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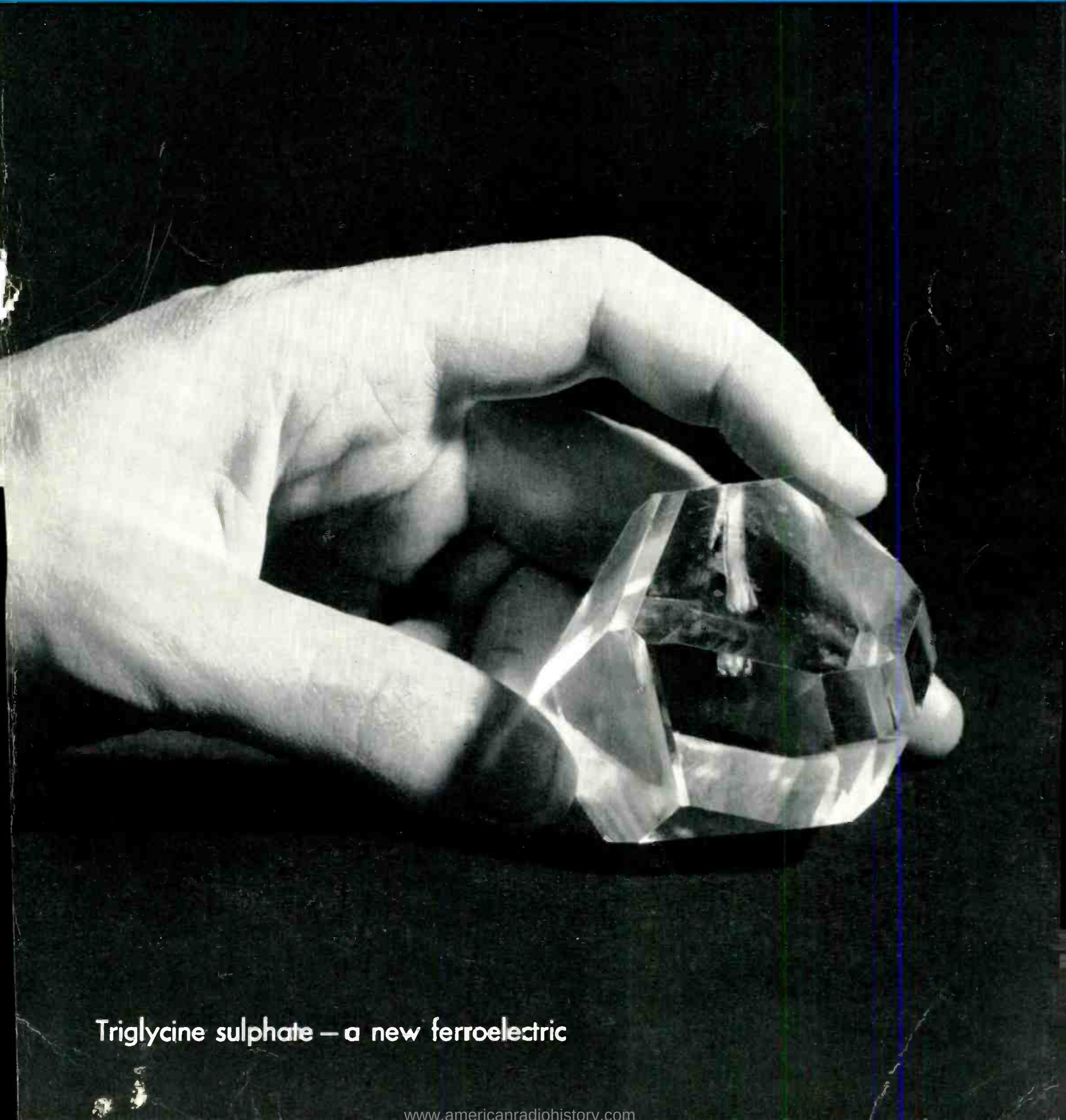

Triglycine sulphate — a new ferroelectric

Bell Laboratories RECORD

CONTENTS

THE COVER: A crystal of triglycine sulphate — a new ferroelectric having important switching and memory characteristics. See page 271. (Photograph by S. O. Jorgensen.)

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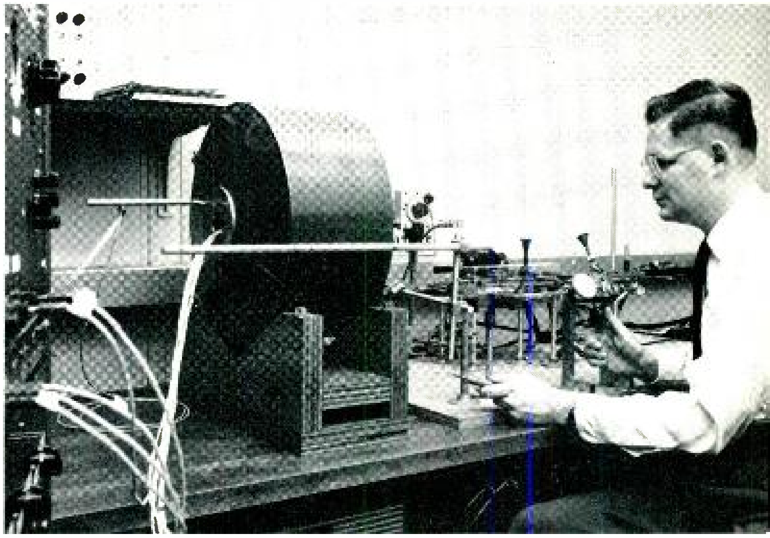
A Versatile Source of Millimeter Waves



C. F. HEMPSTEAD and A. R. STRNAD
Electronics Research

In the region of millimeter wavelengths (frequencies above 30,000 mc), the fabrication of many oscillators often demands very exacting methods of construction. The backward-wave oscillator, however, can be designed for relative ease of fabrication. For this reason, and because it has additional advantages over other generators of mm-wave power, it has become a versatile source of extremely high frequencies. The latest versions of the backward-wave oscillator deliver 5 to 10 milliwatts of power between 45,000 and 57,000 mc, and oscillation has been achieved at 200,000 mc.

There is today a great amount of activity in the field of microwave devices and equipment designed to operate at centimeter wavelengths. This activity is justified by the usefulness of microwaves in communication systems and by the many interesting physical phenomena which occur at the ultra-high and super-high frequencies. The new frontier for microwaves, however, is in the region of millimeter wavelengths (frequencies over 30,000 mc), which by comparison is relatively unexplored. The main reason for the delay in using these tremendously high frequencies is the unavailability of suitable generators. If we can build a mm-wave generator of adequate power output and sufficient tuning range, we can then make possible further studies of radio and radar propagation, magnetic resonance in ferrites, microwave spectra, special communication systems of immense bandwidths, and of many other research and development problems.

Several types of mm-wave generators are presently available, but they usually have one or more serious limitations. Wavelengths shorter than one centimeter can be generated with crystal harmonic multipliers, but these are difficult to adjust, have narrow tuning bands, and have low power output. Millimeter wavelengths can also be generated with klystrons and magnetrons, but the klystron is limited to slow mechanical tuning, the magnetron usually does not give continuous radiation, and both are difficult to make at such short wavelengths.

Many of these difficulties are lessened with another type of generator — the "backward-wave oscillator", or, as it is sometimes called, the "O-type carcinotron." As described previously,* the backward-wave oscillator gets its name from the fact that in this device an electromagnetic wave and a beam of electrons travel in opposite directions. The BWO has the advantages that it is electronically tunable at high rates over a wide range of frequencies and that it provides at least several milliwatts of continuous power. Also, the BWO is less sensitive than the other generators mentioned to changes in external load.

The BWO operates on a now familiar principle used in many traveling-wave devices currently being studied and developed for communications and

* RECORD, *August*, 1953, *page* 281.

research purposes. In the traveling-wave amplifier or oscillator, a beam of electrons interacts with a guided electromagnetic wave which travels relative to the beam in such a way that the desired amplification or oscillation is achieved. To set up backward waves, in which the direction of energy propogation is opposite to that of phase propogation, it is necessary to use a guiding structure which is spatially periodic or repetitive in nature. For example, slots are machined into a metal waveguide wall, or metal ribbon is wound around a supporting structure, with spacings that are periodic in the same sense that the teeth of a comb are periodically spaced along its length.

To maintain the proper phase relationships between the beam and the wave, considerable uniformity of the periodic circuit is required. In the BWO at millimeter wavelengths, the period length may be in the neighborhood of 2/100ths of an inch. Since a critical dimension should be within about one percent of the desired value, the allowable dimensional tolerance will therefore be only about 2/10,000ths of an inch. If the backward-wave type of structure were not used, even smaller dimensions and tolerances would be necessary.

Another requirement is that of holding a large number of electrons in a beam sufficiently close to the periodic circuit — that is, of obtaining a well focused beam of high current density. The BWO to be described here uses a beam current density about five times that of an ordinary electron tube. To focus and hold the beam near the periodic circuit, a strong magnetic field is required.

In spite of these requirements, experimental BWO tubes have been built fairly easily and inexpensively, and their predictability and reproducibility have been good. In the course of many mm-wave investigations at the Laboratories, they have evolved through various types illustrated in Figure 1. An amplifier structure used by S. Millman* is indicated in Figure 1(a), where it is seen that the periodic circuit is formed by milling tiny resonant slots in a ridge of metal contained in a section of waveguide. A. Karp then conceived the idea of forming the periodic circuit shown in Figure 1(b) where, instead of transverse resonant slots as in the Millman circuit, metal tape is wound about the structure to form the top wall of the waveguide. The slotted wall formed by the tape performs the same function as the milled slots of the previous structure. Tape is also used in a third form of this type of periodic circuit, Figure 1(c), which is the one presently

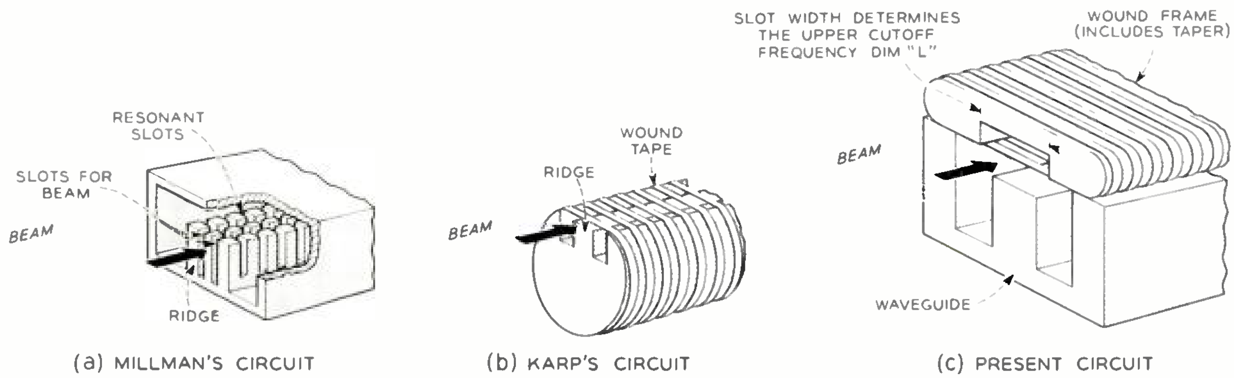


Fig. 1 — Evolution of the backward-wave oscillator; each type includes a periodic circuit.

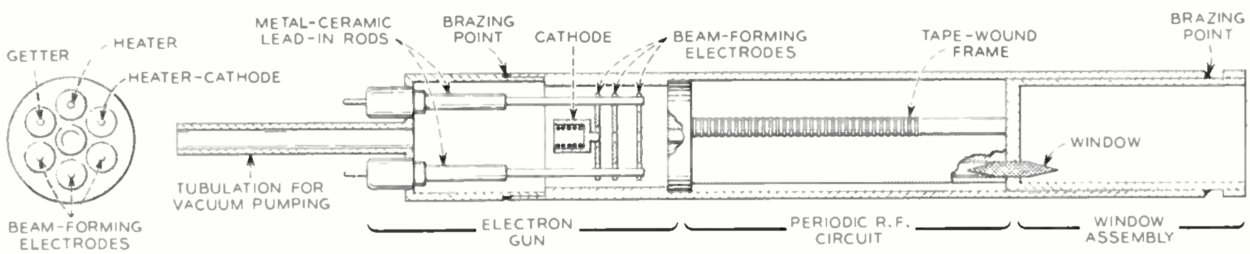


Fig. 2 — The new 5-mm backward-wave oscillator; lead-in rods permit simplified construction.

* RECORD, *November*, 1952, *page* 413.

Fig. 3 — Miss M. R. Daly and A. R. Strnad constructing electron gun assembly, a step in the fabrication of the backward-wave 5-mm oscillator tube.

used. A parallel electron beam floods the region around the tapes, and as an element of the beam travels down the circuit, little closed feedback loops are established over each period to sustain oscillations in the structure.

Since the principles of operation of this type of circuit have been satisfactorily worked out, the design of tubes to oscillate at the higher frequencies is largely a matter of additional refinements and new construction techniques. A great deal of the success of the particular tube described here is due to a number of simplifications in design and improvements in fabrication.

One of the important improvements is a redesigned electron gun assembly. More conventional tubes usually have an internal insulating and supporting structure on which the various gun electrodes are mounted, but in this tube no such supporting structure is used. Instead, each lead-in is constructed in the form of a mechanically strong rod, insulated from the metal envelope by a ceramic material at the base of the tube. Two of the six lead-in rods are indicated in the left part of the cross-sectional drawing, Figure 2, and actual rods around the gun electrodes can be seen labeled as "A" in Figure 4A. Each electrode is spot-welded to its supporting rod, which despite its length is rigid enough to hold the electrode accurately in place. A special jig was constructed to determine the centering and axial position of each electrode.

This assembly method reduces the gun to its simplest form. The elimination of additional supporting and spacing insulators is very advantageous, since such parts can evolve gas which would cause the high vacuum in a tube to deteriorate. The absence of a supporting structure also means that there are no problems of electrical leakage between electrodes, and that it is relatively simple to make changes in the spacing of electrodes.

A single metal-ceramic lead-in rod is shown in Figure 4B. Before it is incorporated into the tube structure, it can be checked for electrical leakage

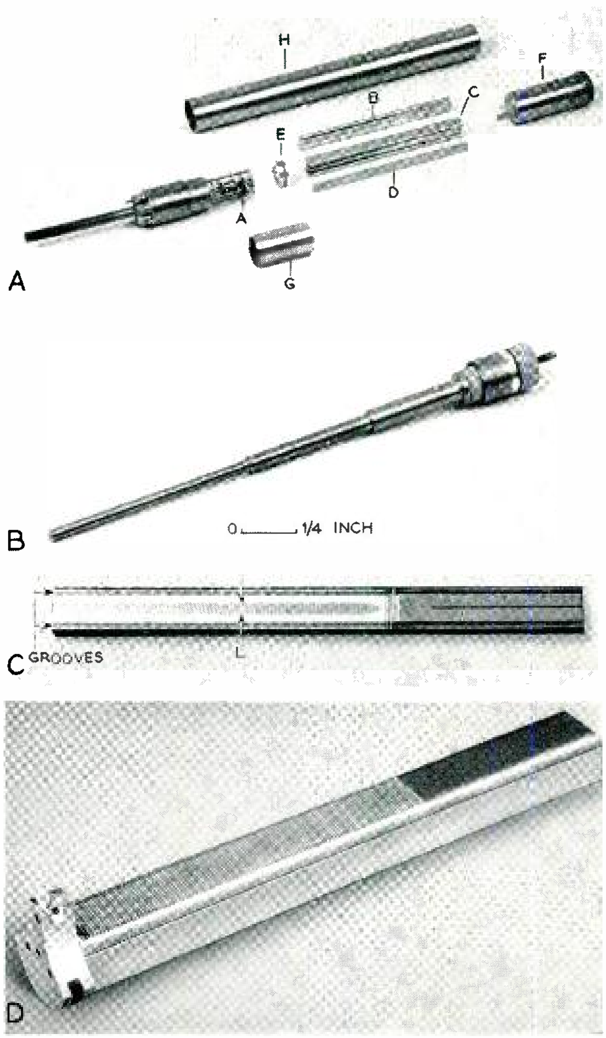


Fig. 4 — "A," Component parts of the 5 mm backward-wave oscillator. "B," A single metal-ceramic lead-in rod. "C," The tape-wound frame of the RF circuit of the tube. "D," The completely assembled RF circuit of the backward-wave oscillator.

Fig. 5 — Miss M. R. Daly and A. R. Strnad brazing metal parts of new backward-wave oscillator tube.

and various flaws. Because only a small mass of ceramic is used, thermal shock characteristics are excellent. Also, it can be used to produce a variety of stem designs. In a completed and evacuated tube, this sub-assembly has been subjected to 6,000 volts without showing signs of electrical arc-over to its surroundings.

In the RF circuit of the tube, similar careful attention was given to the design to achieve efficient operation at mm wavelengths. The parts of this section are labeled "B", "C", "D", and "E" in Figure 4A, and an enlargement of the tape-wound frame is seen as Figure 4C. It is apparent that the structure of this frame is similar to the one discussed above in relation to Figure 1(c).

The range of frequencies over which the tube will oscillate, and the voltage characteristics of the tube, are determined by the size and winding pitch of the metal tape and by the width of the slot indicated by dimension "L" in Figure 1(c). A gold-plated molybdenum ribbon is used, 1 mil thick and from 5.5 to 12.5 mils in width. Gold wire is placed on the frame at the grooves labeled in Figure 4C before the ribbon is wound on the frame. A brazing operation causes the gold to flow into the corners formed where the ribbon touches the frame, producing a smooth "fillet" joint. Such joints provide excellent, uniform electrical contacts which are essential to efficient operation. The wound and brazed frame is then assembled in a jig with the other members of the RF circuit, which have been previously gold plated. The completely assembled RF circuit is shown in Figure 4D.

It is of course necessary to extract the RF energy from the oscillating tube, and for this purpose a waveguide "window" assembly is used. This is part "F" in Figure 4A. The "window", which is transparent to microwave energy, consists of a wedge-shaped piece of aluminum oxide ceramic of rectangular cross section, symmetrically tapered on both ends. The ceramic (trade name Almanox 4462) has a dielectric constant of 9, and its attenuation of mm waves is relatively low. The window is metallized at the center of the untapered portion so that it can be brazed into its metal shell.

Assembly of the tube is completed by using part "G" in Figure 4A to space the electron-gun assembly from the RF circuit, and by incorporating all elements into the long cylinder "H". The completely assembled tube is then brazed with an induction heater at points indicated in Figure 2. The tube is evacuated by pumping through the small metal tubulation extending from the left end of the structure illustrated in Figure 2.

Although a BWO has been made to operate with a beam voltage as low as 400 volts, better performance is obtained by designing for operation at voltages above 1,000. The present version of the tube operates between 1,000 and 3,500 volts, and the tuning range is about 35 per cent of midfrequency. A tube constructed to generate 6-mm power (50,000 mc) has an output of about 10 milliwatts, and the power drops to half this value (3 db down) at points about 10 per cent away from the central frequency. As much as 20 milliwatts has been obtained at one frequency, and other tubes have given about 2 milliwatts at wavelengths as short as 3.3 mm. A. Karp has used a similar circuit to obtain oscillations at 1.5 mm or 200,000 mc.

The power spectrum of a 6 mm BWO is given as Figure 6. The curve shows the ripples that are characteristic of such tubes. These are caused by nonuniformity of pitch of the periodic circuit, imperfect focusing of the electron beam, and by slight

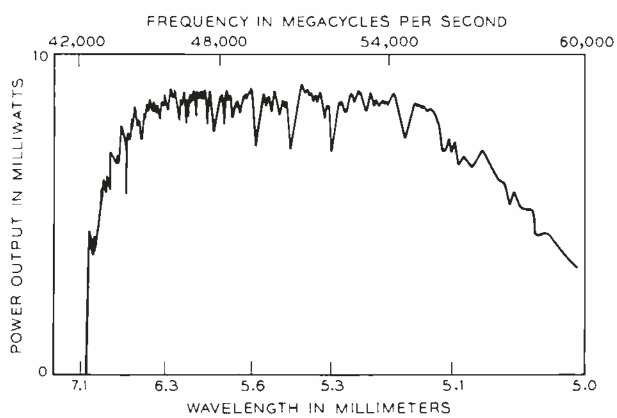


Fig. 6 — Power spectrum of the oscillator, showing output in the 42,000 to 60,000 mc region.

mismatches at various places in the circuit, window, and waveguide. Electronic feedback circuits and ferrite devices have been used in order to smooth out such ripples.

With this new versatile power source at mm wavelengths, it is expected that considerable fundamental research and development of special communications systems can be carried out. Several of these tubes are already in experimental use within the Laboratories.

THE AUTHORS

C. F. HEMPSTEAD, a native of Gloucester, Mass., spent the years 1943 to 1946 in the U. S. Army, and later received the B.S. degree in Physics from Northwestern University in 1949. He subsequently received the Ph.D. degree, also in Physics, from Cornell University in 1955. Mr. Hempstead joined the Electronics Research Department of Bell Laboratories in December, 1954, where he has been concerned principally with research on backward-wave oscillators. Included in this work have been improvements of backward-wave RF circuits, RF windows, and electron-gun assemblies. Mr. Hempstead is a member of Sigma Xi, Phi Beta Kappa and the I.R.E., and also of the I.R.E. Professional Group on Electron Devices.

A. R. STRNAD, a native of Elizabeth, N. J., joined Bell Laboratories in 1942. Prior to World War II, he was associated with the research drafting group, working on electron tube problems. From 1944 to 1946 he was in the Armed Services, where he participated in a special project for the Air Force on a gunnery trainer for remote-control gunnery systems. After the war he returned to the research drafting group at the Laboratories, and later transferred, in 1952, to the electronics research group. In this group, Mr. Strnad has been responsible for the mechanical design and fabrication of electron tubes, including work relative to the improvement of fabrication techniques for microwave amplifier and oscillator tubes.

Diffused-Base Transistors to be Used in Satellite

The diffusion technique, one of the most significant of Laboratories developments in solid-state technology, will find a dramatic and imaginative application in the form of diffused-base transistors in the earth satellite. The Western Electric Co. has recently announced that transistors of this type are to be incorporated into the satellite's transmitter.

In the search for improved ways of controlling amounts of impurities in semiconductors and of fabricating devices with precisely known thicknesses of conductivity layers, the process of diffusion was developed at Bell Laboratories.* After pioneering work by Bell Laboratories and Western Electric engineers, production was begun at the Laureldale (Pa.) shops especially for military applications. The military is contributing heavily to the satellite program, sponsored by the U. S. National Committee for the International Geophysical Year, which was established by the National Academy of Sciences.

The transmitter incorporating the transistors is one unit of a carefully packed, 10½-pound assembly enclosed in a magnesium-skinned sphere 20 inches in diameter. When shot to an altitude of about 300 miles at a speed of about 18,000 mph by a three-stage rocket, the satellite will send back to earth such data as pressure, temperature and densities of matter in outer space; strength of the earth's magnetic field; ultra-violet spectrum of the sun; and information on cosmic radiation.

The diffused-base transistor meets the severe size and weight requirements of satellite components and permits a potential broadcast range of about 4,000 miles, regardless of weather conditions. If the planned-for altitude of 300 miles is reached, the satellite will stay in its orbit about a year and broadcast the data to special receiving stations on earth.

* RECORD, *December, 1956, page* 441.

Pigments in Polymer Materials

JOHN F. AMBROSE *Chemical Research*

Since the dawn of history man has modified his natural materials by incorporating into them finely divided substances to impart desirable properties. The early Egyptians baked chopped straw into their clay bricks for added strength; later, masons added fine sand to slurries of lime to make a hard, strong mortar which was similar to that used in the present day. In modern plastics technology, the use of additives to alter and improve the basic properties of both natural and synthetic polymers has been especially important.

In recent years, a new class of basic material has arisen to supplant or complement those familiar to us through the centuries. The varied applications of polymer materials, whose molecules are made up of a repetition of monomer units of smaller size, are now familiar to all. The widespread use of polymers has become particularly evident since the advent, several decades ago, of the man-made polymers. Through these "tailor-made" molecules of huge dimensions and widely varied compositions and properties, our homes, stores and laboratories have come to abound in a variety of "plastic" utensils, tools, novelties and toys. These new materials have in many cases replaced their naturally occurring polymeric prototypes – rubber, wood, textile fibers, leather and even furs, and indeed are also superseding in many applications inorganic materials such as glass, metals and alloys.

Figure 1 illustrates models of a small segment of the molecular structure of two typical polymers, together with the monomers from which they derive. The large model at the bottom represents polyethylene, which results from the polymerization of ethylene and is used in the Bell System as insulation in the transatlantic cable and in cable sheaths. Similarly, the top model shows polystyrene-butadiene, a co-polymer of two monomers, which is useful as a replacement for rubber.

In the Bell System today, plastics replace only the materials that they can clearly surpass in desirable characteristics. The success that has been attained has derived from the fact that properties not originally present in the plastic may be added, or undesirable properties ameliorated or removed. This the chemist accomplishes by the use of additives – materials added to the polymer – sometimes in infinitesimal proportions, but often as a major component of the mixture.

One of the largest classes of such additives is the pigments, a term that seems familiar from long usage, but is indeed rather difficult to define. The dictionary would insist on "an insoluble powder" that "colors" materials. For the present discussion we must broaden the term, because pigments are often added to plastics for purposes other than coloration. Thus, we will define the term as finely divided materials of an ultimate size greater than atomic or molecular dimensions, which are insoluble in the base material in which they are dispersed. Figure 2 shows some typical carbon black pigments used in cable sheaths and in the insulation for the drop wires which are used to connect customer's houses to telephone poles.

The properties of pigments which give rise to their usefulness in polymer compositions are many and varied. The compounder has need in some cases for their thermal and electrical conductivity, in others for their magnetic susceptibility. The properties deriving from their finely divided state – such as increased light absorption, enhanced chemical reactivity and surface dependent properties (adsorptivity, for instance) – are often of paramount importance. The shape or morphology of the particles themselves can likewise govern their use. In other cases the low cost of the pigment, with respect to the polymer it "extends", determines the usefulness of the material.

One of the largest uses for pigment-filled polymers in the Bell System is in polyethylene cable

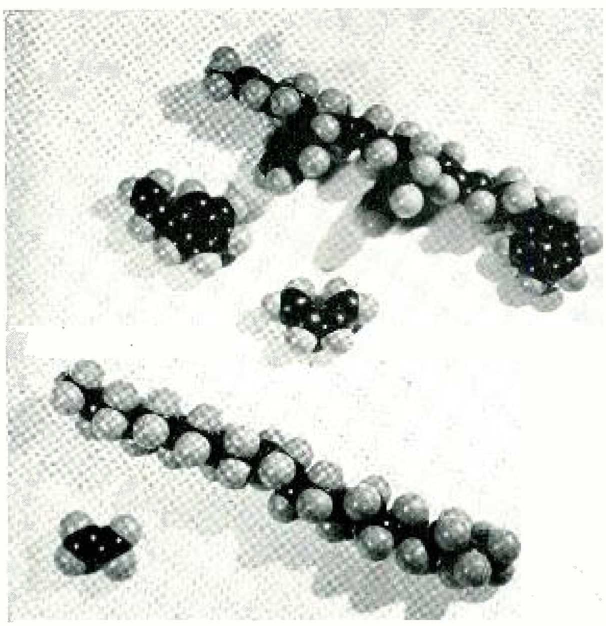


Fig. 1 — Fisher-Hirschfelder-Taylor models of: (from the top) butadiene-styrene copolymer (GRS); butadiene monomer; styrene monomer; polyethylene polymer; ethylene monomer.

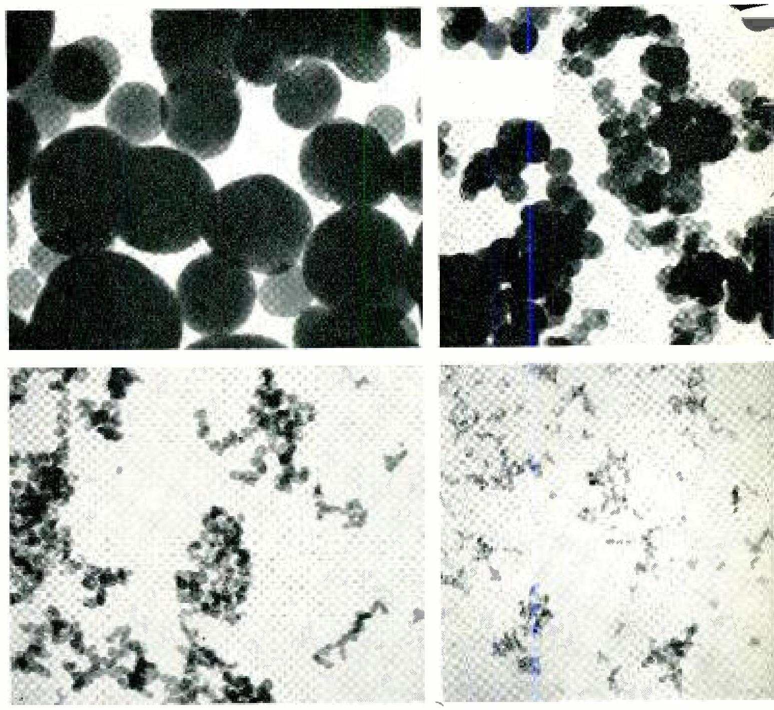


Fig. 2 — Electron micrographs of typical carbon black filler pigments. Top — Thermax, mean diameter, 2680 Angstroms (10^{-8} centimeters) and Furnex, mean diameter 734A; Bottom — Peerless, mean diameter 190A and Royal Spectra Mark I, mean diameter 70A. (Photos courtesy Columbia Carbon Company, Research Laboratories).

sheath.* When being used on a telephone pole, a polyethylene cable sheath not containing carbon black could be expected to last little more than a year. With the incorporation of two per cent by weight of fine particle carbon, however, the life of the sheath is increased to at least twenty years. In this application, the pigment serves as a light screen, absorbing the ultraviolet radiation in sunlight which would otherwise rapidly degrade the polymer. Figure 3 is a family of curves depicting the light absorption of polyethylene containing various carbon blacks as a function of particle size and wavelength of light radiation. The amount of carbon black used in this fashion is very considerable. Cable-sheath compound manufacture by the Western Electric Company for this year is estimated to require several hundred thousand pounds of carbon black.

Similarly, pigments are used for protection of polyvinylchloride wire coverings for B-rural and B-urban wire. In these applications, no exterior jacket is used, as Figure 4 shows. Fillers have been widely used for protection and color-coding on

* RECORD, *Januray,* 1956, *page* 1.

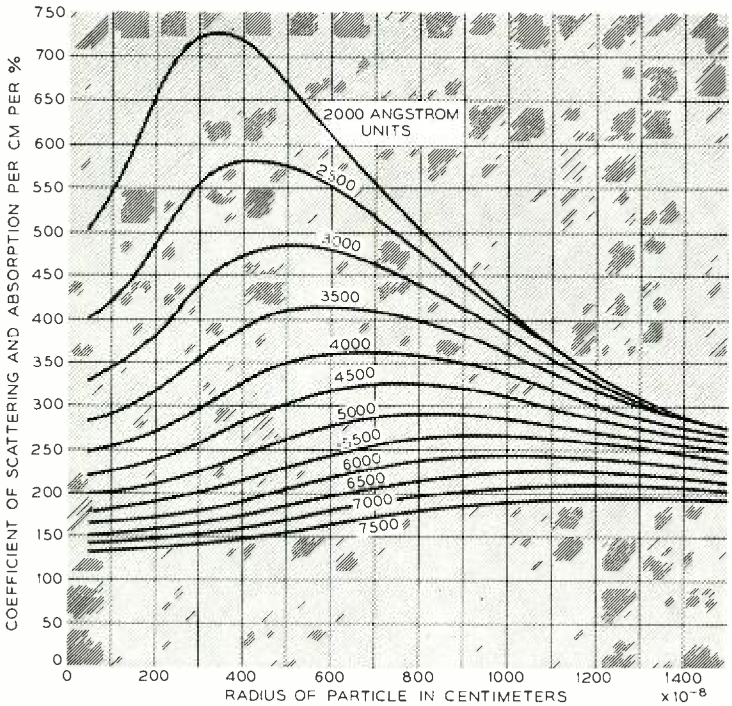


Fig. 3 — Computed attenuation of light of various wavelengths by carbon blacks of different sizes in polyethylene.

coverings for individual wires. The color-coded polyvinylchloride coatings are extruded directly on the wires, with coloring pigments used to afford yellows, reds, blacks, greens, blues and greys. Accelerated tests indicate that these coatings will retain their integrity for many years in locations of average exposure. Additional protection of the vinylchloride polymer itself is accomplished by the addition of about six per cent precoated rutile titanium dioxide. This protection derives from the scattering occasioned by the high refractive index and small particle size of the oxide. Without the pigmentation, these compounds would not survive a year; with its inclusion, however, an adequate service life may be expected.

In the Bell System an unusual case of filler application is encountered in the use of silica in polyester casting resins. These resins are used for "potting" or encasing electronic components for protective purposes. Potting compositions, which initially consist of a mixture of styrene and reactive long-chain molecules, may be poured as liquids of relatively low viscosity and subsequently crosslinked or "cured" to rigid solids by heating.* The resulting hard, stable resin serves to protect and support the components. Heat — generated by the potted components in use, and released in curing — must be dissipated, therefore a conductive filler must be added to the polymer. This conductivity is obtained by the addition of sizable amounts, often fifty per cent by weight, of finely powdered silica. In this application, the filler also helps to avoid undue stress on the potted components, because it reduces shrinkage upon cure. Figure 5 illustrates typical electronic components before and after potting.

Economic considerations underlie a great number of the applications of fillers in polymers; carbon black, for example, costs much less in a compound than the polymer it replaces. Similarly, clays and other mineral fillers utilized in tapes, drop wires, and neoprene jackets for wire, cost only a small fraction of the polymer replaced.

The filler content in an ordinary "rubber" automotive tire is astonishingly high. A typical tread stock formulation calls for fifty or more parts of carbon black for every hundred parts of rubber. When one adds the minor constituents, and further considers the content of textile or other cord in the plies and the metal in the beads or edges, he finds that the rubber content of such a tire is often less than fifty per cent. In this application, the carbon black serves other purposes, such as reinforcement and coloring, but its function as an extender is not to be ignored.

In using a pigment to extend a polymer, it is usually desirable that the inherent mechanical properties be maintained. Added advantages are commonly sought — such as the heat conductivity of silica, the black color of carbon, or improvement in processing ease often obtained with clays. In some

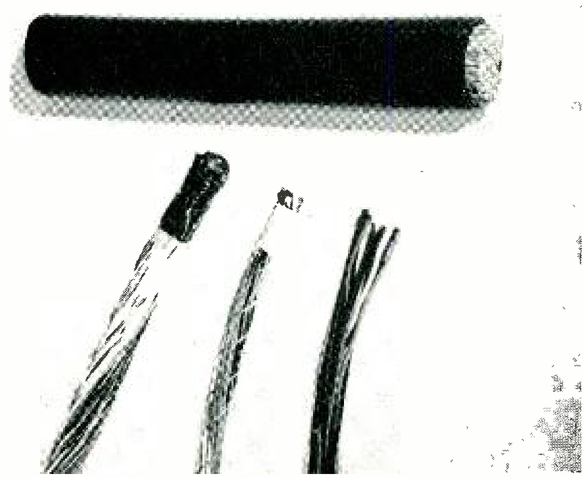


Fig. 4 — Typical sections of B-urban and B-rural wire (below) and Alpeth aerial cable with pigmented polyethylene cable sheath.

* Record, *December,* 1954, *page* 447.

cases, particularly that of carbon black in rubber and other elastic polymers, the mechanical properties, such as abrasion resistance and tensile strength, are remarkably improved. This property of reinforcement is probably the most significant contribution of pigments to modern polymer technology. Polymers such as GRS (the synthetic rubber represented in Figure 1) and butadiene-acrylonitrile copolymer are virtually useless mechanically unless reinforced by pigments. The addition of one type of carbon black, for example, increases the tensile strength of GRS from 300 psi to over 3,000 psi. In no small part, the success of the war-time synthetic rubber program may be attributed to the use of carbon black to improve the physical properties of the polymer. It is not surprising, therefore, that the largest use of pigmented-filled polymers in the Bell System, accounting for four million pounds of carbon black a year, is for neoprene drop wires. The basis of this large consumption is the reinforcing property of the carbon black, for these wires are often subject to severe abrasion from tree limbs, roof tops and other obstructions. Economy, protection from sunlight, and processing ease are important secondary advantages.

It is also often desirable to vary the electrical properties of polymers within wide limits. Thus polymeric compositions for wire insulation require resistivities as high as possible, while other polymer applications, such as seals for waveguides, require polymeric compositions having much lower resistivities. Such seals serve to absorb microwave leakage that would otherwise occur, with damage to the antenna pattern or waveguide mode. These very diverse ends may each be served, using the same base polymer, by variations in the kind and amount of carbon black added. In certain blacks, the particles remain isolated when dispersed in rubber, with little resultant effect on the original conductivity of the polymer, while others maintain a chain-like structure even at low concentration and after severe mixing. For example, a typical chain-forming acetylene black will decrease electrical resistivity in gum rubber from more than 10^{14} ohm-centimeters to 1.1×10^{5} at thirty parts loading, 2.7×10^{2} at fifty parts, and less than a hundred at seventy parts, the loading being expressed as parts per hundred parts of rubber. Similar effects are noted in synthetic rubbers and other polymers.

In wire-insulation compounds of polyvinyl chloride, loadings of about five per cent of fine calcined clay actually serve to raise the resistivity by a factor of five or ten, probably by adsorption of conducting impurities dispersed in the original mixture.

Fig. 5 — Samples of miniaturized components showing how polymer materials are used for potting. Units in clear resin were made to show details of inside construction.

In similar fashion, the magnetic properties of iron oxide powders are put to use in the recording bands used in the current design of the telephone answering set. By combining the oxide with a polyethylene polymer (Hypalon) chosen for its abrasion resistance, a recording band was designed with unique and desirable magnetic and mechanical characteristics not found in other commercial bands. The oxide used is very finely divided (particles less than one micron) and constitutes about thirty per cent by volume of the mixture. The signal output and noise from these memory belts, while not optimum for the circuit, are adequate and represent the best compromise possible considering electrical properties, wear resistance and moldability.

A highly unusual property of pigments derives from their morphology. Dispersions into plastics of certain pigments of "acicular", or needle-like, shape impart a quality of low viscosity at high shear rates, due to the alignment of the particles. Such "thixotropic" behavior is also exhibited by very openly constructed silica particles which have recently become available. These materials behave like hard spheres at high shear rates, and are spongelike at low shear rates, impeding the flow of the matrix under the latter conditions, and causing it to exhibit, therefore, a high viscosity. Such thixotropic property of pigments underlies the use of many fillers, predominantly clays, as processing aids which make possible the extrusion, for example, of many polymer formulations that are otherwise intractable.

The future holds even more impressive applications of particles in plastics. Luggage of polyester materials is now produced, on which a new finish may be applied to mars and scratches merely by rubbing with steel wool. Similar finishes in plastic-bodied sports cars and boats await only the adequate standardization of pigment colors, in order that parts fabricated at widely separated factories may be assembled into a finished product of uniform color. Glass fibers of refractive index closely matching that of the binding resin are being fabricated into transparent, reinforced building panels in many colors. Dies for the fabrication of massive metal parts, such as automotive bodies, are constructed by casting metal filled resins, rather than by machining from steel. Similarly, molds for small runs of parts and samples are cast from reinforced resins. When one considers the enormous strides in metallurgy that have resulted from the alloying of a very limited number of elementary metals, it is clear that similarly great advances in plastics technology will accrue from the incorporation of the immense spectrum of particulate materials into the great variety of polymers.

THE AUTHOR

J. F. Ambrose, a native of Laramie, Wyoming, received the B.S. degree from the University of Santa Clara in 1942, and the Ph.D. degree in Chemistry from Harvard University in 1949. From 1942 to 1946 he was employed by the United States Rubber Company. In 1949, the year he came to the Laboratories, Dr. Ambrose held the du Pont Post-Doctoral Fellowship at Harvard. Since joining the Chemical Research Department, he has been associated with polymer research, particularly the interaction of radiation with polymers containing pigments. He is a member of the American Chemical Society.

Work Begins on Deep-Sea Hawaiian Cable

Laying of the deep-sea sections of the Hawaiian cable system is scheduled to begin this month and to be completed this summer. The California stubs for the 2,400-mile telephone cable system, which will link Hawaii with the United States mainland, have recently been installed. They were placed in position by the cable ship *Basil O. Lenoir* about three and a half miles apart, and they extend ten miles seaward from Point Arena, California.

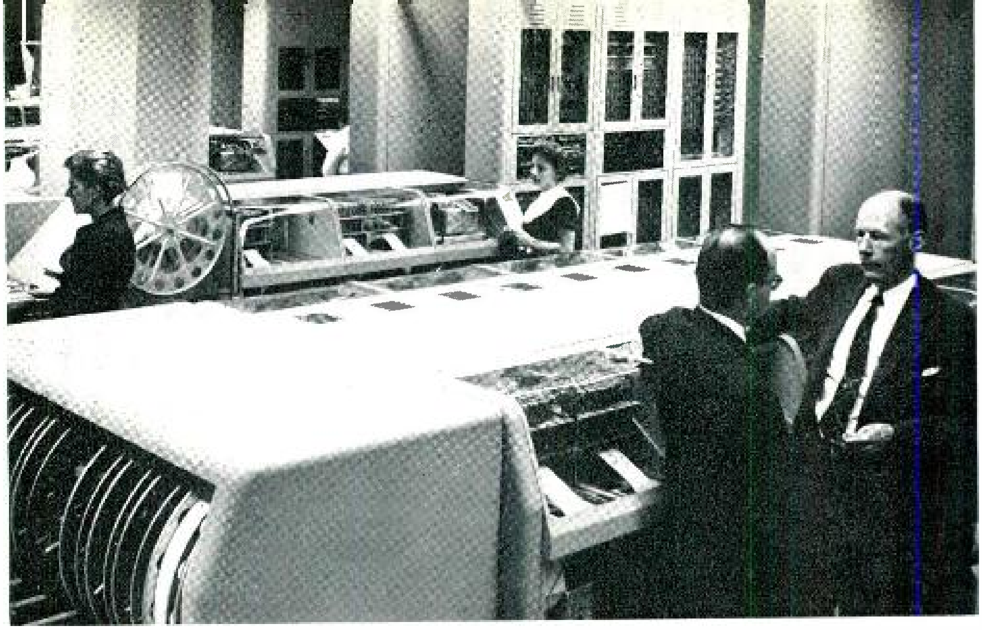
To connect the cable circuits to the Bell System's nationwide telephone network, a 130-mile radio-relay link between Point Arena and Oakland will be provided jointly by the Pacific Telephone and Telegraph Company and Long Lines. Six stations, including the terminals, will make up the route.

Shore ends in the Islands were placed last October. The Hawaiian terminal site is in Hanauma Bay near Koko Head, on the island of Oahu. The cable will interconnect with the inter-island network of the Hawaiian Telephone Company, a partner in this undertaking.

The new cable system is similar in design to those linking the U. S. with Alaska and with Europe, but some changes have been made on the basis of experience gained with the earlier cables. Bell Laboratories has been responsible for changes in the design of the repeater so that its characteristic will be more nearly that of laid cable. Breaking strength of the cable has also been increased because of the greater depth of water between the U. S. mainland and Hawaii.

Among the Laboratories people who will participate in the laying operations, P. W. Rounds will be aboard the ship *Ocean Layer* and W. A. Klute aboard the *Monarch* to supervise equalization techniques, and T. F. Gleichmann will engage in testing operations at the shore ends. R. D. Ehrbar, Project Engineer, will take part in the testing during the initial phases of the laying operations.

Scheduled for service late this year, the new twin-cable system will furnish 36 telephone circuits and will supplement the 14 radio circuits now used for telephone communication with Hawaii. The system will meet the growing demand for telephone service and will provide circuits free from atmospheric disturbance.



Automatic Message Accounting Centers in 1957

If you go into a brand new automatic message accounting center you will find many changes from the original 1948 model. You will miss some of your old friends and find new ones among the accounting center machines. In some cases, you will find none of the old machines. The assembler and computer have dropped out and been replaced by the combined assembler-computer. You will miss the original printer with its unusual adjuncts for handling toll slips. In its place you will find the tape-to-card converter and a simplified printer which may also be used for scanning and comparing tapes. In some areas with flat rate local service or message registers for local area charging, the automatic message accounting center will handle only toll business. In such accounting centers there will be no sorters or summarizers; all of the machines will be of the new type. The automatic message accounting center at New Haven, Connecticut, is the first to have this entirely new look.

Where message unit as well as toll business is handled, sorters and summarizers will continue to be provided. These machines are very nearly the same as the original designs.

The accounting center changes are partly due to evolution in design to increase efficiency and make the system more economical, and partly to a revolution in the subsequent billing processes. The assembler-computer is the product of evolution. This machine performs, in a single stage of processing, a task which formerly required two assembling stages and one computing stage. In addition, it does the job at a higher speed. The over-all result is that it will do the work of about three assemblers and three computers. The tape-to-card converter was developed to fit in with a revolution in the methods of billing message unit and toll messages. This involves the extensive use of business machine cards in place of printed toll slips and summary lists. With the new system the tedious and time consuming two-stage process of assembling call entries is done away with and the tape sorting is confined to the message unit business. The toll tapes from the assembler-computer are taken directly to the tape-to-card converter, where the information for each message is punched in a card. These cards are further processed to determine the charge for each message. At the end of the billing month they are sorted in subscriber number order and used to control the printing of the toll statements.

(In the illustration above, the author and A. L. Palmer of the New York Telephone Company discuss the operation of the AMA perforator unit at an AMA Center in New York City.)

G. Riggs
Special Systems Exploratory Development

Bleeding of Oil-Type Preservatives

J. LEUTRITZ *Outside Plant Development*

Preservatives increase the physical life of a telephone pole from about five to thirty-five years or more. But because of the complexity of woods and methods of treatment, effective preservation requires considerable study and experimentation. Recent investigations at Bell Laboratories have brought out new information on how poles may hold large quantities of liquid without the subsequent loss of wood preservatives through "bleeding."

How much liquid can be held by a piece of wood? Since liquid preservatives are used to increase greatly the life of telephone poles, the answer to this question is of considerable importance to the Bell System. Usually, there is only a relatively small range of useful preservative retentions, from about 6 to 10 pounds of oil preservative per cubic foot of wood. Too little preservative may decrease a pole's service life, and too much will often result in the phenomenon called "bleeding".*

Under any given set of conditions, wood has an equilibrium or "critical non-bleeding retention" of preservative. When the amount of preservative exceeds this value, either at the time of treatment or later as a result of environmental conditions, preservative moves out of the pole to the surface of the wood, and the surface becomes oily or tarry (Figure 1). Such bleeding represents an economic loss and is also sometimes objectionable to the public and to the men who must climb the poles.

Two oil-type liquids – creosote and "penta" (pentachlorophenol in petroleum solution) – are the most commonly used telephone pole preservatives. Both creosote and the petroleum carrier for penta are mixtures of hydrocarbons, but there are important differences. A creosoted pole usually, but not always, tends to bleed on the side of the pole exposed to the heat of the sun, whereas a penta-treated pole tends to bleed from the entire pole surface. Chemically, the important differences between these two preservative materials can be described in terms of their distillation products. Creosote, derived from coal tar, is a highly complex material which has in solution a whole series of aromatic hydrocarbons. Distilled from the creosote, most of these aromatic hydrocarbons are solids at room temperature. By contrast, the aromatics from petroleum are more typical of the ethyl or methyl naphthalenes, which are liquids at normal atmospheric temperatures.

These chemical differences are only one group of variables out of many that must be considered in attempting to specify the behavior of preservatives in telephone poles. Others include the method of treatment, temperature and humidity conditions, and the properties of the wood. Since both the coal tar creosotes and petroleum solutions are liquids, such factors can best be revealed by study of the behavior of liquids in wood, considered in terms of its multiple cellulosic, carbohydrate structure.

In some respects, the fibers of wood act as bundles of capillary tubes, so that the distance a liquid will

* RECORD, *September*, 1953, *page* 321; *December*, 1955, *page* 445.

penetrate should depend upon the diameter of a tube and upon the surface tension and specific gravity of the liquid. To test this effect in the laboratory, randomly selected wood wafers were set in eight petroleum oils with different values of specific gravity (See Table I). It was discovered that there was a significant correlation between absorption and surface tension, as shown in Figure 2, but that there was little or no correlation between absorption and specific gravity. Basically, then, the higher the surface tension of the liquid, the more liquid the wood can hold.

Commercially, instead of depending entirely upon capillary action, pressure treatment is used to force oil into the wood. If more oil is present than would have been taken up by normal capillary absorption, the tendency for the pole to bleed, and the rapidity of bleeding, depend on four major factors. Bleeding is affected by the amount of excess oil over normal capillary absorption, so that poles with large excesses of oil will tend to bleed extensively. Second, poles treated with high surface-tension preservatives will permit higher retention and will have less tendency to bleed. The third factor to be considered is the viscosity of the preservative; low-viscosity preservatives tend to bleed more rapidly from wood. And fourth, notice must be taken of the evaporation rate or distillation pattern. Preservatives with high proportions of the lighter constituents lose these more volatile portions by evaporation.

The effect of viscosity can be shown by measuring the capillary rise of liquid in wood samples, or more conveniently in paper strips. Figure 3 shows the rise for the eight petroleum oils, and it is evident that there is a close relationship between viscosity and capillary action. In the one apparent exception (the lowest-viscosity petroleum "E") the effect of viscosity is masked by evaporation, which prevented the oil from reaching its full height. The role of evaporation itself in the behavior of preservatives in poles is best considered in terms of distillation by the standard method of the American Wood Preservers' Association. There is a direct correlation between this distillation pattern and the rapidity with which the critical non-bleeding retention is reached by evaporation. The faster an oil or portions of the oil are lost by evaporation, the quicker the critical retention will be reached.

Comparing the eight test oils with any standard coal-tar creosote in use today, we find that the petroleums have, at usual atmospheric temperatures, a lower surface tension and a lower viscosity than creosote. Because of the lower surface tension, less

TABLE I THE EIGHT PETROLEUMS USED IN EXPERIMENTS

Petroleum	*Specific Gravity*	*Viscosity (centipoises)*	*50% Distilling Pt. (°F.)*	*Aromatics (%)*
Paraffinic Petroleums:				
A	0.780	1.56	437	0
B	0.829	3.75	501	0
C	0.841	6.75	652	0
D	0.821	11.34	748	0
Aromatic Petroleums:				
E	0.87	0.72	140	100
F	0.903	3.14	480	70
G	0.909	6.34	584	49
H	0.947	191.50	740	84

petroleum is retained by the wood, and because of the lower viscosity, the oil should bleed faster once the critical retention is exceeded. Also, because of the high proportion of liquid constituents in petroleum, the petroleum base of penta should be lost faster. This means that excess petroleum may be lost through evaporation rather than through bleeding. In fact, if a wood is treated with a very light petroleum, evaporation is so rapid that the liquid in the outer fibers of the wood never exceeds the critical retention and bleeding never takes place.

If we now turn our attention away from the properties of the oil and consider the characteristics of the wood, there are again a number of factors that influence bleeding: the specific gravity of the wood, irregularities in the capillaries, the amount of air and moisture in the wood cells, and the method of treatment with preservative.

As we might expect, lightweight woods will take up more preservative than woods with higher specific gravities. Oddly enough, however, critical non-bleeding retention is about the same regardless of

Fig. 1 — When the critical retention is exceeded, a pole may "bleed" some of its preservative.

specific gravity. This was determined by taking twenty-four wood stakes (¾ x ¾ x 36 inches) and treating them with the very viscous high-boiling petroleum oil "H". The stakes were all seasoned in the same manner and were separated into three different specific-gravity groupings before treatment. Initial retentions varied in accordance with specific gravity, but after bleeding, the average equilibrium

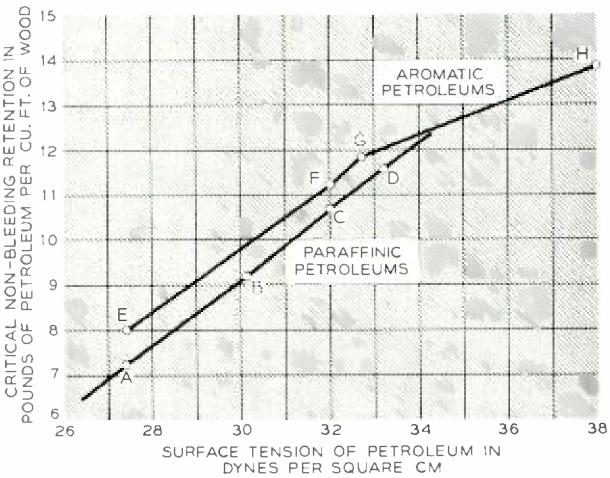


Fig. 2 — Correlation between surface tensions of eight petroleums and critical retentions: wood holds more of the high surface-tension oils.

or critical non-bleeding retention was a constant 7.5 pounds of oil per cubic foot of wood for each group.

These stakes were allowed to bleed for several months until they became dry to the touch, after which they were subjected to an air pressure of 2.5 pounds per square inch above one atmosphere. The stakes bled again and continued bleeding under this pressure until a new, slightly lower equilibrium retention was established. The exit of entrapped air might account for the initial stages of this bleeding, but the more likely explanation for its continuance is that the capillary bores of wood are irregular throughout their lengths. Partial emptying of the wood capillaries changes their effective radii and thus changes the capacity of the cells to hold the liquid petroleum.

The amounts of air and moisture in wood are other factors to be considered in the investigation of preservatives. Temperature increase tends to expand the air and water, which force the oil preservative to the surface. Additional effects of air and water were noticeable in experiments with another set of wood stakes. These were evacuated of air and then treated to saturation with petroleum. The retentions were very high, but because of the absence of air, there was no bleeding. Subsequently, air pressure on these wood samples resulted in bleeding. When these samples were treated with water at 60 pounds per square inch, however, the water displaced some of the surface oil. The result was a lower retention of oil at the surface and less likelihood of bleeding.

In another investigation, the effect of moisture on creosote-treated wood was demonstrated. Samples of wood were prepared with various types of creosotes, different retentions and different conditions of relative humidity, and were then heated with an infra-red lamp. Bleeding occurred only on samples that (1) had the highest retentions, (2) were treated with creosotes having the highest residue distilling above 355° C, and (3) were conditioned after treatment at 97 per cent relative humidity. Bleeding also occurred on similar samples that were conditioned by immersing them in water.

These observations are in accord with the behavior of telephone poles in service. In the Spring, after heavy rains, creosoted poles are likely to bleed. The reason appears to be that the poles, which warm during the day, absorb humid air or water as they cool at night. On the following day, the sun heats the surfaces, and the poles with the higher retentions of creosote begin bleeding. The heat melts the tarry semi-solid constituents of creosote in the outer layers of the wood, and expansion of the internal air and water forces oil outward to the surface. Operating Companies have reported bleeding on poles which are those with the higher retentions

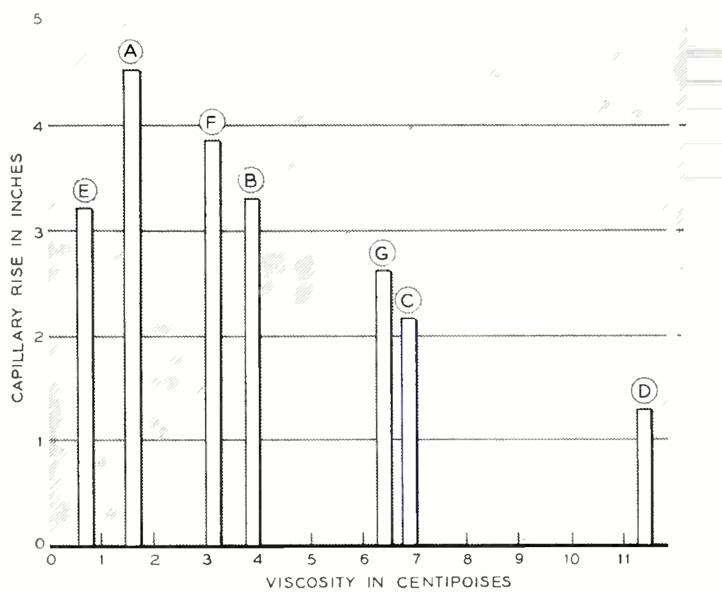


Fig. 3 — The relationship between viscosities of the ei test petroleums and capillary rise. In petroleum "E" ca lary effect is masked by evaporation.

and those treated with creosotes having heavier proportions of higher melting-point constituents.

Experimentally, there are several methods that can be used to treat wood. In actual practice, however, the major commercial treatment of poles is by what is called the "empty cell" method. In this method, southern pine poles are steam conditioned for several hours at 254° to 259° F, followed by a vacuum period of about two hours. Air pressure of 35 to 90 pounds per square inch is then applied for several minutes to an hour, and this air pressure is maintained as the preservative is forced in at up to 200 pounds per square inch. When the pressure is removed, the preservative "kicks back" or partially bubbles out of the wood, after which a final vacuum is drawn on the poles for about an hour. By contrast with the "full cell" method, in which no initial air pressure is applied, the empty cell method results in lower preservative retentions. Also, unless care is exercised, the empty cell method may permit preservative to be brought to the outer fibers and thus increase the likelihood of bleeding. This method has the advantage, however, that it results in better penetration of the wood and thus prevents decay of the internal parts of the pole.

When the poles are removed from the treating cylinders, vapors of preservative and steam can be seen rising from the wood. Subsequently, the surfaces usually become dry, which may be attributed to the vacuum created during cooling of the poles. When lying on skids, creosoted poles normally remain dry, except for a few that begin to bleed in the presence of sunlight. Because of their high surface tensions and semi-solid characteristics, the creosotes tend to remain in the wood at ambient temperatures. The behavior of penta-treated poles is often quite different, however. With poles lying on skids after treatment, it is sometimes noted that bleeding is postponed for several days. Then, as a result of the more fluid petroleum moving downward by gravity, bleeding may take place on the undersides of the poles.

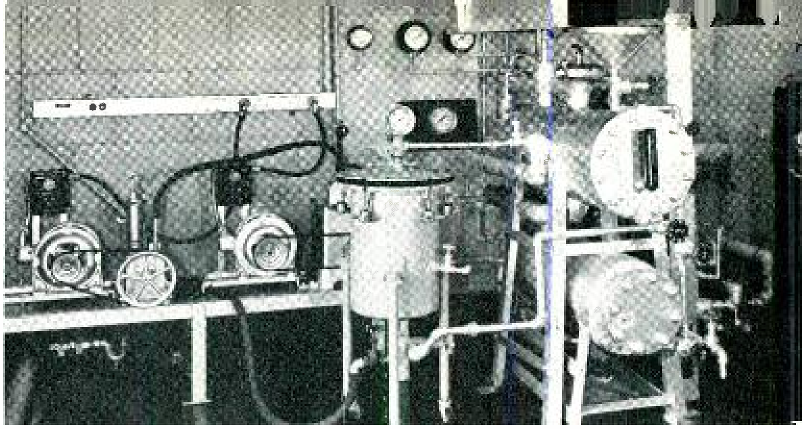


Fig. 4 — Pressure equipment used for experimental tests of wood preservation in the laboratory.

From these experiments, certain conclusions can be drawn. To minimize bleeding, creosotes or petroleums of high surface tension should be used, and the components that are liquid at normal temperatures should be held to a practical minimum. In this connection, it should be remembered that pentachlorophenol may itself affect the surface tension of the petroleum in which it is dissolved. Any solute that lowers the surface tension of the solvent will tend to concentrate in the surface layer, rather than distribute itself throughout the body of the fluid. This could account for the "blooming" or crystallization of pentachlorophenol.

It should also be beneficial to use petroleums that have both a low-boiling-point portion and a high-boiling-point portion in which pentachlorophenol is very soluble. With a relatively large percentage of fluids that evaporate readily from the pole, surface tension of the preservative would increase, and the pole could hold more liquid without bleeding. At the same time, the high-boiling-point portion in the interior of the pole would have less tendency to travel to the surface and bleed because the amount of liquid the wood can hold is not exceeded.

THE AUTHOR

J. Leutritz, a native of Saginaw, Mich., received the B.S. degree in Chemistry from Bowdoin College in 1929, the M.A. degree in Mycology in 1934, and the Ph.D. in Botany from Columbia University in 1946. After joining the Laboratories Chemical Research Department in 1929, he was initially engaged in studies of rubber compounds and later began work in the field of timber preservation. Concerned primarily with problems arising from the effects of humidity and fungi on military equipment during World War II, he served as a consultant to the OSRD and was a member of the Army Air Forces Tropical Science Mission. Transferred to the Outside Plant Department in 1950, he has been engaged in a physical life study of creosoted poles. He is a member of the American Chemical Society, the AAAS, the American Wood Preserver's Association, the Torrey Botanical Group, the New York Academy of Sciences and Sigma Xi.

Transatlantic Submarine Cable Design

J. M. FRASER and M. E. CAMPBELL

Transmission Engineering I and Transmission Systems Development II

During early design conferences, it was decided that the quality of transmission over the deep-sea link of the Transatlantic Submarine Telephone Cable should equal that existing between main switching points in the Bell System national networks. This transmission requirement was satisfied with submarine cable and flexible repeaters with which the Bell System had previous experience. In the design stages, Laboratories engineers not only specified the components that together constitute the cable link, but also incorporated means whereby deviations from the specified transmission quality could be corrected while laying was actually in progress.

The Transatlantic Submarine Cable System, opened for service on September 25, 1956, provides twenty-nine voice circuits between London and New York and six voice circuits between London and Montreal. An additional circuit from London is split between New York and Montreal and may be used for narrow band services to Montreal.

The complete system is built up of a variety of communication links on both sides of the Atlantic. The transatlantic submarine cable is a unique link in this system. It extends approximately 2,000 miles beneath the Atlantic between Clarenville, Newfoundland, and Oban, Scotland. The link consists of two cables, one for each direction of transmission. To compensate for transmission losses, each cable contains 51 repeaters, and each repeater has three long-life electron tubes.

As in all systems design, the particular form of the transmission path for this link and the design properties of its parts resulted from meeting a set of requirements with the materials and techniques available. The major requirements for the submarine cable system design were to provide the maximum possible number of channels consistent with good transmission performance, reliability, and a distinctive set of environmental factors. The materials and techniques that could be used for this system, whose components would be less accessible than any previously existing system, had to have proven reliability. Assurance of reliability required that only elements or procedures be used that had successfully passed the test of prior experience in the Bell System or in the British Post Office.

To provide channels having satisfactory transmission between telephones located on different continents, it was decided that transmission in the over-all New York and Montreal-London system should meet the standards of circuits connecting main switching points within the U. S. national networks. The over-all RMS noise objective in the busy hour at zero transmission level is 38 dba as measured on a Bell System 2B noise meter with F1A weighting. On a mileage basis, the noise objective for the Clarenville-Oban cable link is, therefore, 36 dba at the zero level point. The net loss variation objec-

Above, Dr. M. J. Kelly and J. M. Fraser check transmission quality at the Oban terminal station.

tive for the Clarenville-Oban link has a standard deviation of 0.5 db.

The major system components were selected from those which showed promise of meeting the transmission objectives and which met the reliability requirements. An armored coaxial cable with polyethylene insulation which could be manufactured with a high degree of reproducibility had previously been layed and used successfully in deep water. This type of cable had been investigated by the Laboratories soon after World War II, field tested in the Bahamas area in 1948 and applied on the USAF Missile Test Range Project in 1953. Since the design met the proven-reliability requirement and had sufficiently low loss, it was adopted for use in the transatlantic system.

Previous experience in using the available cable laying equipment to place cable at the depths encountered in the Atlantic indicated that flexible repeaters would be required. To lay the cable and repeaters successfully, it was necessary that the repeater structure be similar to the cable. This would permit laying from the cable ship without stopping the vessel. The repeater container adopted was structurally the same as that which had been in operation since 1950 on the Key West-Havana submarine cable system.

The type of electron tube selected for use in the repeaters was tested in the laboratory before the war, and eighteen have been in use since 1950 on the Key West-Havana system. These tubes are conservative in design, and rugged and shockproof in construction. Most important, their reliability had been established by testing some of them continuously for a period of over thirteen years.

The selection of the cable with a known dc resistance and the electron tubes having known power requirements effectively specified the power required for a repeater section. The restricted volume of the flexible repeater container controlled the size of the bypass capacitors and thus limited the maximum voltage that could be applied to the system. After making allowances for estimated earth potentials and increases in dc current that may be required to off-set repeater tube aging, the conclusion was reached that the maximum number of working repeaters that the system could be designed for was 52 (actually only 51 were used).

Based on an estimated cable length of 1955 nautical miles and 52 repeaters, the repeater spacing was 36.9 nautical miles. Knowing the spacing and the cable attenuation, the required gain of the repeater was then known at each frequency. A study was undertaken to determine how the Havana-Key West repeater circuit could be modified to obtain the maximum band-width consistent with long life and with the transmission objectives. The restricted size and shape of the flexible repeater controlled, to

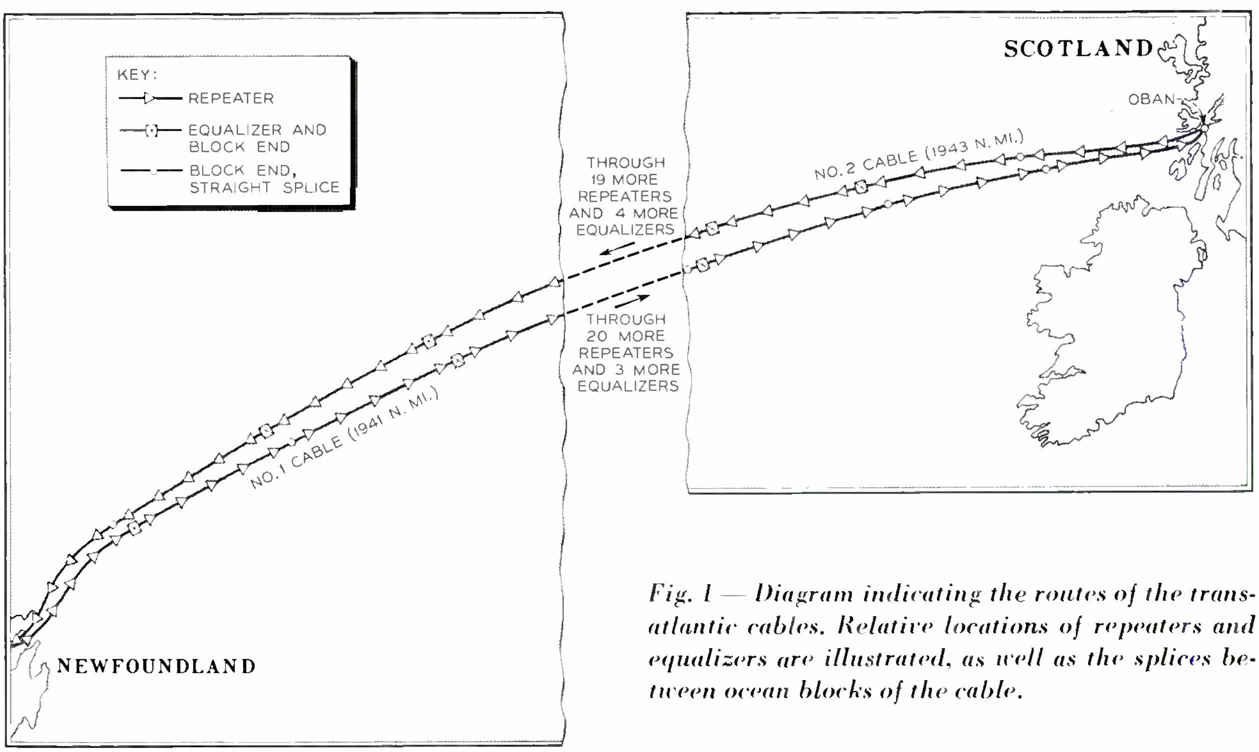


Fig. 1 — Diagram indicating the routes of the transatlantic cables. Relative locations of repeaters and equalizers are illustrated, as well as the splices between ocean blocks of the cable.

a large extent, the parasitic capacitances and the length of the feedback loop, as well as the size of the bypass capacitors. These, in turn, reacted on the feedback which was one of the limitations on the maximum possible number of channels. A repeater design with feedback adequate to provide stability was developed which was capable of compensating for the loss of 36.9 nautical miles of cable in deep water, over a band extending from 20 kc to 164 kc. This bandwidth is capable of providing thirty-six 4-kc channels in the cable.

The design of the transatlantic link did not end after the repeater was designed and the cable specified. The whole plan for laying the cable still had to be developed so that any deviations between repeater gain and loss in the laid portion of the cable could be compensated while laying operations continued. Although the characteristics of the cable and the repeaters would be rigidly controlled in the factory, it was recognized that there would be some uncertainty in specifying the transmission characteristics of a cable which would, in some places, be 2½ miles below the surface of the ocean. Accordingly, a plan for laying the cable in ocean blocks, each approximately 200 miles long, was set up. Continuous transmission measurements made from the shore to the end of the block being laid would indicate

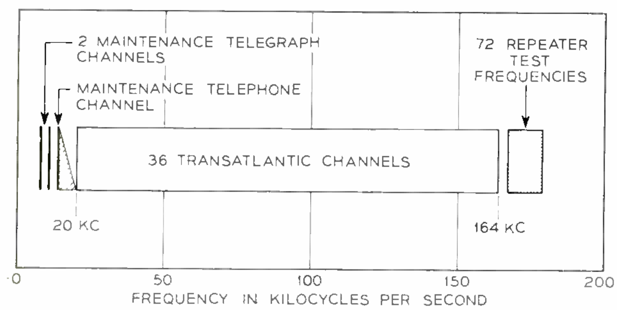


Fig. 2 — Frequency distribution for Clarenville-Oban deep-sea link of the cable.

how much excess gain or loss had accumulated to that point.

Two means were made available to compensate for the accumulated differences between the repeaters and the laid cable at the ends of ocean blocks. One was to add or subtract cable at the junction between ocean blocks. To make this adjustment possible without additional splicing, a small amount of excess cable was included at the beginning of each block. The second was a set of undersea equalizers enclosed in housings similar to those of repeaters which could be spliced between blocks when the accumulated deviations could be reduced by the addition of one of the equalizers.

Careful scheduling of the transmission measurements was required so that the ship did not have to be stopped during laying to make the adjustments at block ends. The detailed laying plan called, therefore, for stopping measurements at a predetermined time before the end of the block was due to go overboard. By extrapolating the transmission data, the amount of cable adjustment or the need for an equalizer could be predicted in time to make the time-consuming splices required between ocean blocks before the ship arrived at the point where they must be laid.

Concurrent with the planning and design work, a theoretical study was carried out to determine the transmission performance that would be obtained when all of the components were combined in a working system. For this study, knowledge was required of the load that each repeater would have to handle. Since the load is mostly due to customers' talking volumes, a study was made to determine the expected speech volumes that would be applied to the cable. This study was based on the most recent measurements made on long distance Bell System circuits. These measurements were adjusted for expected future changes in the Bell System plant in the next few years, and to take into account the fact that the speech volume increases slightly as the circuit length is increased. The resultant speech volume distribution used for the system study has an average value of minus 12.5 volume units at zero transmission level with a standard deviation of 5 db. It is considered to be a normal law distribution. The average value was increased to minus 12 volume units as an allowance for the contribution of signaling tones and system pilots.

In addition to knowing the speech volume distribution on each channel, system load computations require a knowledge of the circuit activity. This is defined as the per cent of time, during the busy hour, that the circuit is actually carrying speech. The circuit activity used for the design of Bell System long distance circuits is 25 per cent. A circuit activity of 30 per cent was used for the cable system design, however, based on the belief that during an international call the customer's activity factor might be higher than on circuits that are used within the United States.

From the estimated load of each channel, the load for 36 channels was computed. This, in turn, was used to determine the maximum allowable output level that a repeater could handle without overloading for more than an extremely small fraction of the busy hour. Once the maximum repeater output level was established, the input level at any frequency was determined by the gain of the repeater. The level differences which would exist between repeaters after they were laid at the bottom of the ocean had to be estimated. The expected major causes of misalignment were: changes in ocean bottom temperature, uncertainties in estimating the temperatures at the time of laying, uncertainties in the temperature and pressure coefficients of the cable, and lack of perfect match between the repeater gain and the cable loss. For computational purposes a total misalignment figure of 12 db at the highest frequency was used.

Knowing all the repeater levels, the total random and modulation noise of the system was computed. These computations showed very little modulation noise, and the total rms noise in every channel met the transmission objectives. In the high frequency channels, the noise objectives were just met, but in the low frequency channels there were substantial margins. The slope across the band was caused primarily by the lower repeater gain required at low frequencies to offset the loss of the cable between successive repeaters.

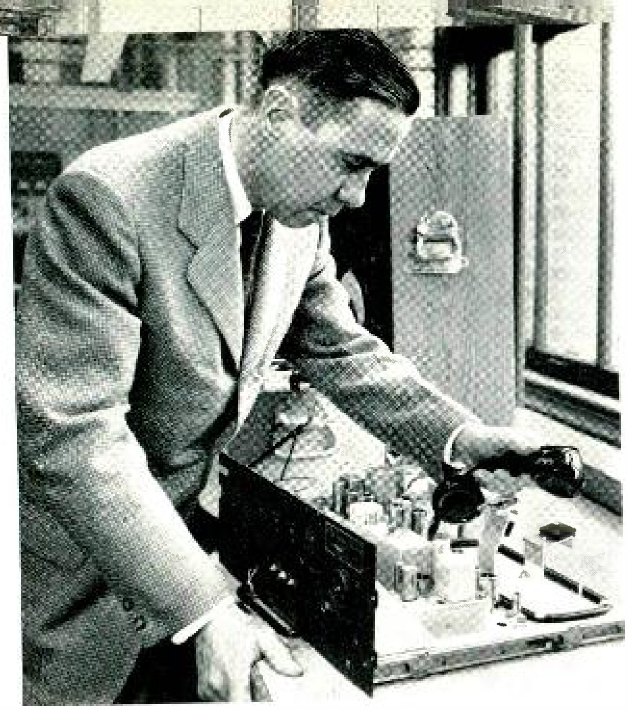
The final results of this theoretical study assured that the transatlantic link being designed would provide 36 high-quality telephone channels in the frequency range between 20 and 164 kc. In addition, a band of frequencies just below 20 kc, shown in Figure 2, would be available for maintenance telephone and telegraph order wires. Above 164 kc, the gain of the repeater was sufficient to provide for frequencies in the range between 167 and 174 kc. This band of frequencies is used for checking the performance of individual repeaters in the cables from shore stations.

The means for making these checks were the same as those used in the Havana-Key West repeaters. Briefly, each repeater has a quartz crystal resonator, tuned to a specific frequency in the 167 to 174 kc range, shunted across the feedback path. This tuned shunt removes the feedback over a very narrow range around the resonant frequency. With the feedback removed, the gain of each repeater is greatly increased. In this narrow band, changes in the repeater tube gain are noticeable because the stabilizing effect of feedback has been eliminated. Thus, if the frequency corresponding to the resonant frequency of a particular repeater is sent out from one shore and the power received at the other shore is measured and compared over the years to the power of a frequency just off resonance, it is possible to keep track of tube aging. In addition, the high gain of each repeater creates a noise peak at the resonant frequency. Each noise peak can be identified at the receiving end by means of a nar-

THE AUTHORS

M. E. Campbell received the BA degree in physics from Pomona College in 1928 and after a year as instructor in physics joined the Laboratories. He took part in the early development and trials of coaxial cable and of the L1 carrier system. During World War II he was concerned with the use of electronic counter measures and with military intelligence. Later he worked on the establishment of the L1 coaxial television-transmission network and was engaged in a study program for the United States Navy until the time that he began work on the transatlantic submarine cable system.

John M. Fraser, a native of Glasgow, Scotland, joined the Laboratories in 1934 and was concerned with the evaluation of subjective factors affecting the transmission performance of telephone systems. This included the design of equipment for simulating transmission systems in the laboratory. During the war his work was chiefly concerned with the design and evaluation of communication systems for the Army and the Navy. Later he was engaged in transmission work on long-distance and short-haul carrier systems. On the transatlantic telephone cable project he was mainly concerned with the system engineering aspects of the cable system. At present, he is engaged in system engineering work on a project for increasing the capacity of cable systems. Mr. Fraser received a B.S. in E.E. from Polytechnic Institute of Brooklyn in 1945.



Bell Laboratories has recently developed a twelve-channel carrier telephone system for the armed forces — a portable system rugged enough to withstand the severe requirements of military service. For adjusting and maintaining the system, an "extra" channel or order circuit is included, along with all the circuits required in making a large number of easily performed tests. With the order circuit and maintenance equipment, operators can monitor the system and take rapid corrective action.

Twelve-Channel Military Carrier: Order Circuit and Maintenance

H. C. FLEMING *Military Communication Systems Engineering*

Recent articles* have described a carrier telephone system designed at Bell Telephone Laboratories for military use — a system that transmits twelve telephone message channels over cable or radio links for distances up to 200 miles between terminals. A carrier system of this type requires an initial adjustment of gain and equalization at successive repeater points along the line, as well as periodic checks and readjustments of transmission to assure high grade circuits. Also, there is need for a fast method of locating trouble when it occurs.

Adjustment and maintenance procedures generally require voice communication between attendants at various points along the line, and for this purpose an order circuit has been made part of the system. Furthermore, it is important that a military system be self-contained to the extent that operation and maintenance may be carried on without the aid of additional test equipment. Accordingly, test circuits have been built into the equipment to provide for the necessary maintenance and trouble-shooting by operating personnel.

In the cable system, operating personnel are always in attendance at the terminals (AN/TCC-7) and at "attended" repeaters (AN/TCC-8) spaced at intervals not greater than 40 miles. Telephone sets and other circuits are available at all attended points for signaling and talking on an order circuit from one point to any other. Between two attended repeaters there may be as many as six additional "unattended" repeaters (AN/TCC-11), spaced about 6 miles apart. Talking and signaling from the unattended repeaters are made possible by a portable test set and telephone.

Engineering considerations indicated that a maximum spacing of 40 miles between order-circuit repeaters was practicable if the upper end of the transmitted frequency band were limited to 1,700 cps. This made it possible to locate the order-circuit repeaters at the same points as the attended repeaters necessary for the carrier circuits. Accordingly, the order circuit is limited to a frequency range from 300 to 1,700 cycles per second. This is a narrower band than is ordinarily used for voice conversation, but it is satisfactory for the purposes of maintenance in the system.

Figures 1, 2 and 3 show respectively the order circuit arrangements for the terminal, attended repeater, and unattended repeater. At an attended re-

* RECORD, *August*, 1955, *page* 290; *January*, 1956, *page* 21; *June*, 1956, *pages* 207, 227; *July*, 1956, *page* 272; *October*, 1956, *page* 388; and *February*, 1957, *page* 72.

peater (Figure 2) the telephone set is bridged across the two transmission paths. This arrangement permits talking and listening to both directions at the same time. The loss of the cable at the frequencies used by the order circuit is nullified by amplifier gain at the attended points. The same transmitting and receiving plug-in amplifier designs are used at all terminal and repeater points.

At all repeaters — attended and unattended — the order circuit is by-passed around the carrier amplifiers by filters which separate the 300 to 1,700 cps order-circuit band from the 12- to 68-kc carrier-frequency band. Thus, except for the cable and the "repeat coils" at the input and output ends of each unit, the order circuit is completely independent of the carrier circuits. Failure of a carrier amplifier or of power for the unattended repeaters will not disturb the order circuit.

Because cable-circuit loss varies with frequency, it is necessary to provide equalization — a complementary variation in the order-circuit gain — to assure a flat over-all frequency response. The design considerations can be illustrated with Figure 4. In this illustration, curve (a) shows the cable loss over the range of frequencies used by the order circuit — that is, the loss of the cable alone, without the associated components in the transmission path. Line repeat coils and line filters, however, considerably modify this characteristic to curve (b), which must be compensated by the equalizers preceding the order-circuit transmitting amplifiers. The magnitude of this effect on the line characteristic is determined by the design of the low-pass filter, and for this reason, optimum design of line filter and equalizer presented a challenging problem. Curve (c) in Figure 4 shows the complementary loss characteristic of a typical order-circuit equalizer network. The degree to which equalization is successful is shown in curve (d), which represents the frequency characteristic of a typical 40-mile order circuit. Equalization is not provided for frequencies above the 1,700 cps upper limit of the order-circuit frequency band.

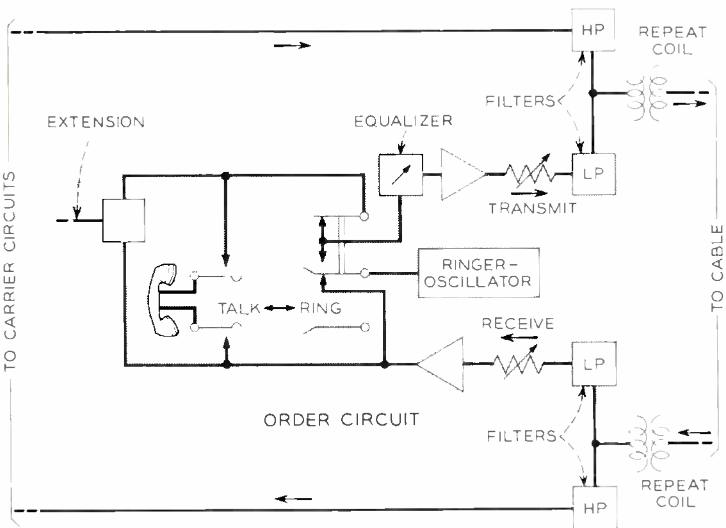


Fig. 1 — Schematic diagram of the order circuit in the terminal (AN/TCC-7) of the twelve-channel military communication system developed at Bell Laboratories.

Attended repeaters and terminals are equipped with a ringer-oscillator circuit, which is a plug-in unit that provides a 1,600-cps tone used for signaling. The unit also includes a receiving circuit that lights a lamp and sounds a buzzer whenever incoming 1,600 cps is present. To provide sufficient margin for poor transmission conditions, the receiving circuit is designed so that the level of 1,600-cps tone may drop 25 db below normal and still cause normal lamp and buzzer indications.

The ringer-oscillator is normally bridged across the transmission path in the receiving condition, and it responds to 1,600 cps signals entering from the cable. To signal personnel at other points, the attendant operates a switch that alters the circuits of the ringer-oscillator and causes it to oscillate at a frequency of 1,600 cps.

At the unattended repeater, signaling is accomplished in a different manner. As illustrated by Figure 3, the test set (TS-712) is plugged into the

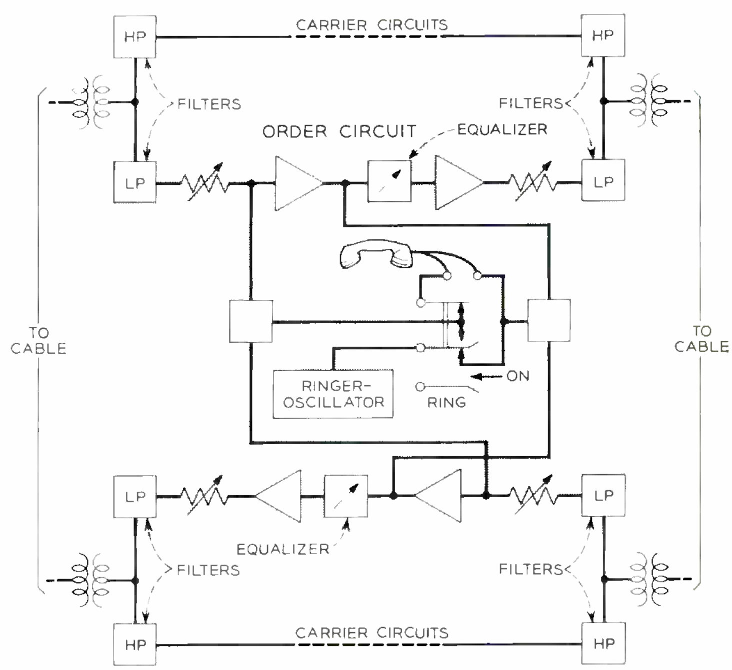


Fig. 2 — Schematic diagram of the order circuit in the attended repeater (AN/TCC-8) of the system.

repeater, and a telephone set (EE-8) connected to the test set. Operation of a switch then connects a transistor oscillator* to the order circuit. The power necessary to produce the 1,600 cps signal is generated by turning the handcrank of the telephone set.

Each attended repeater and terminal has a test panel section containing measuring circuits and sources of test frequencies. Circuits are included for measuring voltages at many critical points in the equipment. Each point is brought out on a conveniently located jack, and measurements are made by inserting a plug-ended cord connected to the test panel. Selector switches on the front panel of the test circuits are used to set up the various tests. Each test gives a meter reading of about 0 db when the system is operating correctly.

The test circuits include sources of a number of frequencies used for various operational and maintenance functions, as follows:

Regulation – The terminal equipment contains a source of 68kc which is always connected to the line. This frequency serves as a pilot for automatic regulation of the gain of the carrier amplifiers at attended points. It is also used to make maintenance checks of the carrier transmission. The test panel of the attended repeater supplies another source of 68 kc, used during the absence or failure of the terminal 68-kc supply.

Gain – A source of 1 kc at the terminal permits adjustment of the over-all transmission level of individual message channels and of the order circuit.

* RECORD, *June*, 1956, *page* 207.

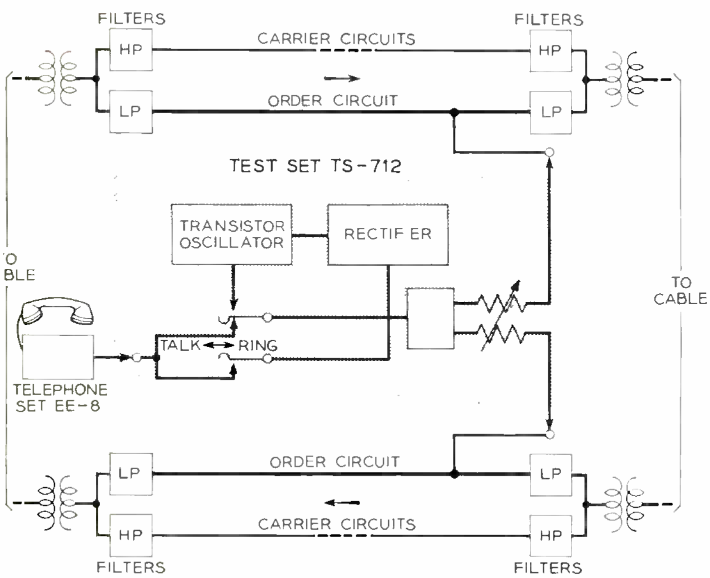


Fig. 3 — Schematic diagrams of the order circuit in the unattended repeater and of the associated test set and telephone set used for maintenance purposes.

Equalization – The terminal supplies 12- and 28-kc frequencies for equalization of the carrier circuits,* which compensates for variation in loss over the 12- to 68-kc band.

Modulation – This carrier system, like all multichannel systems, exhibits inter-modulation between signals present on different channels. When this effect becomes excessive, it appears as unintelligible crosstalk on some of the message channels. The built-in test circuits of the terminals and attended repeaters allow the attendant to measure the modulation performance of the system periodically and also to locate the source of a modulation disturbance when it does occur. To do this, a 65-kc signal is sent out on the line from any attended point. A modulation product of 62 kc (two times 65 kc minus 68 kc equals 62 kc) is generated by the interaction of this 65-kc signal with the 68-kc pilot frequency, which is always present. The test panels

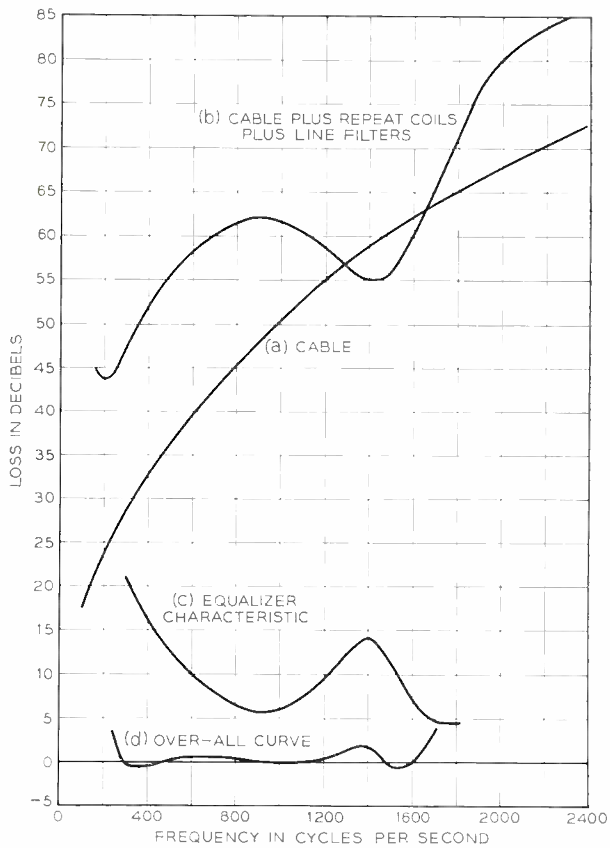


Fig. 4 — Equalization of the order circuit: cable attenuation (a) is modified by repeat coils and filters (b). This is compensated by the equalizer characteristic (c) to produce relatively flat response (d).

* RECORD, *February*, 1957, *page* 72.

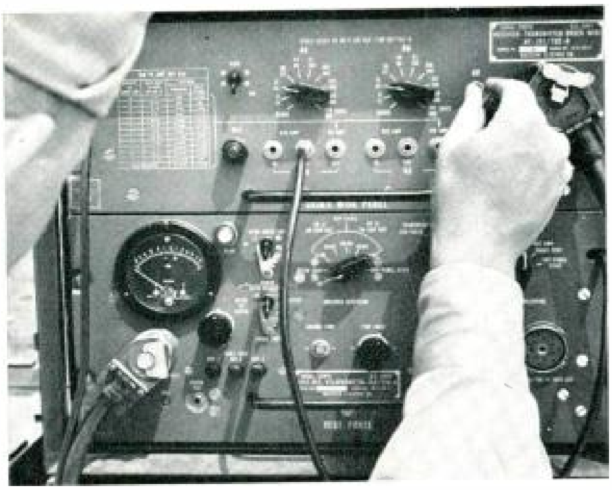


Fig. 5 — Order-circuit panel (above) and test panel (below) of the twelve-channel attended repeater.

at all attended points include sensitive circuits for measuring the magnitude of this 62-kc product. By applying this procedure to various sections of the system, the source of inter-channel modulation may be located in a specific section and eventually in a specific amplifier.

Trouble location — Three additional frequencies — 83, 91 and 99 kc — are used as part of a rapid, simple procedure for locating trouble in event of failure of carrier transmission. When transmission fails, the source of trouble can be narrowed to a particular section of the system (section between attended points) merely by observing at what points the 68-kc pilot has failed. An alarm is provided at each attended point to sound a buzzer and light a lamp if the 68-kc pilot deviates more than ± 1.5 db from normal. The 83-, 91- and 99-kc signals are then used to identify the particular unattended repeater section in trouble. Since there will normally be six unattended repeaters between attended points, three of these can be tested from one side of the section and the remaining three from the other side. Each of a group of three unattended repeaters is arranged to receive and return only one of the 83-, 91- and 99-kc signals. The first unattended repeater in the series returns only 99 kc, the second 91 kc, and the third 83 kc. Thus, for example, an operator at an attended point would send the three signals in succession, and if he received 99 kc but not 91 or 83 kc, he would know that the trouble was located in the second unattended repeater section.

When trouble is located in an unattended repeater by this or other methods, a maintenance man takes the portable test set (TS-712) to the location. The set contains circuits for measuring direct current and signal voltages at various points in the repeater. One such test is a measurement of the filament activity of each electron tube — usually a good indicator of trouble in the tube.

All of the tests described in this article, with the exception of gain adjustments using the 1-kc signal, may be conducted without disturbing regular service over the channels. It is expected that efficient use of the order circuit and maintenance facilities built into the system will permit simple and rapid routine checks of system performance and location of trouble.

THE AUTHOR

H. C. Fleming, a native of Brooklyn, N. Y., received the B.S. degree in 1932 and the Sc.M. degree in 1936, both from New York University. After some years teaching in the Electrical Engineering Department at N.Y.U., he joined the Laboratories in 1937, and was assigned to the Personnel Department, where he conducted training courses for Technical Assistants and others. In 1941 he was transferred to a carrier systems development group and worked on the K2 carrier telephone system. During the war he was concerned with echo-ranging devices for submarine detection. This was followed by a period devoted to development of military carrier telephone systems, and at present he is concerned with military communications systems engineering problems. He is a member of Tau Beta Pi, Iota Alpha, the I.R.E. and the A.I.E.E.

Dr. M. J. Kelly Delivers Keynote Address At European Symposium

M. B. McDavitt Describes TH Microwave System

Dr. M. J. Kelly delivered the keynote address and M. B. McDavitt presented a paper at the European Symposium on Radio Links, which was sponsored by the Italian National Research Council and which opened in Rome on June 5. These reports told of the impact of solid-state electronics on modern telecommunications and announced the development of a new microwave radio-relay system at Bell Telephone Laboratories.

Historical Perspective

In his keynote address, Dr. Kelly reviewed the past half century of progress in telecommunications as background for examining the impact of solid-state technology on the telecommunications of the future. Tracing the progress of development of solid-state devices during their early history, Dr. Kelly went on to describe the present philosophy of work at Bell Laboratories.

"Through theoretical and experimental research," Dr. Kelly said, "the telecommunications laboratory today is obtaining quantitative knowledge of the order and arrangement of atoms in solids, of mechanisms of electrical conduction, of presence of impurities to one atom in one hundred billion. It is creating means to control the amount of such impurities at micro levels and of distributing them in known concentrations throughout planned portions of the solid. It is this fundamental approach that is bringing the new era in electronics."

Dr. M. J. Kelly, in the illustration above, discussing trends in telecommunications at the European Symposium on Radio Links. Left, M. Algeri of the Telecommunications Ministry, and center, U. Quintavalle, Italian industrialist.

Using the transistor as one example of many devices to result from this research and development work, Dr. Kelly described how, once the transistor had been invented, an expanded research and development effort was necessary to achieve the wide variety of functional properties required for extensive telecommunication applications. "The big challenge, therefore, was the attainment of these functional properties. If attained, the rewards to telecommunications economy were obviously very large."

Dr. Kelly pointed out that, as a measure of the present state of progress of the new art, the Bell System in 1957 will require some 5,000,000 diodes and 600,000 transistors. He continued with a discussion of how new techniques, including the diffusion method, were continuously being developed to widen the range of properties and applications of semiconductor devices.

Present and Future Applications

To illustrate the extent to which solid-state technology has had an impact on communication, Dr. Kelly mentioned a few of the many applications in the telephone industry and forecast the expanded use of new and improved devices and systems. He traced applications through early equipments – power rectifiers, signaling facilities, telephone-set amplifiers, and line concentrators – and then through present and future transmission and switching systems. He emphasized the gains in efficiency and economy achieved through the small size and small power requirements of new components and through the use of the "building-block" type of equipment design.

In the field of rural, exchange, and toll transmission, Dr. Kelly pointed to the recent development of a transistorized rural carrier system, the decrease in transmission distance for economical use of carrier exchange systems, and the problems and potentialities of toll systems of great bandwidth. For both exchange and toll systems, Dr. Kelly emphasized the potentially great economies of pulse-code modulation systems, although problems remain to be solved.

In the area of switching systems, Dr. Kelly reviewed several applications of solid-state technology, including the electronic switching system currently being developed at Bell Laboratories. "It will be installed in a 5,000-line office when the laboratory tests are completed," Dr. Kelly said. "Its trial in service is essential to solving the problems of its compatibility with the electromechanical systems with which it must interconnect. Manufacture of systems for service will begin in 1960.

"In the decade since the invention of the transistor, which triggered off the new era, the technology has attained sufficient breadth and depth to make it abundantly clear that solid-state electronics will almost completely instrument telecommunication in the coming decades. It will greatly extend the usable range of the electromagnetic spectrum. It will make large contributions to cost reductions in equipment, installation, operation and maintenance. These lower costs levels will expand the use of communications services. It will make many new services possible. It is ideal for record and data transmission. It will accelerate the growth of this service."

C. R. Moster, H. L. McDowell and J. P. Laico shown here with an early developmental model of the traveling-wave tube amplifier.

Dr. M. J. Kelly (center) and M. B. McDavitt (right) after one of the technical sessions of the Symposium in Italian National Research Council Building.

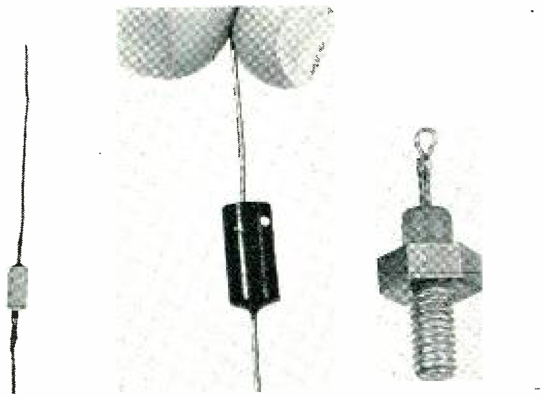
The TH Microwave System

At the same Symposium, M. B. McDavitt, Director of Transmission Development at Bell Laboratories, described a microwave system which has been under development and which is known as the "TH" microwave radio-relay system. This system takes advantage of much of the solid-state and electronic technology developed at Bell Laboratories in recent years, and introduces traveling-wave tubes into the Bell System on an extensive scale. The new system makes highly efficient use of the overcrowded radio spectrum and will increase by more than three times the information-handling capacity of radio-relay systems occupying comparable frequency space.

System Performance

The TH system is designed to operate in the 5,925-to-6,425-mc microwave band. It provides a total of eight 10-mc broadband channels in each direction, plus two narrow-band 0.5-mc channels for maintenance and alarm facilities. Six of these eight bands may be in use at any particular time; the other two are held in reserve as protection channels to be automatically switched into service if needed.

Each broadband channel can provide a number of services: 1,860 voice channels; a black-and-white or color TV signal plus 420 voice channels; or a broadband TV signal such as might be required to transmit a color TV picture of theater-screen size. Various other services such as teletypewriter, facsimile, and data transmission can also be readily accommodated. Present plans call for a substantial installation of a TH system late in 1959.



Example of Laboratories solid-state research and development — diffused silicon power rectifiers of various ratings.

A radio-frequency output of 5 watts, frequency modulated, is radiated at each transmitter. This output is provided by a newly designed traveling-wave tube amplifier, which was adopted mainly because it has wider inherent bandwidth and hence requires fewer adjustments, it involves less circuit and physical complexity, and it is believed to provide greater system reliability. The traveling-wave tube is designed to cover 5,925-6,425-mc band and to give a minimum gain of 30 decibels.

The traveling-wave tube is driven by a frequency converter which boosts the intermediate frequency of 74.1 mc to the final transmitted frequency. Conversion is accomplished by a newly developed gold-bonded diode which can provide gain, if desired, but is operated at a low bias to give a uniform impedance over the IF range and so gives neither gain nor loss. This is the first use in a system of a diode modulator without inherent loss.

Microwave Ferrite Devices

Isolation between forward and reflected signals at various points in the system is provided by "one-way" microwave ferrite isolators, each of which has a loss of only 0.25 db or less in the transmitting direction, and at least 27 db in the reverse direction. A microwave ferrite switch is employed to switch rapidly and automatically between regular and standby critical equipment in case of equipment failure. Switching time is less than one millisecond.

The horn-reflector antennas and round waveguide now being installed in relay towers can be used simultaneously for the new TH system at 6,000 mc, the present transcontinental TD-2 at 4,000 mc, and the new short-haul TJ system at 11,000 mc. Special filters are employed to separate the various signals.

Signals in adjacent channels are alternately horizontally and vertically polarized to provide isolation between channels of 20 db more than would otherwise be available. This permits adjacent channels to be placed much closer together and aids greatly in increasing the use of the available frequency spectrum.

Silicon power rectifiers are employed in the power supplies, thus contributing greatly to reliability. Because of the high efficiency of these rectifiers, power consumption and heat dissipation are both appreciably reduced.

J. J. Kostelnick and F. J. Sansalone testing field-displacement ferrite isolator.

B. T. Matthias holds a specimen of the crystal grown for ferroelectric switching and memory applications.

Laboratories Announces New Ferroelectric

Intensive exploration in the field of ferroelectrics has resulted in the discovery of a new ferroelectric material by B. T. Matthias at Bell Laboratories. Known chemically as triglycine sulphate, the material has a rectangular voltage hysteresis loop and other desirable properties which make it very promising for switching circuits and memory devices. Ferroelectrics are materials which can be switched rapidly from one polarization to another by means of an applied voltage gradient of sufficient magnitude and proper polarity. They will retain a given polarization until switched.

The most popular ferroelectric crystal previously investigated is barium titanate. Triglycine sulphate is superior in that it has a much lower coercive field (220 volts/cm), thus permitting switching with a lower voltage. Its polarization results in a lower output pulse when switched, but the size of the pulse can be increased by increasing the area of the switching electrodes.

Triglycine sulphate is stable chemically and does not decompose when exposed to moisture or to the atmosphere. It has adequate mechanical strength to permit handling in thin sheets. Large single crystals can be grown quite easily, and a number of large-area slices can be cut from each crystal.

Repeated switching does not cause any fatigue in triglycine sulphate, as it does in barium titanate. And a given area will retain a given polarization indefinitely without deterioration. Although heating beyond the Curie point causes the material to lose its ferroelectric properties, these properties are regained in full when it is cooled.

The Curie point of this new material (point at which it loses its ferroelectric properties) is about 47°C. However, by replacing some of the hydrogen atoms with deuterium, easily accomplished when the crystal is grown, it is possible to raise the Curie point to 60°C.

Switching time, an important characteristic in any switching or memory device, depends on the characteristics of the material and the switching voltage. It appears that switching times of the order of one to two microseconds can easily be attained with this new material.

Electrodes can be applied to a slice cut from a single crystal by evaporating thin strips of metal on each side of the slice, the strips on one side being perpendicular to those on the other. Using this technique, thirty or more strips per inch can be applied, resulting in a memory or switching device capable of storing 900 or more "bits" of information on a square inch of crystal. A number of such slices can be assembled in a relatively small volume, resulting in a very compact assembly.

Thickness of the slice can be from 5 to 10 mils, depending on the available pulsing voltage and the desired output. Switching can be accomplished with about 20 volts, a value easily obtained with transistorized circuitry. The actual power required for switching is very small, thus minimizing internal heating of the crystal.

There are very few materials known to have ferroelectric properties. The search for new materials continues, while investigation is under way to apply triglycine sulphate to actual memory and switching devices for communication purposes.

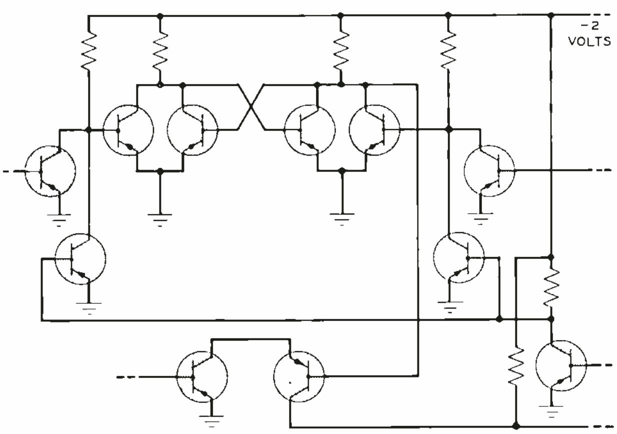
"Leprechaun"

A new high-speed digital computer, "Leprechaun," has been announced by the Laboratories. Developed under an Air Force contract, the new computer is to be used for programing and logical-design research on digital computers for military real-time control applications. Leprechaun is not much larger than a console television set and uses less power.

This drastic reduction in size and power consumption has been wrought by the use of transistors. The size and simplicity of these tiny components make them an obvious choice whenever size and power consumption of equipment are considerations, but an equally important reduction in both size and power has been achieved in Leprechaun by the introduction of direct-coupled transistor logic (DCTL) circuitry. Actually, an important objective in the development of this computer was to demonstrate the feasibility of DCTL circuitry.

The direct-coupled transistor logic technique, recently developed by computer engineers, has three important advantages over previous electron-tube and transistor computer logic circuits. The first of these is low power dissipation. Each DCTL section can perform its logic function and at the same time provide sufficient amplification to power the succeeding computer operation. The other two advantages – reductions in number and variety of components – make the circuits simpler, more compact and lower powered. The accompanying circuit diagram illustrates the simplicity of the circuit.

J. A. Githens and J. A. Baird check the control panel of the new Leprechaun digital computer.



Schematic diagram of typical direct-coupled transistor logic circuit for the Leprechaun computer.

Excluding the magnetic cores used in the memory section of the computer, Leprechaun uses only about 9,000 electronic components. Some 5,000 of these are transistors. Selected germanium alloy junction transistors with a seven megacyle alpha cutoff make up the majority of the DCTL circuitry. Surface barrier units are also employed where accurate timing is required, and power transistors are used for the high current requirements of the memory. The DCTL circuitry dissipates about twenty watts of the total power consumption of 160 watts. Of this twenty watts, less than 2.5 watts are dissipated in the transistors.

Since Leprechaun is to be used for research in computer design for military applications, it was designed to have extreme flexibility. By using hinged-back, "book-and-leaf" construction that is partially modular, mechanical and electrical arrangements are such that various related portions of the computer can be easily connected, disconnected, and interconnected to test proposed new designs. Interconnections consist of jumpers with taper-pin terminals, making it possible to set up or insert entirely new computing circuitry in a relatively short time.

Another feature of Leprechaun is its transistor-driven random-access magnetic core memory. The machine can take instructions immediately from its memory, no matter where the desired instruction may be stored. This process differs from that of computers with a revolving drum memory which require time for the rotation of the drum before getting instructions. Because of its speed of operation, Leprechaun solves problems almost instantaneously. Each instruction consists of the arithmetic operation to be performed and the location of the data in the memory.

The machine can store 1,024 "words" in its memory. Each of these words consists of 18 binary digits which represent either instructions or additional data to be used. Included in the 18-digit word are a "sign" digit and a "parity-check" digit which checks the accuracy of information stored in the memory. Circuits gain access to the memory cores, which are arranged in a grid pattern, through coincidence currents acting on the polarized memory cores. The memory can maintain a twenty-microsecond read and write cycle.

Except for the limitation on word length, Leprechaun may be considered a general-purpose computer. Compared with previous computers, the circuits of Leprechaun are very simple and easily understood, a decided advantage in engineering and maintenance. Leprechaun's simplicity and small number of components not only result in reduced size and weight, but also will permit the use of automation techniques in manufacture. All of these features should contribute to greater reliability.

Leprechaun is named after the elusive sprite of Irish folklore. The word "Leprechaun" is derived from the root words for "little" and "body;" and, as the legend has it, the Leprechaun when captured will lead his captor to hidden treasures. The new computer seems aptly named. For though it is still in the experimental stage, the techniques developed for Leprechaun and the research it is designed to carry on should have many applications in future computer technology.

Western Electric Organizational Changes

As a further step in strengthening its engineering and construction programs, Western Electric Company has made a number of changes which became effective June 1.

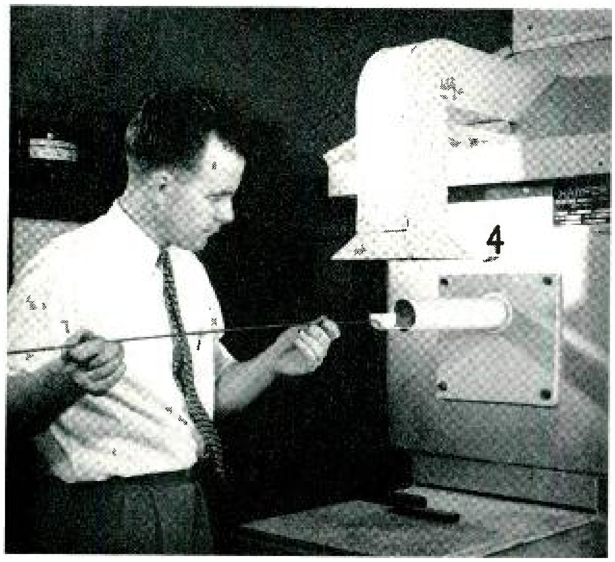
The Engineering Division, as presently constituted, has the responsibility to provide leadership and coordination of all phases of the Western Electric engineering work and also is responsible for long-range planning of plant facilities and for the design and construction of all company-owned buildings. Because of the urgent need for expansion of the company's plant facilities, the long-term planning activities and the volume of plant design and construction work in process and projected for the next several years have increased sharply.

To insure adequate executive attention to this important work, which will have so major an influence on the company's future performance, and which entails such heavy capital expenditures, H. V. Schmidt was appointed Vice President – Plant Design and Construction, reporting to the President, to devote full time to these activities as head of the new Plant Design and Construction Division.

Similarly, the expanding importance of research, development and engineering in many fields, and the need for adequate and effective liaison with outside technical agencies and for coordination of engineering effort with Bell Laboratories on new equipment and apparatus designs, have led to the decision to establish the headquarters activities in these fields as a separate Division, also reporting to the President. This Division is now headed by T. E. Shea, Vice President – Engineering. Mr. Shea was a member of the Laboratories from 1925 to 1939, and returned to serve as a Vice President for several months in 1952.

R. H. McCarthy and J. L. Williams, Directors of Plant Engineering, report to Mr. Schmidt. L. R. Cook's title is changed to Assistant Vice President – Engineering. He and S. E. Brillhart, Director – Research and Development Engineering, report to Mr. Shea. At a meeting of Western Electric's Board of Directors, A. P. Clow was elected a Vice President of the company. He succeeds Mr. Shea as Vice President – Personnel and Public Relations.

M. H. Howarth, Vice President and General Manager of Sandia Corporation, has resigned and accepted a position with Western Electric as Works Manager – Kearny Works, succeeding Mr. Clow. S. P. Schwartz, Assistant Project Manager – Operations and Programing, ADES Project, Defense Projects Division, was elected a Vice President of Sandia Corporation and appointed General Manager, succeeding Mr. Howarth. D. P. Wilkes, Superintendent – Systems and Training, ADES Project, Defense Projects Division, has become Assistant Project Manager – Operations and Programing for that project, succeeding Mr. Schwartz. For the present, organizations previously reporting to Mr. Wilkes will continue to report directly to him.



Alundum tray, containing block of ferrite material, is inserted into firing furnace by L. G. Van Uitert.

Laboratories Metallurgical Research Results in New Microwave Ferrites

New ferrite materials having properties particularly well adapted for a broad range of microwave applications have been developed by L. G. Van Uitert of the Metallurgical Research Department at Bell Laboratories. Their desirable properties include controllable saturation magnetization, low dielectric loss, and a high degree of reproducibility. Microwave measurements indicate that, in general, these new ferrites, containing copper additives, are comparable or even preferable to similar materials which contain no copper.

Many novel microwave circuit elements have grown out of Bell Laboratories' development of the microwave gyrator in 1951 – devices which use ferromagnetic materials such as these ferrites. The gyrator and other applications followed a general upsurge of interest in magnetic oxides, stimulated by developments in this field at the Philips Laboratories in the Netherlands.

The new materials include a nickel-manganese ferrite and a family of magnesium-manganese-aluminum ferrites, in which a small amount of copper replaces some of the nickel or magnesium respectively. A proper combination of copper and manganese added to the original ferrite is advantageous from several points of view. By increasing the reactivity of the mixture, copper decreases the necessary firing temperature by at least 100°C. Under comparable conditions, this results in lower porosity and improved uniformity in the fired material. Also, the manganese addition decreases electrical conductivity and thus the dielectric losses in these low porosity magnetic materials.

Microwave ferrites with low saturation magnetizations are obtained by modifying magnesium ferrite. Controlled decrease of the saturation magnetization of this ferrite can be obtained by substituting aluminum for a part of the iron. While materials compounded in this fashion are basically satisfactory, their refractory nature makes it difficult to reproduce the magnetic properties required for many microwave applications. The added copper minimizes this difficulty, and also increases slightly the Curie temperature for materials with comparable saturation magnetizations.

The new ferrite materials constitute a forward step in production of the unique nonreciprocal microwave devices, such as isolators, in which solid materials perform complex circuit functions.

Contents of the May, 1957, Bell System Technical Journal

The May, 1957, issue of The Bell System Technical Journal contains the following articles:

Radio Propagation Fundamentals by Kenneth Bullington.

A Reflection Theory for Propagation Beyond the Horizon by H. T. Friis, A. B. Crawford, and D. C. Hogg.

Interchannel Interference Due to Klystron Pulling by H. E. Curtis, and S. O. Rice.

Instantaneous Companding of Quantized Signals by Bernard Smith.

An Electrically Operated Hydraulic Control Valve by J. W. Schaefer.

Strength Requirements for Round Conduit by G. F. Weissmann.

Cold Cathode Gas Tubes for Telephone Switching Systems by M. A. Townsend.

Activation of Electrical Contacts by Organic Vapors by L. H. Germer and J. L. Smith.

H. J. McSkimin adjusts diamond specimen on the end of fused-silica "buffer" rod.

Elastic Moduli of Diamond

An ultrasonic technique for measuring the elastic properties of small specimens of many materials has been announced at Bell Laboratories. Such properties – important to fundamental studies of the solid state – are described in terms of the elastic modulus, defined as the stress-strain ratio or pressure required to produce unit strain in a dimension of the solid. Crystalline materials have different moduli for different directions in the crystal.

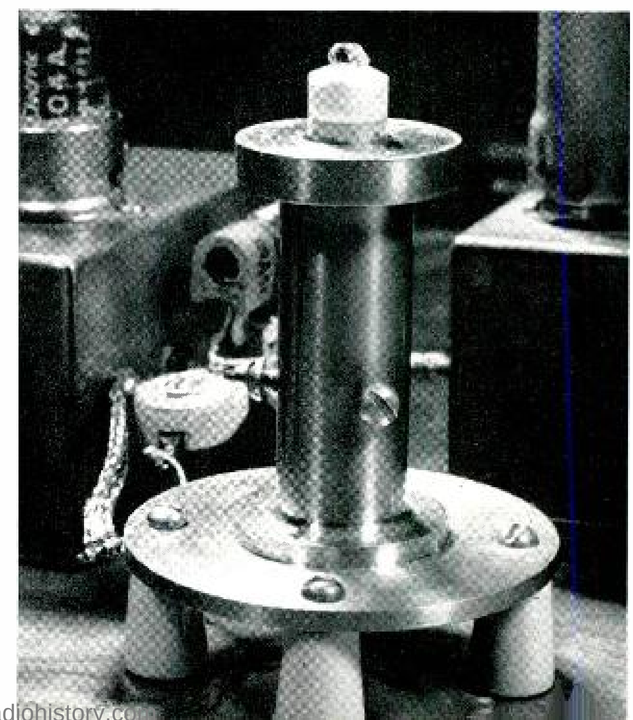
Of particular interest is diamond, which has three elastic moduli. Very few accurate measurements are available in the literature, and for this reason, diamond was studied by the newly developed ultrasonic technique. With suitable auxiliary equipment, the method can be applied to specimens under widely varying conditions of temperature and pressure.

The technique, developed by H. J. McSkimin and W. L. Bond of the Physical Research Department, is indicated in the diagram (next page). It consists of transmitting short trains of high-frequency mechanical waves into the specimen and determining their velocity of propagation. From this data and the known density of the specimen, the elastic moduli can be calculated. In the work with diamond, both longitudinal and shear waves were used.

Flat, parallel surfaces were ground on opposite sides of the diamond specimen, and its thickness was measured very precisely. The specimen was then fastened to one end of a fused silica "buffer" rod by means of a thin film of viscous liquid. A suitable quartz transducer for converting electrical to ultrasonic energy was attached to the opposite end of the buffer.

Repeated trains of ultrasonic waves – at frequencies up to 200 mc – were transmitted along the buffer rod. These wave trains were principally reflected at the buffer-specimen interface, but were also partially transmitted into the specimen and reflected back and forth between its parallel surfaces. The result was a series of multiple reflections. At certain critical frequencies, these echoes were precisely in phase and they combined to give rise to a characteristic pattern on an oscilloscope responsive to the transducer. The velocity of propagation in the specimen could then be determined from the frequencies and the thickness; and from a knowledge of the density, the elastic constants were computed for diamond.

Two diamonds were used in these studies. Each, before cutting, was a natural dodecahedron of a pale yellow color and was quite transparent. Both were Type I diamonds as evidenced by a strong



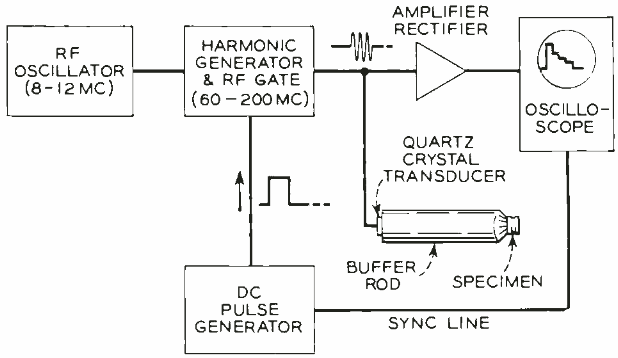
Diamond specimen on top of buffer rod (in vertical cylinder); at bottom of cylinder is transducer.

optical absorption at 8 microns wavelength, and each was a single crystal as determined by x-ray reflection patterns.

The experiments gave data for the c_{11} (extensional), c_{12} (cross-coupling), and c_{44} (shear) moduli. The results, expressed in units of 10^{12} dynes per square centimeter, are as follows:

$$c_{11} \quad - \quad 10.76 \pm 0.6\%$$
$$c_{12} \quad - \quad 1.25 \pm 5.4\%$$
$$c_{44} \quad - \quad 5.76 \pm 0.3\%$$

The c_{11} value agrees reasonably well with previous measurements, but the c_{12} is much smaller and the c_{44} value is larger than other workers in this field have reported.



Reflections of ultrasonic waves between parallel surfaces of diamond specimen produce characteristic oscilloscope patterns for measuring moduli.

"Punched Sleeves" for Cable Splicing

A new Bell System technique called "punched sleeve" splicing has been developed at Bell Laboratories. The use of a pneumatic presser and small, plastic-covered metal tubes provided by Western Electric will make cable-splicing jobs faster and easier. It eliminates insulation-stripping and wire-twisting when joining paper-insulated or pulp-insulated cable conductors.

A splicer brings two or three wires together, and over the ends of the wires he slips one of the special sleeves, which are about one inch long and which range in diameter from about ⅛ to 3/16 of an inch. There is no stripping and no twisting of the conductors. He then places the sleeve inside the jaws of a small pneumatic presser having two sets of small teeth. The presser fits the hand comfortably and is operated by a tank of nitrogen gas.

When the splicer squeezes the trigger on the presser, the teeth, under a force of more than 3,000 pounds, bite through the plastic sleeve insulation, and crush the metal tube. When crushing the metal tube, the jaws of the presser form teeth in the walls of the tube, which in turn penetrate the insulation of the conductors. The result is that the teeth formed in the metal tube remain embedded in the wires and provide an excellent electrical connection.

This year, Western Electric expects to provide millions of sleeves for use with paper- and pulp-insulated aluminum and copper cable conductors. And, for the future, Bell Laboratories is developing a similar method for splicing plastic-insulated cable conductors.

Two conductors after being removed from the presser used in making the punched-sleeve splice.

New Graduate Training Program

A new graduate training program for Bell Laboratories locations outside the metropolitan area will be instituted this fall. The program, which is based on recommendations of representatives at these locations, will be available to new Members of Technical Staff who are recent college graduates and who are selected by their technical departments for such training.

The courses will be directed toward the areas of interest of technical departments at the various locations, and in general will parallel courses at the New York University Graduate Study Center available to members of the Communications Development Training Program. Courses will be taken at graduate schools near the trainee's place of work, and may be credited toward advanced degrees. The Laboratories will pay for books, tuition and reasonable travel expense, and the trainee will receive full-time pay. To give trainees an over-all knowledge of the Laboratories, there will be rotational work assignments at other locations during summer academic vacations.

Talks by Members of the Laboratories

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

1957 Electronic Components Symposium, Chicago.

Bieling, C. A., *Low Loss Ultrasonic Quartz Delay Lines with Barium Titanate Transducers.*

Darnell, P. S., *History, Present Status, and the Future of Electronic Components.*

Healey, R. J., *Characteristics and Applications of a Silicon Reference Diode.*

Hoover, C. W., Jr., *The Design of an Optimum Cathode Ray Tube for a Particular Application.*

Hoover, C. W., Jr., Raag, H., and Nesenbergs, M., *Equipment for Precise Measurement of the Distribution in Intensity of the Light in a Spot on a Cathode Ray Tube Screen.*

Meitzler, A. H., *A Procedure for Determining the Equivalent Circuit Elements Representing Ceramic Transducers Used in Delay Lines.*

Nesenbergs, M., see Hoover, C. W., Jr.

Raag, H., *Fatigue Characteristics of Photomultiplier Tubes.*

Raag, H., see Hoover, C. W., Jr.

Rosenberg, C., *Properties of Ferroelectric Devices as Current Regulating and Frequency Determining Elements.*

Ruggles, D. M., *A Miniaturized Quartz Crystal Unit for the Frequency Range 2 kc to 16 kc.*

Wehe, H. G., and Werner, J. K., *Miniature Low Loss Lacquer Film Capacitors.*

Werner, J. K., see Wehe, H. G.

Electrochemical Society, Semiconductor Symposium, Washington, D. C.

Archer, R. J., *Optical Measurement of Film Growth on Silicon and Germanium Surfaces in Room Air.*

Benson, K. E., see Wernick, J. H.

Bridgers, H. E., see Theuerer, H. C.

Goldey, J. M., Tanenbaum, M., and Holonyak, N., Jr., *Evaporation and Alloying of Metals to Silicon.*

Holonyak, N., Jr., see Goldey, J. M.

Lander, J. J., see Morrison, J.

Logan, R. A., *Diffusion of Oxygen in Silicon.*

Morrison, J., and Lander, J. J., *The Solution of Hydrogen in Nickel Under Hydrogen Ion Bombardment.*

Tanenbaum, M., *Impurity Diffusion in Germanium and Silicon.*

Tanenbaum, M., see Goldey, J. M.

Theuerer, H. C., Bridgers, H. E., Whelan, J. M., *Heat Treatment of Silicon.*

Veloric, H. S., *Pulse Properties and Reliability of Diffused Junction Rectifiers.*

Wernick, J. H., and Benson, K. E., *New Semiconductors.*

Whelan, J. M., see Theuerer, H. C.

59th Annual Meeting, American Ceramic Society, Dallas, Texas

Flaschen, S. S., and Garn P. D., *Detection of Phase Transitions by a Method of Continuous Resistance Analysis.*

Flaschen, S. S., see Sauer, H. A.

Garn, P. D., see Flaschen, S. S.

Nielsen, J. W., see Williams, J. C.

Sauer, H. A., and Flaschen, S. S., *The Importance of Electrodes in the Study and Use of Ceramic Semiconducting Oxides.*

Tidd, E. D., and Williams, J. C., *Properties of High Alumina Hermetically Sealed Terminals.*

Williams, J. C., and Nielsen, J. W., *The Wetting of Original and Metallized High Alumina Surfaces by Molten Brazing Solders.*

Williams, J. C., see Tidd, E. D.

Acoustical Society of America, New York City

Flanagan, J. L., *Pitch Discrimination for Synthetic Vowel Sounds.*

McSkimin, H. J., *An Ultrasonic Pulse Technique for Measuring Acoustic Losses and Velocities of Propagation in Liquids Under Pressure.*

Schroeder, M. R., *New Interpretation of the Stereophonic Effect in Laundsen's and Similar Binaural Experiments.*

Other Talks

Anderson, O. L., *The Frontier of Research on Strength of Glass Fibers,* National Bureau of Standards, Washington, D. C.

Babington, W., *The Effects of Variables in the Die Casting Process,* American Society of Die Casting Engineers, Toledo Chapter, Toledo, Ohio.

Bavelas, A., Deutsch, M., Ford, R. N., Gerard, H. B., and Jenkins, H. M., *Research on Human Communication and Group Interaction at Bell Telephone Laboratories,* Sociology Seminar, Princeton University, Princeton, N. J.

Bennett, D. C., *Single Crystal of Exceptional Perfection and Uniformity by Zone Leveling,* Lehigh Valley Physics Society, Palmerton, Pa.

Talks by Members of the Laboratories, Continued

Biggs, B. S., *The Induction Period in Oxidative Deterioration*, Prevention of Deterioration Center, Washington, D. C.

Church, S. E., *Transatlantic Submarine Telephone Cable System*, U. S. Air Force Reserve, Drew University, Madison, N. J.

Crowe, W. J., *Bridging Effects in the Resonance Isolator and a Related Device*, Symposium on Microwave Ferrites and Devices and Application, New York City.

David, E. E., Jr., *Intelligent Machines*, Graduation Exercises of the RCA Institute, New York City.

Dean, W. A., see Seidel, H.

Deutsch, M., see Bavelas, A.

Dodd, Miss D. M., see Wood, D. L.

Drenick, R., *Mathematics in Modern Life*, Society for Industrial and Applied Mathematics, Franklin Institute, Philadelphia.

Drenick, R., *An Operational View of Equipment Reliability*, 11th Annual Convention, American Society for Quality Control, Detroit.

Fagen, M. D., and Smith, W. L., *Fundamental Studies on an Improved Crystal Controlled Frequency Standard*, 11th Annual Frequency Control Review of Technical Progress, Asbury Park, N. J.

Feher, G., *Electron-Nuclear Double Resonance Experiments*, Symposium on Recent Developments in Research Methods and Instrumentation, Washington, D. C.

Felker, J. H., *Data Transmission and Automation*, Industrial Communication Association Meeting, Atlantic City, N. J.

Ford, R. N., see Bavelas, A.

Frisch, H. L., *An Approach to Equilibrium*, Watson Laboratories, Columbia University, New York City.

Garcia, R. R., *Bell Laboratories' Place in the Bell System*, Colonial Arms Civic Association, Union, N. J.

Gerard, H. B., see Bavelas, A.

Guldner, W. G., *Careers in Chemistry and Chemical Engineering*, Bernards High School, Bernardsville, N. J.

Gupta, S. S., Huyett, Miss M. J., and Sobel, M., *Selection and Ranking Problems with Binomial Populations*, 11th Annual Convention, American Society for Quality Control, Detroit.

Harvey, F. K., *Speech, Music and Hearing*, Roche Research Club, Nutley, N. J.

Herring, C., *Thermomagnetic Effects in Germanium*, Physics Colloquium, Research Laboratory, General Electric Company, Schenectady, N. Y.

Hogg, D. C., see Kummer, W. H.

Huyett, Miss M. J., see Gupta, S. S.

Ingram, S. B., *An Electrical Engineer's World—1957*, Conference on Electrical Engineering Education, Sagamore Conference Center, Syracuse University, Raquette Lake, N. Y.

Iwersen, J. E., Nelson, J. T., and Keywell, F., *A Five-Watt Ten-Megacycle Transistor*, I.R.E., National Conference on Aeronautical Electronics, Dayton, Ohio.

Jacobs, I., *Absorption of Plane Waves in an Optimum Non-Uniform Medium Backed by a Metallic Surface*, Joint Meeting, International Scientific Radio Union and I.R.E. Spring Meeting, Washington, D. C.

Jenkins, H. M., see Bavelas, A.

Keywell, F., see Iwersen, J. E.

King, J. C., *The Anelasticity of Natural and Synthetic Quartz at Very Low Temperatures*, Symposium on Defect Structure of Quartz and Glassy Silica, Mellon Institute, Pittsburgh, Pa.

King, J. C., *The Anelasticity of Natural and Synthetic Crystalline Quartz*, 11th Annual Frequency Control Review of Technical Progress, Asbury Park, N. J.

Kirkwood, L. W., *Tomorrow's Electronic Components*, Eta Kappa Nu, Virginia Polytechnic Institute, Blacksburg, Va.

Kompfner, R., *Teamwork in Research*, I.R.E., National Conference on Aeronautical Electronics, Dayton, Ohio.

Kretzmer, E. R., *Picture and Speech Communication*, A.I.E.E.-I.R.E. 1957 Educational Series, New York City.

Kummer, W. H., and Hogg, D. C., *Characteristics of Signals Received on a Large Aperture Antenna in Propagation Beyond-the-Horizon*, Joint Meeting of the International Scientific Radio Union and I.R.E. Spring Meeting, Washington, D. C.

Legg, V. E., *Selection of the Best Magnetic Material*, Sandia Corp., Albuquerque, N. Mex.

Lince, A. H., *The Transatlantic Telephone Cable*, New Jersey Division of the New York Section A.I.E.E., Newark, N. J.

Loar, H. H., *Semiconductor Devices*, New York Telephone Company, Tarrytown, N. Y.

Mackintosh, I. M., *Semiconductor Devices*, New York Telephone Company, Larchmont, N. Y.

McMillan, B., *Modern Mathematics in Applications*, Association of Teachers of Mathematics, New York City.

McNally, J. O., and Veazie, E. A., *An Electron Tube for a Repeatered Submarine Telephone Cable System*, Aircraft Industries Association Committee Meeting, New York City.

Michael, F. R., *Design and Effect of Engineering Education in Industry*, I.R.E. Meeting, Region IV, Akron, Ohio.

Miller, R. L., *The Waveform of the Glottal Pulse*, International Voice Conference, Northwestern University, Chicago.

Morgan, S. O., *Chemicals and Communication*, Annual Meeting, Chemical Marketing Research Association, New York City.

Nelson, C. E., *Equipment Required and Standards Necessary*, Symposium on the use of Microfilm for Reproduction of Engineering Drawings, Spring Valley, N. Y.

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

Pearson, G. L., *Silicon in Modern Communication*, The American Metals Company, Carteret, N. J.

Read, W. T., *Structural Imperfections in Semiconductors*, Research Laboratory, McGraw-Edison Company, West Orange, N. J.

Reiss, H., *Precipitation of Lithium in Germanium*, Westinghouse Research Laboratories, Pittsburgh, Pa.; U. S. Steel Laboratories, Pittsburgh, Pa.; and University of Illinois, Urbana, Ill.

Reiss, H., *Interaction Among Defects in Semiconductors,* Clevite Research Center, Cleveland, Ohio.

Reiss, H., *Chemical Interactions among Defects in Semiconductors,* Institute of Metals, University of Chicago.

Reiss, H., *Chemical Interaction among Defects in Silicon and Germanium,* Armour Research Institute, Chicago.

Reiss, H., *Interaction among Defects in Solids,* Northwestern University, Chicago.

Rowen, J. H., *Microwave Ferrite Devices,* I.R.E. Lehigh Valley Section, Lehigh University, Bethlehem, Pa.

Scovil, H. E. D., *Solid State Maser,* I.R.E., Professional Group on Microwave Theory and Techniques, New York City.

Scovil, H. E. D., *Spin Relaxation Phenomena in Gadolinium as Applied to a Solid State Maser,* Physics Colloquium, Massachusetts Institutes of Technology, Cambridge, Mass.

Seidel, H., and Dean, W. A., *Longitudinally Magnetized Ferrite Loaded Coaxial Components,* Ferrite Symposium, New York City.

Slichter, W. P., *Nuclear Resonance Studies of Iron Group Fluorides and Some High Polymers,* Department of Chemistry, Harvard University, Cambridge, Mass.

Smith, W. L., see Fagen, M. D.

Sobel, M., see Gupta, S. S.

Stansel, F. R., *Transistors,* Men's Club, Trinitarian Congregational Church, North Andover, Mass.

Thomas, D. E., *Design of Transistor RF and Video Amplifiers, I.R.E.,* Dallas Section, Southern Methodist University, Dallas.

Veazie, E. A., see McNally, J. O.

Wood, D. L., and Dodd, Miss D. M., *Infrared Bands in Crystalline Quartz,* Symposium on Defect Structure of Quartz and Glassy Silica, Mellon Institute, Pittsburgh.

Patents Issued to Members of Bell Telephone Laboratories During April

Abraham, L. G. — *Balancing Arrangement* — 2,788,396.

Beal, O. H., Pomeroy, R. C., Robertson, Gordon H., and Zinn, D. M. — *System for Testing Pulse Generators* — 2,789,267.

Bodle, D. W., and Hays, J. B., Jr. — *Lightning Protection Circuits* — 2,789,254.

Budenbom, H. T. — *Hybrid Ring Coupling Arrangement* — 2,789,271.

Buhrendorf, F. G. — *Magnetic Recording System* — 2,790,-645.

Cutler, C. C. — *Instantaneous Automatic Gain Control for Pulse Circuits* — 2,787,673.

Doering, R. J., Kleinfelder, W. C., and Pawel, H. E. — *Splice Closure for Sheathed Cable* — 2,788.385.

Fox, A. G. — *Magnetically Controlled Ferrite Phase Shifter Having Birefringent Properties* — 2,787,765.

Glass, M. S. — *High Frequency Oscillator* — 2,787,711.

Hamilton, B. H. — *Regulated Rectifying Apparatus* — 2,-790,127.

Hardaway, H. Z. — *Flange Coupling* — 2,788,498.

Hays, J. B., Jr., see Bodle, D. W.

Hines, M. E., and Rice, P. J. — *Traveling Wave Tubes* — 2,790,105.

Kelsay, L. W. — *Cable Terminal and Method of Making Same* — 2,787,652.

Ketchledge, R. W. — *Distortion Corrector* — 2,790,956.

Kleinfelder, W. C., see Doering, R. J.

Lacy, L. Y. — *Frequency Dividing Electrical Circuit* — 2,-789,217.

Linvill, J. G. — *Active Transducer* — 2,788,496.

Lovell, C. A., and Newby, N. D. — *Motor Control for Motor-Driven Telephone Designation Transmitters* — 2,790,-849.

McAfee, K. B., Jr. — *Semiconductor Signal Translating Devices* — 2,790,034.

Metzger, F. W. — *Lockout Circuit* — 2,787,731.

Morton, J. A. — *Traveling Wave Tube* — 2,790,926.

Newby, N. D., see Lovell, C. A.

Pawel, H. E., see Doering, R. J.

Pierce, J. R. — *Traveling Wave Slicer Tube* — 2,790,927.

Pietenpol, W. J. — *Method of Optically Testing Semiconductor Junctions* — 2,790,952.

Pomeroy, R. C., see Beal, D. H.

Priebe, H. F., Jr., and Spencer, A. E., Jr. — *Transistor Multivibrator Circuits* — 2,787,712.

Prince, M. B. — *Silicon Rectifier and Method of Manufacture* — 2,790,940.

Raisbeck, G. — *Magnetically Loaded Conductors* — 2,787,-656.

Reed, E. D. — *Electron Discharge Devices of the Klystron Type* — 2,790,928.

Rice, P. J., see Hines, M. E.

Roberts, Stanley — *Total Calls Registration Arrangement for Telephone Systems* — 2,790,850.

Robertson, Gordon H., see Beal, D. H.

Ruhlig, E. O. — *Shift Register Circuit* — 2,788.443.

Ruhlig, E. O. — *Shift Register Circuits* — 2,790,109.

Schenck, A. K. — *Voice Frequency Alarm and Remote Control System* — 2,790,965.

Shive, J. N. — *Alternating Current Gate* — 2,790,088.

Shockley, W. — *Forming Semiconductive Devices by Ionic Bombardment* — 2,787,564.

Shockley, W. — *Semiconductor Signal Translating Devices* — 2,790,037.

Spencer, A. E., Jr., see Priebe, H. F.

Timms, W. C. — *Indicating System* — 2,790,170.

Zinn, D. M., see Beal, D. H.

Papers Published by Members of the Laboratories

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

Ashkin, A., *Electron Beam Analyzer,* J. Appl. Phys., **28**, pp. 564-569, May, 1957.

Beck, A. C., *Communications Superhighways,* Trans. I.R.E. PGMTT, **MTT-5**, pp. 81-82, April, 1957.

Boyet, H., and Seidel, H., *Analysis of Nonreciprocal Effects in an N-Wire Ferrite-Loaded Transmission Line,* Proc. I.R.E., **45**, pp. 491-495, April, 1957.

Brown, S. C., see Rose, D. J.

Broyer, A. P., see Schlabach, T. D.

Chynoweth, A. G., and McKay, K. G., *Internal Field Emission in Silicon P-N Junctions,* Phys. Rev., **106**, pp. 418-426, May 1, 1956.

Compton, K. G., *Variability in Working Copper Sulfate Half Cells,* Corrosion, **13**, pp. 19-20, March, 1957.

Drenick, R., *An Operational View of Equipment Reliability,* Trans. Annual Convention Am. Soc. Quality Control, **11**, pp. 603-611, May 22, 1957.

Easley, J. W., *The Effect of Collector Capacity on the Transient Response of Junction Transistors,* Trans. I.R.E. PGED, **ED-4**, pp. 6-14, Jan., 1957.

Fagen, R. E., see Hall, A.D.

Freericks, L., *Semiconductors in Switching Circuits,* General Engineering Bulletin (N. Y. Tel. Co.), **7**, pp. 21-25, May 1957.

Galt, J. K., *Losses in Ferrites: Single Crystal Studies,* J. Institution of Electrical Engineers, **104**, pp. 189-197, June, 1957.

Gupta, S. S., Huyett, M. J., and Sobel M., *Selection and Ranking Problems with Binomial Population,* Trans. Annual Convention, Am. Soc. Quality Control, **11**, pp. 635,-718, May 22, 1957.

Hall, A. D., and Fagen, R. E., *Definition of System,* Yearbook, Soc. Advancement of General Systems Theory, **1**, pp. 18-28, April, 1957.

Huyett, M. J., see Gupta, S. S.

Levenbach, G. J., *Accelerated Life Testing of Capacitors.* Trans. I.R.E. PGRQC **RQC-10**, pp. 9-20, June, 1957.

McKay, K. G., see Chynoweth, A. G.

Montgomery, H. C., *Field Effect in Germanium at High Frequencies,* Phys. Rev., **106**, pp. 441-445, May 1, 1957.

Rider, D. K., see Schlabach, T. D.

Rose, D. J., and Brown, S. C., *Microwave Gas Discharge Breakdown in Air, Nitrogen, and Oxygen,* J. Appl. Phys., **28**, pp. 561-563, May, 1957.

Schlabach, T. D., Wright, E. E., Broyer, A. P., and Rider, D. K., *Testing of Foil Clad Laminates for Printed Circuitry,* Bull **A.S.T.M.**, **222**, pp. 25-30, May, 1957.

Shenitzer, A., *On the Problem of Chebyshev Approximation of a Continuous Function by a Class of Functions,* J. Assoc. Computing Machinery, **4**, pp. 30-35 Jan., 1957.

Seidel, H., see Boyet, H.

Sherwood, R. C., see Williams, H. J.

Sobel, M., see Gupta, S. S.

Williams, H. J., and Sherwood, R. C., *Magnetic Domain Patterns on Thin Films,* J. Appl. Phys., **28**, pp. 548-555, May, 1957.

Wright, E. E., see Schlabach, T. D.