article. [5] Record, *March*, 1944, *page* 346, *July*, 1944, *page* 445.

program for general application could be formulated.

To obtain data pertaining to customer dialing performance and to operating procedures, it was essential that the trial office originate a substantial volume of traffic into foreign numbering plan areas, either adjacent or distant. Most of this traffic also had to be originated by customers other than the PBX operators frequently used by business establishments. This latter condition was considered desirable if the data were to represent the actions of private customers having less dialing experience. After a careful survey of existing No. 5 installations, the Englewood, New Jersey, office was found to be best fitted for these conditions.

Since FACD was to be a new customer service that would reach into widespread areas, its introduction involved extensive planning and the coordination of the many components throughout the Bell System that would affect and be affected by the service.

From a long range viewpoint, an important condition governing the use of FACD was set forth early in the planning. This condition is that the area from which FACD calls originate and the area to which such calls are directed must both be on a 2L-5D numbering plan basis. That is, the directory numbers must consist of two letters and five numerals. In November, 1951, there were fifteen such areas, and the Englewood customers had access to only two of the fifteen, namely to offices within their home area (New Jersey) and to offices in New York City, the latter being obtained by prefixing the directing code "1-1" to the directory numbers. Of the remaining areas, two included many of the New York suburban counties (Nassau, Westchester, Rockland, and parts of Orange and Putnam Counties), and the rest consisted of one each for the following cities and their suburbs: Boston, Chicago, Cleveland, Detroit, Milwaukee, Oakland, Philadelphia, Pittsburgh, Providence, Sacramento, and San Francisco. Englewood customers could therefore dial directly to any of these areas, or to a total of about 1,250 central offices.

The trunk routing arrangement employed by these areas during the experimental period (excluding the Englewood home area and New York City) is shown schematically by Figure 4. Direct trunk groups were provided to handle the customer-dialed traffic from the Englewood office to the No. A4A toll crossbar office in Pittsburgh, the No. 4 toll crossbar office in Boston, the No. 4 toll crossbar office in Philadelphia, the No. 4 toll crossbar office in New York City,

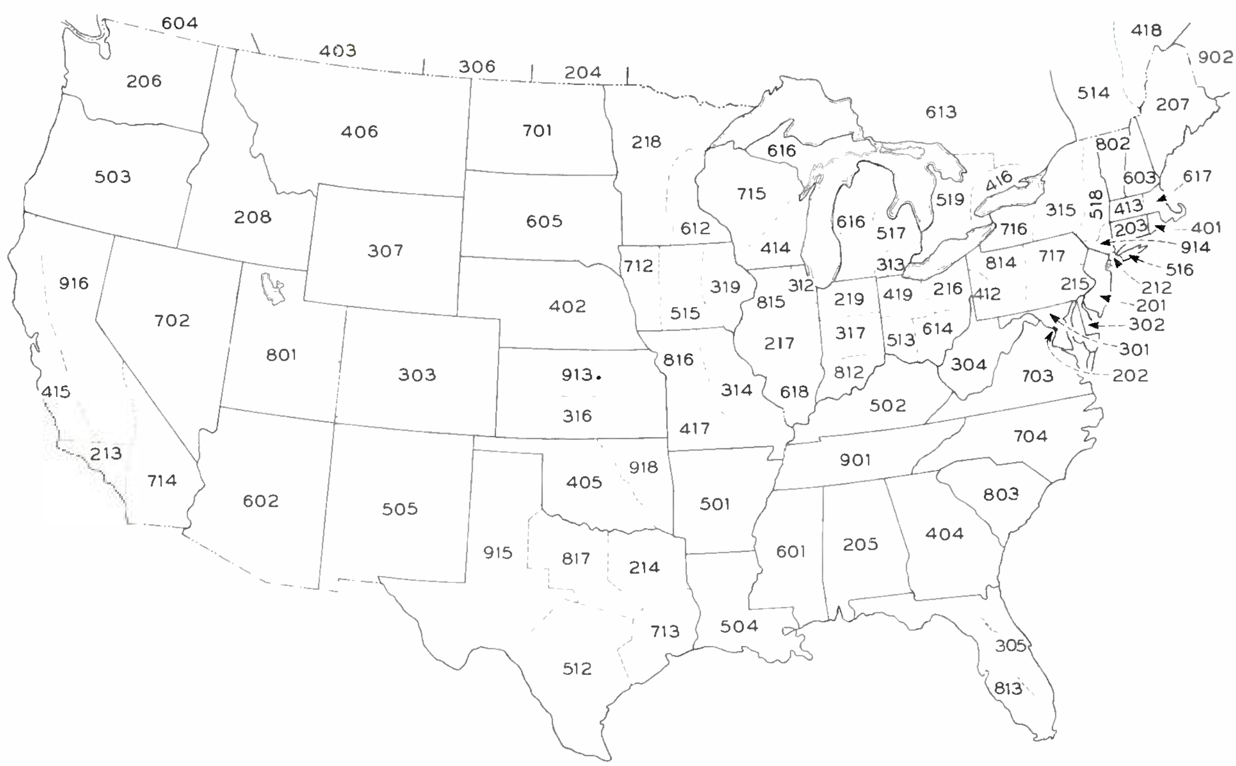


Fig. 3 — The numbering plan divisions in the United States. The three-digit area codes are prefixed to the more familiar directory numbers.

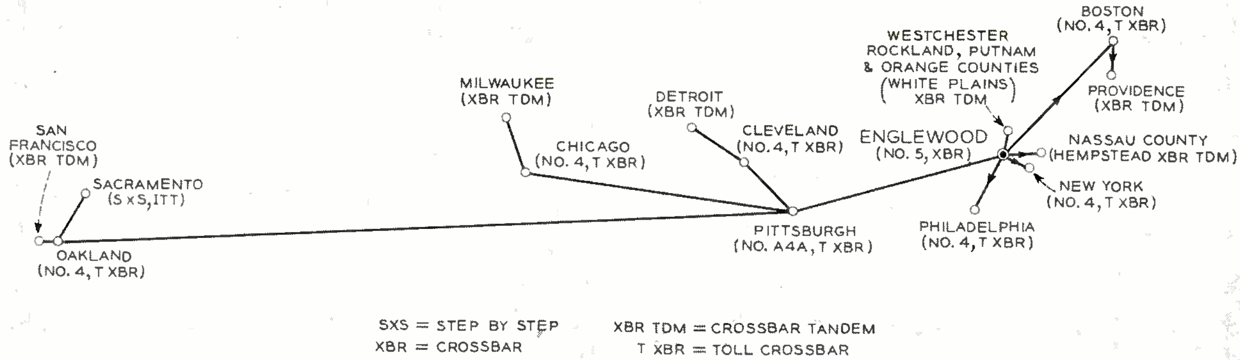


Fig. 4 — Trunking arrangements that permit Englewood customers to dial about 11,000,000 telephones in the United States.

the crossbar tandem office in White Plains (serving Westchester, Rockland, Orange, and Putnam Counties) and the crossbar tandem office in Hempstead, L. I. (serving Nassau County). Calls to all points west of Pittsburgh were switched through the A4A toll crossbar office in Pittsburgh, and calls to some points were switched twice. For example, a call to Detroit is switched through Pittsburgh and Cleveland. The trunk group to the New York City No. 4 toll crossbar office provided an alternate route through the latter equipment to seven of the thirteen areas. This arrangement of trunk groups and routing, however, is being changed, since within the next few months, use will be made of a 4A toll crossbar office in Newark. This change will provide means of switching all Englewood FACD calls through the Newark 4A toll office (with the exception of calls to the six counties suburban to New York City) and will permit abandoning the arrangements that are shown in Figure 4.

Among the necessary preparations for FACD were the instructing of customers in the use of the new service and the gathering of data on the performance and accuracy of customer dialing, and on the customers' need for assistance by an operator. The overall functioning of the equipment, and the training of the plant, traffic, commercial, and accounting personnel in new operating procedures were also very important. The equipment of the Englewood No. 5 office had, of course, to be arranged for the new service, and a comprehensive testing program had to be formulated for every phase of operation. It was also necessary to modify certain of the Newark accounting center equipment to process the FACD entries appearing on the Englewood AMA tapes.

Customer instruction started well in advance of the service date of November 10, 1951. Periodic newspaper articles instructed customers in the use of the new techniques, and a movie short was shown to the audiences of several civic clubs and to audiences in the movie theaters of Englewood and nearby communities. Prior to the cutover of the new service, a booklet was sent to all customers who would participate in the service. This booklet, shown in the headpiece and excerpts of which are shown in Figure 5, was made very complete, and explained in simple terms the slightly more complex procedure involved in dialing a long distance call.

Customer reaction was so favorable and results were so satisfactory that the new service passed from the trial stage to the commercial stage on December 31, 1952, and Englewood is now considered as the first permanent installation of FACD. The highlights of the data assembled during the period November 10, 1951 to December 31, 1952 are presented in Tables I through IV. The data under the heading "short haul" are for FACD traffic to Westchester, Rockland, Orange, Putnam, and Nassau Counties. These tables do not require detailed discussion, but a few remarks are in order.

Referring to Table I, the reader will note that with FACD service there is a substantial per cent shift away from the long-haul non-dialable calls (such as person to person) and toward dialable calls (station to station). This change evidenced itself within the first week of service and continued within a range of 70 per cent to 78 per cent. Variations in successive data intervals were from 1 per cent to the full 8 per cent. The post-FACD calls completed by customers fluctuated slightly around the 63.6 per cent average until the last four months of the data period, when a continued upswing was in progress, reaching 70.8 per cent.

Table II shows weekly traffic averages, but it should also be pointed out that each data interval disclosed a gain in the number of weekly short haul messages dialed (2,210 at the start — 2,934 messages at the end of the trial period). The long haul traffic showed substantial fluctuation in the number of weekly messages for the first nine months of the trial (high of 235 messages in the May, 1952, data period — low of 221 in the July period). After July, however, there was a steady increase, the number of weekly messages reaching 336 at the end of the trial.

The speed-of-service data in Table III shows short-haul calls to be three seconds slower than long-haul calls from the end of dialing to start of ringing or busy. This is due to the fact that many of the offices in the Westchester, Rockland and Nassau County area are manual, and hence calls to these offices require the services of an operator for completion of the call. Operator time in completing a call will vary. As noted under customer dialing performance, dialing irregularities increase with the number of digits dialed. This was anticipated; the only question was how serious this problem would be. FACD dialing irregularities consist principally of dialing vacant area codes, vacant office codes, insufficient number

Four Tables of Englewood FACD Service Data

Table I — Ratio of Dialable Messages (Station to Station) to Total Toll Messages, Including Non-Dialable Person-to-Person Messages.

	PRE-FACD	POST-FACD*
Long-Haul Dialable Messages		
Per cent of total long-haul messages	55%	74 %
Completed by operator.........	55%	10.4%
Completed by customer........	—	63.6%
Short-Haul Dialable Messages		
Per cent of total short-haul messages	98%	98 %
Completed by operator.........	98%	4 %
Completed by customer........	—	94 %
Per cent of total toll calls completed by operator		
Long haul	100%	36.4%
Short haul	100%	6.0%

* Average for the period November 10, 1951, through December 31, 1952.

Table II — Distribution of Customer-Dialed Messages; Weekly Average for the Period November 10, 1951, to December 31, 1952.

AREA CODE	AREA	CUSTOMER-DIALED MESSAGES
	Short-Haul Traffic	
516	Nassau County	549
914	Westchester, Rockland, Orange, and Putnam Counties	2,039
	Total Short Haul...................	2,588
	Long-Haul Traffic	
214	Philadelphia and suburban.............	122
216	Cleveland and suburban................	11
312	Chicago and suburban..................	24
313	Detroit and suburban..................	19
318	San Francisco and suburban.............	3
401	Providence and suburban................	15
412	Pittsburgh and suburban................	10
414	Milwaukee and suburban................	4
415	Oakland and suburban..................	1
617	Boston and suburban...................	79
916	Sacramento and suburban...............	1
	Total Long Haul....................	289

Table III — Speed of Service and Customer Dialing Performance; Average for the Period November 10, 1951, to December 31, 1952.

Speed of Service, Customer Dialing

INTERVAL MEASURED	LONG HAUL	SHORT HAUL
Number of seconds from end of dialing to start of ring or busy	11	14
Number of seconds from end of dialing to called station answer	19	24

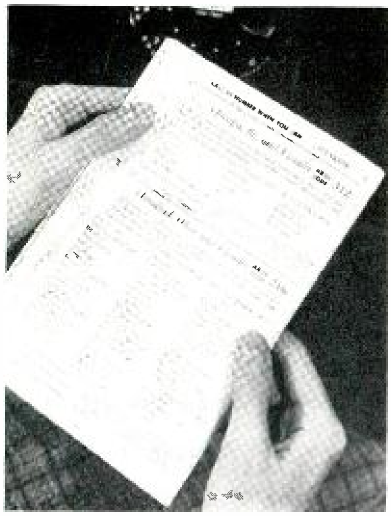
Customer Dialing Performance

TYPE OF SERVICE	NUMBER OF DIGITS DIALED	PER CENT OF CALL ATTEMPTS AFFECTED BY DIALING IRREGULARITIES
Local service in seven-digit area	7 or 8	2.1%
FACD calls to New York City (with Area Code 1-1)....	9	4.1%
FACD calls with three-digit area codes	10 or 11	6.6%

Table IV — Over-all Data; Average for the Period May 1, 1952, to December 31, 1953.

CONDITION OF CALL (PER CENT OF EACH TYPE)	EQUATED LOCAL CALLS	FACD SHORT HAUL	FACD LONG HAUL
Call attempts which became messages ..	71.5%	64.0%	65.2%
Call attempts finding the called station busy	9.3%	12.4%	11.5%
Call attempts resulting in "Don't answer" or "Calling customer did not wait a sufficient length of time."*...	11.6%	13.8%	10.5%
Call attempts abandoned	7.6%	9.8%	12.8%

* The customer's instruction booklet states "Give the called party time to answer: wait at least one minute, ten rings, after ringing begins."



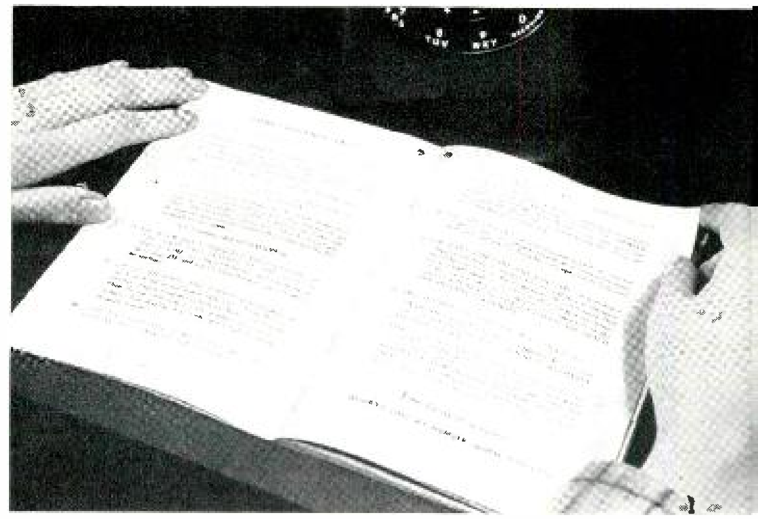


Fig. 5 — Sample pages from "How to Use Long Distance Dialing."

of digits, and wrong numbers. Table IV summarizes over-all customer performance in terms of the average conditions of calls attempted.

There is now no question about the future of FACD. The Englewood experience had definitely demonstrated the acceptance of ten-digit dialing by the customer, and the real question at present is how long it will be before the service becomes general. Many factors must be taken into consideration before this question is answered. Early in this article it was stated that the No. 5 crossbar system was readily adapted for ten-digit dialing, and offices of this type will therefore be the first to be used for the new service. In addition to Englewood, limited FACD service was made available in 1953 to nine No. 5 offices in Westchester and Nassau Counties. One office was also added in Detroit and another in Pittsburgh, this latter office having nationwide dialing similar to that at Englewood. Additional No. 5 offices will have this service in 1954.

The growth of FACD in No. 5 crossbar offices will be determined by economics and by the availability of adequate facilities. In some instances the volume of ten-digit customer-originated calls in a particular office may not be sufficient to justify the cost of FACD arrangements. Also, even when justified, its application may have to await additional toll facilities. FACD service in other types of dial local offices (crossbar No. 1, panel, and step-by-step) is planned, but must wait for a while pending the availability of suitable equipment arrangements. These, however, are merely the growth problems of the Bell System. The ability of the Englewood customers to dial long distance numbers, and their enthusiasm for using FACD, have demonstrated that direct long distance dialing is one of the major trends within the telephone industry.

THE AUTHOR

EMIL L. GETZ started his Bell System career in 1919 as a member of the Development and Research Department, A. T. & T. Co. He was engaged in switching engineering studies and developments of the panel dial system both as a local and a tandem system. Transferring to the Laboratories in 1934, he continued to work in the field of dial switching with particular attention to No. 1 crossbar local and tandem systems, as well as panel. When work was begun on the No. 5 crossbar system he assumed responsibility for related switching engineering activities. The arrangements and preparations of Englewood, N. J., for customer nationwide dialing were also his responsibility. Mr. Getz received the B.S. degree in E.E. from Catholic University of America in 1919.

Color Timing System for Filter Centers

L. E. VAN DAMME *Station Apparatus Development*

As part of the Laboratories' national defense work, a new color timing system has been designed for United States Air Force filter centers, where aircraft flight information is gathered from civilian observers. The time that an airplane passes over an observation post is correlated with a color appearing on a glass panel set into the map table at the filter center. By thus keeping the filter center personnel constantly informed of the times of observations, this system permits accurate information on aircraft tracks to be dispatched quickly to other defense installations.

The Ground Observer Corps is a vital part of the defense system of the continental United States and Canada. It is staffed largely by civilian volunteers who man observation posts situated strategically throughout a particular defense area, and who operate a "filter center" where the observations are plotted and where the essential information is "filtered" from erroneous and out-of-date material. To keep this system operating at maximum efficiency, Bell Telephone Laboratories has cooperated with the Air Force by designing extensive communications facilities and other equipment.*

The changed character of aircraft in recent years has, however, taxed the abilities of the Ground Observer Corps and the Air Defense System. The increased use of fast-flying jet planes, and the resultant necessity of supplying rapid information to defense

*Record, *December* 1941, *page* 87; *July*, 1950, *page* 316; *October*, 1951, *page* 482 and *page* 483; *September*, 1952, *page* 380.

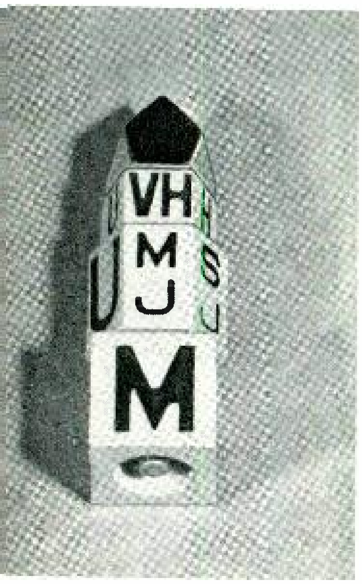


Fig. 1 — A "pip" used to record information as received from ground observers, photographed about actual size. It tells Filter Center personnel that many multi-engined jet aircraft have been observed flying at a very high altitude in the indicated direction.

bases, raises the problem of achieving an accurate synchronization between the observer who spots the aircraft and the plotter who records the information on a map table in the filter center. This problem has been solved by a new color method for recording the times of observations so that only up-to-date information is kept on the map table.

Previous methods involved marking the time of observation on slips of paper, a procedure that tended to complicate the filtering process, particularly during periods of dense traffic. By comparison, the new color method is more automatic and improves both the speed and accuracy of plotting aircraft tracks.

From the point of view of those plotting the observations, the essential feature of this timing system is a circular pane of translucent glass mounted in the center of the map table. One of these can be seen in the headpiece, which shows plotters at work around one of the two map tables in the Air Force Filter Center at White Plains, New York. Below this pane of glass, underneath the map table, are mounted three lamps that are directed upward towards the pane. The lamps are provided with different color filters, red, orange, and green, so that the pane of glass on the table will glow in the color corresponding to the lamp that is lit beneath it. High-wattage reflector-type flood lamps are necessary because of the high level of illumination on the working surface of the map table. The plotters consequently notice that the pane of glass will periodically change color, each color persisting for a definite time interval, normally two minutes.

While working at the map table, any of the plotters may receive an "Aircraft Flash" telephoned in by one of the ground observers. The observer may, for instance, have sighted a group of multi-engined jet aircraft flying at a high altitude. Under ordinary circumstances, there will be no delay in telephoning this information to the plotter, who will record the information on a device known as a "pip." Figure 1 is a photograph of one of these pips, which has four rotatable sections for recording the pertinent data. This particular pip will be read, from bottom to top, "Many multi-jets, very high." The plotter, as in Figure 2, will place this pip on its side in the correct geographical position and will point it in the reported direction of flight.

In addition, the plotter will turn the front segment to, say, the color red, to correspond to the current color of the light in the center of the map table. Later, as the same flight of aircraft is observed in another area, a second observer will probably report essentially the same information, except at a later time. If the second report is received two minutes later, the plotter will place a second pip on the table at the new position and will turn the front segment

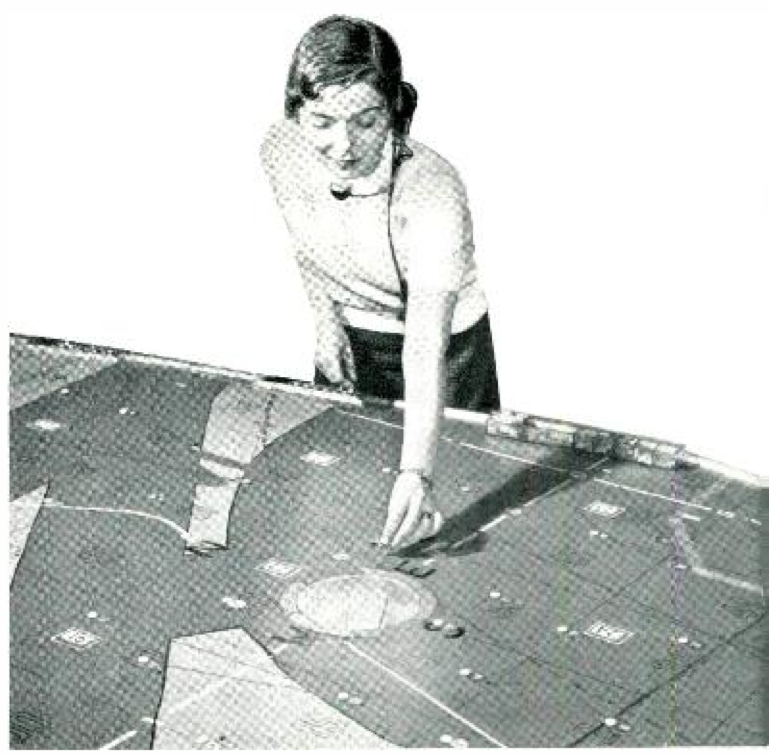


Fig. 2 — A plotter at the White Plains Filter Center placing a pip on the map table. She has turned the front segment of the pip to correspond to the color of the table light in front of her.

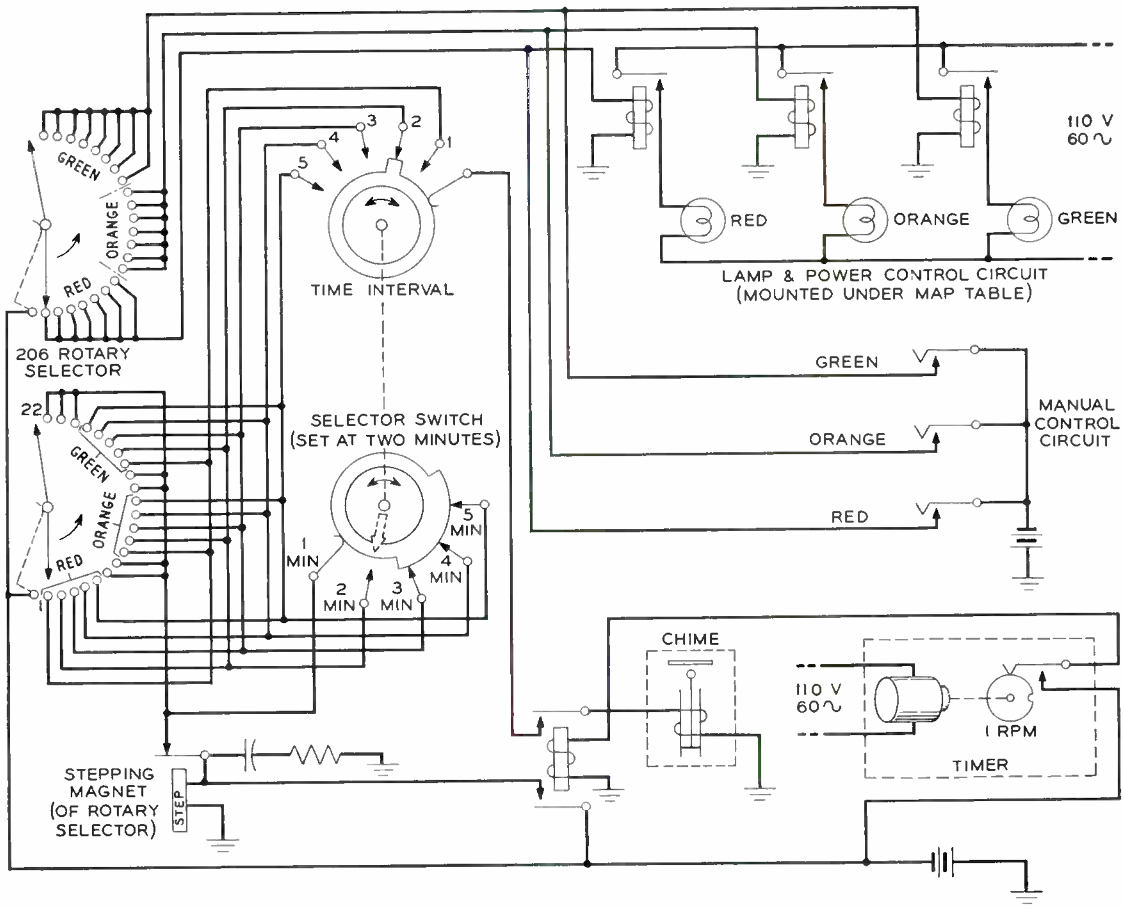


Fig. 3 — Simplified schematic of the color timing system used in aircraft warning Filter Centers.

of the new pip to the orange color, to correspond to the new color of the table light. The filterer on duty, seeing a line of two or more pips, can then decide that the information represents an actual flight to be watched. He will substitute for the pips arrows of the color indicated on the pips and will place a stand giving flight information at the front of the flight. Several of these vertical stands can be seen in the headpiece. They permit other personnel (tellers) at the Filter Center to follow the various flights and to report the information to other defense units.

The utility of this method of recording flight information can be realized by considering the speed and accuracy with which it handles some of the more complicated jobs of the Filter Center. Without a timing system of this sort, a map table might become congested with old information, but under the new arrangements, the colored arrows immediately identify all observations over six minutes old, and these can be quickly removed. Furthermore, during heavy air traffic there is always a danger of confusing different flights of aircraft, or of interpreting a single flight as two or more. With the color timing method, however, the filterer can look at the table and see at a glance the real situation and weed out the irrelevant information. Also, in the few cases where delays are encountered in receiving aircraft flashes, the new system prevents confusion, for the plotter merely turns the front segment of the pip to one of the previous colors of the table light, and thus establishes a correct register between the colored arrow that will appear on the table and the actual time that the aircraft flew over the observation post.

A simplified schematic circuit of the color timing system is shown in Figure 3. The timing mechanism is housed in a small metal cabinet containing a synchronous motor-driven timer, rotary selector, relays, five-position selector switch and miscellaneous components. The timer motor is powered from commercial 60-cycle ac and can therefore be kept accurately synchronized with the Filter Center wall clocks. The five-position switch is accessible from the outside of the housing to permit instant change of time intervals without any wiring modifications. The setting of this switch controls the circuit connections to the timer and rotary selector to provide the desired time interval.

The system is also furnished with a set of control keys usually mounted within easy reach of one of the Filter Center supervisory personnel. These keys provide for turning the system on and off, for synchronizing the illuminated signal with the wall clock, and for emergency manual operation. A chime signal is also provided which sounds once immediately prior to a change in color designation to alert the plotters and filterers.

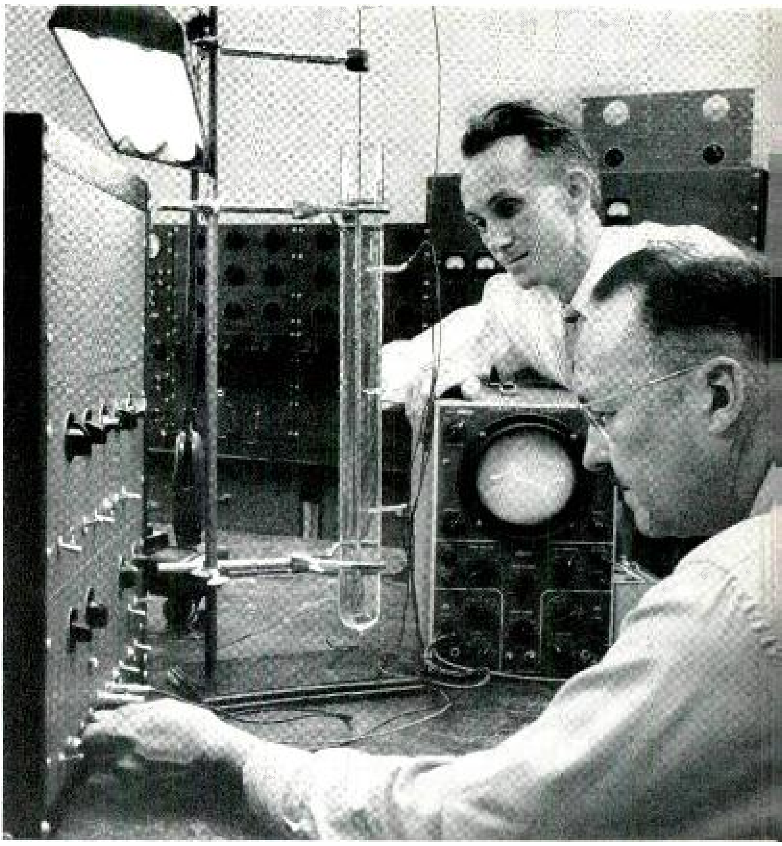
Color timing systems are now in continuous operation in many Filter Centers in the United States and Canada covering extensive areas facing air approach routes. Along with the extensive network of telephone communication provided by the Telephone Companies, these color systems are helping the Ground Observer Corps maintain an effective system of defense against possible enemy air attack.

Fig. 4 — Tellers at the White Plains Filter Center watch tracks of flights recorded on map table.

THE AUTHOR

In twenty-seven years of wiring and circuit design at the Laboratories, LOUIS E. VAN DAMME has been associated with most phases of the development of the coaxial cable, crossbar and air-warning systems. After first concentrating on dial switching systems for three years, he became a Member of Technical Staff in 1930, assigned to ringing and ac signaling studies. For several years he was concerned with wiring and equipment work on the coaxial cable system and then directed his attention to wiring, testing and analyses of panel, crossbar and D.S.A. switchboard circuits. During World War II, Mr. Van Damme was concerned with air-warning systems for civil defense and military use, and remote radio system operation. He has since been engaged in station systems circuit design.

A human nervous system, like the Bell System, consists of a complex network of communication channels. Although both systems use their individual channels for information transmission, the processes involved are quite different: electrochemical in the nerve — electromagnetic in the telephone line. Recent investigations of electrochemical models designed to simulate the operation of physiological nerves, however, indicate that it may be possible to adapt this type of low velocity and essentially unattenuated signal transmission to engineering applications in the communications industry.



"Nerve-Type" Transmission Line

R. L. TAYLOR and H. M. STRAUBE
Chemical and Metallurgical Research, and Transmission Research

Nerves that perform important signal transmission functions in human beings have characteristics that could be useful in certain kinds of telephone circuits. Nerve transmission, in particular, offers pulse propagation which is not only very slow but is also essentially lossless and distortionless. Such low velocity transmission has appeal in modern automatic switching systems in which it is frequently necessary to delay pulse signals until certain supplementary circuit actions take place. Synthetic nerve conductors which provide these characteristics are being investigated in the Research Department at Bell Telephone Laboratories.

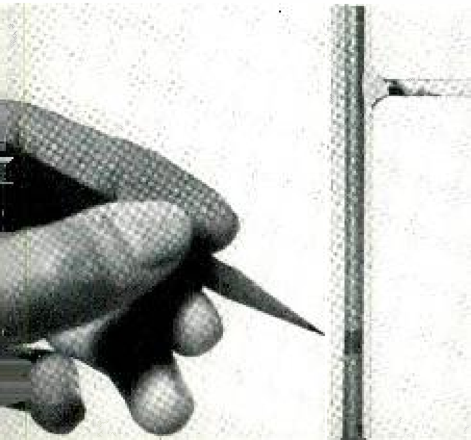


Fig. 1 — Electrochemical impulse as it appears on an iron rod that has been immersed in nitric acid.

Nerve transmission is fundamentally an electrochemical phenomenon involving the movement of relatively massive ions as well as electrons. Accordingly, signal velocity over nerve conductors is a million times lower than over familiar electrical conductors. Moreover, a nerve impulse maintains its magnitude and form through energy derived from chemical changes — energy that is continuously being replaced by body metabolism. A nerve can thus be considered to be a transmission line having built-in repeaters and power supplies distributed continuously along its length.

Synthetic nerves are not new. As early as 1901, Wilhelm Ostwald, a German chemist, had noticed the similarity between the propagation of electrochemical activity on certain metals and that of stimuli on nerves. Later, R. S. Lillie, a physiologist at the University of Chicago, undertook an extensive investigation of the behavior of iron in nitric acid, and demonstrated many interesting analogies between its action and that of a nerve. Lillie emphasized the

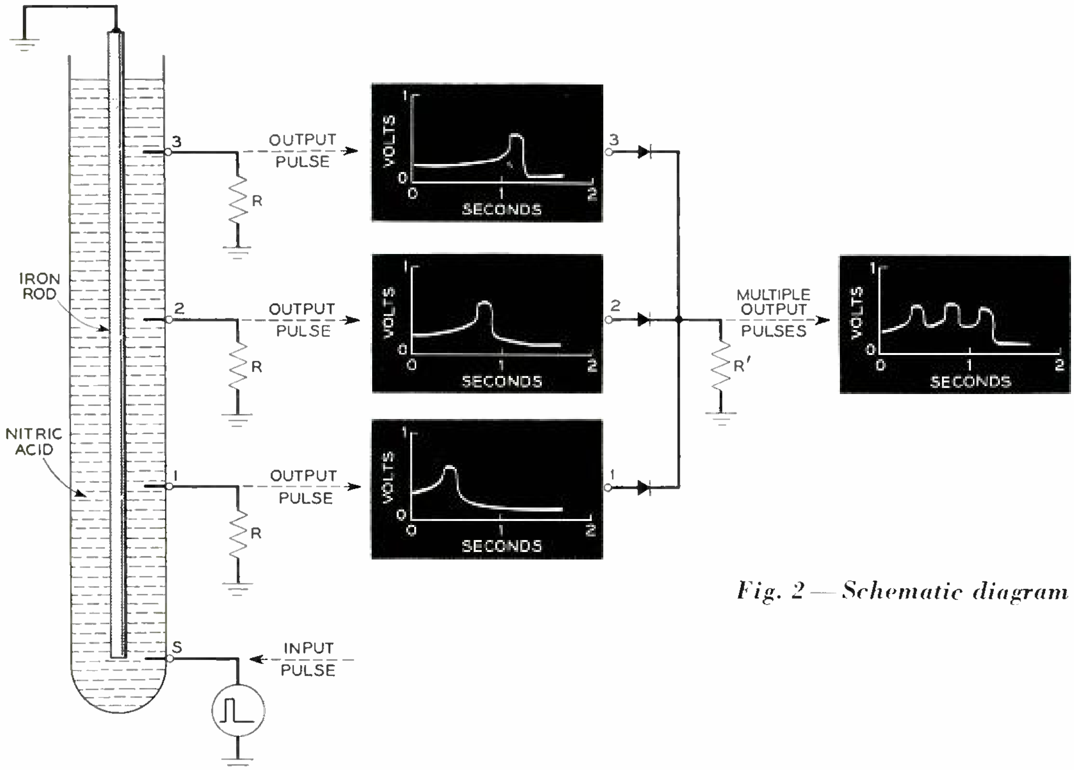


Fig. 2 — Schematic diagram of nerve model.

physiological implications of his nerve model, and was not especially concerned with the possibilities such a structure might have in engineering applications. Present studies at the Laboratories, on the other hand, have been directed toward constructing a modified Lillie nerve model, measuring its performance, and interpreting its behavior in the light of possible applications in the telephone plant.

A schematic diagram of the Laboratories' nerve model is shown in Figure 2. It consists essentially of an iron wire immersed in nitric acid with an input electrode placed near the lower end of the wire and several output electrodes distributed along its length. A wave of electrochemical action (an impulse) which travels along the wire may be initiated by introducing a current pulse between the input electrode and the iron wire. This impulse, indicated by a brown ring which can be seen near the surface of the iron in Figure 1, travels up the wire with a velocity of from one to ten meters per second. As it passes the output electrodes, a voltage pulse of about 0.7 volt — independent of the magnitude of the initiating voltage — appears between each electrode and the wire. As shown in Figure 2, the pulses appearing in succession at Probes 1, 2 and 3 are identical in magnitude and form, but occur at times related to the electrode spacing. If the outputs from the various electrodes are combined through suitable circuit connections, a pulse group is obtained of the type shown at the right of the figure. When an oscilloscope is connected between any two of these output electrodes, rather than from a single electrode to ground, a wave-form of the general type shown in Figure 3a results. This is seen to bear a close correspondence to the typical physiological nerve response shown in Figure 3b. An actual photograph of one such trace from a nerve model is shown in Figure 4.

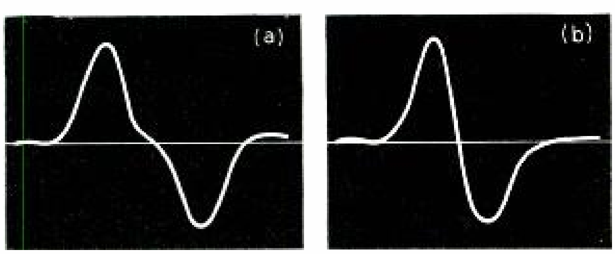


Fig. 3 — Comparison of waveforms resulting from the nerve model, shown at (a), and from a physiological nerve shown at (b).

A laboratory model and equipment for initiating and observing the impulse is shown in the headpiece of this article (H. M. Straube with R. L. Taylor in the foreground). In this model, the iron wire is somewhat less than one meter in length, but other wires up to ten meters long have been used. In such a system the velocity of the propagated impulse depends on a number of system parameters including the time allowed between successive input pulses, the temperature, the acid concentration, the wire diameter, and the inside diameter of the vessel in which the wire and the acid are immersed. Typical experimental results for a nerve model of this type are illustrated in Figure 5.

The mechanism by which an electrochemical impulse is generated and propagated along an iron wire may be described as follows: When the wire is immersed in concentrated nitric acid, it is momentarily attacked by the acid, but the reaction soon stops since the iron becomes passive by acquiring a protective film of oxygen and oxide on its surface. If this film is disrupted, as at the point labeled X in Figure 6, a short-circuited voltaic cell is formed. The iron wire provides the anode in this cell, the nitric acid the electrolyte, and the protective film the cathode. As shown in Figure 6, local galvanic currents then flow primarily in the path X-Y-Z. In the vicinity of point Y, the direction of current flow is such that it causes the protective film to be removed (cathodically reduced). At the anode – region X in Figure 6 – the iron is again oxidized by a series of chemical reactions that ultimately generate a new protective film. This action is not stationary; both the anode and cathode areas move along the wire, and thus a wave of film removal, followed by a wave of film replacement, is propagated. The resulting traveling impulse is essentially a moving voltaic cell.

To initiate such an electrochemical impulse, the protective film can be disrupted by mechanical, electrical, or any of a number of other methods. In the model constructed at the Laboratories the impulse is

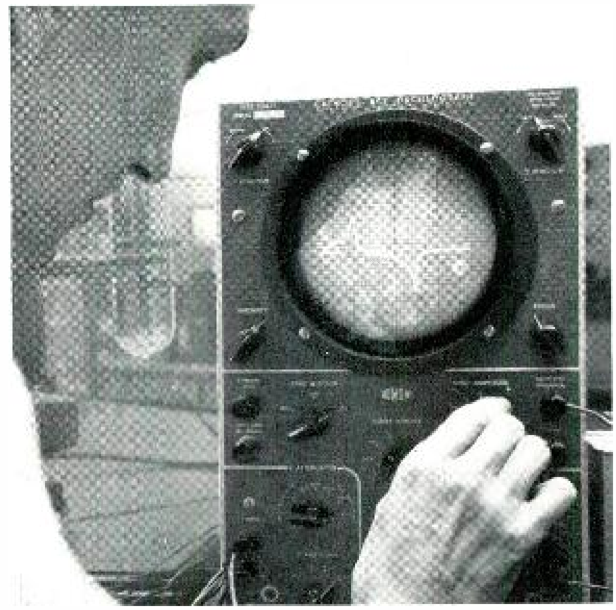
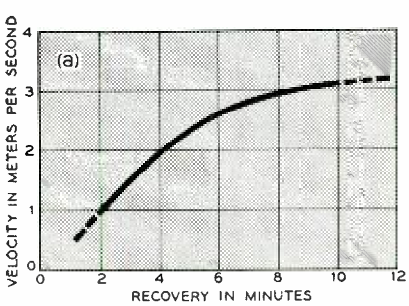


Fig. 4 – Oscilloscope trace from a nerve model impulse.

triggered by breaking the film with a pulse of current from an auxiliary electrode to the wire, as shown in Figure 2. Once initiated, the traveling impulse may be detected by various means. In this model, an electrical method is employed in which the output probes experience a shift in potential corresponding to the emf of the passing voltaic cell.

The iron wire nerve model has a surprisingly large number of characteristics that are common to actual



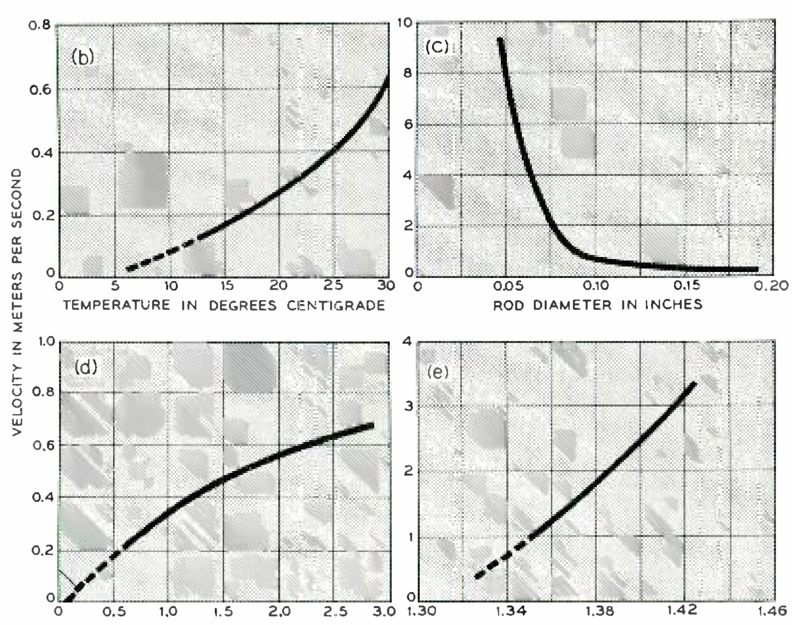


Fig. 5 — Graphs illustrating the dependence of impulse velocity on various system parameters.

nerves. The traveling impulse, for example, has its own wave-form, magnitude, and velocity, essentially independent of the characteristics of the "triggering" pulse. Both systems also require that the starting stimulus exceed a certain "threshold" value. In addition, the velocity of propagation in either system is materially dependent upon the diameter of the structure. Like a nerve, the model requires a short rest or recovery period before the next impulse can be transmitted and, under disturbing or unusual circumstances, either system may experience a complete nervous breakdown.

In one important respect, however, the iron wire model differs from physiological nerves. The model lacks a highly developed maintenance and repair mechanism for resupplying expended materials and removing waste products. Thus with continued use, the iron wire dissolves and the nitric acid solution is polluted. Although it might be possible to provide maintenance features in this model, the practicability of such a system is questionable. It does seem possible, however, to develop other nerve-models that would be more attractive in this respect. Present knowledge of such systems is far from complete, but it seems likely that some of them will find interesting engineering application in the future.

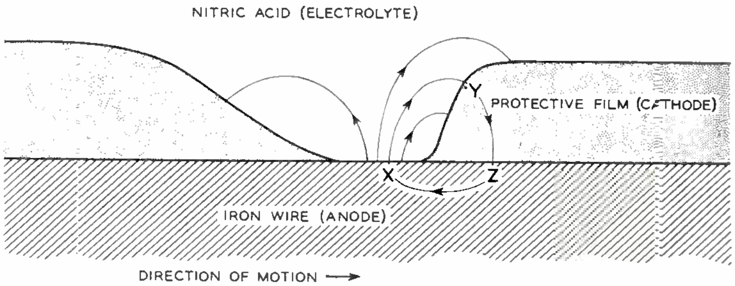


Fig. 6 — Mechanism by which an iron wire nerve model impulse is propagated.

THE AUTHORS

In twelve years with the Laboratories HAROLD M. STRAUBE has worked at Varick Street, West Street, and Murray Hill, first in development studies, later in research. At Varick Street Mr. Straube was associated with panoramic receivers, underwater range devices, and television test equipment. During World War II he worked on radar test equipment. In 1946 he transferred to a group concerned with electronic switching, and in 1950 was engaged in television studies. Since then he has devoted his time to transmission research and high frequency transistors. Mr. Straube received his B.S. degree (1939) in E.E. from the University of Michigan, and studied at Northwestern University for the M.S. degree. He is a member of Sigma Xi and a senior member of the I.R.E.

R. L. TAYLOR joined the Laboratories in 1928 immediately after receiving his B.S. degree in Chemical Engineering from the State College of Washington. In 1939 he received his M.A. in chemistry from Columbia University. At the Laboratories his early work was concerned with the dielectric properties of insulating materials and their reaction to water and sunlight. During World War II he worked with the National Defense Research Committee and the Naval Ordnance Laboratory on the design of sea-water batteries. Since 1945 he has been engaged in research on aluminum and tantalum electrolytic capacitors. Mr. Taylor is a member of the American Chemical Society, the Electrochemical Society, Tau Beta Pi, Phi Lambda Upsilon, Sigma Tau, and Phi Kappa Phi.

Mrs. M. S. Aamodt dialing a number as part of the test procedure. In the foreground is the test director's desk, showing the various equipment used in the utility testing operations.

Testing Telephone Usefulness

In a thorough program of research and development, the seemingly little things often mean the difference between success and failure. When a customer looks at the new 500-type telephone set, for instance, he probably does not pay much conscious attention to the little white dot in the center of each finger hole. But to the Bell System, these dots have real value in reducing circuit-holding time.

The utility of such features stems from the actions of the customer while he is using a telephone set. When he holds the telephone receiver off the hook, he is keeping equipment busy and therefore unavailable to other customers who might want to use their phones at the same time. Since the telephone company must consequently spend money to provide extra circuits, the Bell System is very conscious of circuit-holding time. Every new piece of equipment to be used in the System is normally made so that circuit-holding time will not be increased. The telephone dial is one of these, and the Laboratories is constantly working to improve it so that the customer will be able to dial his number as quickly and accurately as possible. Prior to any field trial, each new design of dial must be tried out in the Laboratory. To evaluate the utility of the new 500-type telephone set, for instance, it was necessary to determine its comparative speed and accuracy.

Two special test rooms and associated equipment were constructed to determine the utility of dialing devices. One of these, furnished as a private office, is where the dialing is done. To avoid distracting the participants, a large partially silvered mirror is mounted in one wall, through which he cannot see, but which permits the test director to observe his actions. On the table there is a telephone, a ready reference directory with the names and telephone numbers he will be asked to call, a pad and pencil for notes or doodling, and two pieces of test equipment. The first of these is the "ready" switch which he is asked to press when he is ready to start a task. The second is a small cabinet mounted immediately in front of him on the table. This cabinet has a window which, when opened, will reveal the name of the party to be called. This is referred to as the "stimulus unit." A few current magazines are scattered on the desk in an attempt to relieve the test atmosphere. The participant is encouraged to take time out between calls to look at these, to comment on whatever subjects interest him, and to relax.

The test director and his assistant and the test equipment are located in the second room. The test director sits at a desk behind the one-way mirror to observe the dialer in action and take notes that may help later to explain anything unusual in the results.

On his desk there is a lamp which lights when the dialer presses the "ready" switch, and a control for the stimulus unit. When the director turns this control to the desired name, it simultaneously turns the stimulus unit and a similar unit on the test assistant's desk to the same name. When the ready lamp lights, the director presses a switch that opens the window shutter of the stimulus unit revealing the name to be called. All operations, including looking up the number, if it is unfamiliar to the dialer, are timed automatically, and a record of the dial pulses furnishes complete information on timing and accuracy. To know immediately whether a number is being dialed correctly, there is a dial pulse counter on the test assistant's desk.

The normal telephone signals are used to make the call seem as natural as possible. If the dialing is completed correctly, the test assistant presses a switch, and the caller hears the distant phone ring as he would an actual call. After a suitable period, the test assistant answers the call as though she were the party called, and a conversation ensues which relaxes the caller and makes him less test-conscious. If a wrong number is dialed, the test assistant acts as an intercept operator and asks the participant, "What number did you call please?" She then requests that he look up the number again and redial it.

New ideas for dial number plates and other dialing devices have been tested by these facilities. The design of the 500-type telephone set, for instance, required extensive utility testing of a number of features relating to the dial and particularly to the dial number plate. The design had to assure dialing convenience, accuracy, and rapid performance in the hands of the dialing public. Also required were favorable production costs, low maintenance, and good appearance.

Such problems as color contrast and typography of the number plate, the relation of the number plate to the fingerwheel and the design and material of the fingerwheel were all examined, in many varieties and combinations. In this way there was assurance that the finally accepted design was properly coordinated with the pertinent characteristics of the people who use it.

Those engaged in the testing procedure considered both the psychological and physical factors that affect dialing. Many people were observed as they dialed to determine how they approached the job, what difficulties they seemed to have, how one dialer differed from another. There are fast dialers, medium speed dialers, slow dialers. There are people who memorize the number and those who write it down before dialing. There are different types of eyesight. Some people use reading glasses, some wear bifocals, some take their glasses off to dial. There are people with large fingers and some with irregular fingers. There are left-handed dialers. Other less obvious but nevertheless significant differences between individuals were also found, and in the dialing tests, participants with one or more of all these characteristics were used so that the panel would be representative of the dialing public.

Certain general considerations of appearance, maintenance, and convenience tended to channel development toward a set with a low, sweeping contour, and with letters and numbers that are visible over a wide angular range. These letters and numbers also had to resist the destructive wear caused by pencils and the like often used for dialing. Such considerations led naturally to a number plate with the numbers and letters outside of the fingerwheel rather than underneath.

This general answer, however, required much utility testing of detailed variations, and necessitated successive modifications leading to the finally accepted design. One example will illustrate the nature of this work. On an earlier model of the 500-type set, the white letters and numbers were placed outside the wheel on a black surface somewhat lower than the fingerwheel. This design gave good visibility and finger action, but it was found that the dialing time was slower than with the older 302-type set. From observing the participants while dialing, it was noticed that the time loss occurred at the end of the period during which the fingerwheel was returning to its rest position. The dialer was slow to recognize when the dial had returned to rest, presumably because the black fingerwheel was revolving over a plain black surface. This difficulty was remedied by inserting a white dot in the center of each finger hole. The resulting number plate was the one adopted for the new 500-type telephone set.

As a result of these utility test methods, designers were assured in advance of production that the new 500-type set would have several advantages. Circuit holding time and errors are minimized, the letters and numbers are more visible and more durable, and when the customer is looking at the dial from an angle, dialing time is decreased.

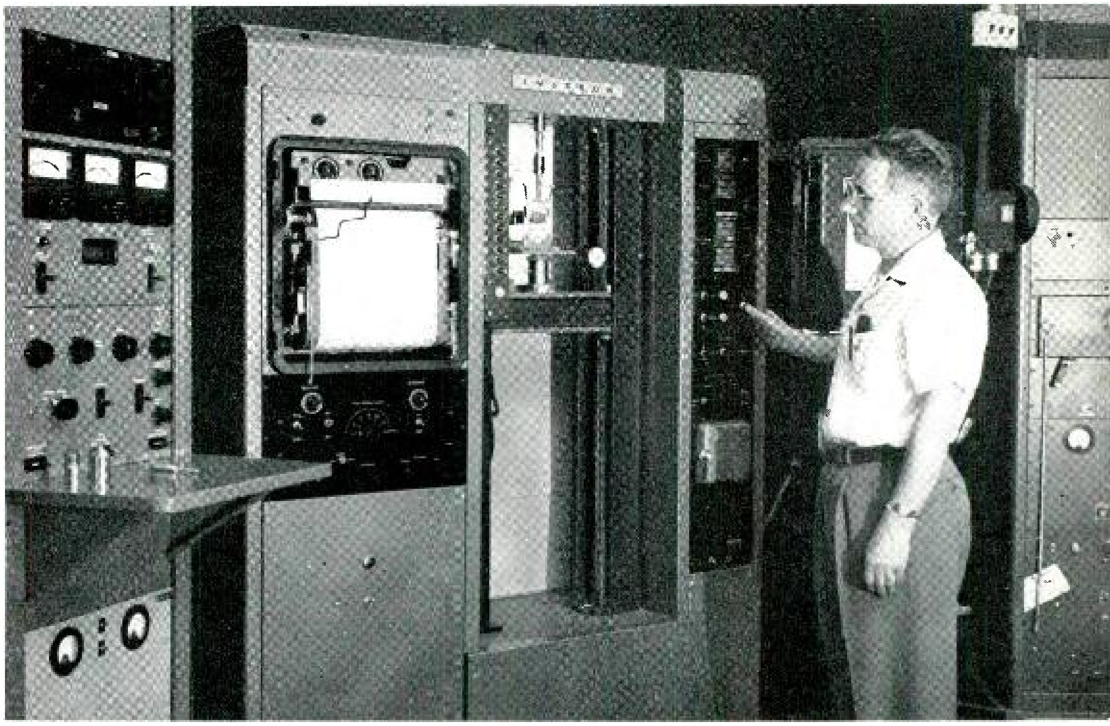
R. Black
Mrs. H. K. Cunningham
Station Apparatus Development

Continuously Recorded Relay Measurements

E. G. WALSH *Switching Apparatus Development*

Apparatus design and development frequently require extremely precise measurements of force as a function of motion or displacement. In a telephone relay, for example, the mechanical load of springs must be measured and correlated with various values of magnet pull. Heretofore, this has been done by laborious plotting of data derived from individual measurements. Now Laboratories engineers have found a way to eliminate such tedious methods by adapting a commercial measuring machine to their peculiar requirements. Using this new machine, it is possible to measure a wide range of conditions and values with very high accuracy.

In the design and development of apparatus, one of the basic considerations is that of force as a function of motion or displacement. Typical applications applying to telephone work include studies of springs of all types, the development of spring loads on relays, switches, and keys, measurements of the pull developed by electromagnets at various power levels, and determinations of the strength and stability of materials. In such telephone applications it is frequently necessary to measure forces as low as one gram with an accuracy of one-tenth gram, or to measure forces as high as several hundred pounds. Displacements must be measured over a range from 0.001 inch, with an accuracy of 0.0001 inch, to as



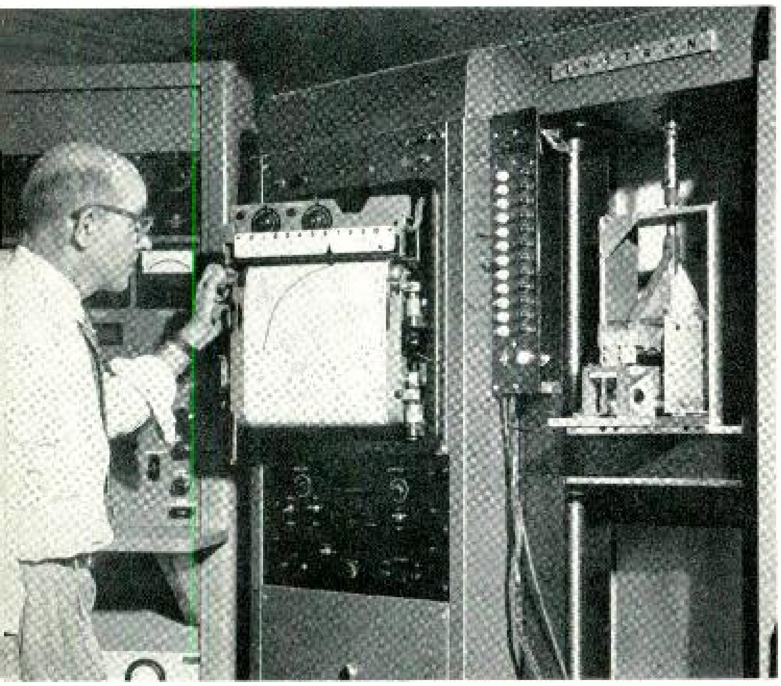
A wire-spring relay being tested by B. Stauss. The automatic pen-type recorder gives a complete, continuous graph of the load and pull characteristics.

great as one inch. Since it is not unusual to find that a project requires hundreds of such measurements, it is important that the measurements be obtained, not only accurately, but easily and rapidly.

Over the past several decades, force-displacement measurements have been made in a variety of ways, depending upon requirements of the project as to range and accuracy. In general, these methods used either "dead weights" or a calibrated spring gauge to measure force, and an accurate thickness gauge or calibrated scale to measure displacement. One such measuring system was an adaptation of a pendulum-type tensile testing machine, for measuring the pull of a magnet with greater ease.* Another device, for measuring load-displacement in relays, was a special type of spring balance designed for that purpose.† However, all these methods involve point-by-point measurements and require tedious repetitions of readings and plotting of curves. Some means was needed for automatically making and recording these measurements over a range from a few grams to several hundred pounds, with the required accuracy.

A machine that came close to fulfilling these requirements was announced in 1949 by the Instron Engineering Corporation.‡ Engineers in the apparatus magnetics studies group requested some modifications that would make the machine applicable to their work, and the modified machine was purchased

Fig. 1 — E. C. Meuer measures the operating magnet from a card translator. Note the heavy jig required.



in 1950. The headpiece shows the machine during a relay test. Basically, it is a tensile-testing machine of the type used in materials-testing laboratories. One end of a specimen is firmly attached to an upper stationary crosshead, and the other end to a lower movable crosshead. Accurately machined lead-screws move the lower crosshead down, applying tensile force to the specimen.

It would, of course, be possible to operate a pen-type recorder directly from the mechanical motions involved, but it was found more convenient and more accurate to change these motions to electrical signals, which then operate the recorder. A block diagram of the machine, as adapted to Laboratories' requirements, is shown in Figure 7. A device called a load cell is used as the top support for a specimen under test, and several interchangeable load cells give the machine its extremely wide range of force measurements. Figure 2 shows the author holding a load cell and pointing to the linkage with which a mounted load cell connects to the specimen. This device provides signals that produce horizontal motion of the recorder pen, and a special adaptation of the machine provides signals that cause the vertical motion of the paper to indicate displacement of the movable crosshead. After the paper is removed from the recorder, it is turned counterclockwise ninety degrees. This then gives a graphical representation with force and displacement in their usual positions.

In relay testing, a special jig is attached to the movable crosshead, Figure 3, to hold the relay core-structure rigid on the crosshead. The relay armature, which is free to move, is coupled to the load cell by a yoke. If the crosshead is now moved a distance equal to the armature travel of the relay, a curve will be drawn on the recorder representing the spring load of the relay. In Figure 5, such a load curve is shown for one particular code of the wire spring relay. The bank of lights mounted on the machine, Figure 3, is connected to the relay contacts, and indicates limits of travel within which all contacts are operated. The recorder is so arranged that marker "pips" can be superimposed on the load curve at these limits, by the operator pressing a button.

Figure 5 also shows that different load curves occur for different directions of armature travel, separated by a small, nearly constant distance on the paper. Frictional forces developed between the moving parts are always in such a direction as to oppose the motion. One curve is shifted along the force scale in

*RECORD, *June*, 1953, *page* 211. †RECORD, *June*, 1953, *page* 215. ‡ELECTRONICS, *May*, 1949, *page* 101.

one direction by the frictional forces, and the other curve shifts in the other direction. The small force measurable between the two curves is thus twice the frictional force.

To measure magnetic pull, the relay must be taken from the jig and inverted, and the spring load must

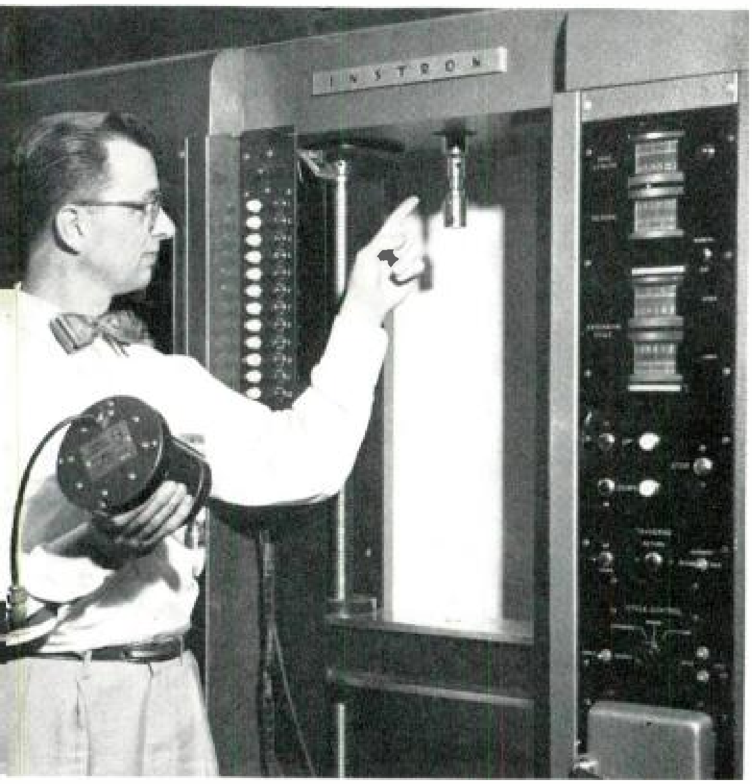


Fig. 2 — The author points to the linkage by which the load cell connects to a load, while holding another load cell.

be removed. Measurements are then made as for load, for several values of constant current in the winding. The resulting family of curves for a typical magnet of a wire spring relay is shown in Figure 4. A look at this family of curves will show that at zero ampere-turns in the winding, the curve does not lie along the zero axis for pull. This discrepancy represents the stiffness of the armature-spring. It is of little importance in most cases, since it is a small error, but it should be taken into account when measuring low values of pull. A circuit could be included in the machine to compensate for this error, but it has not been found necessary as yet. A correcting circuit is included, however, for a similar discrepancy in the displacement.

It is obvious that when a force is applied to a relay under test, it is bound to cause a certain amount of deformation of the mounting jig. In figure 4, if a displacement correcting circuit were not used, each curve would be shifted slightly to the right at its upper end, the amount being proportional to the force at that point. The pull curves would then all lie to the right of the vertical axis, just as they lie above the horizontal axis because of the uncorrected armature-spring deflection. Correction for deformation of the jig is necessary since this effect is not present in normal relay operation.

A much simpler and faster method of calculating pull can be used, without disturbing the relay after a regular load measurement run. If a dead weight is hung on the armature, a new load curve results. This is the same curve as before, but displaced on the force scale a distance corresponding to the known weight. The new load curve must exceed the pull curve at all points. When a known current is then passed through the winding and a measurement run taken, the machine will indicate the algebraic sum of the forces acting on the armature, Figure 6, or the difference between the new load curve and the pull of the magnet. The true pull curve can then be reconstructed from this information. This procedure saves considerable time in those cases where only one pull measurement is required, since most of the time is used in setting up the equipment. The continuous curves drawn by this machine also show small irregularities in pull and load that were not observable with previous methods.

As an example of extremely small measurements possible with this machine, tests made on individual wires of a wire-spring relay gave a very good straight

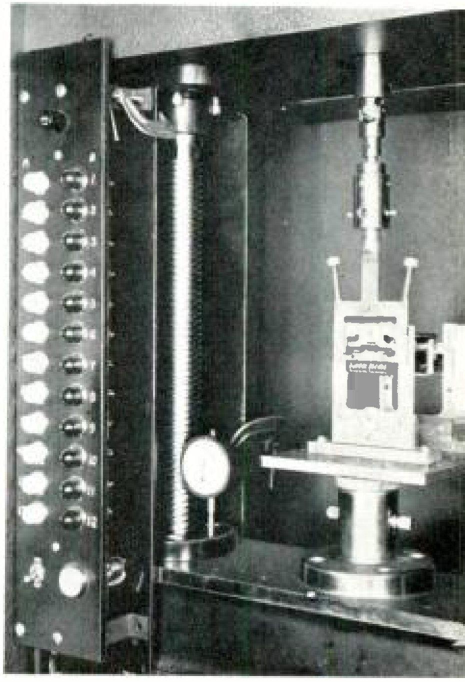


Fig. 3 — A close-up of the operating parts of the Instron machine. A special jig is bolted to the movable crosshead, to support the relay under test. The bank of lamps indicates when individual relay contacts make and break.

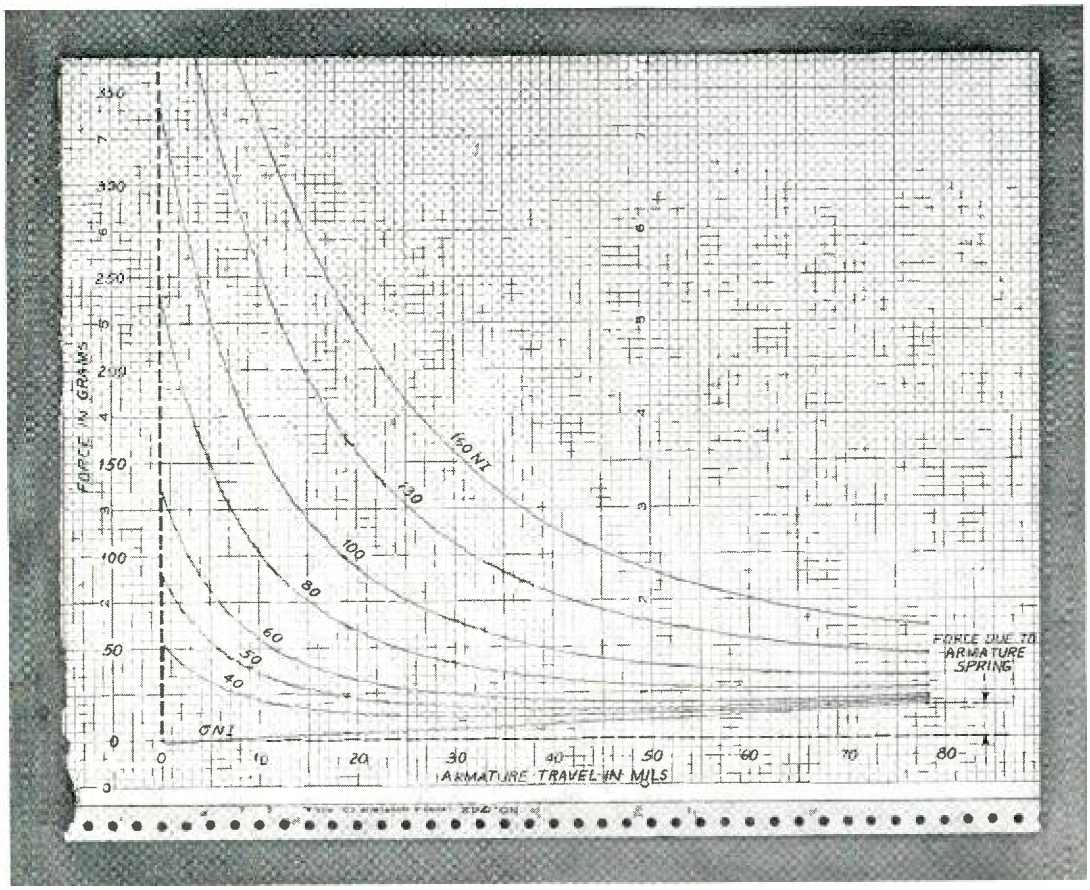


Fig. 4 — A family of pull curves for a wire-spring relay.

line from zero to maximum. Although the deflection of the wire was half an inch, the maximum force required was only nine grams! At the other extreme, tests made on card translator magnets went as high as 600 pounds for normal magnet gaps. This magnet is used to lift the magnetic metal code-cards in the translator. The maximum of about 1,000 cards weighs approximately 85 pounds, and they are normally separated from the pole-face by 0.021 inches. Far more than eighty-five pounds is required, however, for fast operation and to insure that all of the cards will be lifted when some cards lift before others. Figure 1 shows the heavy jig required for testing this magnet.

Naturally, a machine capable of such extremes of measurement and, at the same time, such accuracy, is fairly complex. As mentioned previously, the load cell is responsible for the machine's efficiency. This is a special arrangement of standard electrical strain-gauges, using familiar principles. If a force to be measured is applied to a cantilever beam or a tension bar, and is kept to a value less than the elastic limit of the material, the resulting strain, or deformation, of the material will be proportional to the force. If a special type of resistance-wire is bonded to the beam or bar in its normal position, then any strain in the beam or bar will be accompanied by a strain in the wire. This changes its resistance, and the change can be measured electrically. The Instron machine uses four of these bonded-wire type strain-gauges connected as the arms of a Wheatstone bridge. The four gauges are all enclosed in the single unit called a load cell. The use of interchangeable load cells, Figure 2, of different ranges results in high sensitivity for measuring small forces and a wide range of full-scale load sensitivities.

A stabilized 390-cycle oscillator drives the bridge, and output from the bridge is amplified and rectified. Horizontal travel of the recorder pen is controlled by this rectified signal, giving an indication of applied force. Controls are provided for balancing out initial loads and for varying the sensitivity. These permit setting the full-scale load value and calibrating the scale of the recorder.

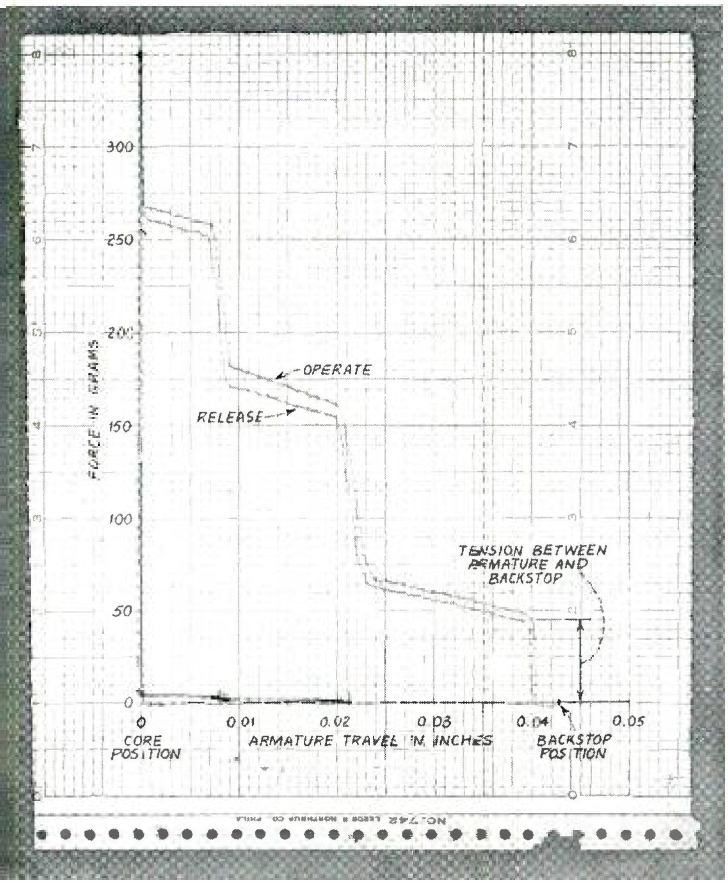


Fig. 5 — A typical load curve of a wire-spring relay. The double curve results from measuring with the crosshead moving both up and down.

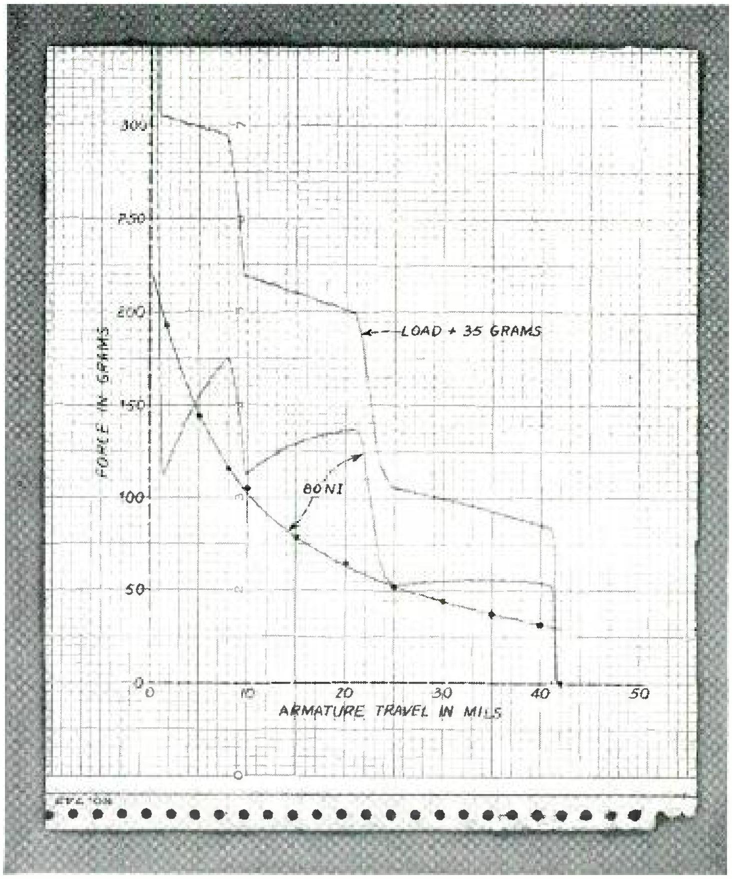


Fig. 6 — A single pull curve may be plotted from a load curve that is measured with a weight hanging from the relay armature and current in the coil.

In measuring displacement, the use of ordinary gear-drives for the movable crosshead and for the paper of the recorder would result in considerable backlash between the two geared units. The crosshead and paper would be out of step most of the time, and motion of the paper would not accurately indicate motion of the crosshead. Admittedly the error would be small, but then so are many of the measurements desired.

A mechanical connection from the lead screws tells a reference circuit the position of the movable crosshead, and the operator sets the proper dials to the desired amount of displacement from that starting position. Operation of the control switches sets a drive unit in motion, which in turn drives a potentiometer. This potentiometer has a power-driven brush, and as the position of the brush varies, so does the voltage picked up by the brush. A motor inside the recorder includes in its circuit another potentiometer, and will drive the paper until the two potentiometer voltages are equal and then stop. The position of the paper thus represents the reference position of the drive unit at all times. This reference, or desired, position is fed to one side of an error-detecting selsyn. Such a device is capable of producing an output proportional to the difference between two separate inputs. Another selsyn, mechanically coupled to the movable crosshead, feeds a signal representing the actual position of the crosshead into the second side of the error-detecting selsyn. Output from the error-detecting selsyn is then proportional to the difference between the desired and actual positions.

This error signal is very small, and is therefore fed to an amplifier. The amplified signal controls an amplidyne, which in turn drives the crosshead motor. An amplidyne is a special type of electric generator that acts very much like a power amplifier. A small input power can control a large amount of output power, and over a wide range of values. Thus the small signal from the electronic amplifier is boosted to a value suitable for driving the crosshead motor.

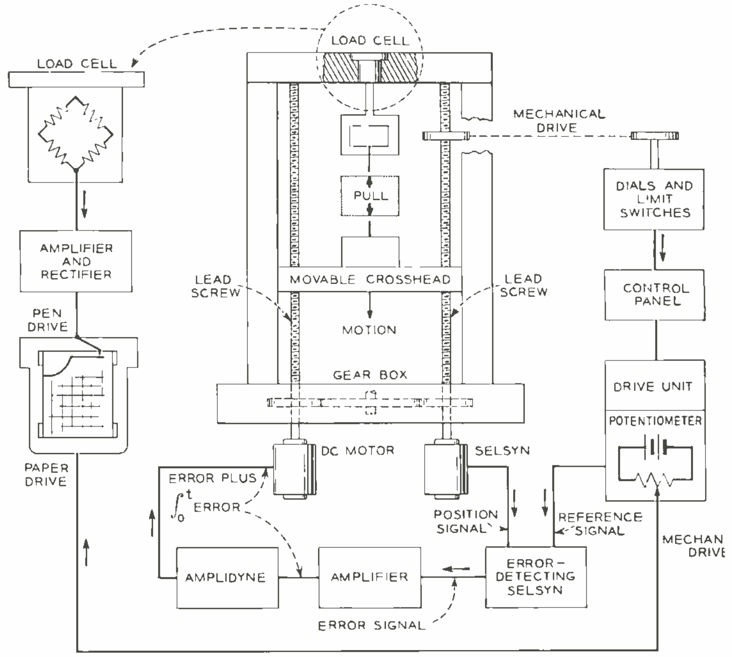


Fig. 7 — A block diagram of the Instron machine which schematically illustrates the load-weighing system and the displacement system. The load cell can be interchanged with other similar cells to cover different ranges of force. The general drive for the crosshead is variable to allow the crosshead to be driven at different rates of speed.

The arrangement is such that any difference between the actual and desired positions causes the system to correct for the difference, reducing it nearly to zero.

In a servo with integral control, the positional error can be eliminated but a small error will still exist for constant velocity motion. Such an error can be minimized by operating with low velocities, and this is done when accurate measurements are necessary. In the Instron machine, the servo has integral control because of circuits in the amplifier. Output from the amplifier is proportional, not to the error alone, but to the error *plus* the time integral of the error. This means that the longer an error exists, the greater will be the correction; all corrections are therefore faster and more complete.

By using a high-range load cell and an auxiliary amplifier on low values of loads, the small error resulting from deformation of the strain-gauges is made negligible; very slow operation of the machine gives nearly static measuring conditions. With this arrangement, the required accuracy at very low loads can be realized.

The versatility of such a machine is limited only by its associated circuits, since its output voltages are proportional to force and displacement. Suitable auxiliary apparatus can be used either to multiply or to change these outputs to logarithmic functions. Under such conditions, the machine could be used to plot such functions as work versus displacement, or to make logarithmic plots.

THE AUTHOR

EDWARD G. WALSH, a member of the Laboratories since 1935, attended Cooper Union night school to receive his B.S. degree in chemical engineering in 1940 and then did graduate work in physics at Columbia University. In his early Laboratories work he was associated with the development of solderless connections and step-by-step preformed cable. He was also concerned with the development of the reed pushbutton and executive station telephone sets. During World War II he devoted time to military projects on the electrical gun computer as well as magnetic proximity fuses. Since then he has been engaged in development on various kinds of relays, and has recently been in charge of a group working on development problems of wire spring relays. For several years he has been active in teaching relay design in the CDT program. He now supervises a group analyzing special magnetic and contact problems involved in relay design.

M. H. Cook New Vice President Succeeding W. H. Martin

M. H. Cook

W. H. Martin

Morris H. Cook has been elected a Vice President of the Laboratories, effective January 1, 1954, succeeding William H. Martin, Vice President in charge of station apparatus and outside plant development, quality assurance, and design engineering. Mr. Martin has accepted an appointment from the Government to serve as Deputy Assistant Secretary of Defense for applications engineering.

Mr. Cook, who has been Director of Design Engineering at the Laboratories since January, 1950, has been with the Bell System for more than twenty-eight years. He received his Bachelor of Science degree in 1921 from the University of Illinois, and was a member of Eta Kappa Nu and Sigma Tau, serving on the national council of the latter from 1928 to 1938 and currently since 1952. During his college years he worked as a draftsman and machine designer, and later as chief draftsman for a manufacturing firm in Chicago. In 1923, he joined the Western Electric Company as an engineer, but resigned the following year to become chief engineer with another corporation. He rejoined Western Electric at Hawthorne in 1926 as a department chief in the Engineer of Manufacture organization on station apparatus and later on Step-by-Step Assembly and Wiring Development.

In 1929 he was made Development Engineer for Station Apparatus, first at Western's new Point Breeze Works and later in the Hawthorne organization in charge of engineering the first Hand Telephone Set Shop. In 1939 he was Manufacturing Engineer for Panel Dial and Step-by-Step exchange equipment. In 1940, he became Superintendent of Manufacturing Engineering for the Station Apparatus Shops and in 1941, with the start of the military program at Hawthorne, he took the same post in the Hawthorne Special Apparatus Shops. Transferring to the Laboratories in 1944 as Director of Specialty Products Development at Whippany, he had also served as Director of Apparatus and Systems Engineering and as Director of Standards and Drafting before becoming Director of Design Engineering.

Mr. Martin, as Vice President, has been responsible for station apparatus, outside plant, and underwater development systems, as well as quality assurance and design engineering. He received a Bachelor of Arts degree from Johns Hopkins in 1909 and a Bachelor of Science degree from Massachusetts Institute of Technology in 1911.

He then joined the American Telephone and Telegraph Company and was engaged in local transmission work in the Engineering Department. When the Department of Development and Research was formed in 1919, he was put in charge of a group doing transmission development work. This department became part of Bell Telephone Laboratories in 1934, and Mr. Martin continued these responsibilities as Local Transmission Development Director until 1935. In that year he became Assistant Director of Transmission Development and in 1937 he became Switching Research Director.

From 1940 to 1944, he was Director of Station Apparatus Development becoming Assistant Director of Apparatus Development and Director of Station Apparatus in 1944. In 1947, he was made Director of Apparatus Development II, and in 1949 he accepted the position of Vice President.

During the last war, Mr. Martin was in charge of Bell Telephone Laboratories' military activities in acoustic and undersea warfare devices. In recognition of this service, he received a Presidential Certificate of Merit.

Bell System Organization Changes

Eugene J. McNeely

H. Randolph Maddox

James W. Cook

Several Bell System executive changes, effective January 1, 1954, have recently been announced by the American Telephone and Telegraph Company and by the Associated Companies concerned.

Eugene J. McNeely, Vice President in charge of the Personnel Relations Department of A.T.&T., will assume the duties of Vice President in charge of Operation and Engineering, succeeding Frederick R. Kappel who was recently elected President of the Western Electric Company. Mr. McNeely is also a member of the Board of Directors of the Laboratories.

H. Randolph Maddox, President of the Chesapeake and Potomac Telephone Companies since 1947, was named as Mr. McNeely's successor.

J. B. Morrison, President of the Wisconsin Telephone Company, was elected President of the Chesapeake and Potomac Companies to succeed Mr. Maddox.

James W. Cook, Vice President of Northwestern Bell Telephone Company, was elected a Vice President of A.T.&T., succeeding Charles E. Wampler in charge of revenue requirements studies. Both Mr. Maddox and Mr. Cook become members of the Long Lines Department Board.

Mr. Wampler has been elected President of the Wisconsin Telephone Company to succeed Mr. Morrison.

All the officers come to their new posts with broad backgrounds of Bell System experience. Mr. McNeely started as a student engineer with Southwestern Bell in St. Louis, Mo., in 1922, and for three years prior to joining A.T.&T. in 1952 was President of Northwestern Bell. Mr. Maddox began his career as a student engineer in Washington, D.C., and has been associated with the Chesapeake and Potomac Companies for over thirty years. Mr. Morrison began his telephone career with the Chesapeake and Potomac in Washington in 1925 as a plant engineering assistant, rose to the position of Vice President and General Manager, and in 1948 moved to the Wisconsin Company to become operating Vice President and then President. Mr. Cook started with the New Jersey Bell Telephone Company in 1929 as a traffic student, later filled posts with The Pacific Telephone and Telegraph Company, and became a Vice President of Northwestern Bell in 1947. Mr. Wampler began his career with the Illinois Bell Telephone Company in 1929, working his way to Assistant Vice President in the O&E Department of A.T.&T. in 1950 and Vice President in 1951.

Charles E. Wampler

J. B. Morrison

Transatlantic Telephone Cable to Become a Reality

Plans to construct the first telephone cable system across the Atlantic Ocean, the culmination of a quarter of a century of planning, research, and development, were announced recently by the American Telephone and Telegraph Company. It will be by far the longest underseas voice cable in the world and the first laid at depths found in mid-ocean.

The announcement stated that an agreement had been signed for construction of the cable, by A.T.&T., the British Post Office, the organization that provides telephone service in Great Britain, and the Canadian Overseas Telecommunication Corporation, which furnishes overseas communications for Canada. It will be owned jointly by these three organizations. The American Company's responsibilities for the project will be carried out by the Long Lines Department working in conjunction with Bell Laboratories and the Western Electric Company. Work will begin immediately on the project, which will cost $35,000,000 and take three years to complete.

This cable will mean greater reliability in transatlantic telephone conversations and greatly expanded facilities. It will provide physical telephone connection between the American continent and the British Isles to supplement radio circuits now in use, and will have three times the present circuit capacity.

The submarine telephone cable system will contain a group of telephone circuits between New York and London, and another group between Montreal and London. At the gateway cities the circuits will connect with the telephone systems of the respective countries.

Spanning the Atlantic with a cable system capable of carrying telephone conversations will be the achievement of a goal visualized many years ago. Many technical and economic problems had to be solved before construction could be undertaken. Developments of the past few years in the art of telephony and the growing demand for overseas service have now made it technically and economically feasible to proceed.

The transatlantic portion of the system, with its many vacuum tube repeaters, will be 2,000 nautical miles in length and will be laid in depths up to three miles on the ocean floor between Scotland and Newfoundland. It will then connect with another submarine cable extending 300 miles westward to Nova Scotia. From there, a 350-mile over-

W. Klute, right, and Gilbert O'Connor perform equalization tests on a model of a submarine cable repeater. The units of the repeater are assembled as they would be in an actual repeater.

land microwave radio-relay system will be built to carry the transatlantic circuits to the United States border where connections will be made with the Bell System network.

Development of the technical design for the deep sea section of the cable project has been under way in Bell Telephone Laboratories for several years. Research by British telephone engineers has produced the design for the Newfoundland-Nova Scotia section of the submarine cable. As a result, the project will make use of the experience of both the Bell System and the British Post Office.

A. H. Schafer, M. C. Wooley, and B. Slade examine a component being developed for the submarine cable repeater.

Some years ago the Bell System recognized that steadily increasing telephone traffic between the United States and the British Isles, together with the limited amount of radio frequency space available for such traffic, called for a new, long-range approach to the problem of overseas telephony. Thus the problems of a submarine cable linking the two countries were undertaken.

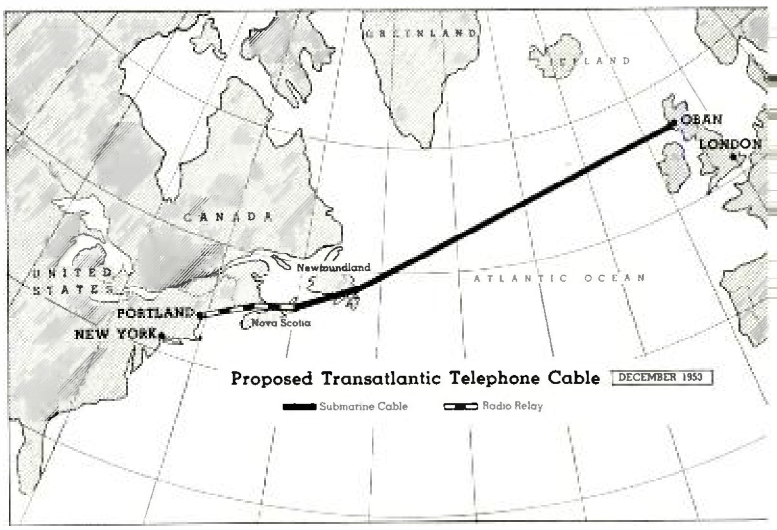
Such a cable would be impossible, however, without a means of amplifying, or "repeatering," the tiny electric currents carrying telephone voices, lest they fade away to nothing, long before they could reach their destination across the ocean. Methods of amplifying such currents have been used since the electron tube made possible the first transcontinental telephone line in 1915, and are commonplace on the many long-distance cables which criss-cross the nation today.

But a submarine cable presented a unique and highly complex problem in that the amplifiers, or repeaters, must lie on the floor of the ocean, in some places more than two miles below the surface, where they are subjected to tremendous pressures of several tons per square inch. Furthermore, such repeaters, with their electron tubes and many other associated parts, must attain an extraordinary degree of reliability and be free from maintenance attention.

When Bell Telephone Laboratories began its studies of deep-sea submarine cable under the leadership of Dr. Oliver E. Buckley, shortly after World War I, the required reliability was unheard of. After a dozen years of intensive research and development, however, including a cable-laying trial in the deep waters of the Bay of Biscay, submerged repeaters appeared to be a practical possibility. Further work led in 1940 to the experimental design of a deep-sea submarine cable system, but World War II put an end to active work at that time.

After the war, this design was reviewed and the results of years of research and laboratory life-testing were incorporated in the installation in 1950 of a submarine cable system between Key West and Havana, a distance of about 120 nautical miles with ocean depths up to one mile. This installation was made to provide additional circuits which were found necessary to take care of the demands for service and, in addition, provide practical experience with the new type of underwater repeater. The Key West-Havana system, composed of two cables, one for each direction of transmission, contains a total of six repeaters. They have given fault-free service since they went into operation.

The problem of extending a system of less than 200 miles to one of 2,000 miles, called for an even higher degree of precision, for the smallest irregularities or variations in the electrical characteristics



Above is the general route of the projected transatlantic telephone cable system, which is to be provided jointly by the American Telephone and Telegraph Company, the British Post Office and the Canadian Overseas Telecommunication Corporation.

of the system could upset the fine balance that must be maintained between loss in the cable and periodic "boosting" by the amplifiers.

Like the Key West-Havana cable, the transoceanic cable will be of the coaxial type consisting essentially of a copper tube, through the center of which runs a single copper conductor, properly insulated from the surrounding outer conductor. High-molecular weight polyethylene is used for insulation.

The cables will be not quite two-thirds of an inch in diameter at the outer conductor. They will be protected against the teredo worm, a marine borer, by wrappings of copper tape. Outside this will be wrappings of heavy jute, steel armor wires for mechanical strength and an outer wrapping of jute to prevent corrosion of the armor wires. The deep-sea sections will be about an inch and a quarter in over-all diameter.

On the 2000-mile main section, two cables will be used, one for east-west transmission and the other for the reverse direction. Together the pair of cables will accommodate thirty-six high-quality telephone conversations simultaneously.

The amplifiers, or repeaters, will be in flexible, pressure-resistant housings. These are shaped like tubes and will appear simply as bulges in the cable. This will permit them to be fed smoothly around the drums and sheaves of the cable ship so that the cable and repeaters can be laid on the ocean floor as a continuous operation.

The repeater housings are only about two inches in diameter under the armor and about seven feet long. Each consists of a thin-walled copper tube, supported internally by over-lapping steel rings, which are capable of withstanding sea pressures up to five tons per square inch. At each end of the housing is a series of three water-tight seals, which taper down to the diameter of the cable itself. The entire housing for the repeater assembly is about 20 feet long.

There will be about fifty such repeater units in each of the cables on the main 2000-mile crossing and they will be spaced about 40 miles apart. Each repeater will consist essentially of a three-stage feed-back amplifier, so that there will be more than 300 long-life electron tubes lying on the ocean floor, together with some 6,000 other electrical components, all designed for reliable, trouble-free operation for twenty years or more.

Electrical power to operate the amplifiers will be fed to them over the central conductor of each cable from the terminal stations on shore. This will require some 2000 volts at each end. The design of the terminal power plant will place special emphasis on current regulation, continuity of service and protection against power surges.

Bell System overseas service opened on January 7, 1927, with a single radiotelephone circuit connecting New York to London. During the first year, service rapidly expanded between the two countries and nearly 2,500 calls were completed. Since then, the service demand to Great Britain has multiplied by more than 30 times. Last year, for example, some 75,000 conversations were completed to Great Britain. The Bell System now furnishes telephone service to 102 foreign countries and annually handles about 1,000,000 overseas messages.

J. O. McNally, W. O. Sharp, W. Gronros, and E. A. Veazie discuss details of the electron tubes used in the submarine cable repeaters.

President Eisenhower Receives the 50-Millionth Telephone

President Eisenhower recently received a new desk telephone, presented to him by Cleo F. Craig, president of the American Telephone & Telegraph Company, and Warren B. Clay, president of the United States Independent Telephone Association. The new telephone, a special 500-type set, is the 50-millionth telephone in the nation.

As he placed the telephone in the hands of President Eisenhower, Mr. Craig said that its presence in the White House would be a further reminder to telephone people of their responsibility to the nation.

"Some 5,300 companies and 800,000 employees," he said, "work closely together at the job of bringing people together by telephone. We are grateful to the American people who have given us such opportunity, and we intend to keep on providing them with the best telephone service in the world."

Installation of the 50-millionth telephone means that the United States has more telephones than all the rest of the world combined. Today there is one telephone to about every three people in the country and, as Mr. Craig said in conversation with President Eisenhower, "None of us has any idea of stopping at 50 million."

The 50-millionth telephone was commemorated on the evening of the presentation at a dinner in the Presidential Ballroom of the Hotel Statler in Washington. Over 300 guests, including government officials and representatives of the nation's telephone industry, attended the dinner. The principal address was given by Postmaster General Arthur E. Summerfield and brief talks were made by Mr. Craig, representing the Bell System companies, and by Warren B. Clay, representing nearly 5,300 independently-owned telephone companies.

In his talk at the commemorative dinner, the Postmaster General said that the communication of ideas and thoughts among free men and women is a "keystone of American liberty," and that communications serve to bind the people of our country together. "Communications," he went on, "are the nerve systems of commerce, industry and our social life. They are the good strong right arm of national defense, essential to our security as a nation, indispensable in times of war as in times of peace."

Speaking in behalf of the Bell System companies, Mr. Craig described President Eisenhower's acceptance of the 50-millionth telephone as "a gracious and inspiring recognition of the part we play in the life of the nation."

Mr. Craig expressed the hope that telephone people would never forget the true nature of telephone service. "The real meaning of 50 million telephones is not in their total number but in the people we bring together in every community in the land."

In a friendly tribute to the independently-owned telephone companies, Mr. Craig said that Bell people were pleased to take part with the independent

President Eisenhower listens with interest as Cleo F. Craig (right), president of A.T.&T., explains special features of the presentation telephone.

companies in marking the joint achievement of the 50-millionth telephone. He described all telephone people, everywhere, as "co-authors of the telephone story."

In commenting on the President's Inaugural Address statement that "destiny has laid on our country the responsibility of the free world's leadership," Mr. Craig said, "The nation's capacity for leadership in the free world begins with unity at home. If Americans are to come together and work together with greatest effectiveness, they must be just as free as possible to talk with each other. They must learn from each other, think with each other, plan with each other, grow with each other. They must communicate. And they must be able to do so with complete ease and freedom, wherever they are and whatever their need."

Mr. Craig said that by being "good neighbors," telephone people could help to make a "nation of neighbors." He said: "That is the way, and the only way, for us to keep on increasing our contribution to the unity of our country, the strength of free people, and hope of peace in the world."

In behalf of the 5,300 independently-owned telephone companies, Mr. Clay stated that the phenomenal development of the telephone industry in this country "was made possible by the initiative and incentive that have been inspired by an atmosphere of freedom and free enterprise in a nation of free men.

"The 5,300 independent telephone companies," he concluded, "are proud to be a part of the United States telephone team. They are proud to be pulling with our good friends in the Bell System in doing a progressively bigger and better communications job for the American people."

The Record's New Appearance

Regular readers of the RECORD will observe — with approval, it is hoped — that with this issue, No. 1, Volume XXXII, the RECORD appears in a new format. The major feature of this is the increased page size, now 8½ by 11 inches as contrasted with the 7 by 10 inches size in which the RECORD has appeared since its first issue.

The change has been made for several reasons, not the least of which is that the larger size has become more or less accepted as standard for many technical magazines of the RECORD'S character and content. This larger size is believed to afford easier reading and more convenient handling, in addition to providing greater opportunity for attractive display of illustrations and drawings. Readers may have noticed during the past year an increased use of pictures, particularly those showing members of the Laboratories operating apparatus and equipment described in the various articles. By changing from a tinted paper to a coated white stock, better reproduction of the illustrations can be achieved.

The purpose of the RECORD, of course, remains the same — to provide in easily readable form an accurate and reasonably complete record of the more significant technical activities of Bell Telephone Laboratories for those interested in the progress of the communications art. Especially the RECORD is aiming at giving its readers a balanced picture of the work of the Laboratories, telling them not only what was done but why it was done and how it fits into the over-all picture, so that the readers can readily relate specific developments to the needs and objectives of the Bell System.

It may be of interest to note that the printer's order for this issue is nearly 18,000 copies. Approximately a third of these are for distribution to members of the Laboratories to whom the RECORD constitutes an information channel on work being done in areas of the Laboratories other than their own. Another third of the RECORD circulation is for distribution in the associated companies of the Bell System. The remaining third goes primarily to colleges, universities and technical schools, libraries, government offices, scientific and engineering societies, independent telephone companies and others interested in the work of Bell Telephone Laboratories. More than 1,000 copies are distributed abroad. The RECORD goes to sixty-four foreign countries, and to Alaska, the Canal Zone, Hawaii and Puerto Rico.

Talks by Members of the Laboratories

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

Baird, J. A., Transistor Operation and Applications, A.I.E.E.-I.R.E. Student Branch, Agricultural and Mechanical College of Texas, College Station, Texas.

Beck, A. C., Microwave Testing with Millimicrosecond Pulses, I.R.E. Professional Groups on Microwave Theory and Techniques, Tubes, and Systems, New York City.

Becker, J. A., The Life History of Adsorbed Atoms, Ions, and Molecules, New York Academy of Sciences, New York City.

Bennett, W. R., Noise, Symposium on Probability and Its Engineering Applications, Sponsored by Philadelphia Chapters of A.I.E.E., I.R.E., and the Society for Industrial and Applied Mathematics, Philadelphia.

Blecher, F. H., Transistor Applications, A.I.E.E. Pittsburgh Section, Pittsburgh.

Bogert, B. P., Current Research on Speech Bandwidth Reduction at Bell Telephone Laboratories, Symposium on Engineering Applications of Speech Analysis and Synthesis, Boston.

Bond, W. L., Crystal Symmetry and How It Affects the Outward Appearance of Crystals, New Jersey Mineralogical Society, Sponsored by Newark Lapidary Society, Plainfield, N. J.

Brattain, W. H., Surface Properties of Silicon and Germanium, Conference on Properties of Surfaces, New York Academy of Sciences, New York City.

Briggs, H. B., R. F. Cummings, H. J. Hrostowski, and M. Tanenbaum, Optical Properties of Some Group III – Group V Compounds, American Physical Society, Chicago.

Calbick, C. J., Electron Microscope Surface Studies, New York Academy of Sciences, New York City.

Calbick, C. J., The Inorganic Film Replicas, Electron Microscope Society of America Symposium, Pocono Manor, Pa.

Campbell, W. E., Fretting Wear, Northern and Southern Sections, American Society of Lubrication Engineers, Berkeley and Los Angeles, Calif.

Cummings, R. F., see H. B. Briggs.

Evans, H. W., Microwaves and Associated Relay and Terminal Equipment, A.I.E.E.-I.R.E. Student Section, Cornell University, Ithaca, N. Y.

Feldmann, W. L., see M. Tanenbaum.

Fleckenstein, W. O., Switching Circuits for Automatic Control, Training Program, Bell Telephone Company of Pennsylvania, Philadelphia.

Fox, A. G., Microwave Properties of Ferrites and Their Waveguide Applications, Physics Colloquium, Rutgers University, New Brunswick, N. J.

Francois, E. E., see J. T. Law.

Harris, J. R., Applications of Transistors, Series of Lectures at University of Toronto, Toronto, Canada.

Heidenreich, R. D., Emission Microscopy of Metals and Alloys, Electron Microscope Society of America, Pocono Manor, Pa.

Hrostowski, H. J., see H. B. Briggs.

Kruger, M. K., Specifying Distribution Requirements in Terms of Quality Control, Southern Conference on Quality Control, Chattanooga, Tenn.

Law, J. T., and E. E. Francois, The Adsorption and Decomposition of Vapors on a Germanium Surface, New York Academy of Sciences, New York City.

Lawson, C. C., Rural Distribution Wire, Wire Association Meeting, Chicago.

Malthaner, W. A., Basic Building Blocks – I, Joint Lecture Series, A.I.E.E.-I.R.E., New York City.

McMillan, B., Information Theory, American Speech and Hearing Association, New York City, and Symposium on Probability and Its Engineering Applications, A.I.E.E.-I.R.E., Philadelphia.

Miller, S. L., The Transistor, Graduate Seminar, Department of Engineering Mechanics and Materials, Cornell University, Ithaca, N. Y.

Monro, S., Setting Tolerances in Relation to Machine Capability, American Society for Quality Control, New York City.

Moore, Miss M. L., An Excursion Into the World of Transistors, Catholic Science Council, New York City.

Pearson, G. L., see M. Tanenbaum.

Pierce, J. R., Microwave Amplifiers for Repeaters, I.R.E. Professional Groups on Microwave Theory and Techniques, Tubes, and Systems, New York City.

Pierce, J. R., Recent Advances in Microwave Tubes, I.R.E. Monmouth Section, Ft. Monmouth, N. J.

Ross, I. M., Field Effect Transistor, Brown University, Providence, R. I., and Polytechnic Institute, Brooklyn, N. Y.

Sparks, M., The Transistor From a Chemical Point of View, Western Connecticut Section, American Chemical Society, Stamford, Connecticut, and Boston Section, American Chemical Society, Boston.

Tanenbaum, M., G. L. Pearson, and W. L. Feldmann, Magnetoresistance in InSb and GaSb Single Crystals, American Physical Society, Chicago.

Tanenbaum, M., see H. B. Briggs.

Terry, M. E., The Analysis of Variance and the Design of Experiments, Basic Science Division, A.I.E.E. New York Section, New York City.

Walker, A. C., Growing Crystals, Raritan Valley Subsection, American Chemical Society, Bound Brook, N. J.

Wallace, R. L. Jr., High Frequency Properties of Junction Tetrode Transistors, New England Section, American Physical Society, University of Connecticut, Storrs, Connecticut.

Washburn, S. H., Boolean Algebra and Its Application to Switching Circuit Design, A.I.E.E. New York Section, New York City.