Electronic Computers and Telephone Switching

W. D. LEWIS *Switching Research*

Because modern telephone switching systems are themselves a form of automatic data-processing equipment, Bell Laboratories has long been vitally concerned with digital computers. The building blocks of today's digital computers are electronic, and one of the objectives of research in switching is to determine how these electronic tools might be used to advantage in the design of telephone systems.

There is a new technical field in the world today. It is concerned partly with the electromagnetic and electronic machines called "digital computers" or "data-processing machines" by their designers, and "machines that think" by the popular press – machines with such names as "Hurricane", "Whirlwind", "Rascal", and "Oracle", or more simply, "IBM 701" or "Bell Model VI". It has to do partly with a host of other matters – control of guided missiles, the automatic factory, and business processes.

This field is important to the Bell System, partly because of its general impact on business, on manufacturing and on national defense, and partly because of its particular relevance to telephone switching and automatic message accounting.

The elementary building blocks of these machines can be relays, electron tubes, or other devices, connected together to carry out logical processes – the same logical processes that Aristotle recognized in the fourth century B.C. as the fundamental laws of thought. The eminent mathematician Norbert Wiener predicted in 1948* that these machines would create another industrial revolu-

* *Cybernetics or Control and Communication in the Animal and the Machine*, The Technology Press, John Wiley and Sons, Inc., 1948.

tion by releasing the mind of man from routine mental tasks in the way that the industrial revolution of the 19th century released man's body and back from tiresome and routine physical work. In 1954, it is evident that Wiener's prediction is coming true, for digital computers and data-processing machines are not only doing many formerly human tasks with new speed and facility, but they are accomplishing some things which without them would have been impossible.

Many kinds of people have helped create this technology. Among them are mathematicians, physicists, engineers, people in universities, in government, in the military, and in industry. Many telephone people belong in this group. Telephone switching people were among the first to become interested in digital data-processing. The early automatic telephone offices were the first systems of any size to perform digital processes by electro-mechanical means. Dial telephone systems constitute by far the largest part of the automatic digital data-processing equipment in the world today.

Fig. 1 — H. E. Vaughan (right) and S. T. Brewer (left) explaining DIAD operation to G. E. Jacoby (second from left) and W. O. Fleckenstein. In the illustration that is shown on page 321, S. T. Brewer (left) and K. S. Dunlap are placing a call through DIAD.

An important early contribution was made by G. R. Stibitz and S. B. Williams of the Laboratories, using the tools of switching – mainly relays.* They were among the first to design computers able to carry out long sequences of arithmetical operations without human intervention. Since that time, many contributions to the digital computer field have resulted from the Laboratories' work in switching and in military electronics, and from its fundamental research in materials, components, and circuits.

Pushed forward by work both within and outside of the Laboratories, digital computation and data-processing have become a primarily electronic art. The internal operations of modern digital computers are performed in microseconds. Digital computer designers are more concerned now with electronic counters than with relays, and with magnetic drums or storage tubes than with punched cards or paper tape. They talk of transistors and ferromagnetics more than of contacts and motors.

Switching research engineers are vitally interested in this new electronic art. The reason for their interest is clear. They hope to find a basis for better and more economical telephone systems. Whether and when this is possible for any particular application or service is hard to predict, since so many technical and economic factors are involved. But they have broad reasons for faith in ultimate large applications of electronics to telephone switching.

Perhaps the most cogent general reason for this faith in an electronic future for switching can be seen by noting that electronic tools are supplanting electromechanical ones in the digital computer field and by noting the close resemblance between digital computers and telephone switching systems.

An obvious resemblance between a digital computer and a telephone switching system is that both are digital. Telephone customers are identified by digital numbers, and it is natural that machinery which enables a customer to select another customer should be digital. But the similarity between these two systems extends beyond the machinery. It is functional as well.

The close resemblance, electrical and mechanical, between electronic telephone offices and digital computers appeared in the Bell Laboratories' ex-

* RECORD, *October*, 1940, *page* V of News Notes; *February*, 1947, page 49.

perimental telephone system known as ECASS.* It is even more obvious in DIAD,† which will be described in a later issue of the RECORD. DIAD, in common with many modern computers, has a magnetic drum storage unit, rectifying diode logic circuits, and hot cathode tubes for amplifiers and temporary registers. Some of the DIAD equipment is shown in Figures 1 and 2. To digital-computer people, Figure 2 would be familiar, since similar bays are found in modern computer equipment.

Just what advantages may the newer electronic tools have for switching and computing? The most conspicuous one is speed. This speed can be used in a large office to handle the flood of control operations necessary to keep up with incoming telephone traffic. As many as a dozen relay markers have been used in a No. 5 crossbar office. One electronic marker might replace all of these. Of course, such a simple replacement would hardly give the best design. It would be better to redesign from the ground up.

A picture of how speed might be used to advantage in a large telephone office may be had by thinking first of a manual office small enough that a single operator can handle all calls. She does this when responding to each calling customer's signal by plugging into his jack, listening as he gives the desired called number, then setting up the other end of the same cord to this number. She must also take down both ends of the cord when the circuit is no longer in use, handle calls to other telephone offices, provide information, record charges, and perform a variety of other duties. If the number of customers in this small office is increased, they would normally be served by adding more operators. Imagine, however, an operator who is human in every way except that she can operate at electronic speeds. Would she be able to take care of a much larger number of customers? The answer is "No," since she does not have the time to listen patiently as each customer repeats the number he wishes. During a busy period, ten calls a second is a possible traffic load in a large office. If each number required five seconds on the average to give by voice, at least fifty operators would be required, even though all other functions could be compressed to zero time.

This fast electronic operator could then, obviously, do little without something else to help her. If she could have a "bulletin board", however, on which calling customers in their slow human way could "write" the calls they wished to make, and if she could read this bulletin board in her fast electronic way, then sufficient speed would enable her to set up or take down each call and still have time to spare for other necessary tasks. But this bulletin board would necessarily require what telephone switching and computer designers mean by storage, or memory.

Therefore the essential elements of a common-

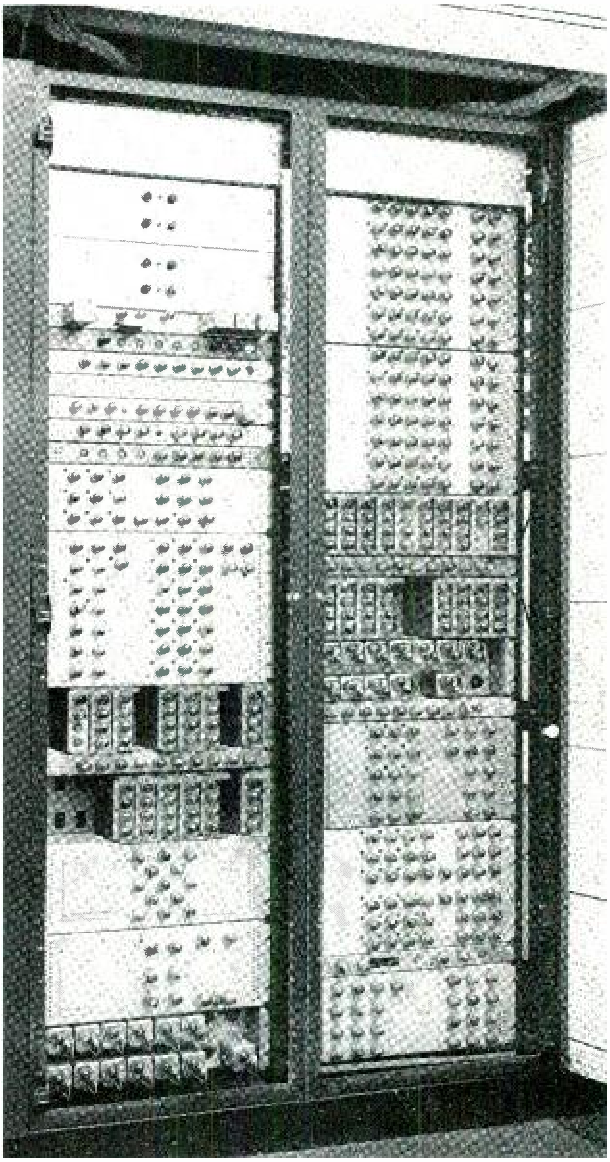


Fig. 2 — Trunk bays of DIAD. Computer engineers will note a striking resemblance to similar bays of digital computers.

* *An Experimental Electronically Controlled Automatic Switching System* by W. A. Malthaner and H. E. Vaughan, B.S.T.J., 31, *May*, 1952, *page* 433.

† Drum Information Assembler and Dispatcher.

control electronic telephone office, besides the switching network, include a high-speed marker corresponding to the control unit, and storage means corresponding to the memory in the digital computer. The input and output devices of the computer are in the office, too. They include dials, switches, charge-recording equipment, and attention and trouble signals. The most important output of the computer is computed results, and the most important output of the telephone office is service in the form of wanted connections.

The close functional resemblance between an electronic telephone office and a digital computer is made graphic in Figure 3, where possible simple block diagrams of the two systems are placed one above the other. Except for relabeling, they are identical. The resemblance between the two fields is such that veteran switching systems designers sometimes claim computers as special examples of their product. The reverse claim could no doubt be made with equal justice.

Despite these functional similarities, there are physical differences between the arithmetical unit and its analogue in the office – the switching network. These do different physical things, and occupy different proportions of the total equipment. The network must do much more than handle binary information. It must switch many simultaneous and independent voice channels with low attenuation, low noise, and low mutual interaction. If the full possibilities of electronics are realized, it seems likely that the equipment for performing the two functions of control and memory can be reduced to a small fraction of its present cost and size. Unless a comparable method of reducing the connecting network is found, this will then become the largest part of the exchange. Fortunately, ways of reducing the network are on the horizon.

In one of these ways, gas tubes would be used as talking-path switches. In the DIAD system an array of gas tubes is associated with the relay switches and is used for their control. This array selects a path at electronic speeds and holds the selected path until the corresponding metallic relay-path can be set up. In the proposed simplification, the gas tubes themselves would be used for talking and would thereby eliminate much bulky and expensive relay equipment. This would require specially designed, noise-free gas tubes.

In another proposed scheme for reducing cost and size of the talking network of a telephone office, far fewer switches are needed because they are shared on a "time-division" basis. Information

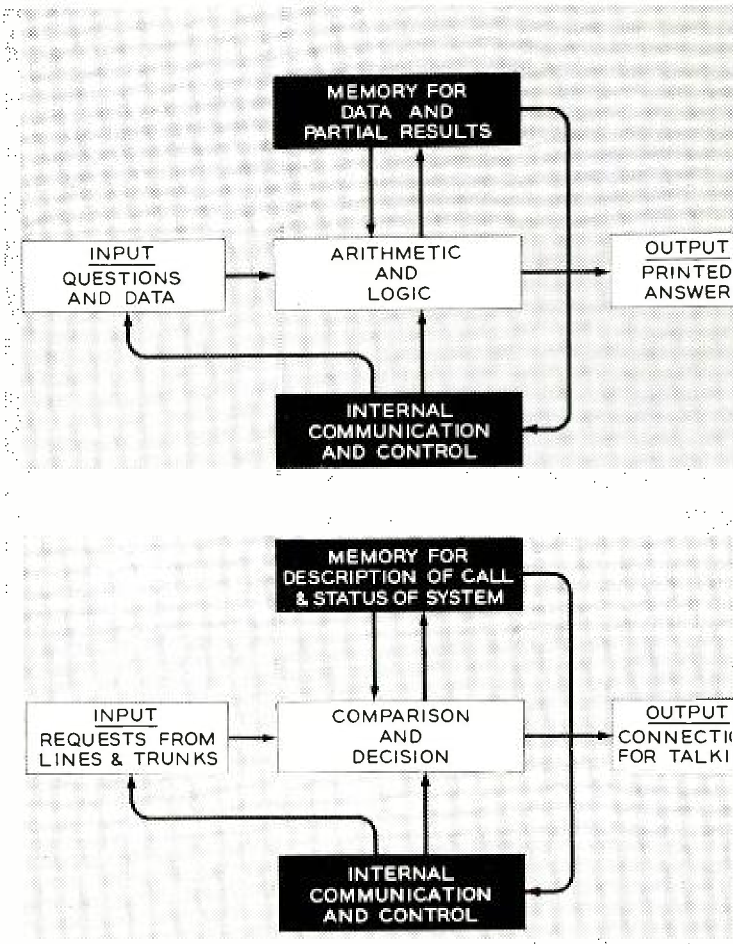


Fig. 3 — Block schematics of digital computer (above) and telephone switching exchange (below), showing similarity of functions.

is transmitted between customers over the switches by means of amplitude-modulated pulses. As is well known to engineers who have worked on time-division transmission systems, a good voice channel can be provided if the pulses in a given connection are repeated at a ten-kc rate. This is possible only with switches operating at electronic speeds.

Electronic devices have other advantages for switching besides speed. One advantage is size. Some of the most valuable space in the world is occupied by switching equipment in downtown Manhattan. An electronic system would probably cut this space to a fraction of its present size. Another advantage lies in power consumption. Most relays absorb about a watt of power. A semiconductor information-processing circuit containing a transistor and a few germanium diodes absorbs only a few milliwatts and can handle far more information per second.

The foregoing indicates why so many of those engaged in telephone switching follow the electronic computer art and hope that switching systems of the future will profit from electronics as transmission systems have in the past. The profit will not be all one way. Switching research and development will contribute to computing. Contributions are possible in at least three areas: to devices, to reliability, and to systems employing two or more computers.

The contributions to devices will be made simply because, as telephone data-storage and processing problems are solved, computer-device problems are solved also. Digital transistor research and fundamental development are equally valuable to the two fields. The same applies to other devices, for example, to diodes, storage tubes, ferrites, and ferroelectrics.

The contributions to reliability will be made during research and development work on electronic switching systems. To be satisfactory for a switching office, reliability must be greater than is now acceptable in the large digital computers used for scientific computation or accounting purposes. This is true whether the reliability is achieved through better components or through self-protecting circuit and systems design. Such improvements may not be too significant in the mathematical computers, where circuit or program checks will guard against error. On the other hand, they will be significant wherever it is desired to use a computer to control or to keep up with a real situation that must go forward regardless of the readiness of the computer.

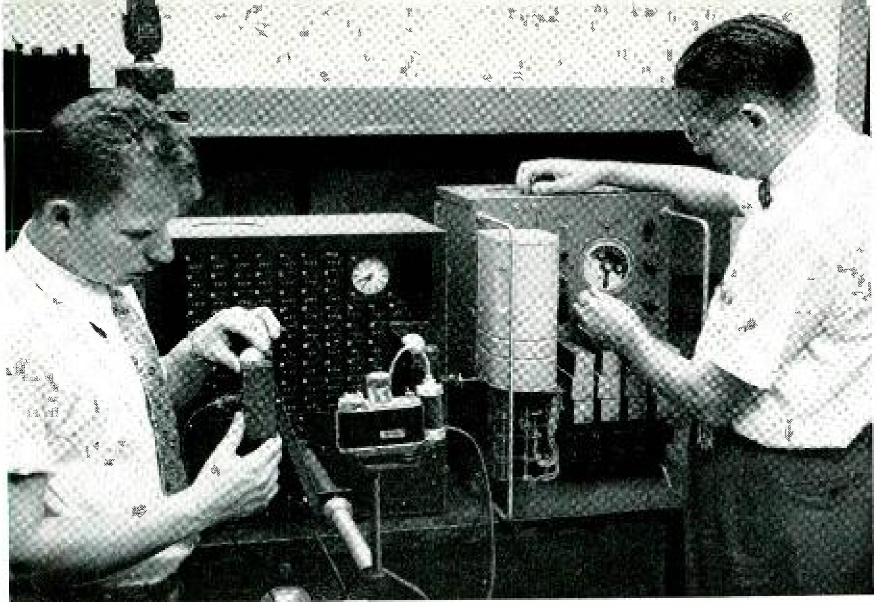
To see the possible contribution of switching to systems employing two or more computers may require a longer look into the future. It is based upon an analogy with the way in which switching is done in a large city. A single telephone call may be handled by two or more central offices: an originating office, a terminating office, and often one or more intermediate or "tandem" offices. Applying this to computers, there emerges the possibility of joint action of two or more computers to solve problems that are too big for any one alone. It would perhaps be economically sound to get away from the ideal of the general-purpose computer and to design specialized computers which would be most efficient in one field, but which could call upon other computers for help when approached on problems outside of their best range of skills.

Since big computers are likely to be separated geographically, this would require means for high-speed transmission and reception of digital information. And, since computers are coded according to many different schemes, they would be incompatible without appropriate translating equipment. If the group of computers were to handle more than one problem at a time, as the need for efficient use of the system would demand, rules and means would have to be devised for doing this without confusion. All of these functions have parallels in telephone switching, for all are being done millions of times each day by present switching techniques. Future switching technology should suggest, if not actually provide, means for performing them in systems of electronic computers.

All of the above can be summarized simply: nature seems to lead digital computing and telephone switching into parallel paths. This association will be profitable to switching, and it will also benefit digital computing.

THE AUTHOR

W. D. LEWIS joined the Radio Research Department of the Laboratories at Holmdel in 1941. Until 1945 he was concerned with radar research and later with research on microwave filters, light route radio relay systems and switching systems. In 1951 he transferred to Murray Hill where he is Director of Switching Research. He received an A.B. degree from Harvard College in 1935, then went as a Rhodes Scholar to Oxford University, where he received B.A. and M.A. degrees. He returned to Harvard for a Ph.D. degree in mathematical physics. Dr. Lewis has recently become a member of the Committee to visit the Division of Applied Science at Harvard. He is Secretary-Treasurer of the Joint Computer Committee, a Fellow of the Institute of Radio Engineers, a member of the American Physical Society, of the Association for Computing Machinery, and of the American Association of Rhodes Scholars.



Measuring Telephone Traffic

D. H. BARNES
Switching Engineering

Traffic measurements are important to traffic engineers who plan for optimum service with available equipment and for better and faster future service to customers. Data must be compiled not only on the basis of the number of calls handled, but also in terms of the lengths of the telephone conversations. Newly designed traffic usage recorder equipment was recently installed in the Newark 4A toll crossbar office. It will give a more complete, accurate, and meaningful survey of traffic loads than was possible with older and less mechanized traffic measuring methods.

Industry in general is intensifying the search for more efficient ways of doing business to meet the challenge of rising costs, and we feel that the Bell System is an outstanding example of success in this field. The unprecedented demand for telephone service emphasizes the need for the most efficient use of available equipment in order to clear held orders and still maintain a satisfactory and balanced grade of service to all customers. Efficient use of equipment and plant investment requires close operational control, which in turn depends upon adequate and accurate traffic data. Our experience in mechanizing the operating job convinces us that there are benefits to be derived from also mechanizing the job of obtaining and analyzing traffic data. More data will be obtained with greater accuracy at less cost, and the clerical job itself will be made less routine and more interesting by field use of mechanical aids.

The Traffic Department of an Operating Company plays an important part in furnishing telephone service, and the new traffic usage recorder equipment that has been designed is a step toward the mechanization of its work. In a dial office, the Traffic Department not only must make sure that equipment is provided to handle the office's present rate of traffic, but must plan carefully to anticipate future trends. This planning for future equipment is termed "traffic engineering," and the assignment of lines and balancing of traffic loads on the equipment in dial offices is called "dial administration."

Traffic engineering and dial administration, of course, require dependable traffic data. The service planned for is thought of in terms of the degree of delay a customer encounters in completing a call or in terms of the number of times he attempts to complete a call and is not successful. Perfect "no delay" service is theoretically possible, but would be prohibitively expensive; the practical goal is fast service with a minimum of delays, at prices that customers can afford.

In organizing traffic data, a Traffic Department uses the tools of statistics and probability which, for telephone applications, require some definitions. Traffic "delay" is expressed as the probability (from the customer's viewpoint) that a call will be de-

Above — Modified type-B portable traffic usage recorder built for Bell Telephone Laboratories traffic studies. S. Falk (left) installing lamps for photographing traffic registers as C. H. Erving, Jr. sets key on control panel.

layed over a stated length of time. Failure to complete a call is similarly expressed as the probability of not finding a path available for a particular call. Since the telephone industry must be geared to a high level of traffic, both probabilities are based on service during the busiest hour of a day in the busiest season of the year. Probability formulas may be used to calculate adequately these chances for delay or failure if the "per cent occupancy" is known. "Per cent occupancy" is the average per cent use of the telephone equipment during the busy hour.

One of the major problems of a Traffic Department is the forecasting of this "occupancy" for some future time when new equipment will have to be considered, and it is for this reason that new traffic-measuring devices are being designed. They will give traffic engineers a more complete survey of the loads handled by telephone offices, and will do so with greater accuracy, greater speed, and with less labor than was possible with older measuring methods. The new traffic-measuring devices will also be extremely valuable for division of revenue and rate studies.

Traffic data is now routinely collected largely in terms of calls or attempts, that is, for example, in terms of calls carried, calls overflowing, or calls finding all paths busy. The counting of calls, or "peg counting," is the traditional method of measuring traffic, and dates back to the early manual days. Its present use generally presumes certain adjustment factors, and it also requires an estimate of "holding time," or the time a customer will keep circuits busy on an average telephone call. This additional information is necessary to permit the conversion of peg count data to a form equivalent to occupancy, so that the probability tables can be used.

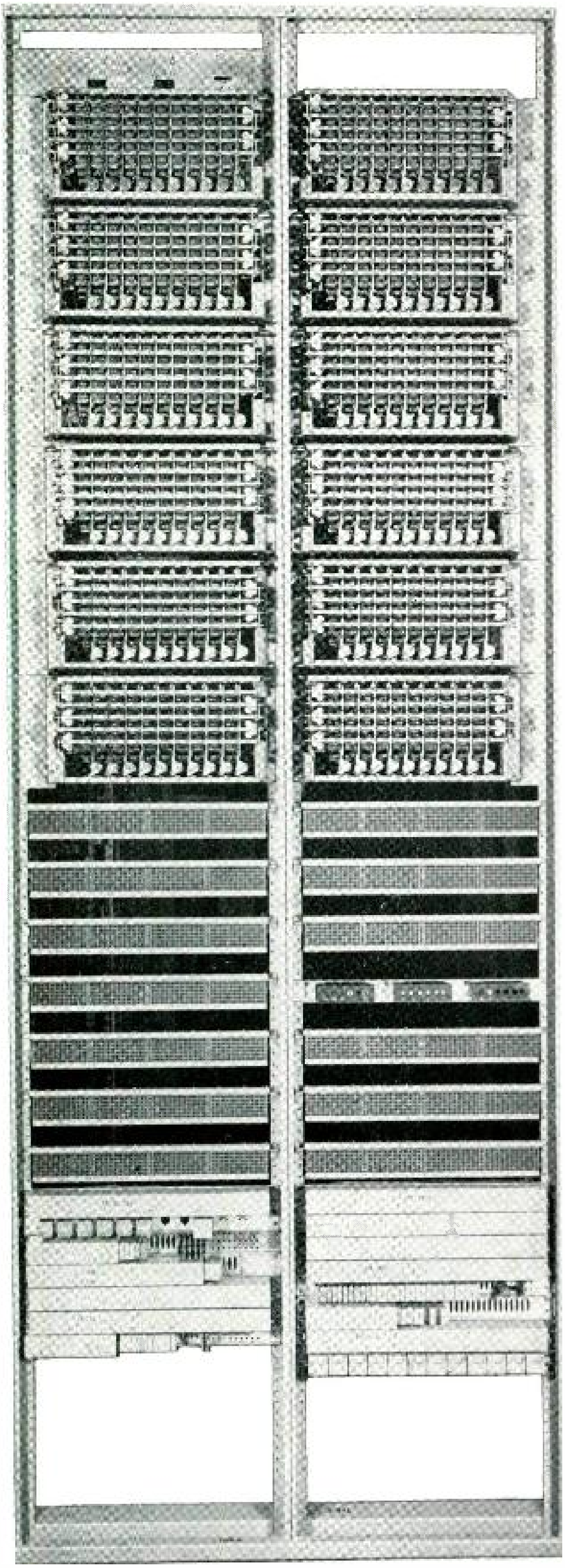
With automatic switching systems, however, the major interest is in the traffic load, or "usage," carried by the component parts of the system and measured usually in CCS (hundred call-seconds). In other words, modern switching methods demand that the traffic engineer should know, in addition to how many calls customers make, how long they are apt to hold circuits busy. The product of these two parameters of traffic measurement is equivalent to "usage" when they are measured simultaneously.

Holding times and usage are at present measured by sampling methods using manual techniques or mechanical devices wired to circuits by plant maintenance personnel. These mechanical devices include the 1B and 1C holding time cabinets that have been in use for many years, the portable Types A and B usage recorders, page 326, recently manufactured in limited quantities by the Western Electric Company from designs furnished by the Michigan and New Jersey Companies, and numerous other locally designed measuring devices. Holding time studies by these means have necessarily been infrequent because of high wiring and handling costs and because of the manual work involved. Furthermore, because of the personnel required, measurements are difficult on all circuits during busy hours of the busy season, when samples are most significant.

Fig. 1 — The author at control panel of a Laboratories traffic usage recorder.

Recent research and development have therefore emphasized the direct measurement of usage with equipment that is designed as an integral part of the telephone office and that requires little maintenance or attention by either plant or traffic personnel. The ultimate goal is to provide modern dial offices with measurement devices permanently wired to switching equipment, with a set of easily accessible controls for starting a measurement at any convenient time (Figure 1), and with automatic recording equipment that will deliver processed data.

Because of the magnitude of the problem, however, and because of immediate needs, this de-



velopment has been divided into two parts. The first involves the measuring equipment itself and the means of making connections to the circuits to be measured; the second involves the automatic recording of the usage measurements, the automatic summarization into hourly or half-hourly records, the automatic computing into the most readily usable form, and the printing of the results in the ways found best adapted to the several uses for the data.

The first part is essentially complete and consists of the "Traffic Usage Recorder" (Figure 2), the designation on equipment drawings of all points of connection, and the "Traffic Register Camera" (Figure 3) for photographing traffic registers and thus automatically recording the results.

This equipment is presently being developed for use in No. 1, No. 4A, No. 4M, and No. 5 crossbar, crossbar tandem, panel and step-by-step offices, and for switchboard trunks. Portable equipment is also being planned for small offices.

The design of such equipment depends on a great number of factors relating both to the ultimate goal and to existing situations. Fortunately, the differences between the various switching systems, with a few exceptions, do not restrict the design of a standard usage recorder. A standard recorder is expected to require about 2,500 cabled leads for each 10,000 terminals of capacity. The smallest installation may require 1,000 leads, an average building about 6,500 leads, and a maximum installation possibly 20,000 leads.

In the design work, a choice had to be made among various methods of measuring usage. Considerations of cost and the use to be made of data dictated the "switch-count method" as the most appropriate. This method consists of the repeated scanning at regular intervals of busy test terminals, and of the cumulative recording (at present on traffic registers) of the number of terminals busy on each scan for each group. At the end of any period of time, the average traffic load carried by the group can be determined by taking into account the number of scans during the period and the total number of "busy's" encountered. By setting certain values to the number of scans, direct readings may be made in whatever traffic units are desired. If, for instance, the scan rate is set at 36 per hour, the accumulated number of "busy's"

Fig. 2 — Traffic usage recorder frame showing, from top to bottom, crossbar switches, cross-connection field, and control and detector circuits.

at the end of an hour will indicate the load directly in hundred calls second (CCS).

The scanning rate is in itself another design feature having a great effect on the accuracy of the measurements. Predictions of traffic load are subject to many errors, of which the measurement error is only one. The measurement error is significant only in relation to the size and distribution of errors in the other variables. Regardless of the other errors, however, any gain in accuracy from more frequent scanning becomes negligible as the scanning interval approaches the average holding time of the circuit measured. Since present studies of both relay and electronic switching methods indicate that there is a definite cost penalty incurred with higher scan rates, a one hundred second scanning interval has been selected as the best for most purposes. A few circuits, however, will require more frequent scanning, and these can best be handled by multipling the test lead for duplicate scan appearances or by providing a separate small scanner to work in conjunction with the main scanning equipment.

Another design requirement is the provision for maximum flexibility in the assigning and cabling of leads, the association of leads into traffic groups, and the allowance for future growth or change. And here again a choice had to be made among various methods of connecting the traffic usage recorder to the circuits under test, and of associating the leads through the scanner with the desired traffic groups. Among the methods considered and rejected were the use of cross-connecting frames between the leads and the recorder, the use of a "cut-in" control within the recorder to associate leads into small groups that may be multipled

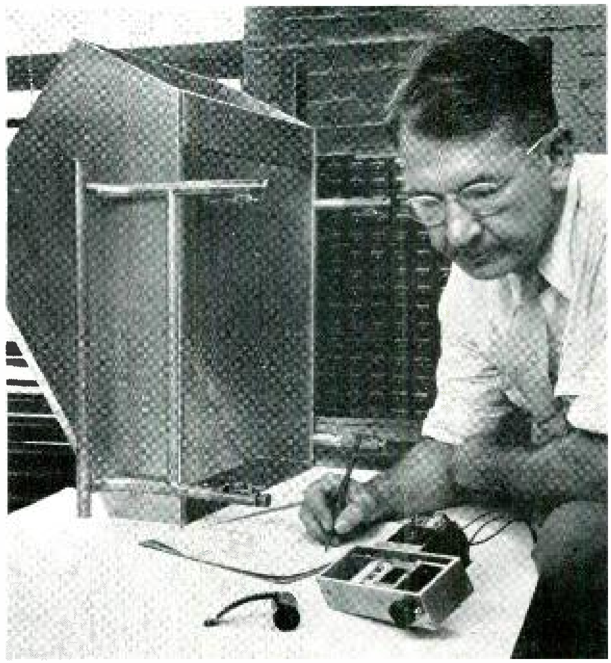


Fig. 3 — W. J. Rutter with preliminary model of camera to be used for traffic recording. The camera, lamps, and controls are mounted in the holder (left) and fitted over the group of traffic registers that can be seen in the background.

together to match varying group sizes, and third, the identification of leads by the recorded position, with the data being unscrambled at a central processing center from master records necessarily maintained by clerical methods. The method finally chosen, however, uses a duplicate of each scanning switch as a means of associating leads with traffic groups. This scheme minimizes the number of busy-detecting circuits required and permits the

THE AUTHOR

D. H. Barnes joined the Bell Telephone Laboratories in 1951 following ten years service in the Traffic Department of the Ohio Bell Telephone Company. After two years in the field organization of the Telephone Company he moved into the Traffic Engineering Department and at various times was concerned with the traffic engineering aspects of step-by-step local manual and toll systems. Just before joining the Laboratories he was concerned with division of revenue and rate case problems. Mr. Barnes received the B.S. degree in Industrial Engineering from Lehigh in 1938. Since joining the Laboratories' Switching Engineering Department he has been chiefly concerned with traffic engineering and traffic measurement, establishing requirements for the development of the traffic usage recorder, the traffic register camera and for the future development of facilities for automatic recording and processing of traffic usage data.

association of any input lead with any group. It consequently simplifies cabling, permits growth or change without rearrangement of leads, and saves recorder terminals. It also allows for complete automation at a central processing point without excessive cost at the central office.

In a sense, the utility of all these design features depends on the accurate identification of the busy versus idle circuit condition. There are at least twelve different busy-idle signal combinations to be found in the various switching systems, and in a few cases the limits of busy and idle signals are quite close together. With careful design, three different detectors provided in the traffic usage recorder will recognize all conditions, and usually only two will be needed for a given installation. These detectors have to be high impedance circuits to prevent interference with switching functions. Furthermore, the timing and duration of the detector's look at the circuit must be carefully controlled. It must be long enough to permit an unmistakable identification of the busy or idle condition, but must be kept as short as possible (the so-called "knife-edge look") to prevent an error should the circuit condition change during the identification interval.

These in outline are some of the problems of the measurement of telephone traffic and a few of the design features of the necessary equipment. The specific circuit designs will be discussed in a future Record article. The traffic usage recorder installed in the Newark 4A office on October 24, 1953 comprised the first application of these latest principles of traffic measurement. Such recorders are expected to keep pace with the increasing mechanization of telephone switching and thus contribute to the constant improvement of service to the customers of the Bell System.

Talks by Members of the Laboratories

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

Bond, W. L., An Automatic Recording X-Ray Diffractometer and Plotting Device, International Union of Crystallography, Paris, France.

Brown, W. L., see Fletcher, R. C.

Brown, W. L., Fletcher, R. C., and Wright, K. A. Traps Produced by Electron Bombardment of Germanium at Low Temperature, American Physical Society Meeting, Minneapolis, June 29, 1954.

Dacey, G. C., Transistor Physics, Green Engineering Camp of the Cooper Union Institute, Erskine Lakes, N. J.

Darrow, K. K., Some Current Work at Bell Telephone Laboratories, Institute of Physics, London, England.

Ebers, J. J., Junction Transistors in Switching Circuits, M.I.T. Special Summer Program on Transistors and Their Applications, Cambridge, Mass.

Fletcher, R. C., see Brown, W. L.

Fletcher, R. C., Brown, W. L., and Wright, K. A., The Absence of Bombardment Annealing in the Electron Bombardment of Germanium, American Physical Society Meeting, Minneapolis, June 29, 1954.

Galt, J. K., Motion of Individual Ferromagnetic Domain Walls, American Physical Society, Seattle.

Geballe, T. H., see Hull, G. W.

Geballe, T. H., and Hull, G. W., Seebeck Effect in Silicon, American Physical Society, Seattle.

Honaman, R. K., Development and Research in the Bell System, Economic Workshop, Syracuse.

Hull, G. W., see Geballe, T.

Hull, G. W., and Geballe, T. H., Thermal Conductivity of Single Crystal Silicon, American Physical Society, Seattle.

LeLacheur, R. M., Semiconductor Devices, Cooper Union Alumni Association Summer Session in the Ramapo Mountains.

Linvill, J. G., Linear Application of Junction Transistors, M.I.T. Special Summer Program on Transistors and Their Applications, Cambridge, Mass.

Pearson, G. L., see Read, W. T., Jr.

Read, W. T., Jr., and Pearson, G. L., The Electrical Effects of Dislocations in Semiconductors, Conference on Defects in Crystalline Solids, University of Bristol, England.

Read, W. T. Jr., Dislocations and the Forces Between Atoms, Conference on Mechanical Effects of Dislocations in Crystals, University of Birmingham, Birmingham, England.

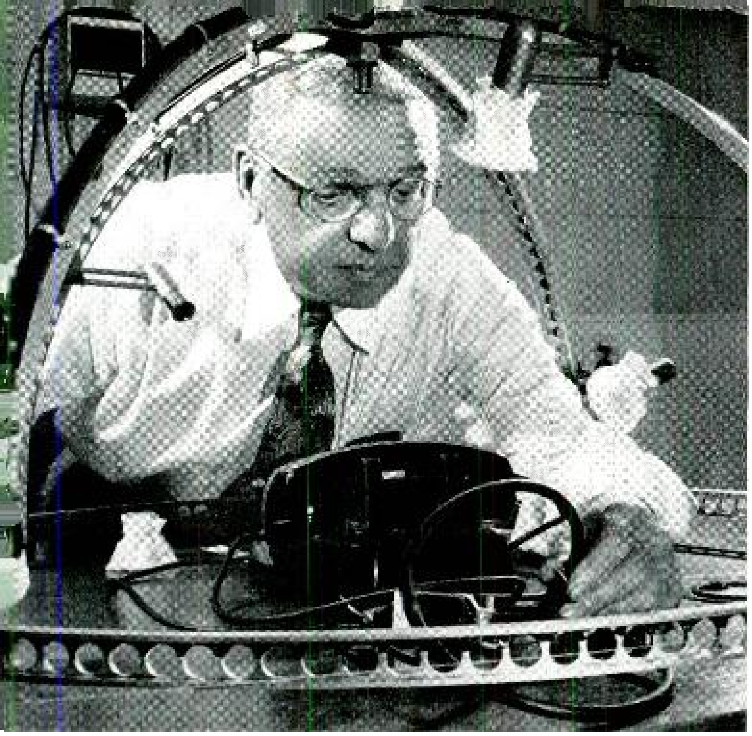
Ryder, R. M., Implications of Reliability for the Future of Transistors, M.I.T. Special Summer Program on Transistors and Their Applications, Cambridge, Mass.

Schimpf, L. G., Transistor Circuit Applications, Green Engineering Camp of the Cooper Union, Ringwood, N. J.

Wallace, R. L., Junction Tetrodes and Their Applications, M.I.T. Special Summer Program on Transistors and Their Applications, Cambridge, Mass.

Wright, K. A., see Brown, W. L.

Wright, K. A., see Fletcher, R. C.



A New Sound Integrator

R. T. JENKINS *Station Apparatus Development*

In a new telephone like the 500 set, care must be taken that the ringing signal and volume control are developed to fit the customer's needs. A new sound integrator now measures ringing power by means of calibrated microphones revolving in a hemisphere about the telephone set. Over-all power and power in specific frequency bands can be measured. The integrator is widely used in the study and development of signaling devices and in noise studies of station apparatus components.

Devices for transforming electrical energy into acoustic energy (electro-acoustic transducers) are of two general classes: (1) those designed to develop an acoustic pressure in a small cavity, such as the ear canal, and (2) those designed to radiate sound energy into free space. In the former class are telephone receivers, which are coupled directly to the ear. The efficiency of these devices may be conveniently measured in terms of the acoustic pressure developed in the cavity. The latter class of transducers includes telephone ringers, loudspeakers, signal horns and bells, which radiate acoustical energy in a three-dimensional pattern. In this case, the directional properties of the sound source become important, and measurements of the radiated sound field must be made to evaluate performance.

Acoustic pressures developed in space are determined by the sound power radiated and by the distance from the source. To rate the performance of a radiating source in terms of pressures developed, the distance from the source would have to be specified. On the other hand, the sound power radiated is a function only of the efficiency of conversion of electrical energy into acoustic energy and is therefore a significant criterion of performance well suited to universal application.

Above — The author placing a 500-type telephone set in position for measurement of sound power.

Since the intensity pattern of the sound from devices radiating into free space is seldom uniform, accurate determination of the sound power output necessitates measurement and integration of acoustic pressures developed at a large number of points lying on a spherical envelope of known area. This operation, if performed on a point-to-point basis, obviously would be both difficult and time-consuming. A new sound integrator recently developed at Bell Laboratories provides a comparatively rapid and accurate means of overcoming this difficulty by continuous scanning with microphones. The integrator, shown in operation on the cover, was developed primarily for acoustical studies of telephone ringers, but has application in other apparatus development studies.

Sound power measurements provide an accurate means of rating sound-radiating devices by allowing the calculation of efficiency in terms of the power supplied. They also permit the evaluation of such factors as gongs, armature and clapper assemblies, resonators, sound output volume controls, clearances of moving parts, materials, tolerances and design changes.

Since the purpose of a telephone ringer is to attract attention, the sound power output must be ample for various conditions of use, including those of ambient noise and various degrees of hearing ability. Characteristic gong tones involve a fundamental frequency and an extensive range of inharmonically related overtones; and the contribution of these component frequency outputs to the sound power level of the ringer is important. The new integrator readily determines these component outputs as well as the total spectrum sound power output. In some types of ringers, resonators associated with the gongs are used to amplify the sound output of the fundamental frequencies. This gain in output is easily evaluated with the integrator. The design of distinctive tone gongs was facilitated by use of the sound integrator in studies of their sound spectra. The integrator was also used extensively in determining the size and placement of openings in telephone sets so that the ringing signal could be radiated with sufficient volume to accomplish its purpose.

Sound power is related to integrated pressure and radiation area, and is defined as the total energy radiated by the source per unit of time. It is most conveniently derived from calibrated microphone measurements of pressure in the sound field. Pressures established by the sound source are, in general, dependent upon the azimuth, elevation, and distance of points in the sound field with respect to the source. Thus, a determination of sound power involves pressure measurement at a great many points in the field.

An integrator of earlier design, Figure 1, has been in operation in the Station Apparatus Development Department for a number of years.* In this model the sound source was placed on a turntable and rotated, and a microphone was mounted at the end of a cam-actuated arm so that the microphone moved in an arc in the vertical plane. The turntable served as a baffle so that radiation was restricted to one hemisphere. Thus, a hemispherical area of radiation was scanned. In this earlier model the inherent noise level of the moving parts and the integration time involved were such that only sources having relatively large and continuous sound power outputs could be measured. Also, only those devices not affected by the centrifugal forces from turntable rotation were suitable for measurement.

Fig. 1 — W. Kalin placing a telephone ringer in an integrator of earlier design.

Because of the development of a ringer with sound volume control for the 500-type telephone set, and because of the necessity for various sound measurements in studies of station apparatus components, a new integrator having broader application was indicated. Its design objectives included a lower inherent noise level, shorter integration time, and freedom from centrifugal force influences. In the design of this new integrator, a different approach to the method and technique of measurement was taken. The device to be measured is placed at a hemispherical center on a fixed table. Four microphones are rotated in a horizontal plane. Each is supported in the middle of one of four zones of equal height and therefore of equal area of the hemisphere. Thus, the sound power of the source is determined by a summation of integrations in each of the four zones of the hemispherical sound field. Preliminary measurements involving as many as twelve zones established that, for the new integrator, integration in four zones would give a sufficiently accurate determination of sound power. Since the sound source is not rotated, no centrifugal forces are present which might affect its performance.

To calculate the sound power readily, the source must radiate into space so that a substantially free,

* Record, *July*, 1941, *page* 342.

progressive, sound wave is established. It is usually sufficient, however, to restrict the sound radiation to a hemisphere by employing a suitable baffle. The radius at which a measurement is made must be sufficiently large so that the curvature of the wave front is small and the wave front, therefore, substantially plane. From pressure observations over the hemispherical area, the sound power is calculated as follows:

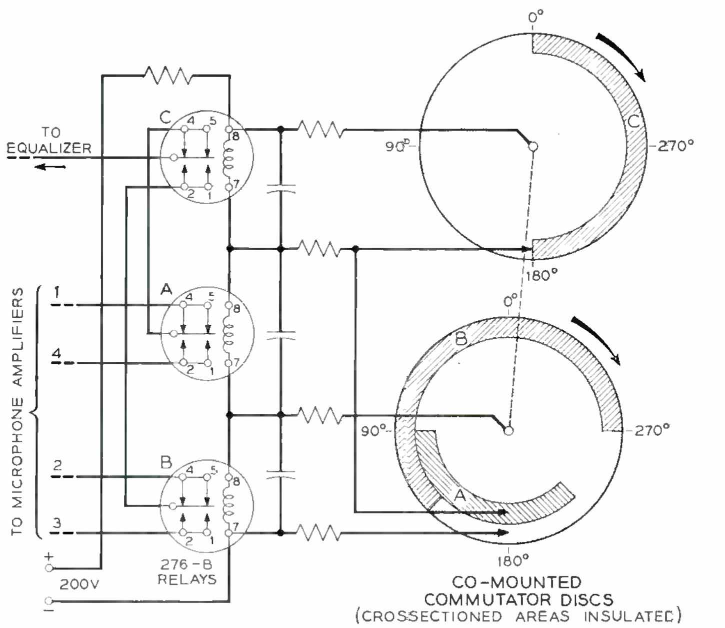
$$W = \frac{\overline{p^2} \cdot 10^{-7}}{\rho c} \cdot A \text{ watts}$$

In this expression W is the sound power in watts, $\overline{p^2}$ is the average squared pressure for p in microbars (1 microbar = 1 dyne per cm^2.), ρ is the density of air in gms per cm^3, c is the velocity of propagation of sound in cm per sec., and A is the hemispherical area in cm^2. The denominator ρc is the characteristic resistance of air to a progressive plane wave and has a nominal value of 41.5 mechanical ohms. The factor $\frac{\overline{p^2} \cdot 10^{-7}}{\rho c}$ is the average sound intensity or power per unit area of the hemisphere in watts per cm^2. Multiplying this sound intensity by the surface area of the hemisphere gives the sound power in watts. Sound pressure and power are usually expressed as levels in decibels relative to a specified reference. Sound pressure level and intensity level (power per unit area) are quantities measured by the well-known sound level meter, for which the associated references are 0.0002 microbars and 10^{-16} watts, respectively.

The integrator microphones have closely matched frequency response characteristics. Their voltage outputs are amplified and supplied to an analyzer which may be used to analyze the sound frequency spectrum of the source, i.e., to determine the power level within specified frequency bandwidths in the sound spectrum, or to measure the over-all sound power level.

The measuring circuit of the analyzer has a response proportional to the square of the radiated sound pressure (p^2). As seen from the equation, this provides a measure of the total sound power radiated by the source under test when averaged over the hemispherical surface scanned by the four measuring microphones. Measurements are read directly in decibel level on the analyzer. In scanning the sound field, measurements in the zonal areas are made by sequential connection of the microphones by means of a commutator connected to their outputs. This is done to avoid pressure cancellation which might occur because of phase differences at any particular frequency if simultaneous measurements were made in all four zones.

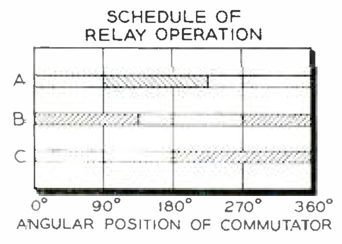
In the photograph on the first page of this article, the four microphones are shown mounted on a hemispherically shaped rotor, which is supported on a rectangular frame. The hemispherical radius at the microphones is about 14 inches. The rotor is motor driven by a pulley and belt arrangement at a speed of 1¼ revolutions per second. Because motion of the microphones causes air turbulence at their diaphragms, with resultant noise interference, cloth bags, as shown on page 331, are placed over the microphones to reduce this turbulence. A loosely woven thin material is used for these wind screens so that there is no disturbance of the acoustic field radiated by the sound source. The equipment is mounted on a bench which serves as a baffle, effectively restricting propagation from the sound source to one hemisphere.



SEQUENCE OF MICROPHONE OPERATION

REV	MICROPHONES				
1	1	4	2	3	1
2	4	2	3	1	4
3	2	3	1	4	2
4	3	1	4	2	3

0° 72° 144° 216° 288° 360°
ANGULAR ROTATION OF ROTOR



RELAYS OPERATE WHEN COMMUTATOR CIRCUIT IS OPENED

COMMUTATOR ROTATES 90° WHEN MICROPHONES ROTATE 72°

Fig. 2 — Schematic presentation of microphone commutating circuit operation.

The source being measured rests on the bench and is centered on the vertical axis of the rotor. The driving motor is mounted on flexible supports in an acoustically treated housing underneath the bench. The rectangular frame supports four amplifiers and an equalizer in addition to the rotor. Frame surfaces facing the platform are covered with sound-absorbing material to minimize reflections. The amplifiers have 600-ohm output impedances for connection to the equalizer and are designed to have sufficient power capacity to handle the large peak outputs which may be encountered in measurements of sound sources such as ringers and signal bells. Connection to the equalizer output may be made at either 135 ohms for general use or at 30 ohms for use with the analyzer. The microphones are fed into the amplifier inputs through slip rings. The commutator actuates three relays which connect the amplifiers into the circuit and is geared to the rotor with fibre gears to minimize mechanical noise. Relays are used to circumvent electrical noise inherent in the commutator and brush assembly, and the commutator is connected to the relay windings through suppression networks to minimize transient interference in the measuring circuit. A schematic of the commutation circuit is shown in Figure 2. Power for the amplifiers and relays is furnished by two rectifiers which supply direct current voltages, the amplifiers being direct-current operated for quiet performance. The rectifiers and frequency analyzer are operated from 60-cycle line voltage.

The commutator employs two discs mounted on a common shaft. Gearing to the rotor is such that the ratio of speeds is 5:4, so that the commutator moves through an angle of 450° for each 360° revolution of the microphones. A microphone is connected into the circuit for 72° of its rotation as the commutator moves through an angle of 90°. The sequence of operation of the microphones for the four revolutions of a complete integration and the relationship of each microphone to the angular position of the commutator are also shown on the schematic of Figure 2. Microphone designations correspond to zones, beginning at the bottom of the hemisphere. For each revolution of the microphones, one of them is connected into the circuit twice and the other three microphones once. It therefore requires four revolutions of the microphones or 3.2 seconds to complete the integration of all four zones. Scanning in this way by distributed sampling of the sound field results in a more nearly uniform commutated output, so that average level determinations are thereby simplified.

A functional circuit schematic of the method of measurement is shown in Figure 3. The 640AA condenser microphones are connected through series resistances to amplifier inputs. Each channel is independently calibrated by a 1000-cycle voltage introduced into the circuit across the appropriate series resistance, and for this purpose the channels are connected separately into the circuit by means of the channel selector rotary switch. This switch is also used to connect a commutator (for sequential operation of the microphones) into the circuit. The frequency response of the system is made flat by an equalizer, on the basis of the free field pressure* response of the microphones.

The power-level indicating circuit consists of a Western Electric 3A frequency analyzer and an

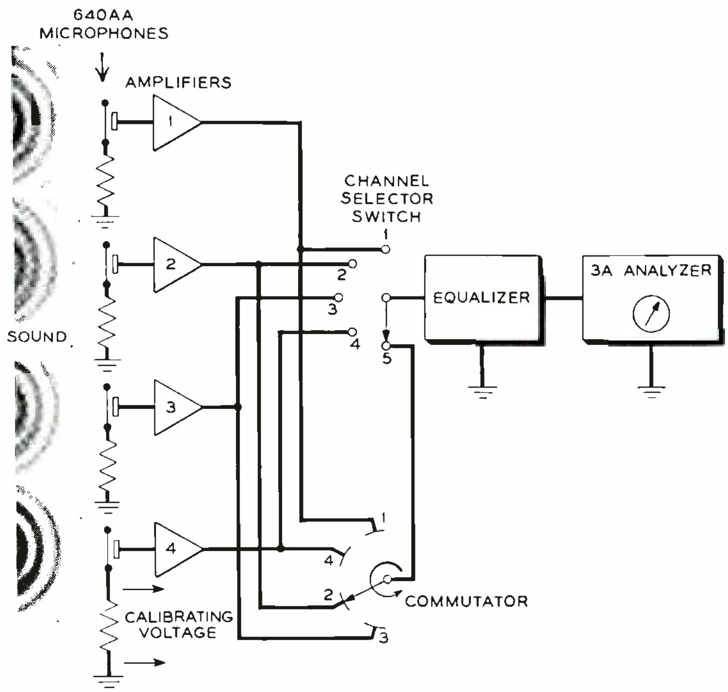


Fig. 3 — Block diagram of measuring circuits.

associated measuring circuit. The analyzer may be used either as a frequency band pass device which is continuously swept through the frequency range for spectrum analysis, or as a simple sound level meter for over-all, wide frequency band measurements. An attenuator scale and a meter are calibrated to read in decibels, and the readings may be added together to obtain the sound power level. To insure that a substantially free field, progressive

* Pressures at the microphone position in the sound field for a progressive, unobstructed sound wave.

wave is being measured, the equipment is operated in an acoustically treated room so that reflected energy is negligible.

The integrator may be used for wide band or spectrum analysis measurements from about 250 to 16,000 cycles. The minimum sound power level that can be measured depends upon the ratio of signal to noise level and, in general, the noise level increases with the band width of measurement. For the over-all band width, sound powers as low as about 0.05 microwatt may be measured. For sounds of duration times shorter than the 3.2 seconds required for integration of all four zones, measurements may be made separately in each zone by means of the rotary switch. In this way, sounds of as short a duration as one second may be measured. The outputs for each channel are totaled to give the sound power of the source. If desired, the sound outputs of each channel may be recorded on a tape or other medium and continuously fed into the analyzer circuit for analysis and measurement.

Because of its unique construction and low inherent noise level, the new integrator is well adapted to application in development and design studies of many acoustic devices. A typical example of sound power measurement with the integrator is given in Figure 4, which shows the spectrum of a C2A ringer used in the 500-type telephone set. The spectrum component outputs consist of narrow bands of energy at discrete frequency intervals. An analyzer pass band about 50 cycles wide is required for measurement. The ringer is equipped with two gongs whose fundamental frequencies are related in approximately a major third musical interval. These frequencies are 1300 and 1620 cycles. For efficient radiation from a sound source, the source must be dimensionally comparable to the wavelength of the sound being radiated. Therefore, because of the small size of the ringer gongs compared to the wavelength of sound at the fundamental frequency, the sound power output at this frequency is inherently relatively low. The level of the fundamental outputs is increased by about twenty decibels by the use of resonators, so that it is comparable to the output levels of the higher frequency overtones. In the figure, sound power levels of the fundamental frequency and overtone outputs of the gongs are shown. In this case the over-all sound power level of the ringer measured 132.5 decibels above a reference power of 10^{-16} watts, corresponding to a power output of about 1.8 milliwatts. The combined sound power output of the fundamentals as determined by summation is found to be about 0.4 of this value, or 0.7 milliwatts.

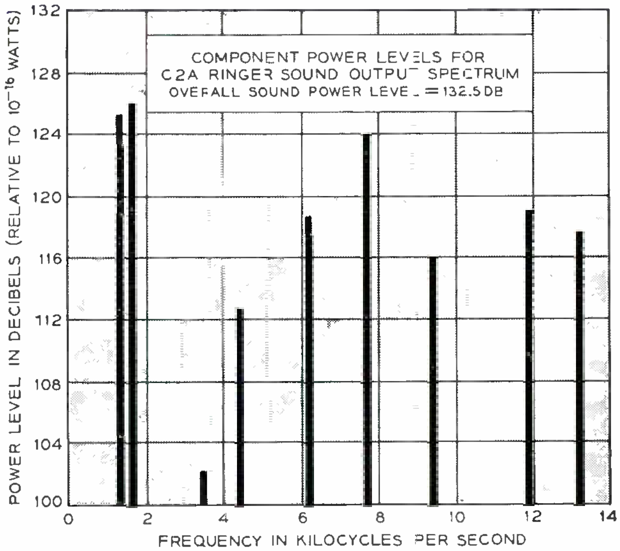
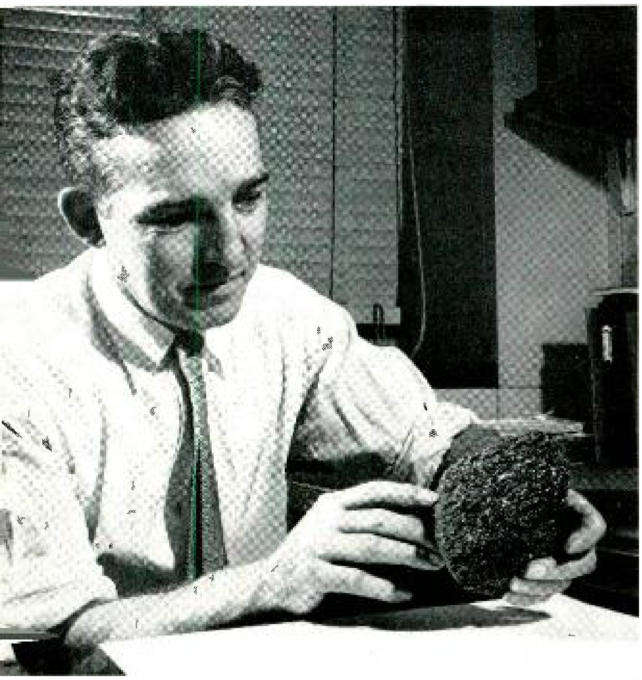


Fig. 4 — Sound power spectrum of the C2A ringer.

THE AUTHOR

Reginald T. Jenkins received his B.S. degree in 1917 and his E.E. degree in 1920 from Cooper Union. He had been connected with the Western Electric Company's Engineering Department since 1916. His early work was concerned with the development of methods for testing telephone transmitters and receivers and with telephone transmission problems and he developed an "artificial ear" for telephone receiver measurements. After Bell Telephone Laboratories was incorporated, he concentrated on the development and calibration of microphones and on methods for measuring the acoustical characteristics of telephone instruments. From 1942 to 1946 he worked on special acoustical investigations for the N.D.R.C. and on the development of thermistor bolometers for the Navy Department. He has specialized in developing methods for acoustical measurements of station apparatus and instruments since 1946. He is a member of the Acoustical Society of America and the American Institute of Physics.

Improved Silicon Carbide Varistors



C. J. FROSCH *Chemical Physics*

An important part of many research and development programs at Bell Telephone Laboratories consists of investigating means whereby the required apparatus components can be manufactured economically from readily available raw materials. It was found, for example, that commercially available silicon carbide was inadequate to meet the electrical requirements for varistors in the 500-type telephone set. Although it was possible to make satisfactory models in the laboratory by carefully selecting the raw material, this procedure could not be used economically for mass production. Hence, a new method was developed to provide an improved grade of silicon carbide.

A "varistor" is a circuit element constructed of a semi-conducting material and having a non-linear current-voltage characteristic. The most familiar of such devices are the widely used rectifying diodes of copper oxide, silicon, silicon carbide, or germanium. In the case of the silicon carbide varistors, each unit contains a large number of small particles arranged in series and parallel chains. Every particle is a possible source of one or more rectifying regions, and the direction of easy flow of electricity for these regions is randomly oriented. The statistical result is a symmetrical, though non-linear, circuit element.

With the introduction of silicon carbide varistors as important components in the 500-type telephone set, it was necessary to develop a new silicon carbide raw material, and to devise improved processing techniques to meet the electrical requirements and the demands of large scale production. Patents have been applied for on these techniques. Although this general type of varistor has been used in the telephone plant for many years, the silicon carbide materials and processing techniques formerly employed were inadequate for the new telephone set requirements. A range of non-linear resistance-voltage characteristics not previously obtainable with this type of device was required, and large scale production combined with low unit cost were necessary. By developing these improved silicon carbide varistors at Bell Telephone Laboratories it has been possible to make changes in circuit design that result in substantial savings in the production of the 500-type telephone set.

Two silicon carbide varistors, which may be classified as "line" and "network" varistors respectively, are used to provide equalization in the new telephone set. A simplified diagram of the transmission circuit giving their location is shown in Fig. 1. These "line" and "network" varistors, together with associated equipment, automatically compensate for variations in loop (or line) resistance to provide transmission equalization and side-tone balance. Since the "network" varistor is thinner and operates at lower voltages than the "line" unit, it is more difficult to produce, and this discussion will therefore be restricted largely to the requirements and developments relating to the "network" unit.

This new type of varistor, shown in Figure 2, is made in the form of a thin disc, with electrical contacts provided by spraying hot metal symmetrically on each face. These discs consist essentially of fine silicon carbide particles held in contact by a ceramic bond. Their direct current characteristics can be described approximately by the equation

$$I = AE^n \qquad (1)$$

where I is the direct current through the varistor, E is the dc voltage across the terminals, and A and n are constants, when n equals 1, this equation reduces to Ohm's law. Increasing values of n, therefore, represent increasing non-linearity in the voltage-current characteristics.

In a telephone set, the alternating current signals are small relative to the direct currents. However, the silicon carbide varistor control of the transmission equalization and side-tone depends on how the ac resistance to small signals varies with the direct current. The ac resistance to small signals, dE/dI, is found by differentiating equation (1) with respect to I. This results in the equation,

$$\frac{dE}{dI} = \frac{1}{n} \cdot \frac{E}{I} \qquad (2)$$

where E/I is the dc resistance at a particular value of current at which "n" is known. The ac resistance of the varistor, therefore, is equal to the dc resistance divided by "n" or in other words, the ac resistance is controlled by the direct current value. Thus, dc voltage limits at two current values are sufficient to satisfy the telephone set requirements. These voltage requirements for the "network" varistor in the 500-set made it necessary to obtain a higher value of n than was possible with commercially available silicon carbide.

These requirements for the "network" varistor can be represented by the shaded area in Figure 3. As shown, electrical measurements on varistor discs produced from regular commercial silicon carbide generally fall within the band in the lower portion of the figure. Electrical measurements on varistor discs produced from improved silicon carbide, on the other hand, usually fall within the upper band. Variations in the electrical values within both indicated bands are largely the result of differences in carbon content of the varistor mixture, varistor processing conditions, or disc thickness. The advantageous shift in the voltage-current relation resulting from the use of the improved silicon carbide represents an appreciable increase in the value of the exponent "n". Largely through this increase in the value of "n", production yields of usable "network" varistors by the Western Electric

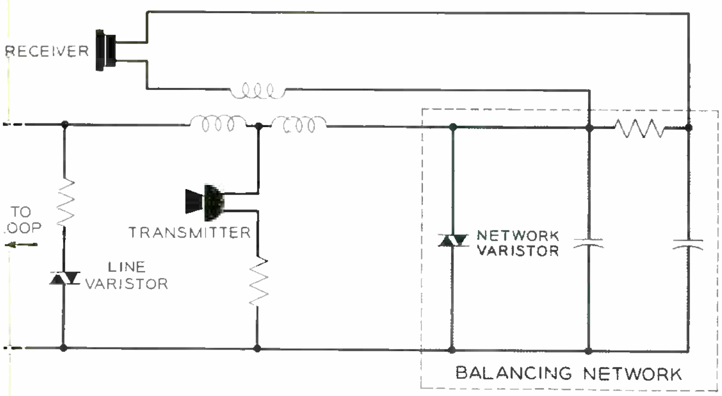


Fig. 1 — Diagram of 500-type telephone transmission circuit showing locations of the two silicon carbide varistors.

Fig. 2 — Experimental discs with electrodes in place (top) and completed discs with terminals attached (bottom).

Company have been increased from an initial figure of 0-15 per cent to a current rate of more than 70 per cent.

Silicon carbide such as that used in fabricating varistors is produced commercially in large ingots by electrically heating sand and coke to high temperatures. These ingots are then broken into chunks similar to the one shown in the headpiece of this article. They are then crushed, washed, and screened into several particle sizes to yield the usual commercial abrasive grit. This grit contains white, yellow, green, and blue particles with the latter present in the highest concentration.

Since pure silicon carbide is colorless, these colors indicate the presence of impurities. Green and yellow particles – generally located in fairly large and definite regions of the original chunks shown at the first page of this article (headpiece) – are especially undesirable since they reduce the value of the exponent "n" by an amount determined by their concentration. It is possible, however, to select original chunks that are essentially free from the undesirable material identified by these colors.

Little fundamental knowledge about silicon carbide as a semi-conductor is available, and hence, a laboratory investigation based on empirical methods was undertaken to study means of obtaining higher quality varistor material. In this investigation, chunks of silicon carbide reasonably free of yellow or green material are reduced to grit by the small hammer mill shown in Figure 4. In this operation, the chunks are fed slowly into a set of rapidly rotating hammers. The high speed impact breaks the chunks into small particles as shown by the pile of material in the lower part of the photograph. Varistors produced from this selected material are found to have appreciably higher values of "n" than those obtainable from regular commercial silicon carbide.

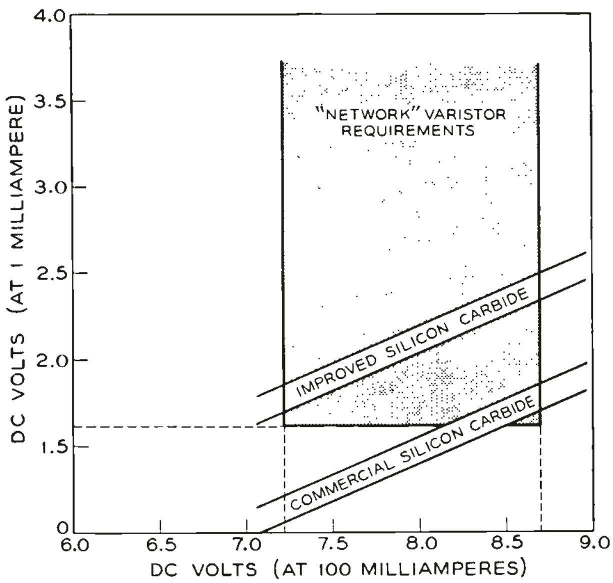


Fig. 3 — DC voltages at one and 100 milliamperes that are obtainable with commercial and improved silicon carbide.

In addition to the various colors, silicon carbide ingots contain varying proportions of relatively large, shiny crystals and fine, dull crystals. These two types of material have been carefully separated and processed into grit in the manner previously described. It was found that varistors produced from the shiny crystalline material yielded appreciably higher values of "n" than those from the dull material. During processing studies it was also learned that the fine, dull crystalline material was more readily reduced to finer grits – smaller particles – than the other material. Since the green and yellow silicon carbide is also present largely in the dull, fine crystals, the first crushing operation tends to reduce the undesirable material to small particles more rapidly than it does the desired material. Removing the finer particles by screening, therefore, results in larger particles containing substantially reduced concentrations of green and yellow material, as well as the dull particles. A further crushing of these coarser particles into the desired grit size yields the previously mentioned improved silicon carbon for varistors. This process, readily adaptable to established commercial operations, makes chunk selection unnecessary. The improved silicon carbide currently used by the Western Electric Company in fairly large quantities for "network" varistors is being produced commercially by reprocessing the coarser grit retained from the first crushing operation. It is probable that, in time, other varistor types will also be produced from this improved material.

In the production of actual varistors from the improved silicon carbide, clay, carbon, and water are homogenized. In this process, the operator adds a definite concentration of carbon since this is a factor in determining the impedance of the finished varistor. A uniform homogenization time and procedure is also necessary to obtain reproducible results. Since silicon carbide is highly abrasive, it cannot be added during homogenization. Hence, the mixture is first transferred to a dough-type mixer before the required amount of silicon carbide grit is added as shown in Figure 5. The water content in this mixture is reduced to the desired concentration by immersing the kettle in a heated water bath as shown. To avoid separation of the components, the mixture is stirred constantly during this process. The mixture forms into round pellets about the size of a pea when the moisture content has been reduced to approximately the proper concentration – a water content of five to six per cent is most desirable for pressing the varistor discs. These pellets are then granulated to pass through a 40 mesh (approximately 17 mil openings) standard screen.

The resulting granulated mixture is pressed into discs of the required thickness on equipment such as that shown in Figure 6. In this operation, a cavity

Fig. 4 — L. Derick operating a hammer mill that reduces chunks of silicon carbide to a fine grit.

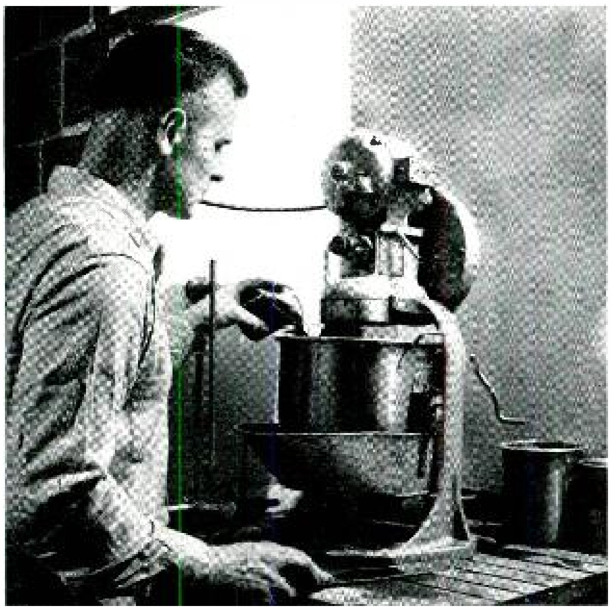


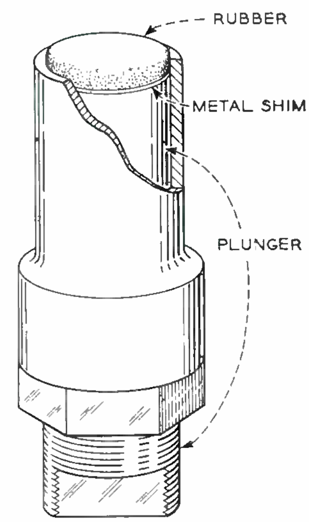
Fig. 5 — Silicon carbide grit is added to the clay matrix in a dough-type mixer.

Fig. 6 — E. B. Berry operating a press used to form varistor discs.

of definite depth is uniformly filled with the mixture which is then compressed. Prior to the development of the "network" varistor, steel faced punches were used in this disc pressing operation. Although these steel punches were satisfactory for the relatively small scale production of earlier varistor models, they were found to be inadequate for telephone set production. This was particularly true for "network" varistors which are only about 20 mils thick. Of primary importance was the high breakage of these "network" varistors during processing operations subsequent to pressing. The development of rubber-faced punches proved to be a satisfactory solution to this problem.

The essential details of a production-type rubber faced punch are illustrated in Figure 7. As shown, the rubber projects slightly beyond the outer steel

Fig. 7 — Detail of a rubber-faced punch.



rim to result in a pressed disc with a thickened outer rim as illustrated in Figure 8. This relatively thick rim provides greater disc strength without affecting the critical thickness of the part of the varistor between the electrode surfaces. The rough nature of the electrode area on the rubber pressed disc as compared to that pressed by a steel faced punch as shown in Figure 8 is an even more important advantage. The smooth surface of the steel pressed disc requires a grit blasting—surface roughening—to obtain proper adherence and electrical contact between the metal electrodes and the silicon carbide particles. As might be expected, this grit blasting operation results in serious breakage problems, especially with the thin "network" varistors. This process is no longer required for rubber pressed discs, however, since the electrode surface is sufficiently rough for proper adherence. Such a rough surface results from the ability of the rubber

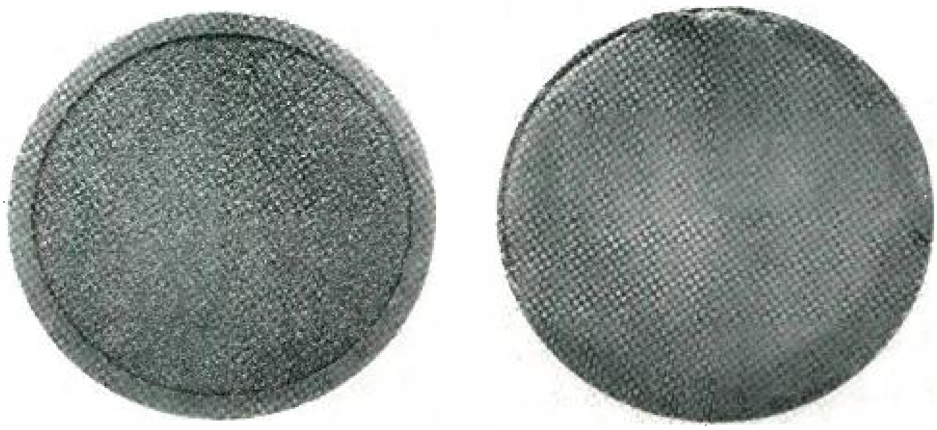


Fig. 8 — Varistor discs as formed by a rubber-faced punch (left) and a steel-faced punch (right).

to act hydraulically over short distances. The rubber squeezes the clay-carbon matrix into the interstices around the rigid silicon carbide particle stacks leaving the latter protruding from the surface.

In addition to improving disc strength and eliminating grit blasting, production type rubber-faced punches, developed by Western Electric Company engineers, have greatly increased tool life and eliminated a serious sticking problem. This development has been of great importance in the mechanization of varistor production, to reduce unit costs, and to meet the large scale demands of the new telephone set. Both the "line" and "network" varistors are manufactured by the rubber pressing process.

After pressing, the discs are closely packed in suitable ceramic containers called "boats". These boats are then fed continuously at a fixed rate through a tube furnace operating at 1100 to 1300 degrees C in an atmosphere of nitrogen, hydrogen, or mixtures of both. Variations in the disc composition and thickness together with the firing conditions provide the means for adjusting the electrical characteristics of varistors to meet particular voltage requirements.

Metal electrodes are applied to both varistor surfaces after firing. Units in this stage of processing are shown in the upper part of Figure 2. Terminals soldered to these electrodes complete the varistor as shown by the two units illustrated in the lower part of Figure 2. These varistors are being produced currently by the Western Electric Company at an annual rate of approximately five million units comprising equal numbers of "line" and "network" varistors.

THE AUTHOR

C. J. Frosch joined the Laboratories in 1929 following his graduation from Union College where he received his B.S. degree in Chemistry. He attended a Summer session in colloid chemistry at M.I.T. in 1934. From 1929 through 1934 Mr. Frosch worked on wood preservation problems. Following this work, he began studies of high molecular weight organic polymers. Since 1940 he has been engaged in the fabrication and development of plastics for telephone use. He has also been concerned with condensers and is presently engaged in work with semiconductors. Mr. Frosch is a member of the Society of Plastic Engineers, American Chemical Society, National Research Council and Sigma Xi.

Type-O carrier has greatly increased the number of telephone messages that can be transmitted over short-haul open-wire lines without the necessity of stringing new wire. Part of the flexibility and dependable operation of type-O is the result of the individual channel units and twin-channel units used. They are plug-in assemblies using die-cast frameworks and plug-in subassemblies. These features, plus efficient and economical designs, make type-O a relatively inexpensive yet highly effective carrier system.

Type-O Channel Circuits

O. R. GARFIELD *Transmission Systems Development I*

Previous articles on type-O carrier* have treated the requirements, objectives, and the over-all system. In general, type-O is a relatively inexpensive sixteen-channel carrier system designed for short-haul open-wire lines, to reduce or eliminate the need for stringing new wire. Type-O is not a single system; rather, it is a grouping of four channels each into four separate systems, known as OA, OB, OC, and OD. Line frequencies are so allocated that each system uses 36 kc (OA uses 34 kc) with frequency separation between the systems, as shown in Figure 1. In these four systems, a separate channel unit, Figure 2, is required at a terminal for each two-way telephone conversation. Such a unit contains parts of the terminal equipment common only to one channel.

In Figure 3, an OB terminal is shown in block schematic form. Four channel units are associated with two "twin-channel" units, and these in turn are connected through a combining multiple to two group units – one receiving and one transmitting. Each twin-channel unit supplies a carrier that is used by two different channels for transmitting, and provides a receiving regulating amplifier for the same two channels in the other direction. The group units could just as aptly be called "system" units, since one of their functions is to separate the four channels of one system from those of other type-O systems on a given line.

Each channel unit consists of three different plug-in subassemblies; complete channel units are shown in the headpiece. Two of these three, the compressor and expandor-signaling subassemblies, were borrowed from type-N carrier† with their design substantially unchanged; together they form a "compandor".‡ The compressor raises the level of weak speech at the transmitting terminal by about 28 db while the expandor introduces a compensating 28 db loss to weak speech and line noise. For strong speech, the compressor introduces no

Above — The author points out a feature of a twin-channel unit to G. T. Cindric. Complete channel-unit assemblies may be seen on the table.

* Record, *June*, 1954, *pages* 209 *and* 215.
† Record, *July*, 1952, *page* 277.
‡ Record, *November*, 1953, *page* 450.

gain and the expandor no loss. The combination of compressor and expandor thus maintains the proper relationship between strong and weak speech at the receiving end, yet reduces noise or crosstalk picked up on lines, in repeaters, or in either terminal between the compressor and expandor. These are ideal conditions and the maximum improvement of 28 db is seldom realized because of a variety of factors. In practice, the signal-to-noise ratio is improved by about 22-23 db.

A 3,700-cycle signaling system* is included as part of the expandor subassembly, to take care of all necessary signaling on the channel. Central office signaling leads control a 3,700-cycle tone at the transmitting terminal; a 3,700-cycle receiver controls outgoing signaling leads at the receiving terminal. Filters in each channel unit limit the upper frequency range of transmitted speech to

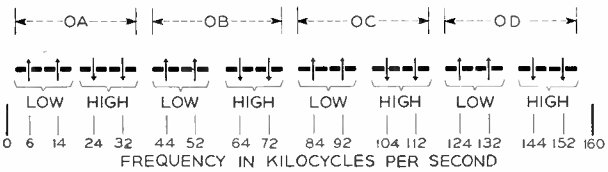


Fig. 1 — Line frequency allocations of the four type-O systems. In each system, a separate channel unit is required for each two-way conversation.

about 3,100 cycles, permitting the 3,700-cycle signaling system to operate "out-of-band," or above the speech frequencies, but still within the carrier channel of 4 kc.

The third subassembly of each channel unit is physically somewhat similar to, but is electrically considerably different from, the carrier-frequency subassembly used in type-N carrier. This subassembly in type O contains the transmitting modulator, the receiving demodulator, and a receiving amplifier. Figure 4 shows the circuit arrangement. Both the modulator and demodulator are shunt-type circuits using semiconductor rectifiers arranged as a bridge. For one half-cycle of the carrier-frequency, the shunt is high impedance and the input is connected to the next unit. On the other half-cycle of the carrier, the shunt is an effective short circuit across the message channel, and the input is shorted out. This type of modulation is a simple, inexpensive arrangement, first used in the early 1930's.

* Record, *April*, 1953, *page* 136.

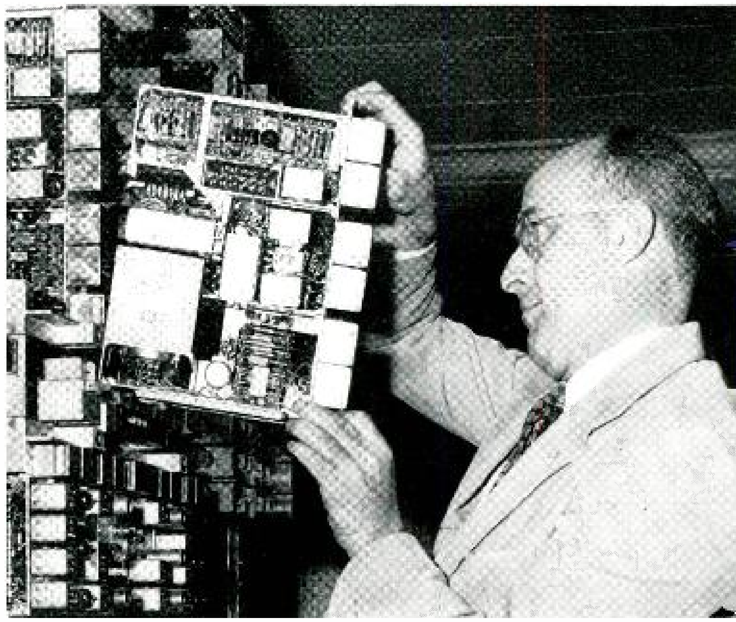
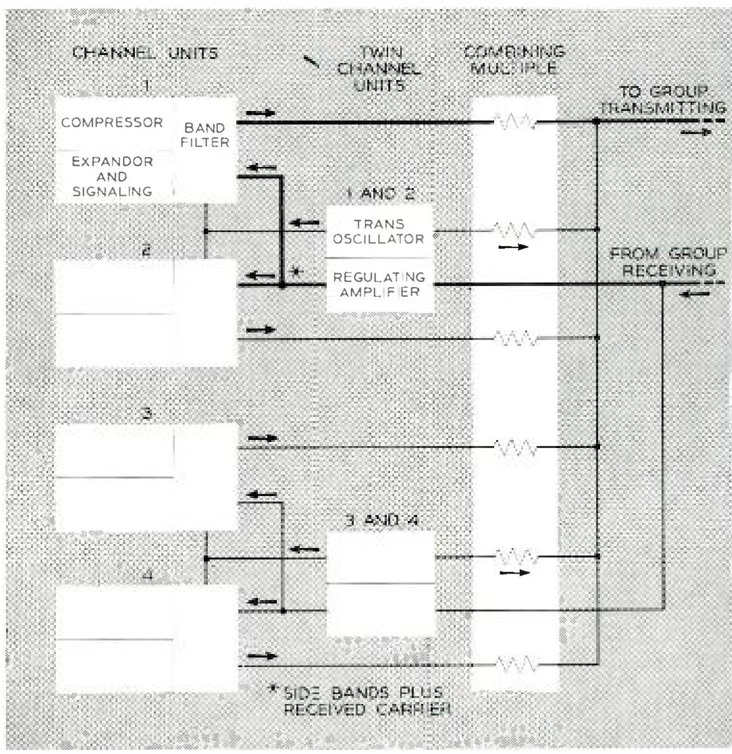


Fig. 2 — C. W. Irby inserts a channel unit in its plug-in mounting in an OB installation.

Instead of double-sideband transmission as used in type N, the type-O systems use single-sideband transmission, as do most other Bell System carrier arrangements. Although single-sideband transmission requires the use of additional and costlier fil-

Fig. 3 — A block diagram of an OB channel terminal.



ters, it is more economical of frequency space. Since the transposition of open-wire pairs also becomes expensive for frequencies above 150-160 kc, this economy of frequency space was the deciding factor. However, the extra cost of filters is partially offset by using a "twin-channel" arrangement, eliminating half the oscillators and some circuits normally used. Each twin-channel carrier is associated with two separate telephone channels, the carrier being common to both channels. Figure 5 shows how this is done.

with a reinserted carrier, at a predetermined level.

Compensating for variations in line attenuation is comparatively simple if a strong carrier is transmitted, since the carrier level is used by regulating circuits as a guide to the amplifier gain needed for constant output. However, it is undesirable to load up the amplifiers with a strong carrier, since intelligence is transmitted only by the sidebands. In type O, a compromise value of +6 dbm* is used for the transmitted carrier at the group unit output where the message sideband level is O db. At this

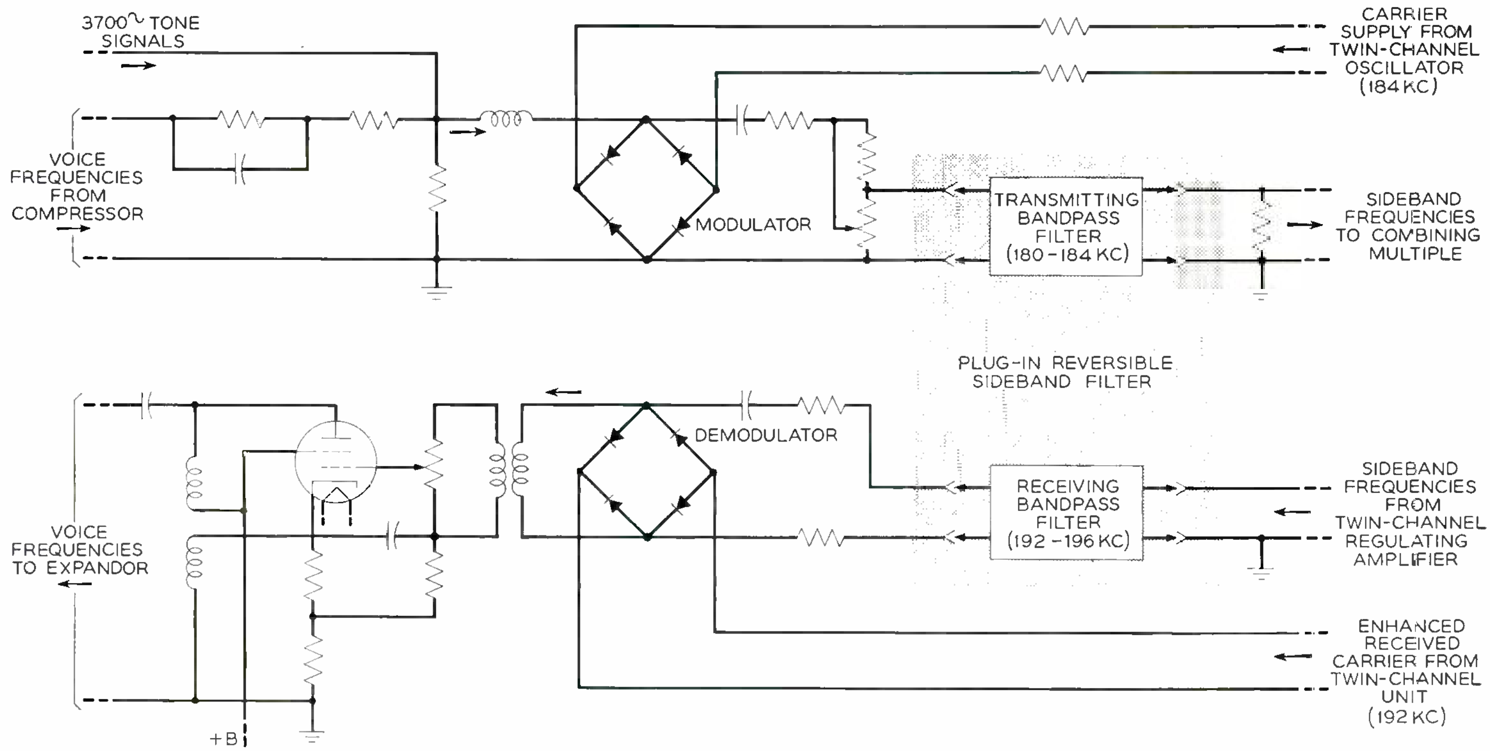


Fig. 4 — Simplified schematic of the carrier-frequency subassembly of a channel unit.

Channel 1 is modulated onto a carrier supplied by a twin-channel unit, and the upper sideband is then removed by a filter. A second channel is also modulated onto the same carrier in a second modulator, and this time the lower sideband is removed. Since the carrier lies on the steep slope of the filter response, and it is impractical to manufacture a large number of channel band filters with identical responses, the carrier will be reduced in amplitude by differing amounts for different filters. To obviate this difficulty, each carrier is balanced out during modulation, leaving only the individual sidebands. At a combining multiple, then, the proper sidebands of two channels are combined with each other and

same point, the signaling power is O dbm.

Channel frequency assignments for all type-O systems are shown in Figure 6. It should be noted that only two carrier frequencies are used, regardless of the particular system or type of terminal involved. If low-group transmission is used, for example, channel 1 is transmitted as the lower sideband of 184 kc and is received as the upper sideband of 192 kc. Channel 2, on the other hand, is transmitted as the upper sideband of 184 kc and is received as the lower sideband of 192 kc. Channels 3 and 4 are then handled by the second twin-

* dbm — decibels above 1 milliwatt.

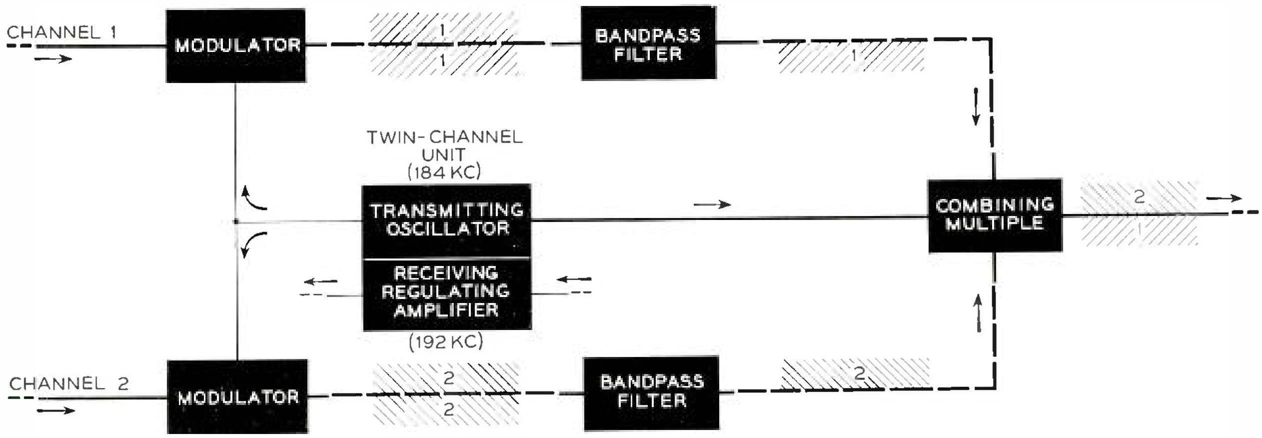


Fig. 5 — Two telephone channels are associated with a single carrier frequency in twin-channel operation. Carriers between modulators and the combining multiple are shown only for clarity; they are balanced out in the modulators.

channel unit in exactly the same manner, except that the carrier frequencies are interchanged. In this way, only two channel filter units are needed; one passes the two bands 180-184 kc and 192-196 kc, while the other passes 184-188 kc and 188-192 kc. Each filter unit may be plugged into its socket in either of two orientations, so that two different filter codes and two orientations can take care of all possible system arrangements.

Twin-channel units supply the carrier frequencies from crystal oscillators, and also contain receiving regulating amplifiers. Such a unit may be seen in the headpiece. Each crystal oscillator is of the electron-coupled type, the cathode, grid, and screen forming a Colpitts oscillator; the crystal, with its series frequency-adjusting capacitor, acts as an inductance. The use of the crystal results in an extremely stable oscillator because the apparent inductance changes very rapidly for small changes in frequency.

The output transformer is tuned to eliminate harmonics, but additional suppression is needed for the second harmonic. This is supplied by an anti-resonant circuit in series with the output to the combining multiple. In the receiving direction, a carrier pick-off filter and an amplifier provide sufficient carrier for demodulation. The regulating amplifier provides regulation of better than 1 db for input variations up to 12 db in the receiving direction. By using a small dc voltage as a standard against which the rectified signal level is compared, a very flat regulating characteristic is achieved. If, for example, the rectified carrier provides 15 volts, an increase of 1 volt will be only a $6\frac{2}{3}$ per cent change. If the 15 volts is compared to a 12 volt standard, the control voltage will be 3 volts. An increase of 1 volt will now make this 4 volts, a change of $33\frac{1}{3}$ per cent. The net result is a much better regulating characteristic.

Regulators in repeaters and group receiving units take care of variations in line attenuation resulting from changing weather conditions. Frequency frogging removes most of the line slope, particularly if there are an odd number of repeaters. Line slope is a variation in attenuation with frequency that is present to some degree on all communication lines. There will, however, always be some residual line slope, the amount depending on weather conditions. For this reason, the two received carriers of a system will be slightly different in amplitude; regulators in the two twin-channel units compen-

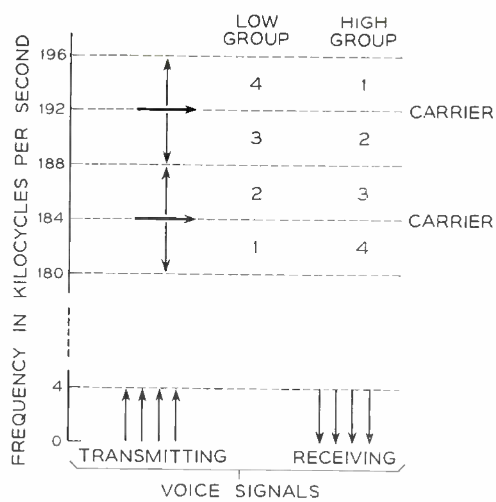


Fig. 6 — The basic channel frequencies of all type-O systems are the same.

sate for this difference, holding their carrier outputs constant at the same value. In this way, the variation in output between channels is reduced to a negligible amount.

A complete four-channel type-O terminal for one system thus contains four individual channel units, two twin-channel units, and three group units. These group units will be described in a later RECORD article but, since they are common to all four channels of a given type-O system, a brief description of group operation is included in the following paragraph.

The output of two channels is associated with a single carrier; two carriers, with their four message sidebands (180 to 196) are then fed into a group transmitting unit. A group oscillator modulates the four channels (two carriers) to their proper allocation in the frequency spectrum, for transmission over the open-wire line. At the receiving end, a group receiving unit modulates the received line frequencies back to the correct frequencies (180-196 kc) for channel operation. Since all channels of all four type-O systems use the same two carrier frequencies (184 and 192 kc) for both transmitting and receiving, the group units must modulate these frequencies to and from the appropriate line frequencies for the particular system. They must also separate the transmitting and receiving line frequency groups, and separate the system from other carrier systems on the line.

THE AUTHOR

O. R. GARFIELD has been in the Transmission Development Department since joining the Laboratories in 1930, first at 180 Varick Street and since the completion of Building 2 at Murray Hill. He has worked on parts of Type-C and type-J carrier, echo suppressors, several radio control terminals, two radio privacy systems, several short-haul carrier systems, and compandors. During World War II he was engaged in several underwater sound projects for the Navy. Since the war he has had a part in the development of type-O and type-ON carrier and currently is engaged in a project involving the use of junction transistors. Mr. Garfield received both his B.S. and M.S. degrees in E.E. from Massachusetts Institute of Technology in 1930.

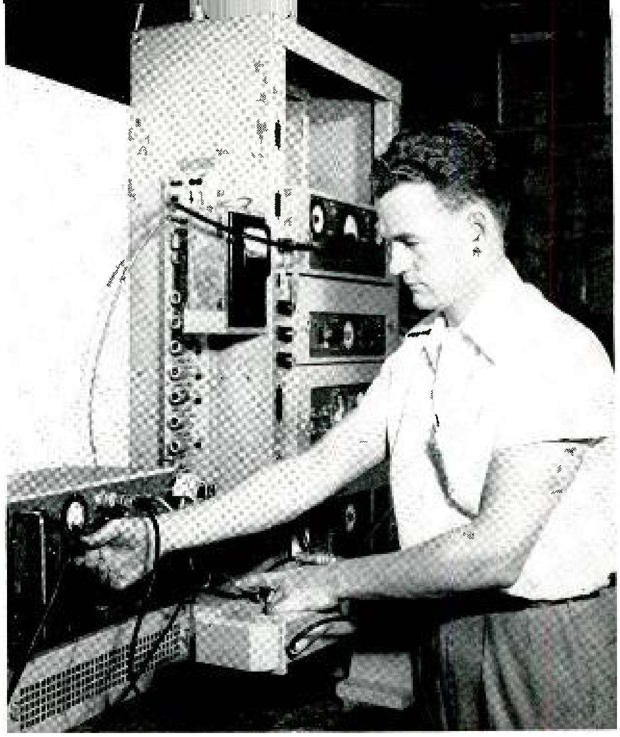
W. A. Shewhart Honored by Rutgers

Dr. Walter A. Shewhart, a member of the Laboratories' mathematical research department and a pioneer in statistical quality control techniques, has been awarded Rutgers University's first honorary professorship in statistical quality control. He is one of eight scientists who have received honorary professorships from Rutgers, and the only one to have received such an appointment in the field of statistical quality control.

Throughout his Bell System career, which began in 1918 with the Western Electric Company's research department, Dr. Shewhart has specialized in the application of statistics in engineering and standardization, and the theory and practice of quality control of products. He invented the Shewhart control chart which is widely used in industry as a basic tool in statistical quality control.

Dr. Shewhart is a graduate of the University of Illinois, and received the Ph.D. degree from the University of California. He has lectured on statistics and quality control at universities and before technical societies in this country, Europe and Asia. In his honor the American Society for Quality Control established its Shewhart Medal. This medal is awarded annually for distinction in the field of quality control.

A Noise-Figure Test Set for the TD-2 Radio System



Above — G. D. Brown using the test set to measure the noise figure of a TD-2 converter-preamplifier. The fluorescent tube noise source in the foreground is stored in the test set compartment.

D. H. HESSELGRAVE
Transmission Systems Development I

Since noise in a communication system reduces the intelligibility of information transmitted over the system, it is extremely important to know how much noise is being added by various portions of the system. A term called the "noise figure" is used to evaluate noise, and a new portable noise-figure test set has been developed especially for use with the TD-2 radio relay system. Two charts included with the test set enable rapid calculation of the noise figure without complicated mathematics.

A common problem exists for both a vociferous Cleveland "Indian" fan in Yankee Stadium, and for the TD-2 radio system – how to convey information in the presence of noise. Although no ready solution is available to the hapless "Indian" fan, a test set has been developed to aid in noise reduction in the TD-2 radio system. This set, shown in Figure 1, is used to evaluate the noise added by a TD-2 radio receiver to a signal impressed at its input.

Of what use are noise measurements, and how does the noise-figure test set work? To understand the test set, we must know something about this unwanted noise.

Noise sources of the TD-2 radio system lie predominantly in the equipment, since atmospheric noise is virtually non-existent in the microwave spectrum. Equipment noise falls into three categories: (1) electron-tube noise, such as "shot" effect, and partition noise caused by changes in relative current flow to screen grid, plate and any other tube elements that draw current; (2) varistor noise, arising at the diode modulators in the receiver input circuit, and (3) thermal agitation noise (Johnson noise) caused by random electron motion in conductors and resistors.

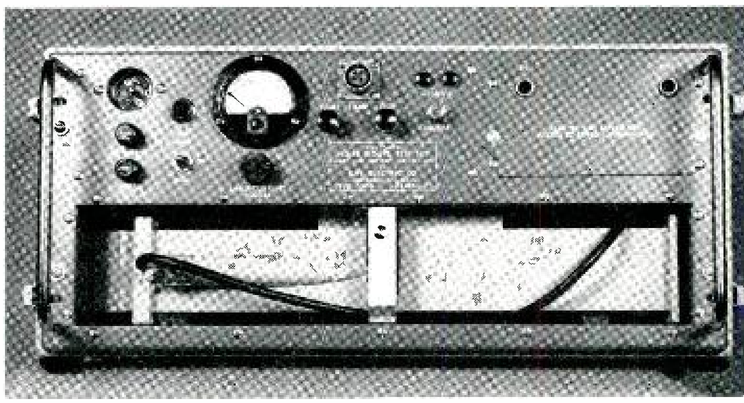


Fig. 1 — A front panel view of the noise figure test set, showing how the noise source is stored.

In the microwave region, all of these sources can be considered as "white noise"; that is, having a uniform energy distribution over the entire frequency spectrum. A "white-noise" source delivers the same amount of power into any given bandwidth, whether in the audio, high frequency, or microwave region.

The power level of this noise at the receiver output will depend not only upon receiver amplification but also upon the bandwidth of the receiver. The wider the receiver bandwidth, the greater the noise energy coming through the receiver. It can be seen that a simple measurement of the absolute noise power output of the receiver has no value in determining receiver-added noise unless the bandwidth and amplification are known. A noisy, low-gain receiver might have no more output noise than a quiet, high-gain receiver. Similarly, a wide-band, low-gain receiver could have the same output noise as a narrow-band, high-gain receiver. However, the latter receiver would, in either case, have a much higher signal-to-noise ratio; in communication work we strive for this high ratio.

Here, now, is a possible method for figuring receiver-added noise. Why not measure the signal-to-noise ratio—first at the receiver input, and then at the receiver output? The difference between these two signal-to-noise ratios will tell us how much noise the receiver adds to the signal. From such a measurement we get the "noise figure". This noise figure, usually expressed in db, is a ratio of two power ratios – the signal-to-noise ratio at the input of the receiver divided by the signal-to-noise ratio at the output of the receiver. The noise figure, then, shows the change in signal-to-noise ratio of any signal passing through the receiver.

A second way of looking at the noise figure, one that relates an actual receiver to an *ideal* receiver, is as follows:

(a) First, an ideal receiver with a given bandwidth and gain has no internal noise. However, it must have an input termination – a transmission line or an antenna – which, being resistive, will generate "Johnson" noise. The actual noise power output results from this input noise being amplified.

(b) Second, an *actual* receiver with the same bandwidth and gain has additional noise from electron tubes and other circuit elements. The total noise power output results from all these noises being amplified.

(c) The noise figure is the ratio of noise power outputs – the noise power from an actual receiver divided by the noise power from an ideal receiver.

From this definition, we can get another relation. We stated that both receivers had the same bandwidth and the same gain; each receiver will thus amplify a given band of input noise the same amount. Therefore, if we assume *all* noise in an actual receiver to arise at the input circuit, the noise figure is the ratio of two noise power *inputs* – the noise power input of an actual receiver divided by the noise power input of a theoretical receiver. This noise figure definition will be very useful a little later, in discussing how to measure the noise figure of a TD-2 receiver.

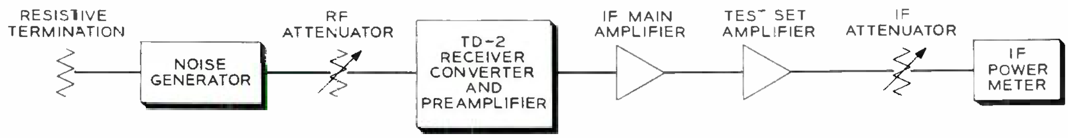


Fig. 2 — A block diagram of a typical test set-up using the noise figure test set.

The noise figure test set provides an easy way to make noise-figure measurements. It consists of three units: a white-noise generator, a wideband amplifier similar to those used for the 70-mc IF stages of the TD-2 radio system, and ac operated power supplies. In addition, an IF power meter and RF and IF attenuators, normally available at all TD-2 stations, are used in "noise figure" measurements.

Our white noise generator is a standard household and office item – nothing more than an ordinary fluorescent lamp.* Instead of alternating current, direct current is used to light this lamp and eliminate 60-cycle ac modulation of the noise power output. Any lamp will do, regardless of size or type. The only important features are the type of gas and the gas pressure inside the lamp. The ordinary fluorescent lamp contains a mixture of argon and mercury, at a pressure that is closely monitored during manufacture. Since all these lamps are so closely similar, no special adjustments are needed when installing or replacing them in the test set.

The *available* power output of a lamp is usually

* Record, *March*, 1951, *page* 116.

Fig. 3 — The author inserts a fluorescent tube into its special diagonal mounting in the waveguide. This mounting matches the waveguide and produces optimum noise power.

specified in relation to the thermal-agitation noise existing in any resistor, and is 16 db higher, or about 40 times greater, than that of a resistor at room temperature. Other lamps, having different gases and pressures, reveal available noise powers up to 8 db higher than an ordinary fluorescent lamp. For any of these lamps, noise is produced by a random motion of electrons excited by the lamp current. The *actual* noise power output depends upon the type of lamp mounting, the direct current flowing through the lamp, and the temperature. When used to test a TD-2 receiver, a noise generator must put out white noise in the microwave region. For the best impedance match (and consequent maximum noise power output) over a broad microwave frequency band, a fluorescent lamp is mounted diagonally through the broad faces of a waveguide. This type of mounting for a T-5 (⅝ inch diameter) lamp is shown in Figure 3.

Another factor — the direct current flowing through the lamp — affects the noise power delivered. Below a certain critical current, the impedance of a fluorescent lamp varies continuously at an audio-frequency rate. Above this critical current point, the impedance and noise output remain substantially constant. Lamp temperature has a minor effect on noise power output, causing a decrease of about 0.1 db for every 2°C increase in temperature above 26°C. Although this lamp noise power output is 16 db more than that of a room-temperature resistor, it is only −158 dbm per cycle.

That doesn't look like a usable power, but consider for a moment. This noise generator is used with a TD-2 radio receiver which has a bandwidth of 36 mc and a minimum gain of about 60 db. In a receiver that will pass a 36-mc signal, this gives a total input noise power of −82 dbm. With a receiver gain of 60 db (ignoring, for the moment, any receiver-added noise), there is a total receiver noise power output of −22 dbm. The additional gain of the test set amplifier then brings up this power level sufficiently to measure on a meter.

Now, how can a white noise generator be used in measuring noise figures? First of all, we know that receiver output noise consists of unavoidable resistor "Johnson" noise at the input plus all the lumped receiver noises. Now, if we *add* a known amount of noise to the input, sufficient to double (or increase by any given amount) the output noise, we have an indirect measure of the input noise. Our noise generator supplies this known amount of added noise.

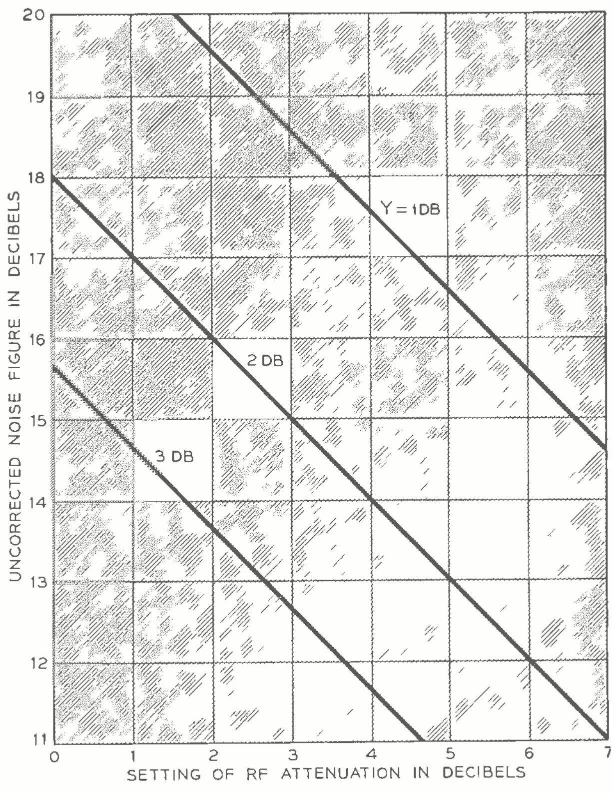


Fig. 4 — This chart indicates the noise figure for various RF attenuator settings and three values of the change in output power when noise is added.

A complete mathematical expression for the noise figure, from relations established by H. T. Friis and W. W. Mumford, is as follows:

$$F = 15.7 - Kt - A - 10 \log_{10}\left[\left(\text{antilog} \frac{Y}{10}\right) - 1 \right]$$

where

F = noise figure in db.

A = loss of RF attenuator in db.

Y = ratio (in db) of noise output power with the noise generator connected at the receiver input, to the noise output power with a matched termination (at 34°C) connected at the receiver input.

Kt = temperature correction (0.055 db per °C) based on 34°C.

Certainly an unwieldy expression. However, the two graphs shown in Figures 4 and 5 reduce the mathematics to simple addition. To measure a typical TD-2 receiver for its noise figure, the equipment arrangement shown in Figure 2 is used, and the graphs simplify the calculation. We start with the noise lamp unlit and the RF attenuator set for 20 db loss, to match the receiver input with a resistive load. The receiver now has a room-temperature noise source at its input. Next, the IF main amplifier is adjusted for a convenient power meter indication. The test set amplifier boosts the receiver noise power to about 0 dbm, the working region of the power meter. This reference noise level consists of the resistive input noise and all receiver noise being amplified.

Next, power is applied to the noise lamp to get a gaseous-discharge noise. We decrease the loss in the RF attenuator, letting enough extra noise come through the receiver to substantially increase the original noise power.

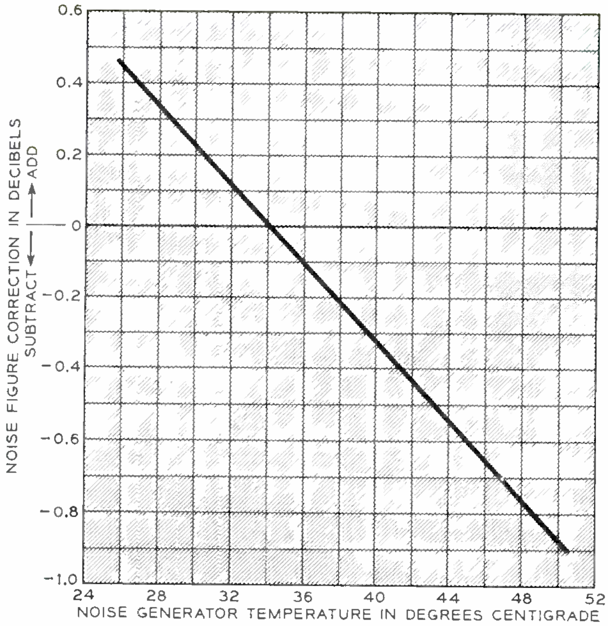


Fig. 5 — For more exact values of noise figure than possible with Figure 4, this chart supplies correction values for various temperatures.

To avoid relying on the power meter accuracy, we set the IF attenuator for a few db of loss and then set the RF attenuator for the *same* power meter indication we had with the receiver noise only. Now we record the readings for this typical TD-2 receiver:

Setting of RF attenuator (A) = 1.9 db.

Change in output power with the noise source applied (Y) = 2 db.

Temperature of noise source = 32°C.

From the graph of Figure 4, and with the above values, the *uncorrected* noise figure is 16.2 db. The graph of Figure 5 shows that the temperature cor-

THE AUTHOR

D. H. Hesselgrave received his B.E.E. degree from Fenn College in Cleveland, Ohio in 1947 and a few months later joined the Long Lines Department of A.T.&T. He was concerned chiefly with the transcontinental radio relay system, working on field testing and on initial installations with the Western Electric Co. Since joining the Laboratories in 1951, Mr. Hesselgrave has continued to work on the transcontinental relay system, first concentrating on Bell System practices and later on the noise figure test set. More recently he has been engaged in the development of the automatic switching system for TD-2, including the development of test equipment for the switching system and the preparation of Bell System practices.

rection is +0.1 db. The receiver noise figure is, then, 16.2 + 0.1 or 16.3 db.

How does noise produced in the IF main amplifier and the test set amplifier affect the noise figure measurement? Very slightly, since the effect of any one amplifier stage's noise figure is modified by the gain preceding it. The gain of the first two or three stages in a receiver is sufficiently high to mask any noise added by latter stages. For this reason, only the "front end" – the first few stages – of a receiver is important in noise figure measurement and reduction.

The typical receiver just measured adds 16.3 db more noise to any incoming signal than would an "ideal" noiseless receiver. Noise hinders signal information; it tends to put "snow" in a television picture and a hissing sound in carrier telephone channels. The noise in this TD-2 receiver could come from many sources. The receiver may have noisy receiver-converter varistors; it may have an input circuit not adjusted for maximum signal to noise; or it may have electron tubes that are at the end of their life. Whatever may be the difficulty, we can now make adjustments and replace parts to minimize the added noise, using the noise figure test set to evaluate any improvement.

Members of Laboratories on I.R.E. Committees, 1954

Many Laboratories people have been appointed to General and Technical Committees of the Institute of Radio Engineers for the fiscal year 1954-1955.

General Committees: *Executive,* J. R. Pierce. *Awards,* J. F. Morrison. *Appointments,* A. G. Jensen. *Constitution and Laws,* R. A. Heising. *Editorial Board,* J. R. Pierce, Chairman.

Also *Editorial Review,* H. A. Affel, Jr., W. J. Albersheim, A. E. Anderson, J. T. Bangert, J. M. Barstow, P. H. Betts, Kenneth Bullington, A. B. Crawford, C. C. Cutler, G. C. Dacey, Sidney Darlington, A. C. Dickieson, W. H. Doherty, C. H. Elmendorf, J. H. Felker, A. G. Fox, W. M. Goodall, A. J. Grossman, A. G. Jensen, W. E. Kock, Rudolph Kompfner, J. G. Linvill, F. B. Llewellyn, S. P. Lloyd, W. H. MacWilliams, Jr., W. P. Mason, Brockway McMillan, Pierre Mertz, S. E. Miller, J. F. Morrison, J. R. Pierce, C. F. Quate, D. H. Ring, R. M. Ryder, S. A. Schelkunoff, David Slepian, E. K. Van Tassel and R. L. Wallace, Jr. *Education,* F. R. Stansel. *Policy Advisory,* A. G. Jensen. *Professional Groups,* R. A. Heising. *Tellers,* J. P. Molnar.

Technical Committees: *Standards Committee,* M. W. Baldwin, Jr., Vice Chairman, W. R. Bennett, A. G. Jensen, J. G. Kreer, W. P. Mason, P. H. Smith and J. E. Ward. *Antennas and Wave Guides,* P. H. Smith, Chairman and A. G. Fox. *Audio Techniques,* H. W. Augustadt, W. Lindsay Black, F. L. Hooper and R. A. Miller. *Circuits,* W. R. Bennett, Chairman, J. T. Bangert, A. R. D'Heedene, T. R. Finch, J. G. Linvill and E. H. Perkins. *Electroacoustics,* H. L. Barney and W. D. Goodale, Jr. *Facsimile,* P. Mertz and K. W. Pfleger. *Feedback Control Systems,* J. E. Ward, Chairman, and J. C. Lozier. *Information Theory and Modulation Systems,* J. G. Kreer, Jr., Vice Chairman, W. R. Bennett, E. R. Kretzmer and L. A. Meacham. *Measurements and Instrumentation,* C. D. Owens. *Mobile Communication Systems,* N. Monk. *Piezoelectric Crystals,* W. P. Mason, Chairman, I. E. Fair, W. J. Merz, P. L. Smith and R. A. Sykes. *Radio Transmitters,* A. Brown and A. E. Kerwien. *Television Systems,* W. T. Wintringham, Vice Chairman, M. W. Baldwin, Jr., and A. G. Jensen. *Video Techniques,* S. Doba, Jr., and J. R. Hefele. *Wave Propagation,* K. Bullington and A. B. Crawford. *Special Committees,* IRE-IEE *International Liaison Committee,* Ralph Bown and F. B. Llewellyn.

Institute Representatives on Other Bodies:

ASA Standards Council, A. G. Jensen.

ASA Electrical Standards Board, F. B. Llewellyn and A. G. Jensen.

ASA Sectional Committee (C42) on Definitions of Electrical Terms, M. W. Baldwin, Jr., and A. G. Jensen.

ASA Subcommittee (C42.13) on Communications, J. C. Schelleng.

ASA Sectional Committee (C61) on Electric and Magnetic Magnitudes and Units, S. A. Schelkunoff.

ASA Sectional Committee (Y32) on Graphical Symbols and Designations, A. F. Pomeroy, Alternate.

ASA Sectional Committee (Z24) on Acoustical Measurements and Terminology, W. D. Goodale, Jr.

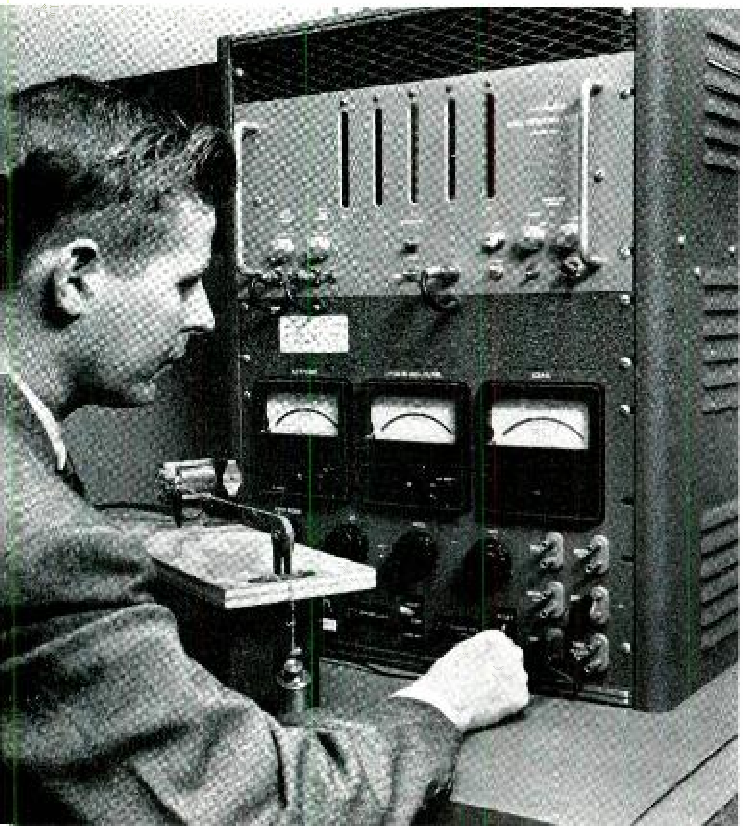
U. S. National Committee, International Electrotechnical Commission, Advisers on Symbols, A. F. Pomeroy, Alternate.

U. S. National Committee of the International Electrotechnical Commission, F. B. Llewellyn and A. G. Jensen.

International Radio Consultative Committee, Executive Committee of U. S. Delegation, A. G. Jensen.

Joint IRE-SMPTE-NARTB Committee for Inter-Society Coordination (Television) (JCIC), M. W. Baldwin, Jr., Alternate.

National Research Council, Division of Engineering and Industrial Research, F. B. Llewellyn (7/1/54-6/30/57) 3 years.



Although the main trend in telephone switching is toward rapid operation for faster handling of telephone calls, certain applications require a special relay that acts slowly within definite time limits. With the introduction of the wire-spring relay, a complementary slow release type was developed. This relay incorporates the advantages of wire-spring construction, and achieves other important improvements over the older slow release types.

Slow Release Wire-Spring Relay

O. C. WORLEY *Switching Apparatus Development*

Among the relays used in telephone switching systems, there is a special kind known as the slow release relay. These relays are used in timing operations. Ordinarily, when the current in the circuit winding of a relay is interrupted, the design engineer wants the contacts of the relay to make or break almost immediately. But when the winding current of a slow release relay is interrupted, there is a considerable delay in its operation, called the release time, before the armature actuating the contacts is released.

The "register advance" relay is one of the most familiar and important applications of the slow release principle, since a wrong number would be registered if this relay did not delay certain operations properly. The register advance relay in a central office guides the dialed number into the proper registers. The customer dials the pulses, and the register advance relay must recognize when the pulses for one digit end and those for a new digit begin. It must be able to tell, for instance, that a customer has just dialed the two digits "1-1" and not the single digit "2". It is able to make this distinction because the telephone dial is so designed that the customer must pause slightly between individual digits of the number he is dialing. When the customer dials, say "7", the slow release register advance relay will not release while the seven pulses are being received, but during the pause before the next digit is dialed, the relay releases after the delay time, thus signaling the register that here is the interval between two distinct digits.

The slow release principle is incorporated in the Y type relay*, used in many existing installations.

Above — The author testing release time of an AG type wire-spring relay. Various weights are attached to give the effect of different spring loads.

* Record, *May*, 1938, *page* 310, and *April*, 1948, *page* 161.

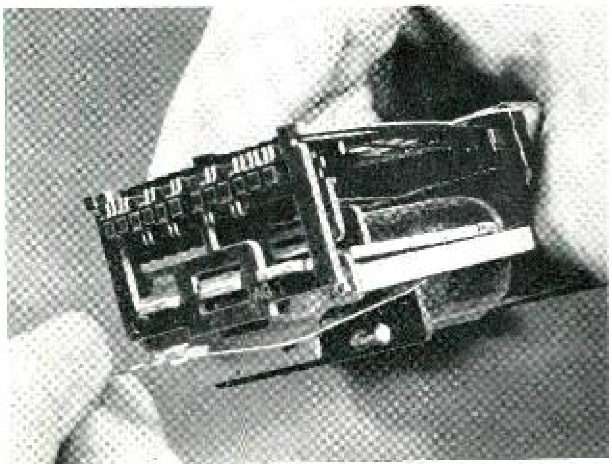


Fig. 1 — The new AG slow release relay, incorporating the features of wire-spring construction.

This relay is a modification of the U type general purpose relay, and both have performed satisfactorily for a number of years. It recently became apparent, however, that lower manufacturing costs and improved performance could best be obtained by a completely new design. As a result, the new wire-spring family has been developed, and it includes the AG slow release type shown in Figure 1. This relay is intended eventually to replace the Y type relay.

This wire-spring family, in addition to the AG, includes the AF general purpose and the AJ special purpose types,* and is being introduced in the No. 5 Crossbar switching system. All of these wire-spring relays are of similar construction and look a great deal alike. Wherever possible common parts and manufacturing tooling have been used, since this results in the lowest production costs and in a standardized method of mounting and wiring.

A major advantage of the general purpose wire-spring relays is that their over-all cost is less than that of the comparable U and UB types, because the design permits greater mechanization of assembly in manufacture and greatly reduces adjustment effort. Among their other advantages, they also have longer life, increased stability, and lower power requirements.

The features necessary to adapt the general purpose wire-spring relay to the slow release type fall into two classes: those that provide a long release time, and those that are required to control variations in this release time. Figure 2 identifies most of the parts of the AG slow release relay. Many of these features represent modifications of those incorporated in the older Y type.*

In the first category, that of providing a long release time, the AG relay uses a special armature and a metal sleeve that mounts on the core inside the winding. In visualizing how these components function, the relay can be thought of as being controlled by two opposing forces. Magnetic flux, in some ways analogous to electrical current, "flows" through the iron parts of the magnet and tends to draw the armature and core together (magnetic pull), but opposing this force is another resulting from the action of the contact springs (spring load). After the relay has operated, it releases when the magnetic pull becomes less than the spring load. For a long release time it is therefore necessary to prevent the flux from decaying rapidly from the high level that exists when the relay is operated.

* RECORD, *November*, 1953, *page* 417.

* RECORD, *May*, 1938, *page* 310.

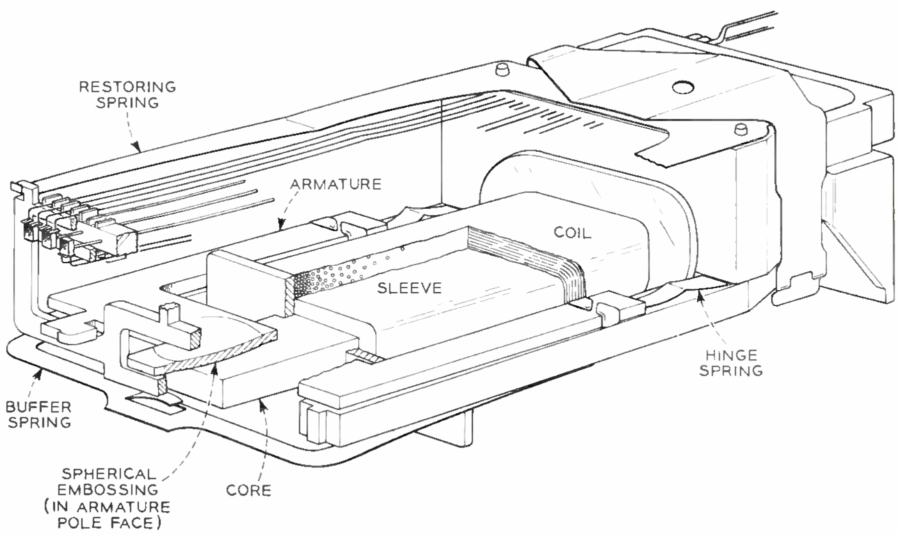


Fig. 2—Cutaway view of the AG slow release wire-spring relay.

The metal sleeve that fits on the core has a voltage induced in it when the winding circuit is interrupted, and the resulting sleeve current tends to maintain the flux. These currents are dissipated slowly because of the high conductance of the sleeve, and various sleeves are provided for different applications to permit a wide range of release times. Figure 4 shows this range for different types of sleeves and for different numbers of contacts on the relay.

The special armature rests directly against the center core leg when the relay is operated, thus providing an iron-to-iron fit except for the finish on the parts. In contrast, on general purpose relays non-magnetic spacers are attached to the armature to provide a larger gap when operated. With the smaller separation on the AG relay, a given flux level is maintained by less sleeve current, the current decays further before release occurs for a given spring load, and a longer release time is obtained.

The second category, that of controlling variations in release time, is of great importance in providing accurate, trouble-free service for long periods of time. Some slow release relays are expected to function efficiently for at least one hundred million operations. Because of the AG relay's low reluctance (low resistance to the flow of magnetic flux), it is sensitive to variations in the magnet. To control these variations, and consequently to stabilize release times, the AG relay, like its predecessor the Y type, incorporates (1) an anneal of the magnetic parts in a hydrogen atmosphere, (2) a spherical dome embossed in the armature pole face, (3) a chromium finish on the magnetic parts, and (4) a "buffer spring". The spherical dome and the buffer spring can be seen in Figure 2. The AG relay also uses a heavier restoring spring than do the other wire-spring types.

The primary purpose of the hydrogen anneal is to obtain a low "coercive force", which is a measure of the extent to which the relay is permanently magnetized after it has been operated. Magnetic flux at release is caused partially by the currents induced in the sleeve and core, and partially by the coercive force. If this force is increased, and the load kept constant, the sleeve currents must decay further before the flux reaches the release level, and the release time is therefore increased. Manufacturing variations in coercive force, however, are about plus or minus thirty per cent of the nominal value. Consequently, the magnitude of these variations and the resultant variations in release time are held to a minimum by using a low nominal value of coercive force. For a given spring load and release time, the lower coercive force may be compensated for by a lower reluctance magnetic circuit or by a higher conductance sleeve. Manufacturing variations in these features can be controlled more precisely, and better over-all stability is therefore obtained.

The hydrogen anneal produces a lower coercive force in the one per cent silicon iron used in the AG relay than in the magnetic iron parts of the Y type relay. It was possible to adopt this improvement, yet obtain the desired release times with somewhat smaller (lower conductance) sleeves,

Fig. 3 — Mrs. K. R. Randall measuring coercive force of magnetic parts of the AG relay.

because the spring loads were much lower than on the Y type and because the armature dome was made flatter to increase the magnetic pull. These modifications illustrate how the design factors were balanced to meet the performance objectives.

The spherical embossing on the armature, similar to that used on the Y relay, is a second device for stabilizing the operation of the relay. If the contact surface of the armature were perfectly flat, it could possibly provide the increase in flux necessary in the slow-release types, since there would be a large area of metal-to-metal contact. In practice, however, it is difficult to get a precise parallel alignment between the armature and core. The dome on the armature is a good solution to this problem because, regardless of a small misalignment between the armature and core, the dome presents almost the same contact area to the core, and the variations in magnetic flux are consequently slight. The flatter surface of the dome improves stability further, since the greater area of contact minimizes wear.

As a third control, a chromium finish is used on the AG relay magnet to prevent the iron from rusting and to provide high resistance to wear. This finish is only about one-tenth as thick as a human hair. Control of its thickness is therefore very important, since the spring load required to release the magnet increases greatly with a very small decrease in the amount of chromium applied.

Finally, the buffer spring and the restoring spring are also used to control the release time. Since the magnet releases when the pull due to the flux becomes less than the spring load, an adjustment of the spring tensions will change the release flux level and consequently the release time. Both the restoring and buffer spring loads are adjusted by changing the angle of bend in the springs with a special tool. A buffer spring is necessary because of the action of the armature dome. As the dome approaches the core, the magnetic pull increases sharply, and the buffer spring is engaged to counteract the excess pull in the operated position. To avoid increasing the spring load at midstroke, however, the little tab is bent to cause pickup of the buffer spring only a short distance before the armature touches the core.

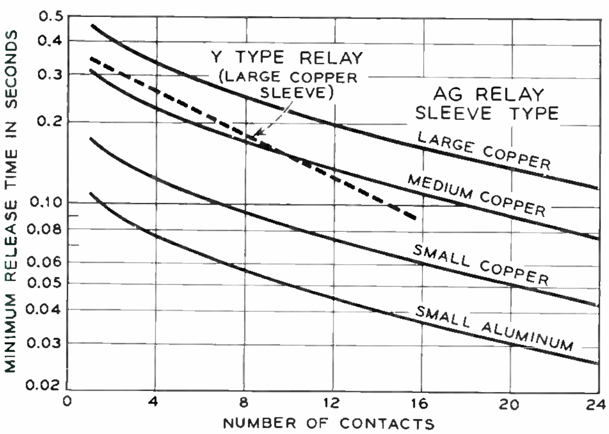


Fig. 4—Release times of AG relay for various types of sleeves and different numbers of contacts. Dotted line indicates performance of Y type relay with large copper sleeve.

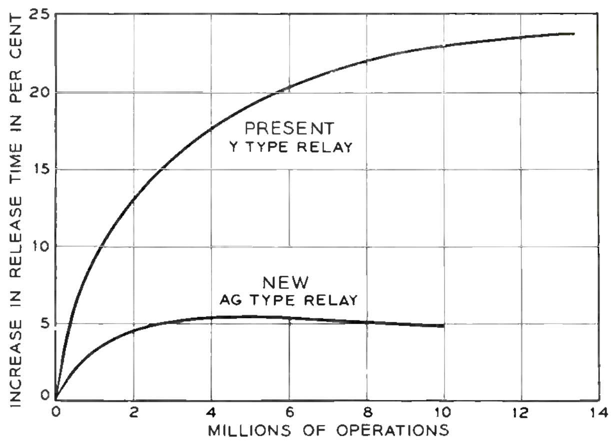


Fig. 5 — Curves comparing Y and AG relays, showing AG's greatly improved stability with life.

In practice, these spring-load adjustments are used to compensate for manufacturing variations in the magnet which affect release time. If a particular relay has a release time near the design minimum, the total spring load is adjusted to a low value, and the buffer may even be disengaged. When variations combine on another relay to increase its release time, the restoring and buffer spring loads are increased. The maximum release time of any AG relay manufactured can be adjusted so as not to exceed the design minimum by more than fifty per cent.

These are the main features of the slow release member of the wire-spring family, but some additional comparisons of the AG with the older Y relay will point up other improvements in performance. The spring assembly of the AG relay, like that of the general purpose relays, has fewer parts, and no adjustment of contact force is required. Variations in contact force are small, both during manufacture and with life, permitting a lower nominal value. As a result, the maximum spring load per contact is about one third as large on the AG relay as on the Y type relay. As already pointed out, this was a major factor in permitting the use of a lower coercive force.

The spacing between the side legs of the armature and the core has been increased compared to the Y type, resulting in a more stable reluctance of the air-gaps between the parts in these areas. Of course the increased spacing tends to increase the airgap reluctance, but this was compensated for by the long armature side legs, which provide a greatly increased overlapping area of side airgaps.

In addition, the curves of Figure 4 show that, for a given release time, the AG relay can be

Fig. 6 — E. C. Mener setting up an AG relay for contact spring load tests.

Fig. 7 — B. Stauss preparing an AG relay for static flux measurements.

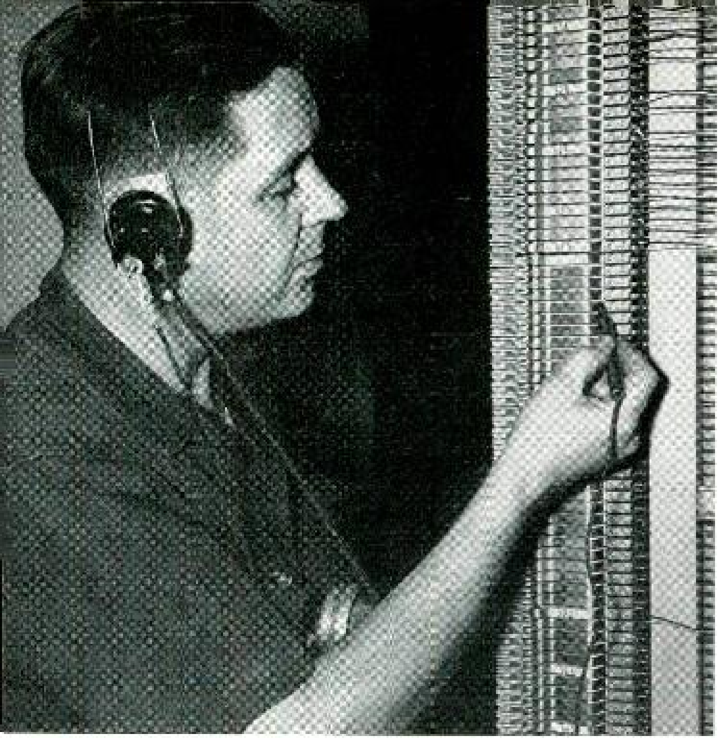
equipped with at least two more contacts than the Y type. Figure 5 illustrates the AG's improved stability with life. After ten million operations, the release time of the AG has changed only one-fifth as much as the older Y relay.

Finally, the AG relay is only about one-seventh as susceptible as the Y type to magnetic interference from adjacent relays. The Y relay must be shielded with magnetic covers or isolated by mounting to minimize this interference, but the AG without any kind of shielding is practically equal to the Y type with covers. It is anticipated that there will be no shields and virtually no mounting restrictions on this new relay.

An economic advantage results from the AG's greater contact capacity, which should permit fewer relays in some applications. The improved stability will result in less maintenance expense, and the markedly lower susceptibility to magnetic interference will represent savings both in shields and in adjustment effort. The AG relay is thus a valuable addition to the wire-spring family, which is contributing to more reliable, longer life, and lower cost telephone switching systems.

THE AUTHOR

O. Carroll Worley received his B.S. and M.S. degrees in engineering from the University of Illinois, and he joined the Laboratories in 1942. During World War II he worked on military projects such as a gun-fire control computer, a proximity fuze and radar components. After the war he concentrated on automatic message accounting apparatus development until 1947 when he transferred to the Western Electric Company to work on inspection and quality control problems. On his return to the Laboratories in 1948 he engaged in the analysis of dimensional control problems on wire spring relays. Later he turned to magnetic studies of multi-contact and wire spring relay electromagnets and transistor network development. He is now in military systems engineering. Mr. Worley is a member of Tau Beta Pi, Sigma Xi and other honorary fraternities.



An Improved Splicer's Test Point

G. R. Steinheim, New Jersey Bell installer at Murray Hill, demonstrates the way a given pair is located at the main frame protector, using the new test point.

It is often necessary for a cable splicer, in repairing troubles in cable, to determine where a certain pair terminates on the main distributing frame of the central office. He then must establish connections to it. Heretofore, to identify the pair, the splicer's helper used the two-part pencil-shaped test point shown at the top of Figure 1, running the conical point along the protector springs of the main frame until the buzzer indicated completion of the circuit. He then unscrewed the cord end to expose the chisel point, which he inserted under the protector spring to hold the connection. Since splicer's helpers are like all human beings, while using the chisel point they sometimes misplaced the other part. From then on, if the uninsulated chisel point were used for all testing work, simultaneous contacts of adjacent springs and consequent short circuited and crossed circuits might result.

A suggestion for a one-piece test point having a retractable tip and no removable part was made by E. J. Goll of the New York Telephone Company. The Goll point is illustrated in the center of Figure 1. Some Laboratories' modifications of this design have been made to better adapt it to both manufacture and use. The resultant tool is shown at the bottom of Figure 1. This point employs a spring-loaded insulating sleeve instead of a retractable tip. For identification work the tool is used as shown above, but for holding the connection, the sleeve is automatically pushed back as the point is inserted under the protector spring, as shown in Figure 2. Conversely, it automatically returns to position as the point is removed.

G. E. Hadley
Underwater Systems Development
Formerly Outside Plant Development

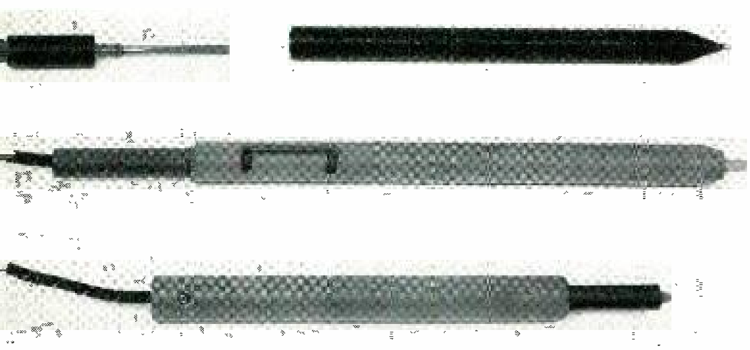
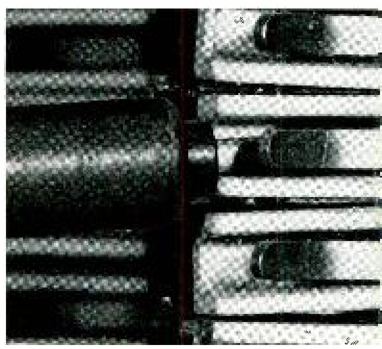


Fig. 1 (left) — Top, previous standard splicer's test point. Middle, one-piece test point. Bottom, new standard test point.

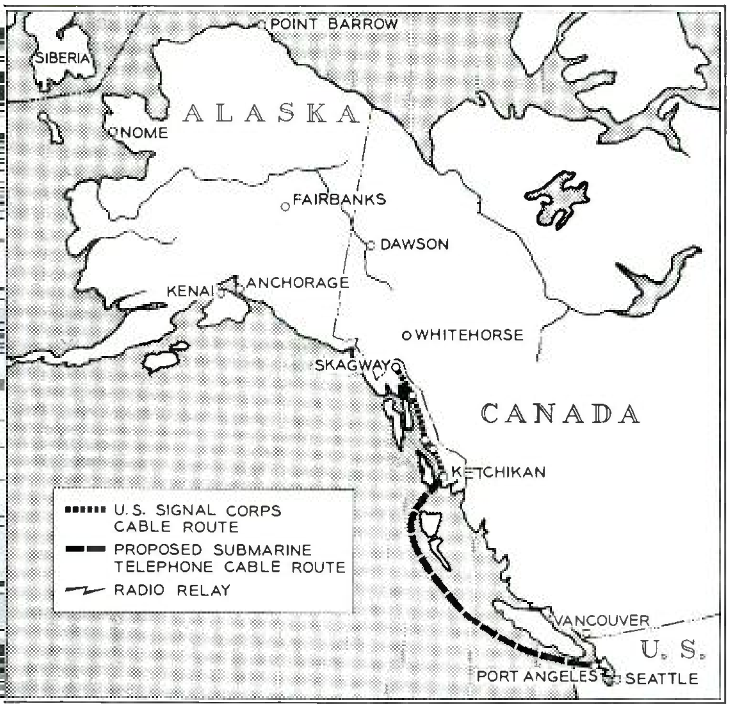
Fig. 2 (right) — Close-up view — holding a connection.



Submarine Telephone Cable To Alaska Planned

Plans for an underwater telephone cable system linking the United States and Alaska have been announced by the Long Lines Department of the American Telephone and Telegraph Company. The proposed cable will stretch 800 nautical miles between Port Angeles, Wash., and Ketchikan, Alaska. An additional 370 miles of cable, already under construction between Ketchikan and Skagway, Alaska, is being laid by the Alaskan Communications System, a branch of the U. S. Signal Corps.

The entire system from Port Angeles to Skagway is expected to be completed by late 1956 and will provide, for both public and defense purposes, a speedier and more reliable means of telephone communication between Alaska and the United States proper. The A. T. and T. Co. also proposes to build a radio relay route to carry the circuits from Port Angeles to Seattle, Washington, where they can be connected to the United States network of long-distance facilities. The proposed A. T. and T. Co. cable and radio relay system will have a capacity of 36 message circuits and will cost an estimated $14,000,000. Telephone service between Alaska and the United States is currently provided over 13 radio and land-line circuits, which are inadequate to handle current and estimated future traffic requirements. The new cable will replace this system which is subject to frequent interruptions and delays on account of the length of the route and the difficult terrain it crosses. The proposed submarine cable will provide a short and direct telephone route between Alaska and the United States that will require little maintenance, and that will not be exposed to damage from storms and the elements.



Proposed submarine cable route from Port Angeles, Wash., to Skagway, Alaska.

Demand for message telephone and private line services between the United States and Alaska is expected to grow rapidly as a result of the economic and industrial development of Alaska and the military activity centered there.

The Alaskan project will be the second big submarine cable to be undertaken recently by the Bell System. On December 1, 1953, the A. T. and T. Co., the British Post Office and the Canadian Overseas Telecommunication Corporation announced plans to start construction of the world's first transoceanic telephone cable system, which is to be laid across the Atlantic floor from Newfoundland to Scotland. It will provide 36 direct telephone circuits between New York and London.

The Seattle-Ketchikan submarine cable system would be similar in design to the transatlantic system. It will consist of two deep-sea submarine cables to be laid several miles apart, one for northbound transmission, and the other for southbound transmission. The core of each cable will consist of a central conductor composed of a solid copper wire, insulated with a water-impervious material (polyethylene) and provided with a return conductor consisting of six thin copper tapes along the surface of the insulation. In the submarine portion, the core will be protected by armor. The land portion will be buried cable. Built-in repeaters will be spaced about 40 miles apart. Each deep-sea repeater requires three vacuum tubes and is housed in a flexible copper tube about seven feet long and 1½ inches in diameter. This tube is supported by steel rings to form a structure that is built into the cable and appears as a tapering bulge. This design permits the repeaters to pass through the cable ship's gear along with the cable so that laying will be orderly and uninterrupted.

Dr. Kelly Chairman of Hoover Commission Subcommittee

Dr. M. J. Kelly, President of the Laboratories, was recently appointed chairman of a subcommittee to study research activities in the Defense Department. The appointment was announced by C. R. Hook, president of the Committee on Business Organization of the Hoover Commission on Government Reorganization.

A. B. Goetze Named Vice President-Finance of Western Company

Arthur B. Goetze has been appointed vice president-finance of the Western Electric Company, succeeding Frederick W. Bierwirth who retires August 31 under the age retirement rule. Mr. Goetze was formerly vice president-manufacturing, eastern area, and is a director of Western Electric. In his new assignment, he will supervise the organizations of comptroller, treasury, secretary, patent licensing, public relations, and purchasing and traffic.

Mr. Goetze entered Western Electric as a draftsman in 1917 and subsequently held posts in the engineering and cost control organizations, and the telephone sales, personnel and manufacturing divisions. In 1949 he became vice president in charge of the personnel department of the Chesapeake and Potomac Telephone Companies, and a year later vice president in charge of operations of the Ohio Bell Telephone Company and a member of its board of directors. He returned to Western Electric in 1952 as vice president and works manager of the Kearny Works. He was named vice president-manufacturing of the eastern area in September, 1952.

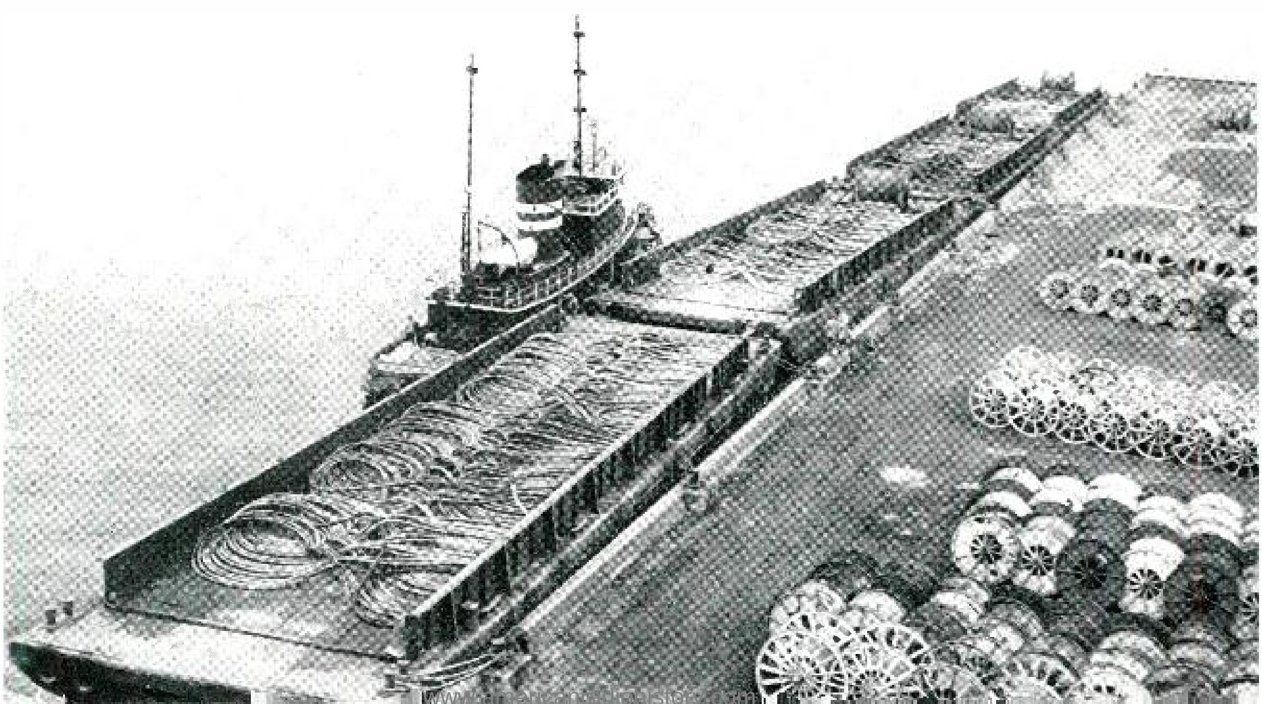
Mr. Bierwirth rounds out a career of almost 42 years with the firm, having joined Western Electric at the Hawthorne Works as a clerk in 1912. After advancing through increasingly responsible posts, in 1942 he became vice president and manager of the telephone sales division. He was elected a director of Western Electric the next year. In 1952 he assumed his present post, and earlier this year direction of the purchasing and traffic activities of the company were added to his responsibilities. Mr. Bierwirth has served as a director of the Laboratories since 1942.

Biggest Inland Submarine Cable Placed in Service Across Hudson

The biggest inland submarine telephone cable project ever undertaken in this country was recently opened across the Hudson River, 20 miles north of New York City. The cable system, stretching from Nyack to Tarrytown, New York, consists of three parallel cables, each three miles in length. It will have an initial capacity of 1,500 simultaneous conversations, as compared with the present cable capacity of 50 conversations. These underwater cables are part of a new communications route extending from Newark, N. J., through White Plains, N. Y., to West Haven, Conn. Parts of the route are still under construction, as is the new Long Lines switching center at White Plains.

The intricate network of facilities, with White

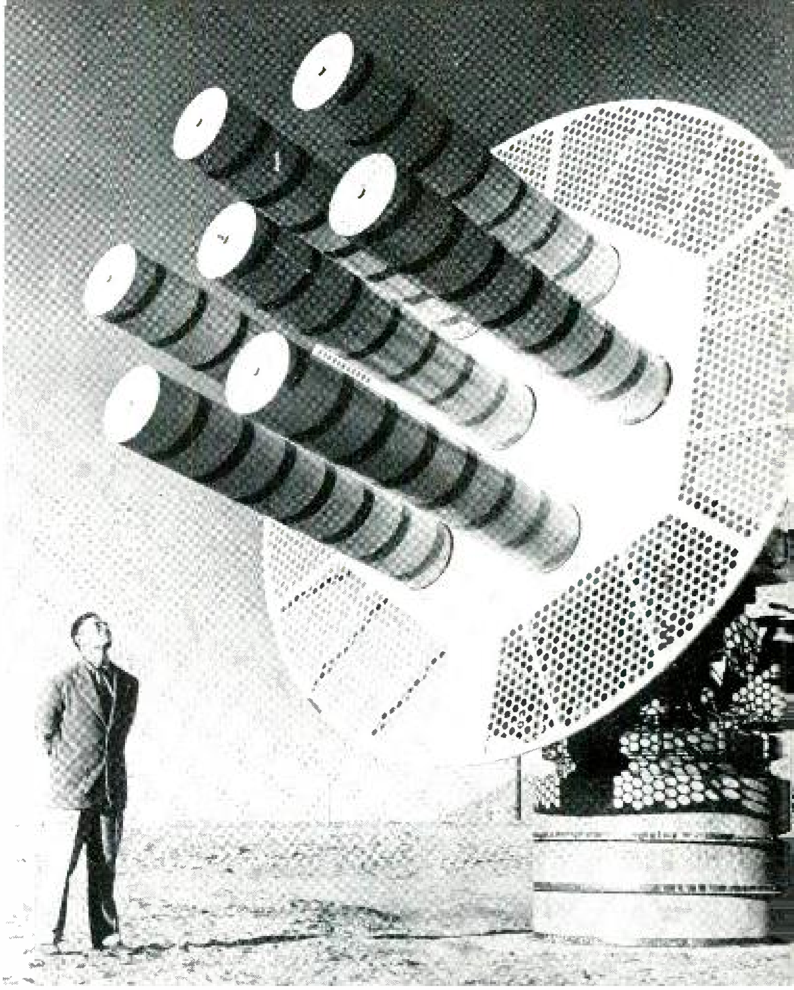
Warped into the cable dock at Western Electric's Point Breeze Works are the loaded barges ready to carry the submarine cable to the site of its installation between Nyack and Tarrytown, New York.



Plains as the hub, is expected to be in full operation by November and will provide a by-pass around New York City for long-distance calls to and from New York State and the New England States. Each of these three cables contain six coaxial conductors protected with layers of lead and steel, jute and asphalt. With this armor the cables measure 4⅜ inches in diameter and weigh 26 pounds per linear foot. The nine miles of submarine cable was made by the Western Electric Company at Point Breeze and transported to Tarrytown on barges. At Tarrytown, the eighteen cable sections, averaging 3,200 feet in length, were spliced together, then connected to existing facilities on either side of the river through a series of underground conduits.

The cables were laid in a specially prepared trench in the river bottom as protection against dragging anchors and debris carried along the bottom by the current. Divers, working closely with the barges, kept a constant check on the position of the cables and helped to jockey them into place.

The entire submarine project, from the start of the cable's manufacture to the final splicing to land lines, took two years to complete. The cable is jointly owned by New York Telephone Company, Long Lines and New Jersey Bell.



The odd-looking dish with protruding barber poles is not some giant telephone cable of the future in cross-section. It's an "apota." At least, that's what it is called at Sandia Laboratory in New Mexico, where Western Electric and Bell Telephone Laboratories direct work on military applications of atomic energy for the government. "Apota" is a contraction of "Automatic Positioning of Telemetering Antenna."

Arthur C. Fegel Elected President of Nassau Smelting and Refining

Arthur C. Fegel was recently elected president of the Nassau Smelting and Refining Company, a Western Electric subsidiary which reclaims nonferrous materials from outworn telephone apparatus. Mr. Fegel, who has been with the Bell System since 1937, has been executive vice president of Nassau since February, 1954.

He succeeds William A. Scheuch who is retiring after 38 years' service with the Bell System. Mr. Scheuch started with the Western Electric Company in 1916 as a research metallurgist. He became the first plant manager of Nassau after its purchase by Western Electric in 1931 and became president of Nassau in 1936.

Dr. Kelly Attends Transatlantic Cable Conferences in London

Dr. M. J. Kelly recently traveled to London for a series of conferences with British Post Office Officials concerning the proposed transatlantic cable. He later went to the continent and visited offices of telephone companies in Munich, Ulm, Frankfort and Amsterdam.

New Network Television Facilities for Northeast

A new television pathway 2,400 miles long, linking stations in the northeastern quarter of the nation, was placed in operation, August 1. The network provides four video channels, two in each direction, along a radio relay route extending from New York to Chicago via Buffalo and back via St. Louis, Pittsburgh and Washington.

The new facilities are designed to make inter-city television transmission more flexible. The route is a closed-loop arrangement of multi-station facilities, making it possible for any station connected to the route to receive programs from any other station in the loop or to transmit to the other stations with a minimum of switching.

Patents Issued to Members of Bell Telephone Laboratories During July

Andrews, E. G. – *Calculator Sign Control* – 2,679,977.

Avery, R. C. – *Translating Arrangement* – 2,680,781.

Bobis, S., and Lundry, W. R. – *Equalizer* – 2,682,037.

Brehm, H. B., Kinzer, J. P., Smith, A. A., and Wilson, I. G. – *Automatic Line Testing and Switching Circuit* – 2,680,162.

Dorff, L. A. – *Arrangement for Single-Channel Time Sharing* – 2,680,154.

Edson, J. O. – *Time Division Multiplex System* – 2,682,575.

Garrison, J. L., and Whistler, J. P. – *Compensating Network* – 2,680,230.

King, A. P. – *Selective Mode Transducer* – 2,682,610.

Kinzer, J. P., see Brehm, H. B.

Knapp, H. M. – *Relay* – 2,692,584.

Knapp, H. M., and Spahn, C. F., Jr. – *Electromagnetic Relay* – 2,682,585.

Kohman, G. T., and McMahon, W. – *Electrical Condensers and Dielectric Compositions Useful Therein* – 2,682,024.

Lundry, W. R., see Bobis, S.

McMahon, W., see Kohman, G. T.

Miloche, H. A. – *Wiring Tools* – 2,682,063.

Oliver, B. M. – *Reduction of Signal Redundancy* – 2,681,385.

Oliver, B. M. – *Vestigial Sideband Detector* – 2,681,988.

Rea, W. T. – *Electronic Switching Circuit* – 2,680,777.

Shockley, W. – *Circuit Element Utilizing Semiconductive Materials* – 2,681,993.

Smith, A. A., see Brehm, H. B.

Spahn, C. F., Jr., see Knapp, H. M.

Stubner F. W.– *Accelerometer* – 2,682,003.

Teal, G. K. – *Preparation of Two-Sided Mosaic Screen* – 2,681,886.

Teal, G. K. – *Preparation of Two-Sided Mosaic* – 2,682,501.

Townsend, M. A. – *Gaseous Discharge Stepping Device* – 2,682,015.

Wallace, R. L., Jr. – *Transistor Oscillators* – 2,681,996.

Whistler, J. P., see Garrison, J. L.

Wilson, I. G., see Brehm, H. B.

Yaeger, R. E. – *Bias Circuit for Transistor Amplifiers* – 2,680,160.

Young, W. R., Jr. – *Radiotelephone Receiving System* – 2,680,194.

Papers Published by Members of the Laboratories

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

Ahearn, A. J., see Hannay, N. B.

Beach, A. L., see Guldner, W. G.

Biddulph, R., Short Term Autocorrelation Analysis and Correlatogram of Spoken Digits, J. Acoust. Soc. Am., **26**, No. 4, pp. 539-541, July, 1954.

Fine, M. E., and Kenney, Nancy T., Moduli and Internal Friction of Magnetite as Affected by the Low-Temperature Transformation, Phys. Rev., **94**, No. 6, pp. 1573-1576, June 15, 1954.

Gambrell, J. B., Jr., What Is a Printed Publication within the Meaning of the Patent Act, J. Patent Office Society, **36**, No. 6, pp. 391-405, June, 1954.

Green, E. I., Creative Thinking in Scientific Work, Elec. Eng., 73, No. 6, pp. 489-494, June, 1954.

Guldner, W. G., and Beach, A. L., Gasometric Method for Determination of Hydrogen in Carbon, Analytical Chemistry, **26**, No. 7, pp. 1199-1202, July, 1954.

Hannay, N. B., A Mass Spectrograph for the Analysis of Solids, Rev. Sci. Instr., **25**, No. 7, pp. 644-648, July, 1954.

Hannay, N. B. and Ahearn, A. J., Mass Spectrographic Analysis of Solids, Analytical Chemistry, **26**, No. 6, pp. 1056-1058, June, 1954.

Hogan, C. L., see Van Uitert, L. G.

Karlin, J. E., see Munson, W. A.

Kenney, Nancy T., see Fine, M. E.

Lovell, L. C., see Vogel, F. L.

Maita, J. P., see Morin, F. J.

Morin, F. J., and Maita, J. P., Conductivity and Hall Effect in the Intrinsic Range of Germanium, Phys. Rev., **94**, No. 6, pp. 1525-1529, June 15, 1954.

Munson, W. A., and Karlin, J. E., The Measurement of Human Channel Transmission Characteristics, J. Acoust. Soc. Am., **26**, No. 4, pp. 542-553, July, 1954.

Read, W. T., see Vogel, F. L.

Shockley, W., see Van Roosbroeck, W.

Tien, Ping King, Bifilar Helix for Backward Wave Oscillators, Proc. I.R.E., **42**, No. 7, pp. 1137-1143, July, 1954.

Van Roosbroeck, W., and Shockley, W., Photo-Radiative Recombination of Electrons and Holes in Germanium, Phys. Rev., **94**, No. 6, pp. 1558-1560, June 15, 1954.

Van Uitert, L. G., Schafer, J. P., and Hogan, C. L., Low Loss Ferrites for Applications at 4000 Millicycles per Second, Letter to the Editor, J. Appl. Phys., **25**, No. 7, p. 925, July, 1954.

Vogel, F. L., Read, W. T., and Lovell, L. C., Recombination of Holes and Electrons at Lineage Boundaries in Germanium, Letter to the Editor, Phys. Rev., **94**, No. 6, pp. 1791-1792, June 15, 1954.

Wolff, P. A., Theory of Secondary Electron Cascade in Metals, Phys. Rev., **95**, No. 1, pp. 56-66, July 1, 1954.