BELL LABORATORIES RECORD

RAPID TRANSMISSION MEASURING SET
T. SLONCZEWSKI

RUBBER RESEARCH
A. R. KEMP

REGENERATIVE TELEGRAPH REPEATER
T. A. McCANN

OCTOBER 1936 Vol. XV No. 2

BELL LABORATORIES RECORD

Published Monthly by BELL TELEPHONE LABORATORIES, INC.

SINGLE COPIES $0.25; subscriptions are accepted at $2.00 per year; foreign postage $0.60 extra per year. Subscriptions should be addressed to Bell Laboratories Record, 463 West Street, New York City

In this Issue

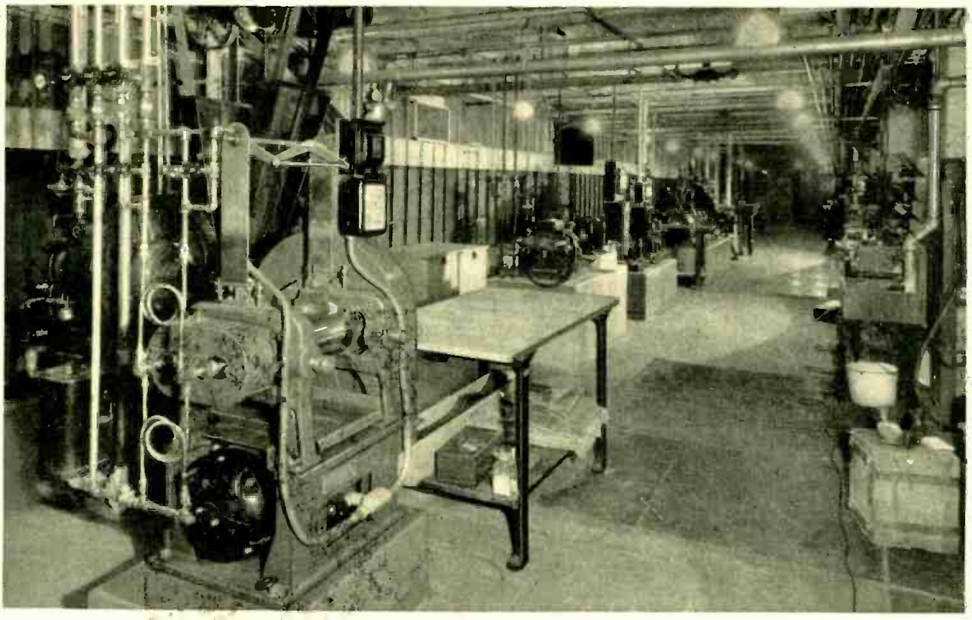
Volume 15—*Number* 2—*October*, 1936

BELL LABORATORIES RECORD

Machining the edge of a copper anode where it is to be sealed to glass for an experimental 250-kilowatt triode

OCTOBER, 1936

VOLUME FIFTEEN—NUMBER TWO



Rubber Research

By A. R. KEMP
Chemical Laboratories

IT is now nearly a hundred years since Charles Goodyear discovered that plastic rubber could be made strong, elastic, and resistant to high and low temperatures through the process of mixing sulphur with it and heating the mixture for a few hours. This process is known as vulcanization, and has made possible the development of the rubber industry as we know it today. Until a few years ago, it was customary to add a large excess of sulphur to the rubber and to vulcanize it for hours. The resulting product was poor both in physical and aging properties. The development of organic accelerators and antioxidants which has taken place during the past fifteen years, for the most part by the tire industry, has changed all this.

Whereas Goodyear employed hours to vulcanize soft rubber, it is now possible to vulcanize completely in a fraction of a minute by the use of these high-speed accelerators. Rubber insulation is now being applied to wire and simultaneously vulcanized at speeds of several hundred feet per minute in the Western Electric continuous-vulcanizing process employed at its Baltimore factory for the manufacture of nearly all of the System's rubber-covered wire. This process not only makes more uniform wire, but results in many advantages as compared with the older process of coiling the wire on reels, or in pans filled with soapstone powder, and vulcanizing it in large autoclaves for periods ranging generally from one to five hours.

The compounding of rubber to meet the many and varied needs of today requires a very wide knowledge of materials. There are hundreds of different substances available for admixture with rubber, which serve to change its properties in the direction desired to meet factory process requirements and to make it perform satisfactorily under the numerous conditions and uses to which it is put. These materials may be grouped in accordance with the functions they perform. Crude rubber constitutes the body or continuous phase of the product. Reclaimed rubber is sometimes added to supplement crude rubber, to aid factory processing, and to reduce costs. Rubber substitutes, such as vulcanized vegetable oils, are added to produce special properties as in eraser stocks or to produce a velvety surface. To assist in plasticizing and softening rubber many different oils, asphalts, pitches, waxes, resins, and fatty acids are added. Hundreds of different fillers and pigments, organic and inorganic, such as whiting, barytes, clay, metallic oxides, organic dyes and carbon black are available additions to aid factory processing and to produce varied colors. Many of these materials contribute toughness and hardness and reduce costs.

In addition to sulphur, selenium and tellurium are sometimes added as supplementary vulcanizing agents; and vulcanization is speeded up by the addition of accelerators. Rubber, free from corrosive sulphur, can be prepared by replacing the sulphur with a sulphur-bearing

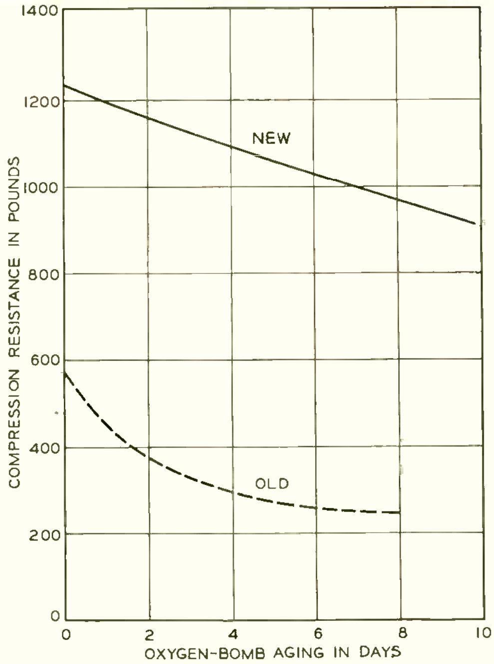


Fig. 2—Improvements in drop-wire insulation brought about by rubber research

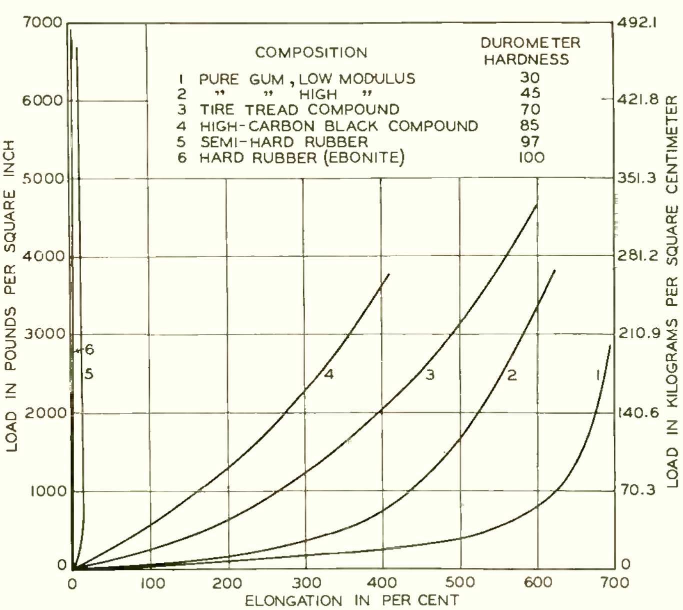


Fig. 1—The range of stress-strain characteristics obtainable with various rubber compounds

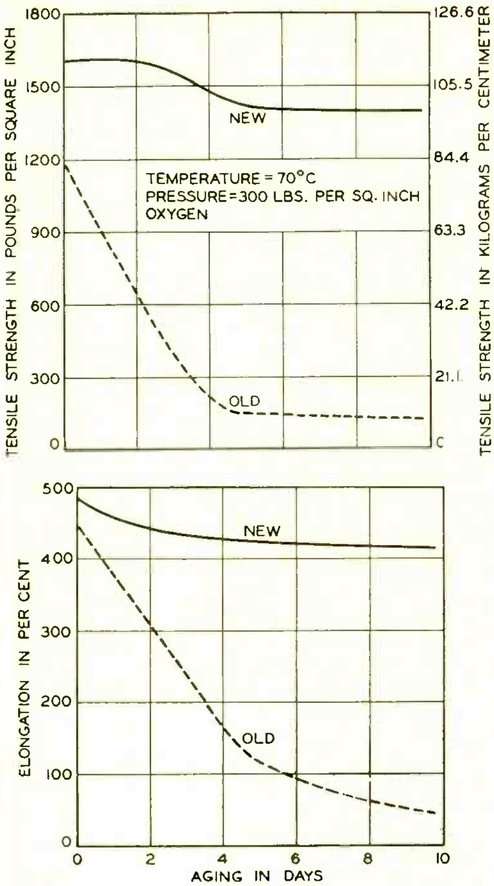


Fig. 3—Improvement in physical and aging characteristics of the rubber insulation of tinsel conductors

accelerator which releases active sulphur during vulcanization. Besides greatly shortening the time of cure, the addition of accelerators produces stronger and better aging rubber. Accelerator activators and retarders are added to control accelerator action. Antioxidants, which are synthetic organic chemicals, are added to reduce the tendency of the rubber to oxidize (age) in service with results of deterioration in its physical and electrical properties. The odor of rubber can be neutralized, or changed, by the addition of various reodorants, essential oils or perfumes. The approximate range of physical properties attainable in rubber compositions is illustrated in Figure 1.

No other material exhibits such a wide range of properties or has more diverse uses than rubber. Literally thousands of different articles are made from rubber or employ it in its various manufactured forms. In the telephone industry soft rubber finds its widest use as the insulation on the billions of feet of aerial and inside wires. Most important of these wires is the so-called drop wire or outside distributing wire, the annual production of which runs into many millions of feet. Much improvement, as indicated in Figure 2, has been brought about in the quality of the insulation on this wire during the past few years. Similar improvements have been effected in other types of wire leading to considerable immediate and prospective savings.

Rubber insulation in varied colors has recently been developed as a substitute for the textile insulation of tinsel conductors in cords, with a resulting large improvement in their moisture resistance. It is now possible,

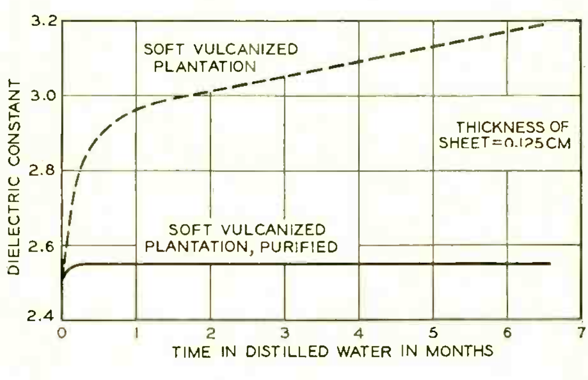


Fig. 4—Effect of the purification of rubber on its electrical stability in water

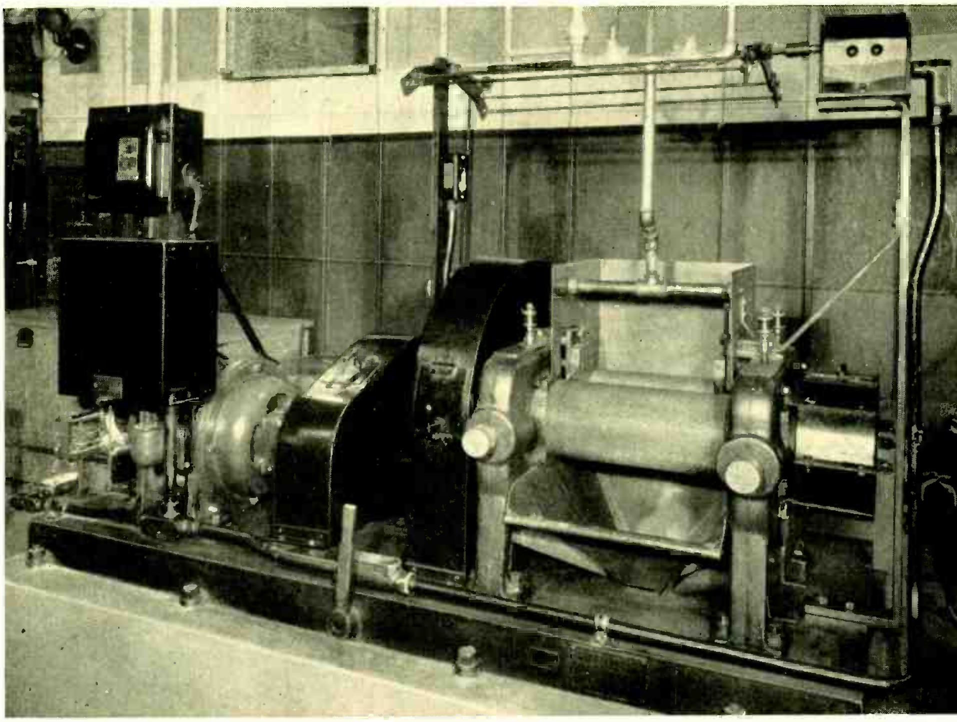


Fig. 5—A "washer" in the rubber research laboratory. On this machine the crude rubber is thoroughly washed before it is ready for compounding

by the use of extremely small amounts of sulphur for vulcanization, to insulate tinsel conductors without the rubber compound's having the corrosive effect on the tinsel which was unavoidable with the old types of rubber compound. This has also resulted in a decided improvement in the physical and aging characteristics of the insulation as shown in Figure 3.

Soft rubber finds many other important uses in the Bell System in the form of molded parts, insulating tapes, electricians' gloves and other items. Hard rubber also serves many important insulating functions because of its excellent dielectric properties; and is an important item of manufacture. Recently an improved hard rubber has been developed for use as the disk insulation in coaxial cables. The improvement in the quality of rubber for these and other varied uses is constantly receiving attention in our laboratories.

About 15 years ago Bell Laboratories, then the Engineering Department of the Western Electric Company, undertook extensive researches in the field of submarine insulation. New methods of purifying and of compounding rubber and gutta-percha were developed. These resulted in great improvement in the electrical properties and water resistance of these materials. One result of this work was the development of the thermo-plastic insulation called paragutta.*

Paragutta has a dielectric constant of 2.6 and a power factor of 0.1 per cent as compared with values of 3.3

*Record, *May*, 1931, *p.* 422.

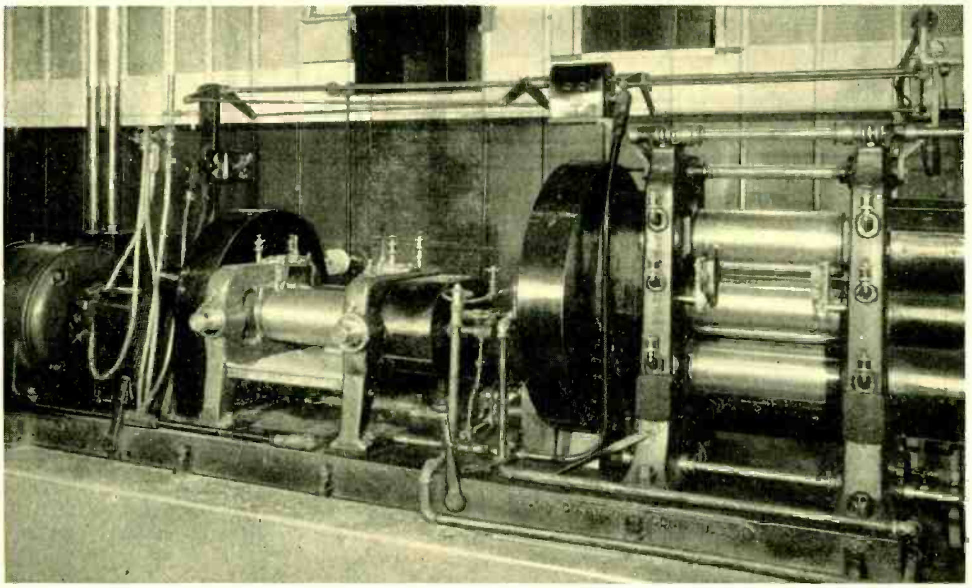


Fig. 6—A warming-up mill and calender used for rolling rubber sheet

and 1.5 per cent respectively for gutta-percha, when measured at 2000 cycles and 25° C. The superiority of paragutta is even greater for sea-bottom conditions. This dielectric superiority of paragutta over ordinary gutta-percha has been an important factor in the recent construction of long, high-frequency multichannel submarine telephone cables, such as the ones between Key West and Havana, Hakkaido and Sagaien, and the recently installed Australian-Tasmanian cable.

Soft vulcanized rubber can also be made electrically stable when immersed in water as shown in Figure 4. This is accomplished by employing crude rubber that has been freed by chemical treatment from proteins, sugars, salts, and other water absorbing impurities. Besides its use for submarine cables, this stable vulcanized rubber seems very likely to prove valuable as the insulation of wires that are installed in wet places either underground or in building ducts.

Crude rubber, which now comes almost entirely from plantations in the Far East, is a complicated mixture, and varies somewhat in composition and characteristics due to natural causes. These variations may be reflected adversely in the final product unless steps are taken to avoid them. Its main constituent is a highly polymeric, unsaturated hydrocarbon, having a molecular composition of C_5H_8, and containing what has variously been estimated as more than a thousand of these groups in a long chain structure. The hydrocarbon is present in the best plantation rubber to the extent of about 93 per cent. It is this hydrocarbon which combines chemically with ½ to 4 per cent sulphur to produce soft vulcanized rubber, and with 25 to 32 per cent sulphur to produce hard rubber as a result of the vulcanization process. The other main ingredients are resin and protein. The resin fraction contains many substances such as fatty acids, sterols, sterol esters, amino acids, and sugars.

Many engineers are still skeptical regarding the life of rubber goods. This is because rubber articles are still being sold which age poorly. It should be remembered, however, that the improvement which has been made in the quality of rubber during the past few years is only reflected in an article of manufacture when proper steps are taken in its fabrication. The purchaser can insure that these steps will be taken by employing suitable specifications. Since the Bell System manufactures most of its rubber requirements, control is exercised both through compounding and performance tests. Well equipped laboratories are maintained for the mixing and testing of rubber compounds and for the production of samples for test purposes. The staff endeavors to keep fully informed of the varied developments occurring in kindred industries, and to adapt them to special Bell System needs. Views of the compounding and testing laboratories at 463 West Street are shown in the photographs at the head and foot of this article. A very wide range of chemical, physical and electrical tests is employed to evaluate rubber products and those requiring special types of testing equipment. Work on rubber insulation for wire is under the supervision of J. H. Ingmanson, while the work connected with other applications of rubber is supervised by F. S. Malm.

Along with the development of new rubber compositions for Bell System use, has come the development of better testing procedures. The compression machine* for factory and laboratory testing of wire has proven valuable in connection with the whole program. Rubber has also been made recently for use in telephone apparatus which is very resistant to heating in air as shown in Figure 7. Accelerated aging tests, such as the Bierer and Davis test, in which rubber is heated under oxygen pressure, have been very valuable in predicting the life of rubber in service.

Rubber exposed to light while under strain is likely to crack rather rapidly. This is one of the problems for future solution. In the absence of direct sunlight under normal conditions, however, rubber is now being manufactured to last twenty years or longer. These results are accomplished by employing scientific compounding and suitable testing procedures for controlling the product. Synthetic rubber-like materials such as polyvinyl chloride (duprene) and olefin polysulfides (thiokols) are now commercially available. These products are more resistant to light, ozone, and oil than is rubber. They are finding uses in various applications where the need is sufficient to justify their higher cost.

Thousands of rubber compounds

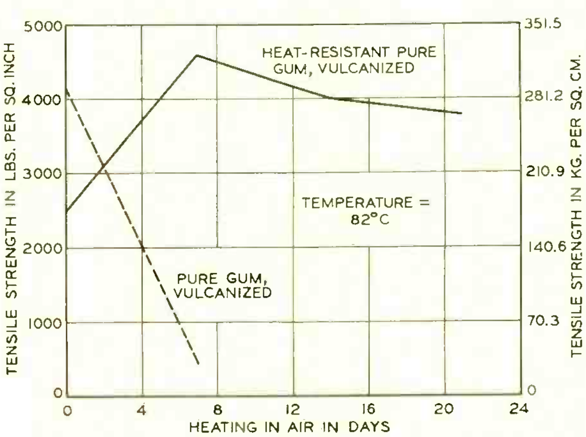
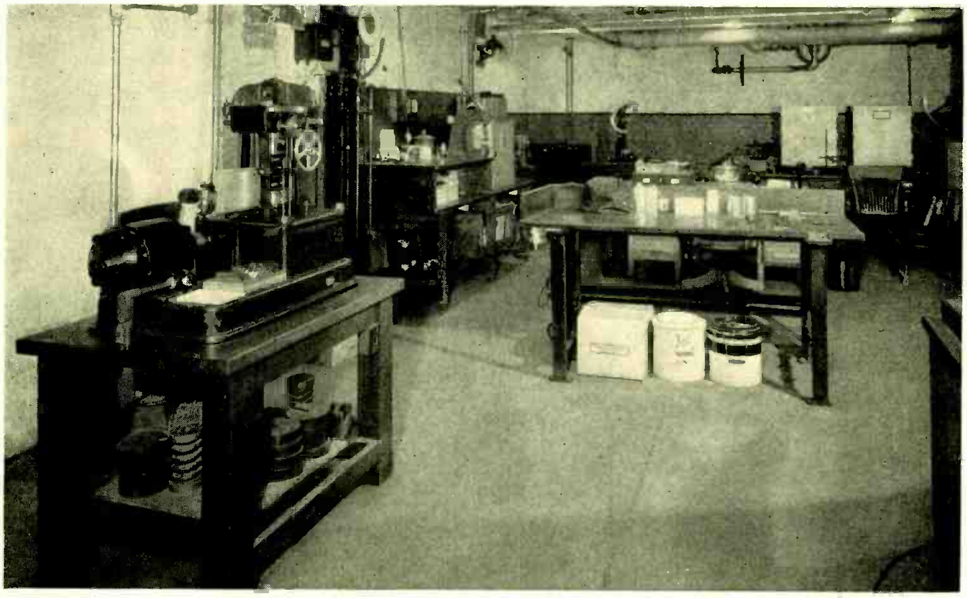


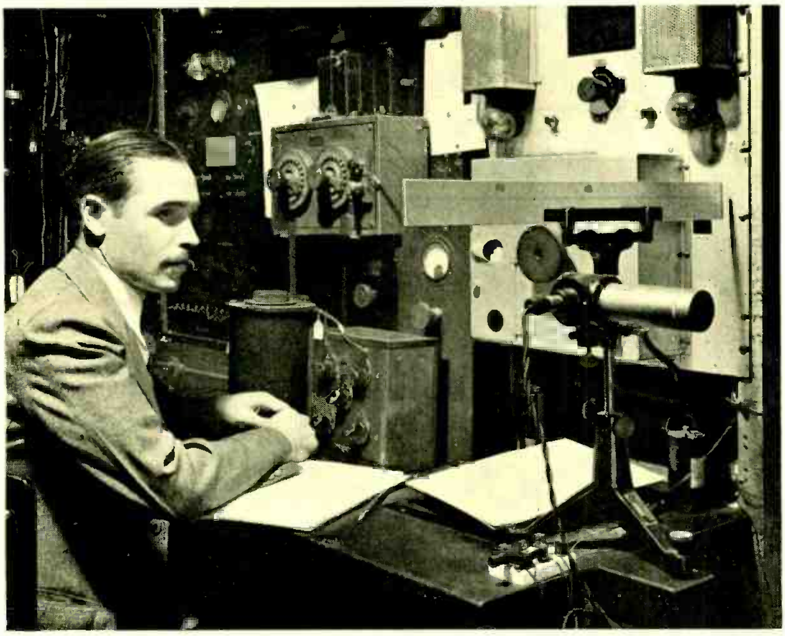
Fig. 7—Effect on tensile strength of heating rubber in air at 82 degrees Centigrade

*Record, *January*, 1928, *p.* 153.

have been prepared and tested in our research laboratories; and the effects of various treatments and additive materials on the aging, physical, electrical, and moisture-absorption properties of these compositions have been determined. As a result of this work, much information has been accumulated which is constantly being applied to improving and extending the use of rubber throughout the Bell Telephone System.



A view of the rubber testing laboratory



Determining Circuit Characteristics at Low Frequencies

By K. W. PFLEGER
Transmission Development Department

In the design of nearly all types of transmission systems it is necessary to determine a number of circuit characteristics such as loss, phase angle, and delay. Of particular importance for telegraph circuits is transfer admittance, which is the ratio of received current to transmitting-end voltage. To simplify the determination of these parameters for frequencies up to 100 cycles, the range of particular importance for d-c telegraph transmission, a measuring circuit has recently been developed which allows all these characteristics to be readily calculated from a single set of original data. The circuit may also be used to measure driving-point admittance, or the ratio of current to voltage at the sending end of a line, and thus serves as a convenient low-frequency impedance bridge.

The fundamental element of the circuit is an electrodynamometer, which is employed for measuring the real and imaginary components of a sinusoidal testing current. An electrodynamometer consists essentially of two coils of wire at right angles to each other, mounted symmetrically with respect to a common diameter as the axis. One coil is fixed and the other is free to rotate through a small angle against the torsional force of its suspension spring. When alternating current flows in both coils, the deflection is substantially proportional to the product of the currents in the two coils and the cosine of the phase angle between them. If the current in the fixed coil is maintained constant and considered as the reference current, the torque is proportional to I cos θ, where I is the current in the movable coil and θ is the phase angle between the two currents. Under these conditions the torque becomes a measure of the in-phase component of the current in the movable coil. By shifting the phase of the reference current 90°, the phase angle between the two currents becomes 90-θ, and since cos (90-θ) is sin θ, the torque becomes proportional to I sin θ, and thus proportional to the quadrature component of the current in the movable coil.

A dynamometer thus provides a simple means of measuring the in-phase and quadrature components of an alternating current flowing in a circuit; and from pairs of values, determined at various frequencies, most of the circuit parameters may be readily calculated. Thus the ratio of the quadrature component to the in-phase component gives the tangent of the phase angle; the square root of the sum of the squares of the two components gives the total current; the ratio of the total current, with the meter at the receiving end of the circuit, to the sending end voltage gives the transfer admittance; and other parameters may be calculated in this way with comparable facility.

A heterodyne oscillator, furnishing sinusoidal voltages in the range from 1 to 100 cycles, was designed by L. C. Roberts as the source of current for the measuring circuit. It consists of a fixed frequency oscillator of 1000 cycles and a variable frequency oscillator adjustable over the range 1001-1100 cycles. The low frequency is obtained by passing these two frequencies through amplifiers and copper oxide modulators, and suppressing unwanted frequencies by filters. There are two independent low frequency outputs, one to supply current to the moving coil of the dynamometer through the line or calibrating resistor, and the other to supply current to the fixed coil. The voltages appearing at both of these outputs have the same frequency, but differ in phase according to settings of networks producing phase shifts in the two branches of the output of the fixed frequency oscillator. Switches are provided in the form of keys to control the zero or ninety-degree phase shifter located in the upper branch as well as to complete the circuit of phase 1 through either the calibrating resistor or the circuit that is being measured.

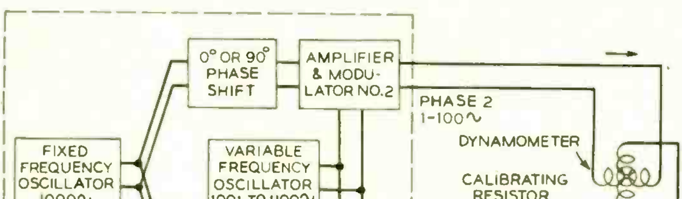


Fig. 1—Block schematic of the new admittance-measuring set

To make a measurement the switches are first thrown to the up position to connect the calibrating resistor into the circuit. This circuit, including the output impedance of phase 1, the resistor, and the dynamometer winding, has substantially a zero phase angle, and thus a zero quadrature component of its admittance; and the real, or in-phase, component is known. The phase shifter in the upper branch is first set to insert a 90° phase shift, and then the variable phase shifter in the lower branch is adjusted to give a zero dynamometer reading, which indicates that the two phases are in exact quadrature. This latter adjustment is necessary to correct for any small phase shift in the amplifiers or associated circuits that might have modified the 90° relationship desired. The phase shifter in the upper branch is then changed to zero phase shift, and the magnitude of the oscillator voltage is adjusted until the meter reading indicates directly the correct value of admittance for the calibrating circuit.

After the set has thus been calibrated the switches are thrown to the down position to put the telegraph circuit to be measured in place of the calibrating resistor. Since the voltage is held constant, the meter will now read the value of the transfer admittance of the telegraph circuit. With zero phase shift in the reference branch, the dynamometer will read the real part of the transfer admittance, and by changing to 90° phase shift in the reference branch, the quadrature component of the transfer admittance is read.

To eliminate a correction for the impedance of the dynamometer when measuring a telegraph line, the receiving relay of the line is replaced by a network whose impedance, added to that of the dynamometer, equals that of the receiving relay. To eliminate similarly a correction for the output impedance of the amplifier-modulator in the measuring branch, its impedance is built out to simulate the impedance of the battery supply of the direct-current telegraph systems.

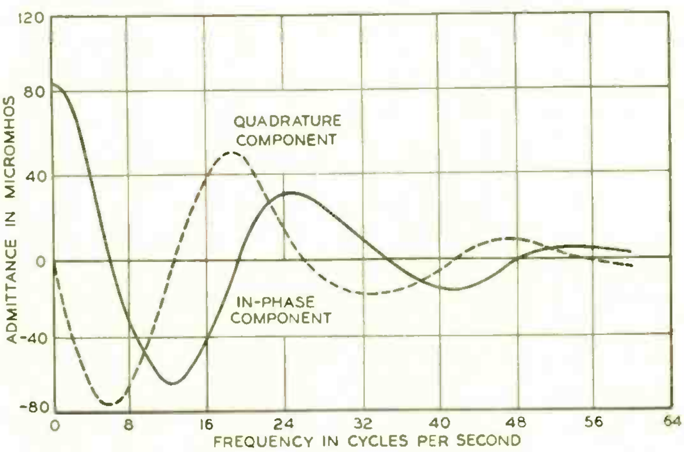
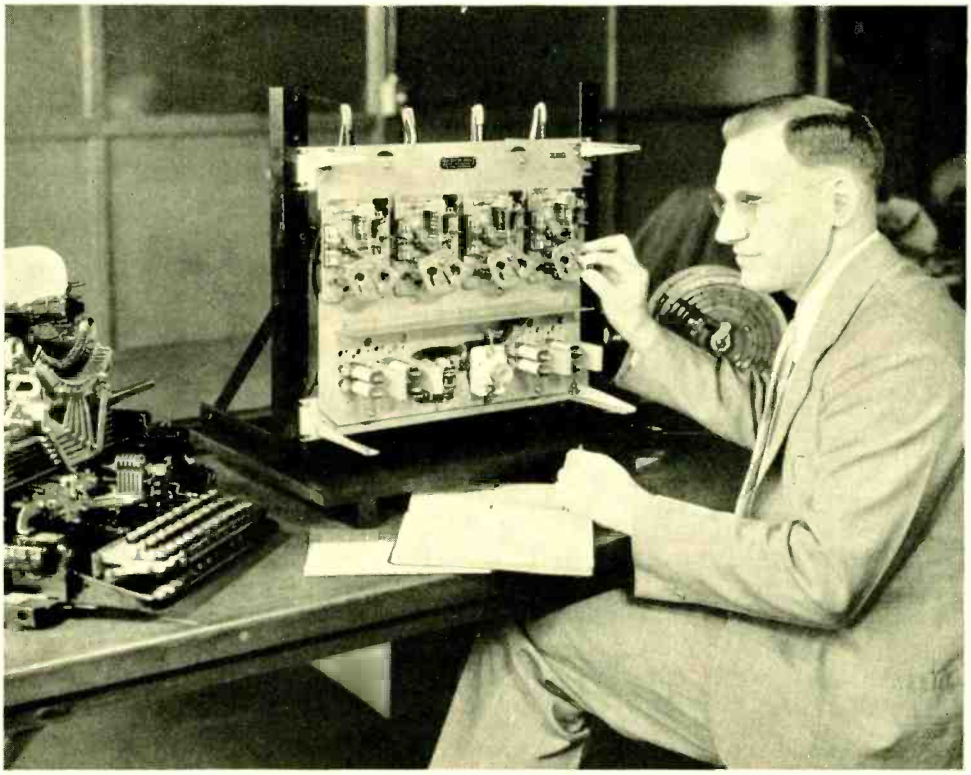


Fig. 2—Curves of in-phase and quadrature components of transfer admittance of 100 *miles of telegraph circuit*

With these provisions, the set gives the correct values for the telegraph circuit itself including such apparatus as may be associated with it. A plot of the in-phase and quadrature components of transfer admittance for various frequencies, obtained from measurements on 100 miles of composited 19-gauge H-44-25 side circuit, is given in Figure 2. From such a plot of the meter readings, many of the other characteristics of the circuit may be calculated for any desired frequency as already indicated. The value for zero frequency was obtained with a resistance bridge because of the unsteadiness of the dynamometer at frequencies less than one cycle.

To measure driving-point admittance, the telegraph line (Figure 1) is removed. In place of one of its conductors a strap is used; and the other conductor is replaced by the two-terminal network to be investigated. The in-phase and quadrature components of the admittance of the network in series wth the dynamometer and with the output of the amplifier may be obtained by the procedure explained above. By taking the reciprocal of the measured admittance and subtracting from it the known impedances of the dynamometer and the amplifier output, the network impedance may be obtained.

Individual grid batteries are used for the amplifiers, and the plate supply is stabilized by use of a voltage regulator in series with the input of the power pack and by floating dry cells on the output of the power pack. By careful checking of the oscillator frequency, and by comparing the 90° phase shifter with a suitable standard, the set will measure accurately to approximately one per cent.



W. J. Zenner, of Teletype Corporation, making final tests on the new mechanical unit of the 106A1 regenerative telegraph repeater

Developing the 106A1 Regenerative Telegraph Repeater

By T. A. McCANN
Telegraph Facilities Department

THE train of electrical impulses comprising a teletypewriter signal is distorted as it passes over a circuit. If the distortion became too great, the teletypewriters at the far end would not correctly interpret the signals, and erroneous copy would result. To avoid such a possibility, regenerative repeaters are employed in the longer circuits. Their function is to receive distorted signals, and to send out a new set duplicating those that left the sending teletypewriter. The regenerative repeater thus prevents the distortion introduced by one section of line from being passed on to the succeeding section, with the result that the transmission over a very long line is thus made practically as good as over a single section. Some of the present teletypewriter networks involve several thousand miles of circuit, and as many as three regenerative repeaters are used in tandem in order to sectionalize some of these longer connections.

The advantage of regenerative repeaters for sectionalizing long telegraph circuits so that they could be operated as effectively as a single line section was appreciated by Bell System engineers even before the growth of teletypewriter service had made the use of such repeaters necessary. The engineers of the American Telephone and Telegraph Company who now comprise the Telegraph Facilities group of the Laboratories were engaged as early as 1919 in theoretical studies and field tests of regenerative repeaters to determine the characteristics they should have to meet Bell System requirements. Following a trial of a test model in commercial service in 1925, requirements were forwarded to the Laboratories which resulted in the standardization of the 102A1 repeater* in 1926. It was designed to meet the needs of an expand-

*RECORD, *August*, 1930, *p.* 570.

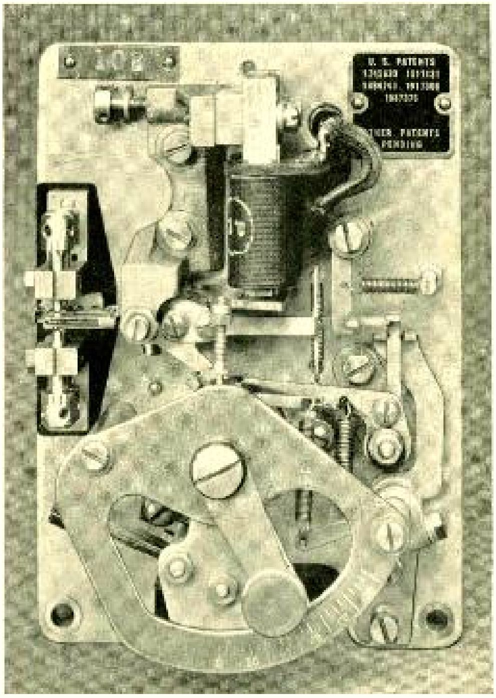


Fig. 1—*The mechanical unit of the* 106*A*1 *regenerative telegraph repeater*

Fig. 2—Four of the repeater units are mounted with their accessory equipment on a single panel for use in the Bell System plant

ing teletypewriter service that was coming more and more to require the use of long and complicated circuits.

Since 1925 Bell System teletypewriter service has grown manyfold, and the reliability of service has also increased considerably. With the constant improvement of teletypewriter station equipment, corresponding improvements in regenerative repeaters were desirable, and certain improvements were devised and incorporated in the 102A1 repeater from time to time to keep its performance abreast of the demands on the teletypewriter system as a whole. Several years ago, studies of this repeater indicated that ultimately a completely new design would afford a more profitable increase in efficiency and dependability than could be obtained by further improvement of the 102A1 equipment.

The timing element is, of course, the heart of a regenerative repeater, but there are many ways of providing timing besides the motor driven distributor, which the 102A1 employed. Vibrating relay circuits, vacuum tube circuits, and tuning forks were given consideration. Designs of repeaters built around these timing systems were carefully studied, and some of them were tested in the laboratory. Besides the purely technical considerations, the problem of selecting a satisfactory design involves also the consideration of the facility of maintenance and adjustment. In this respect it is desirable to have the repeater employ a mechanism allied to that of the teletypewriter, the action of which it duplicates in many respects. This principle of design had been applied to the 102A1 repeater, which employed a distributor essentially like that incorporated in the teletypewriter in use when the repeater was developed.

The newer teletypewriters employ a cam-type timing mechanism, and the success of these machines suggested embodying the same timing mechanism in a new regenerative repeater. Schematic designs of such a repeater and the requirements to be met were forwarded to the circuit and apparatus design groups for consideration. It was decided to ask the Teletype Corporation, which developed and built the present teletypewriter, to develop and supply the mechanism for the repeater. After careful study, they submitted a model to the

Laboratories for test. As with any newly designed equipment there were difficulties to be surmounted and changes to be made to get the best performance from the design. In this work, the facilities group closely co-operated with the circuit and apparatus design groups. The machine was thoroughly tested, its action was observed with high-speed motion picture cameras, and its design features were studied theoretically.

The appearance of the regenerator unit as it emerged from these numerous studies and tests is shown in Figure 1. The cam mechanism, which is not shown very clearly in the photograph, has already been described in the RECORD.* The unit shown is essentially a complete one-way regenerative repeater. Four of these units are grouped with their auxiliary relay and control equipment to comprise two two-way half-duplex, or four one-way, regenerative repeaters. This equipment unit is shown in Figure 2. A single motor, mounted on the back of the panel, drives the four repeaters through spiral gears and a countershaft as shown in Figure 3.

Provision is made for adapting the repeater circuits for either private line or for teletypewriter exchange service. For private line service, the repeater terminates at the telegraph board on jacks or cords. It is usually assigned to a particular service contract, but the terminating arrangement is such that the repeater may be patched as desired into any circuit regardless of the type of facility used for the contract. For teletypewriter exchange service, the repeater terminates at the switchboard in such a way that the operator may connect in the repeater when building up a connection requiring its use. The control circuits are arranged to start the motor and apply battery to the repeater automatically when connection is made to it at the switchboard.

The development for Bell System use of a new device such as a regenerative repeater, does not conclude with completion of design work and laboratory tests. Field tests or service trials are almost invariably made to prove the dependability of the device under actual service conditions. The organization of such a trial requires the preparation of descriptive, operating, and testing information for guidance of the field forces, and also the specification of information required on reports to be returned from the field. The trial should be so organized that a

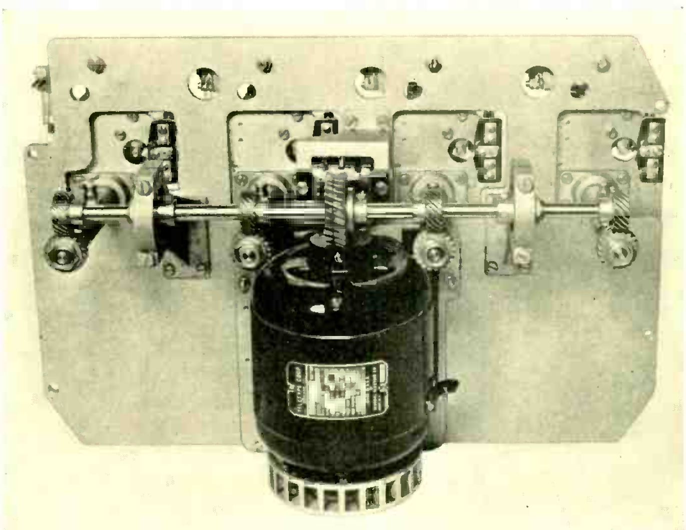


Fig. 3—A single motor drives the four repeater elements of an equipment unit through spiral gears and a countershaft

*July, 1936, p. 355.

summary of the reports will at once indicate both the experience of the operating people with the equipment and the technical performance of the apparatus. The information required must, of course, be obtainable with existing testing facilities, and the reported results should be capable of accurate interpretation. Errors in measurements or mistakes in testing or maintenance methods should be obvious from the report data so that they may not be misinterpreted as faults in the equipment.

In the trial of the 106A1 repeater, reports were forwarded to the Laboratories weekly. A running analysis was kept of these reports in the form of charts which immediately indicated mechanical stability, tolerance of received-signal distortion, quality of output signals, and the condition of contacts and other important mechanical parts that are subject to wear. Besides furnishing a check on the operation of the equipment, the service trial also gives an indication of the effectiveness of the operating and testing information, which serves eventually as the basis of the required Bell System Practices to be furnished when the repeater is standardized.

Although the progress of the trial was followed closely, the operating and maintenance forces were left entirely "on their own" to use the equipment as specified in the prepared instructions, but Laboratory engineers discussed with them any questions or difficulties encountered, the solution of which was not clear to them. At the conclusion of the trial, a summary of the data, together with the comments of field engineers and operating people indicated that the new repeater should satisfactorily meet the requirements for stability and effectiveness in service, and that only minor modifications were necessary in the standardized unit. The tolerance of the repeater for distortion in received signals is equal to or better than that generally found in modern teletypewriters, and the quality of the retransmitted signals is at least equal to that of signals sent from the teletypewriters.

The new repeater is readily adaptable to operation at speeds other than the present standard of 60 words per minute and to systems using other than the five-unit selecting code, although such adaptations have not yet been standardized. Modification of the repeater for operation at other speeds requires only a change of driving gears, and adaptation to a six-unit selecting code is accomplished by changing the cam assembly. As a result of its satisfactory behavior in the field trials and laboratory tests, the repeater has been approved and standardized for Bell System service.

I

Rotary glass-blowing machine in the Vacuum Tube Laboratory.

II

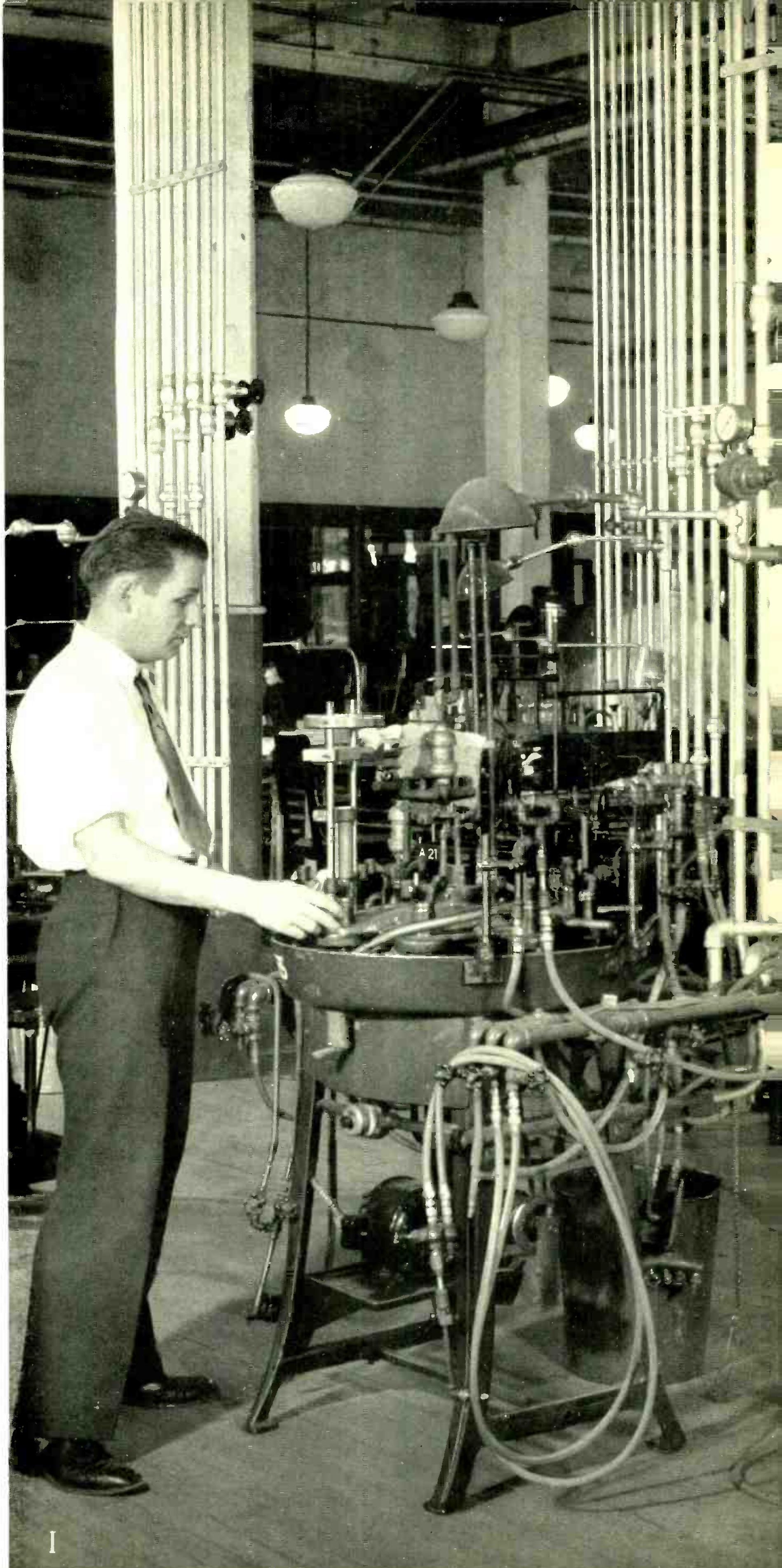
X-Ray examination of a vacuum tube.

III

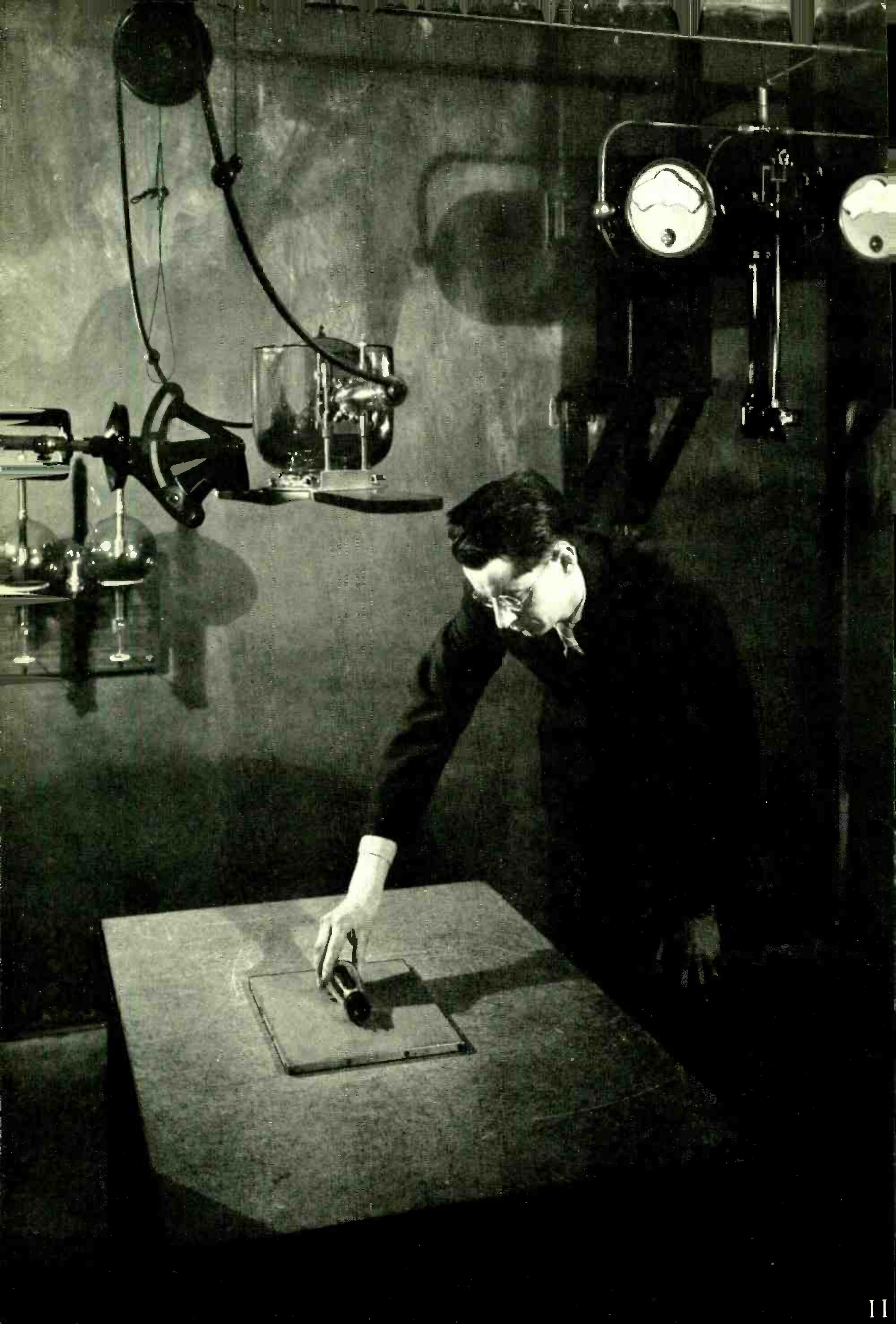
Coaxial cable being drawn into conduit.

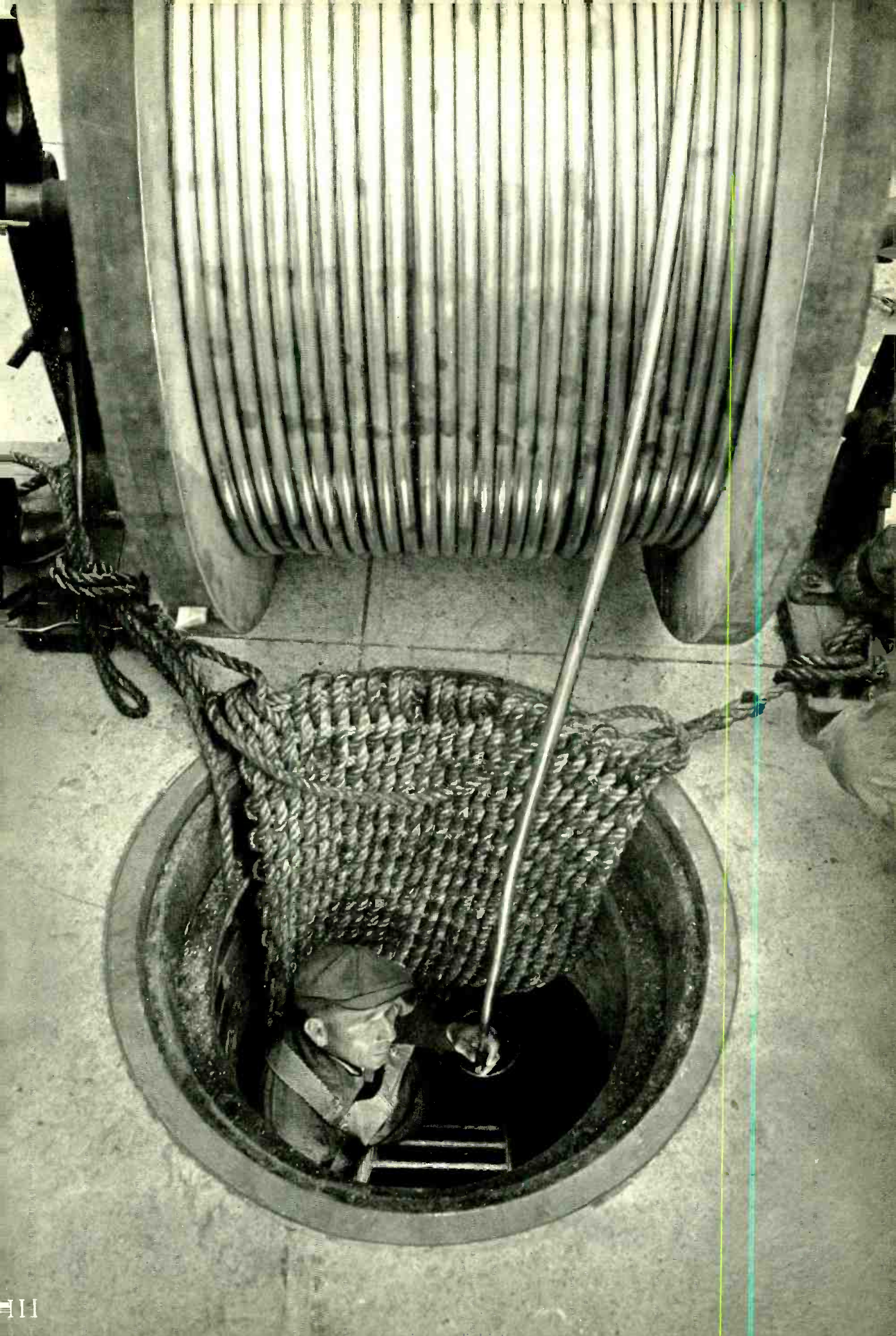
IV

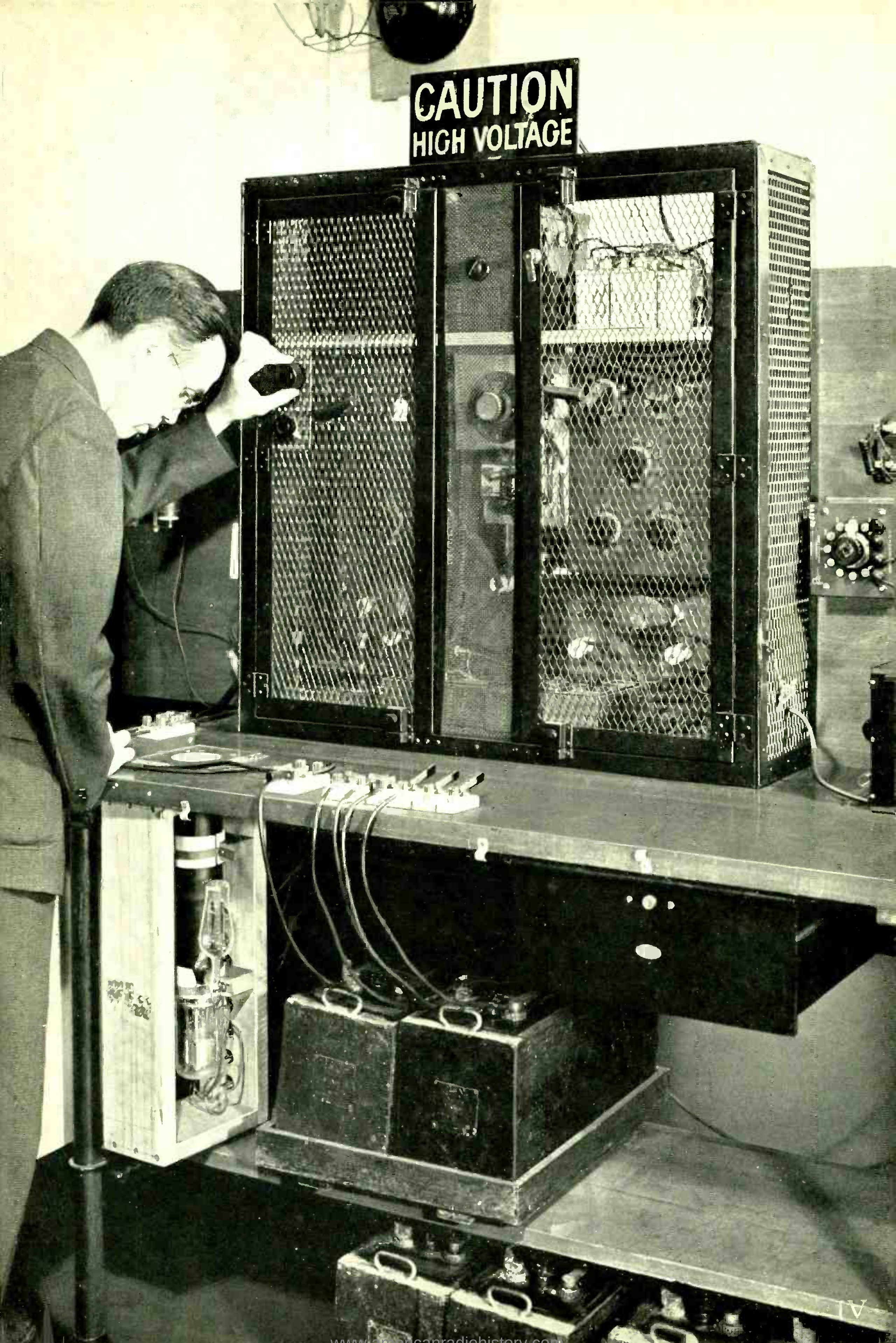
An electron microscope used in studies of thermionic emission.



I




III



IV

Remote Control for Radio Receivers

By J. C. BAIN
Radio Development

With the advent in recent years of numerous new instruments now considered essential equipment of the modern airplane, manufacturers have found it increasingly difficult to provide space in the cockpit for all of the apparatus desired. As a result the designers have been forced either to reduce the size of the apparatus or to devise means for remote control of operation. This has applied particularly to the radio apparatus, the early designs of which were relatively large and totally unsuited for the smaller types of planes, used mostly for pleasure and business by private individuals. When the demand for radio equipment in this field became definitely established, however, the communication problems of the itinerant flyer were at least temporarily solved by the introduction of radio transmitters and receivers that were of remarkably light and compact construction. Typical of the apparatus of this type were the Western Electric 19A transmitter* and 17A receiver,† either of which occupied less than half a cubic foot of space.

The increased use of radio in private planes soon created a demand for receivers that covered several frequency ranges and embodied many of the latest refinements in the art, together with a performance comparable to that of the equipment of the large transport planes. This demand prompted the development of the Western Electric Company's 20 type radio receiver,‡ which has four frequency ranges, with either continuously variable tuning or crystal operation in the communication bands. Although this receiver is only slightly larger than the 17 type, it seemed advisable to design it for either local or remote operation, so as to meet both present and future needs of the up-to-date private flyer. It was for this reason that the 27A control unit was designed and developed.

*Record, *December*, 1935, *page* 136.

†Record, *January*, 1936, *page* 161.

‡Record, *September*, 1936, *page* 2.

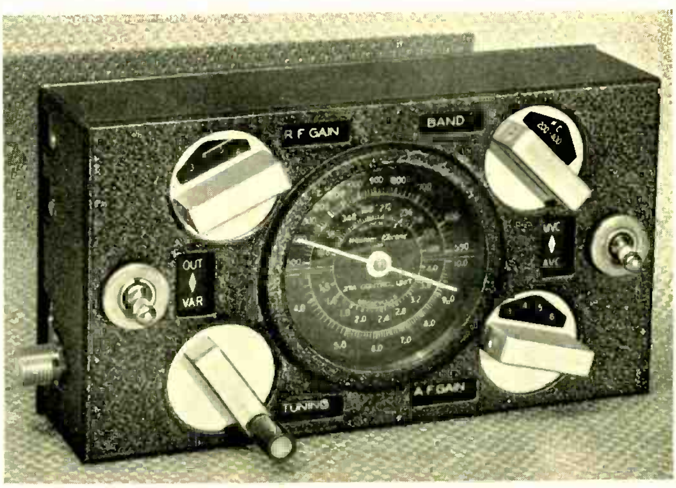


Fig. 1—The 27A control unit incorporates six controls and a dial, in a volume only one-tenth of that of the radio receiver

Among the many requirements placed on remote control apparatus for this particular service, size, cost, and performance are probably the most important. Size is obviously a major consideration, since it is size alone that justifies the development of remote control apparatus, but too high a cost, on the other hand, would make its use impossible for the ordinary private flyer. Inadequate performance would, of course, offset all possible advantages, so that these three major requirements had to be kept constantly in mind during the development stages.

A front view of the control unit is shown in Figure 1. It measures approximately 7½ by 4½ by 2 inches, and weighs only 2¼ pounds, with a volume somewhat less than one-tenth of the 20B receiver that it is designed to control. All the controls project from the front of the unit, while the flexible shafts and wiring cable pass through the left end. As furnished, the unit is thus suitable for mounting in front or at the left side of the pilot, but it may be adapted for mounting at the right side by inverting the unit and replacing the dial with a special one supplied for the purpose. Four elastic clinch nuts are assembled on the rear plate for securing the unit to the plane structure either by screwing it directly to a flat surface or by attaching it to tubular framework by simple brackets formed to suit individual requirements.

Except for the gears, shafts, and associated parts, the control unit is made entirely from an aluminum alloy that insures adequate strength with minimum weight. The front cover is slotted to reveal the various control designations, and is mounted on the shanks of the toggle switches so that it may be readily removed for replacing dial lights or other purposes. The dial has white translucent figures, and in addition to the four calibrated frequency scales in the central circle carries the designations for all controls, the gain control graduations, and the band-switch positions. It is indirectly illuminated when power is applied to the receiver, and the various frequency scales and corresponding band-switch positions are distinguished by different colors. The intensity of illumination may be varied by an adjustable resistor in series with the dial lights, which makes it possible to eliminate the glare that pilots find very objectionable in night flying. A non-inflammable and unbreakable crystal, similar to the watch type, protects the dial pointer of the unit.

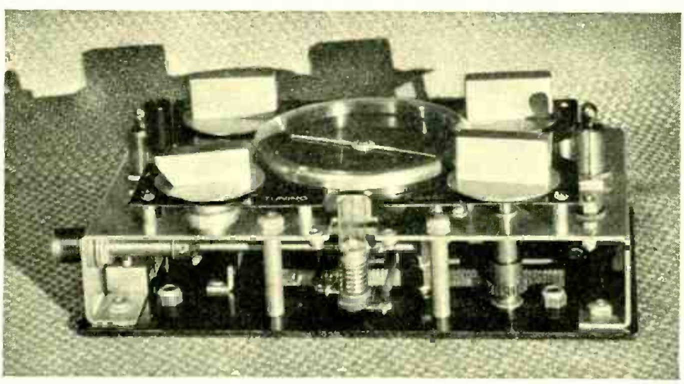


Fig. 2—Side view of control unit with cover removed, showing the audio-frequency rack and pinion, part of the tuning device, the dial with unbreakable crystal, and the dial lamp

The 27A control unit permits the remote operation of all the receiver controls up to distances of twenty-one feet with an unusually high degree of accuracy. It may be used at even greater distances if the flexible shafts are run reasonably straight so as to hold the friction losses to a minimum. Tuning, band-switch, and audio-frequency gain adjustments are made mechanically from the control unit, while the radio-frequency gain, automatic volume control, and varistor are controlled electrically. The tuning control operates a flexible shaft of the rotating type through a pair of miter gears, and also operates the dial pointer through a worm drive with a ratio of 100 to 1, corresponding to the gear ratio of the tuning condenser drive at the receiver. A worm drive is particularly valuable for this purpose since it automatically locks the tuning adjustment, and in addition, the high gear reduction makes the small torsional deflection in the flexible shaft have little effect on the correspondence between condenser setting and pointer indication.

Fig. 3—The 27A control unit as installed in the Fairchild plane of the Laboratories

Both the four-position band-switch and the audio-frequency gain control operate flexible shafts of the push-pull type. This is probably the first application of shafts of this type to radio apparatus, but their dependability has been thoroughly demonstrated over an extended period in other applications. It differs from the rotary type chiefly in the construction of its inner member, which consists of a closely wound steel spring with a core of stranded steel cable soldered to it at both ends to provide the necessary tension and compression resistance. The gain control shaft, at its extreme position, also operates the receiver on-off switch. The control knobs operate the shaft through a pinion and rack, evident in Figure 2. The rectangular style of knob was selected mainly for ease of operation.

The installation of remote controlled radio equipment in airplanes has heretofore involved considerable delay and additional expense because the flexible shafts were either made to order for individual equipments, or the services of a skilled mechanic were required to cut the shafts to the correct length at the time of installation. These difficulties have been largely eliminated in this equipment by stocking shafts of various lengths covering the anticipated demand for the apparatus, so that the complete equipment can be delivered ready for installation on orders specifying the approximate length of a suitable path for the shafts between the control unit and the radio receiver. The time required to make the installation should not exceed one hour with the use of only a screw driver and a soldering iron.

Automatic Comparator for Characters on Perforated Teletypewriter Tape

By AUSTIN BAILEY
Radio Transmission Development

TELETYPEWRITER transmission tests frequently require a comparison of sent and received copy to determine accurately the per cent of errors resulting from transmission. This method of evaluating a transmission medium intended for teletypewriter use is of particular convenience in tests on radio circuits, where the transmission may be affected by random occurrences such as noise and fading. In earlier tests the received copy, typed by the receiving machine, was compared with the typed record made at the sending terminal. By such a comparison, however, inaccuracies are frequently introduced for a number of reasons, the most important of which is that many of the transmitted characters, such as figure shift, letter shift, or carriage return signals, are not necessarily indicated on either the transmitted or received copy. Two of such signals, for example, might be sent in sequence without affecting the typed copy.

To make it possible to obtain a more accurate comparison of the sent and received signals, a method has been developed using a re-perforator to put the received signals in the form of a perforated type. This tape is then compared automatically with the perforated tape used at the sending end. Besides avoiding a great amount of tedious comparison by reading, this method increases the accuracy since all signals sent will appear on the received tape except those that have been obliterated during transmission.

The comparison of the tapes is made automatic by the use of two Western Electric 1B tape transmitters, shown in Figure 1, and a circuit that counts the number of times the punchings on the two tapes, run through the two machines in synchronism, differ from each other. These machines are driven by a vibrating relay, which sends about 300 pulses per minute into the operating magnets. When these magnets release, five fingers are driven upward from beneath the tape, and—depending on the perforation pattern—either make or fail to make a contact. At the next operation of the magnet, the fingers return and the tape is moved ahead to bring the next row of perforations over the fingers. When used for actual transmission, the fingers of these machines are wired so that the proper sequence of pulses will be sent over the line. For the comparison of tapes, however, this wiring is changed as shown in Figure 2.

The five fingers are indicated by the straight lines with arrows at each end. When the magnets release, if a finger is opposite a hole in the tape it will make contact to the bar marked M, while if there is no hole in the tape at this position, the finger will remain in contact with the S bar. The received tape is run through one machine, and the sending tape through the other, and both machines are operated in synchronism by the vibrating relay. Corresponding fingers and corresponding bars of the two machines are connected together as shown. Battery is connected to the M bars, while the S bars are connected to ground through the control relay.

As may readily be seen from the diagram, there will be no flow of current through the control relay so long as corresponding fingers on the two machines are connected to the corresponding bars. If, however, a finger of one machine is connected to the M bar while the corresponding finger on the other machine is connected to the S bar, a current will flow, and the control relay will operate, and in doing so will complete a circuit through the counting magnet. So long as the punchings on the two tapes are alike, corresponding fingers on the two machines will always be connected to corresponding bars, but whenever the punchings differ, one or more of the corresponding fingers on the two machines will be connected to opposite bars, and as a result, the counting magnet will be operated to indicate one error.

This much of the circuit would be sufficient to count the errors correctly, if all the signals that started out from the sending end were recorded on the received tape. Where a radio channel is employed for transmission, however, there is the possibility that, due to fading or to certain forms of interference, a complete code group or even several of them may be entirely lost. Since in making the record on the receiving tape, the machine moves the tape forward only after a signal has been recorded, the complete absence of a signal will leave no record of the omission on the tape —the first signal received after the omission will appear immediately following the one before the omission. As the result of such an omission, the tapes on the two comparison machines would become out of step, and all corresponding signals thereafter would differ except for the chance occurrence of similar letters. After such an omission, the apparatus would record a continuous sequence of errors. To avoid such a situation, an additional circuit is required which will stop the comparison and sound an alarm so that the tapes may be brought into synchronism again before the comparison is continued.

This circuit takes advantage of the fact that such an omitted signal will result in a continuous sequence of errors, and provides a selector which,

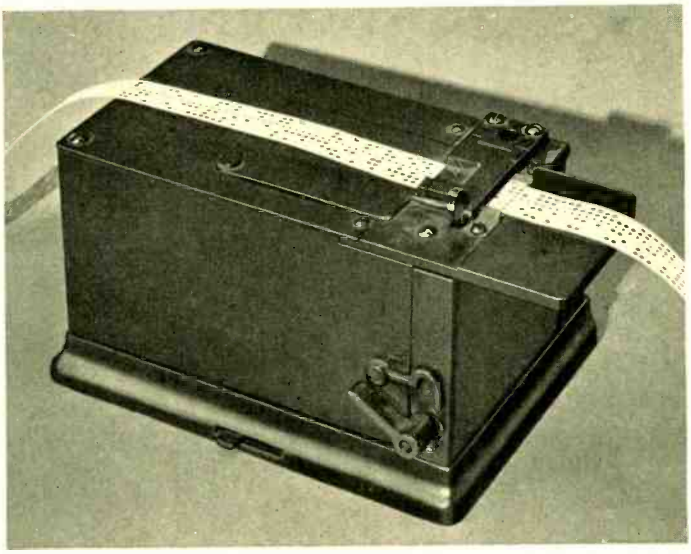


Fig. 1—Western Electric 1B Tape Transmitters are used for comparing a sent and received tape

after five consecutive errors have been recorded, will stop the comparison and ring a bell. The selector is operated through stepping and release magnets connected to a second armature on the control relay. This armature connects to ground when the

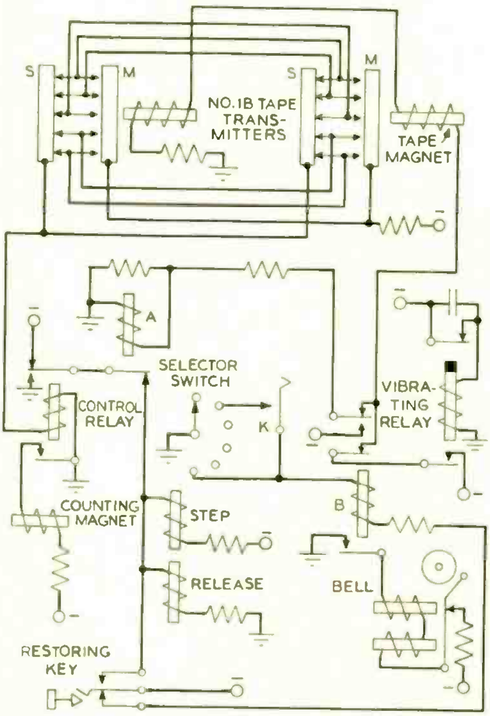


Fig. 2—Simplified schematic of the comparing circuit

control relay is operated, and to battery when it is released, and the stepping magnet is connected to battery, and the release magnet to ground. As a result, the stepping magnet will operate whenever the control relay is operated to count a failure, and the release magnet will operate whenever, due to a correspondence of signals on the two tapes, the control relay remains unoperated.

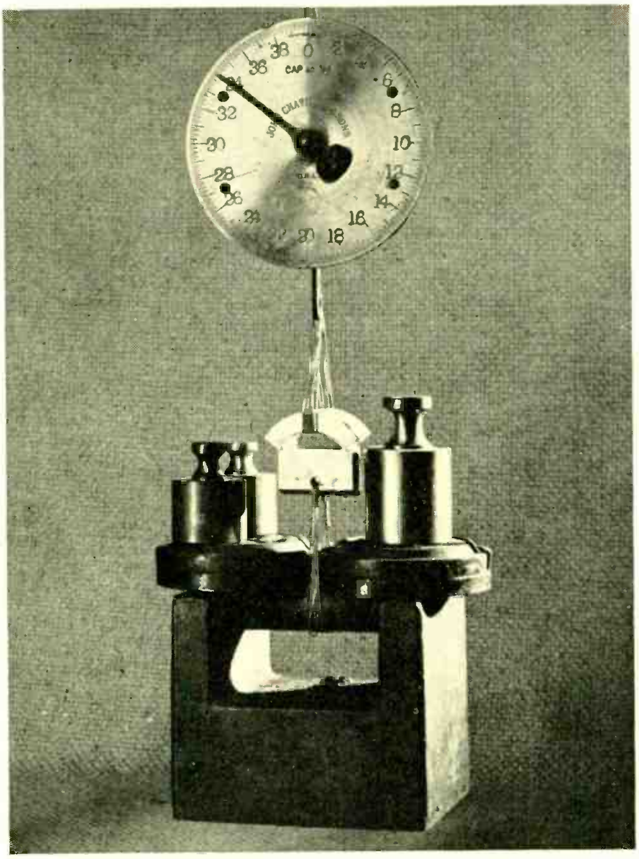
An essential part of the circuit is the relay A that operates with each pulse sent to the operating magnets of the tape machines. This relay is given a slow-release characteristic by a resistance shunt, and thus does not release until a short interval after the tape magnets have released. This delay allows sufficient time for the control relay to operate before the circuit is extended to the selector magnets.

If, as the fingers are positioned at the release of the tape magnets, a lack of correspondence between the two tapes is found, the control relay will operate, and when relay A releases immediately after, a circuit will be completed through the stepping magnet of the selector. At the next pulse to the tape magnets, this circuit will be opened at relay A until after the fingers have been again positioned. If no error is found at this position the control relay will not operate, and when relay A releases, battery will be applied to the release magnet of the selector through a back contact of the control relay, and the selector will be returned to normal. If, however, an error existed in this second position also, the stepping magnet of the relay would have been operated instead of the release magnet, and the selector would move ahead again.

After five successive forward moves, the selector connects ground to relay B, which through a front contact rings a bell, and by opening a back contact breaks the circuit of the tape magnets to stop the operation of the machines. When this happens an attendant may go to the machines, inspect the tapes, and if the succession of errors was due to the omission of one or more characters, he may synchronize the tapes. The number of characters omitted may then be determined by comparing the tapes.

Under some circumstances it is desirable to stop the tapes after each error, so that the particular impulses mutilated by the interference may be determined. To make this possible the key K has been provided. When this key is closed, the selector will stop the machine and ring the alarm after each error. A restoring key is also provided to release the selector and start the machines after they have been stopped.

This tape comparator equipment, which was developed by T. A. McCann, has made it possible to carry on the actual analysis of the sent and received tapes while the tests are being made. Besides making it possible to secure transmission information more quickly, the new equipment has greatly reduced the tedious labor required in comparing sent and received copy, and has, in addition, increased the accuracy of the test results.



"Permendur" pole-pieces and armature make it possible for the small curved permanent magnet of alloy steel, shown at the center of the photograph, to sustain a total load 132 *times the weight of the magnet itself. "Permendur" is one of the magnetic alloys which have been developed by the Laboratories. A typical composition is* 50 *per cent iron and* 50 *per cent cobalt. The outstanding magnetic property of this alloy is the high flux density of* 18,000 *to* 23,000 *gausses which can be attained with moderate magnetizing forces. This makes it particularly useful for pole-pieces in loud speakers and receivers and in similar apparatus where high flux densities are desired*

Automatic Measurement of Transmission

By T. SLONCZEWSKI
Apparatus Development Department

A comparatively simple method of measuring transmission-frequency characteristics is to insert the network to be measured between an oscillator and an adjustable attenuator, which, in turn, is connected to a rectifier so that the output level of the circuit can be readily observed. If necessary, gain can be introduced by the insertion of an amplifier. With such a circuit, the operator adjusts the attenuator to obtain a convenient output reading, and notes the frequency and the attenuator setting. The frequency of the oscillator is then changed by a small amount, and the attenuator readjusted to bring the output to the same level as before. The difference in the two attenuator settings is the difference in the loss in the network at the two frequencies. A plot of a series of attenuator settings against frequency gives the transmission-frequency characteristic of the network. This method of measurement lends itself particularly well to automatic methods. It has been used as the basic scheme of an automatic transmission measuring set recently built in the Laboratories and used here to make studies of frequency characteristics of type C carrier systems.

To make such a system automatic, it was necessary to solve three problems. First, an oscillator of constant emf and proper impedance had to be provided, whose frequency could be varied continuously over the desired band at a known rate. Second, an attenuator was required whose setting could be recorded in correlation with the frequency of the oscillator. Third, automatic means had to be provided

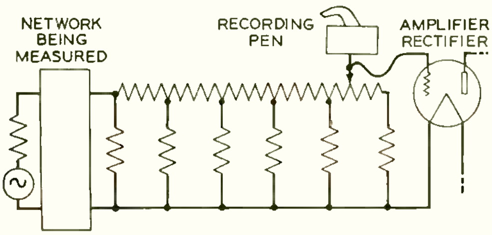


Fig. 1—A ladder-type network constructed as a slide wire provides attenuation loss

for adjusting the attenuator in such a way as to keep the output level of the circuit constant.

The frequency band over which it was desired to have the recorder operate runs from 200 to 10,000 cycles. The most suitable oscillator available for the purpose is the 13A heterodyne oscillator, which gives the desired frequency range by turning a single tuning condenser. A small synchronous motor is geared to this condenser in order to change the frequency at the desired rate.

A suitable attenuator was provided by winding a bakelite strip, twenty inches long, with resistance wire, and tapping to it resistance units at equally spaced points. This gives a ladder network as shown in Figure 1, and the attenuation in db produced by it is proportional to the displacement of a brush riding along the strip. A syphon pen, carried by the brush structure, makes a record of the displacement on a continuous chart. The maximum loss inserted by the attenuator is 20 db and the scale of the chart permits reading down to 0.2 db.

The chart is driven at a constant speed by a synchronous motor, which is started by the same switch that starts the motor driving the tuning condenser of the oscillator. Under these conditions it is possible—by a simple calibration—to correlate positions along the chart with the fre-

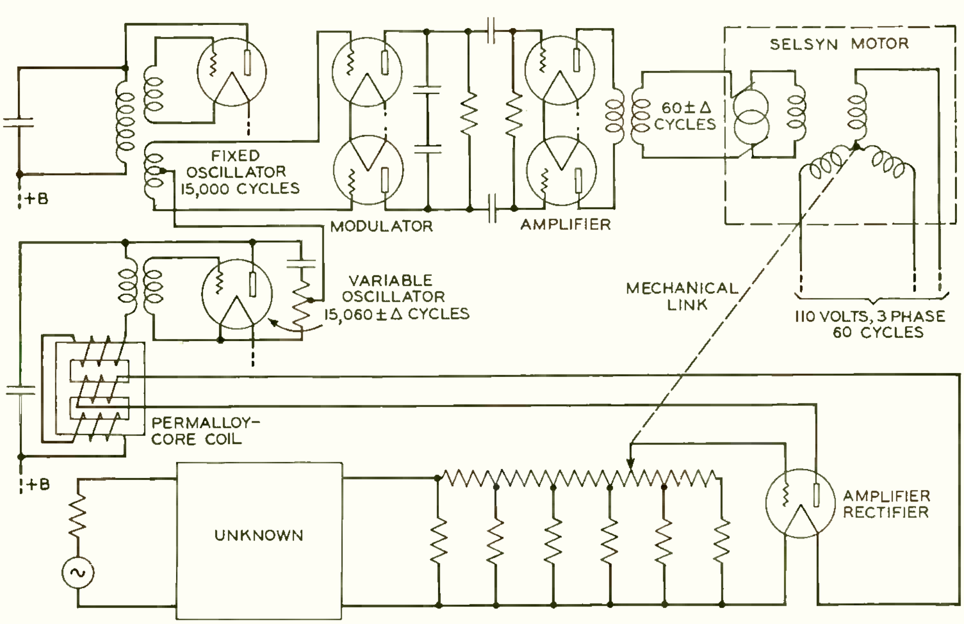


Fig. 2—Simplified schematic of the brush control circuit

quency of the oscillator. If the brush of the attenuator is moved so as to maintain the overall attenuation of the attenuator and the network being measured at the same value, the curve drawn will be the required loss-frequency characteristic.

Most difficult of the three problems was that of moving the brush along the attenuator so as to keep the total loss in the circuit at the same value at all times, and thus to balance a change of loss in the unknown by an equal but opposite change in the attenuator. As the frequency of the testing signal changes, the transmission loss of the network being measured also changes, and the brush of the attenuator will have to be moved a certain amount in one direction or the other to restore the overall loss to the original value. A mechanism must be provided, therefore, which when such an unbalance exists will move the brush in the correct direction to restore the balance. The success of the instrument in drawing a satisfactory transmission curve will depend to a large extent on the law of motion controlling the movement of the brush.

Under ideal conditions the brush should start to move the moment the transmission changes, and should move fast enough to follow the most rapid change in transmission and yet should stop the moment the position of balance is reached. Ideal conditions are never secured in mechanical apparatus, and recording devices of similar nature, such as various types of level recorders, have employed one method or another which produce curves deviating from the true values by approximately equal amounts to each side. Thus, the brush can be made to move toward the point of equilibrium

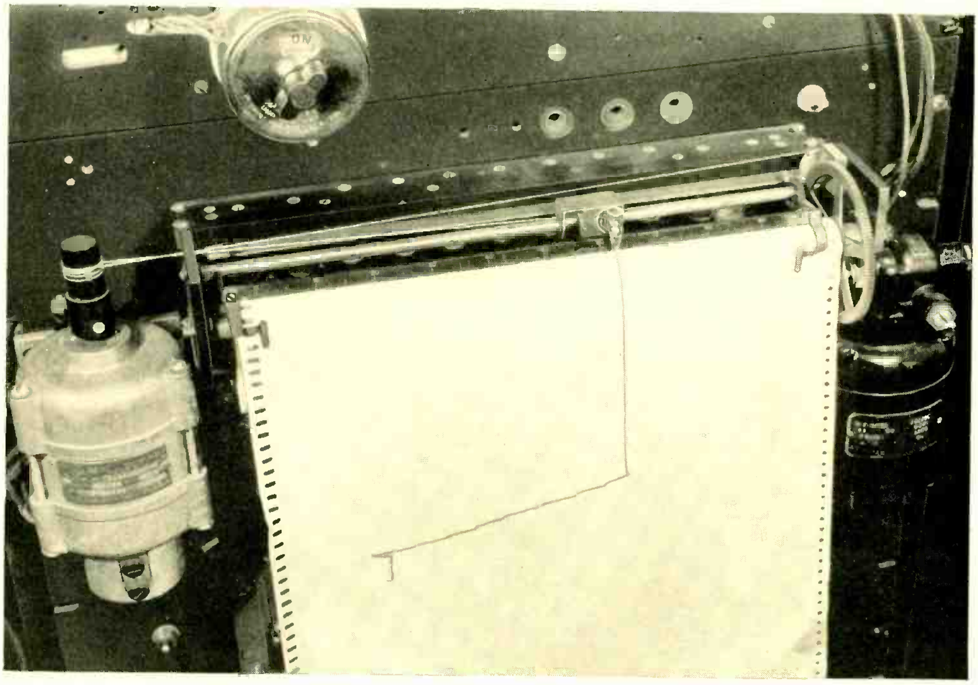


Fig. 3—The Selsyn motor, at the left, drives the brush through an endless cord, wound around a drum on its shaft, which passes around a pulley at the far end

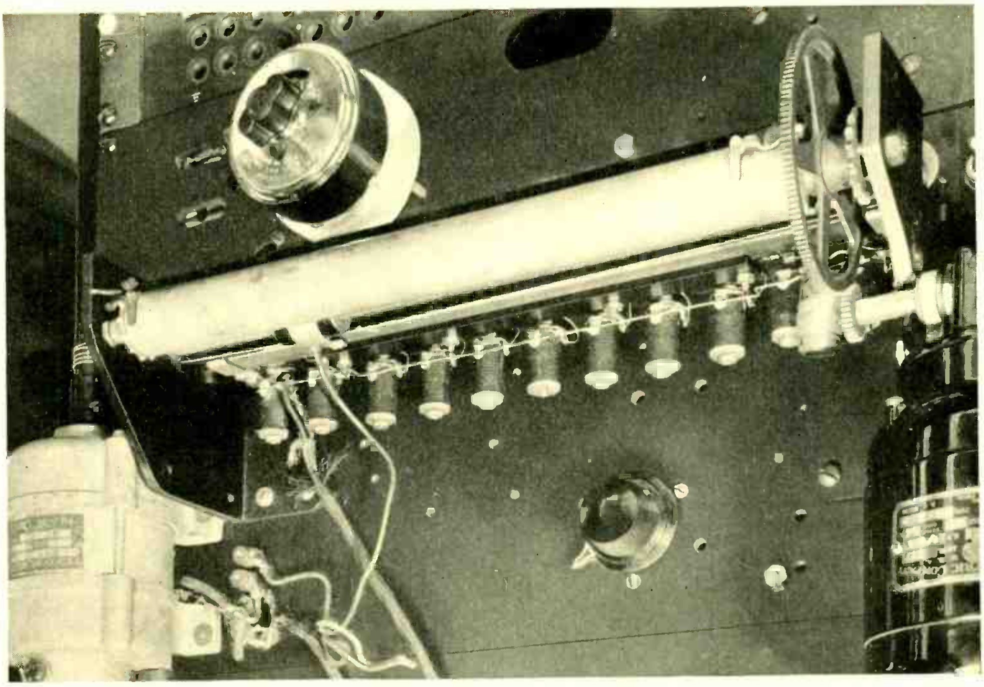


Fig. 4—A photograph from below the attenuator, with chart supply roll removed, shows the bakelite strip and the shunt resistance units tapped to it

with constant velocity once a critical value of departure is reached, or the acceleration of the mechanism may be made proportional to the departure. In the former case the graph will consist of short sections of straight lines, either horizontal or sloping up or down at the same angle; and in the latter case the curve will oscillate about the true value.

Another and more desirable possibility is to have the velocity of the brush proportional to its departure from the position of equilibrium. With this arrangement, the brush would start to move the moment the overall loss changed, and the greater the change in loss, the greater would be the velocity of the brush, but there would be no overswinging since the velocity would approach zero as the departure from the balance position approached zero. The degree of fidelity with which such a graph would follow the true characteristics of the network being measured depends on the relative values of the rate of change in loss in db per cycle and the proportionality factor that relates the velocity of the pen to its displacement from the balance position. This principle was employed in the new recorder, and to a large extent is responsible for the good results obtained. It was suggested by J. R. Bird, formerly a student assistant in the writer's group, who did most of the development work.

To secure this action the pen is driven by a small Selsyn motor. This motor has a three-phase 60-cycle winding on the stator and a single-phase winding on the rotor. With a 60-cycle current in the rotor winding, the motor remains stationary, while if the frequency of the rotor current is other than 60 cycles the speed of the motor

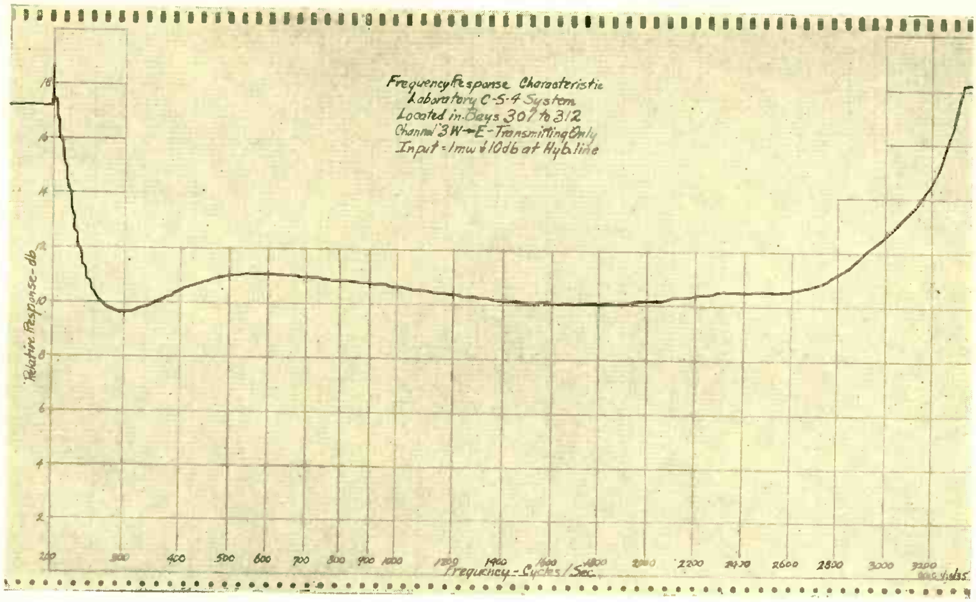


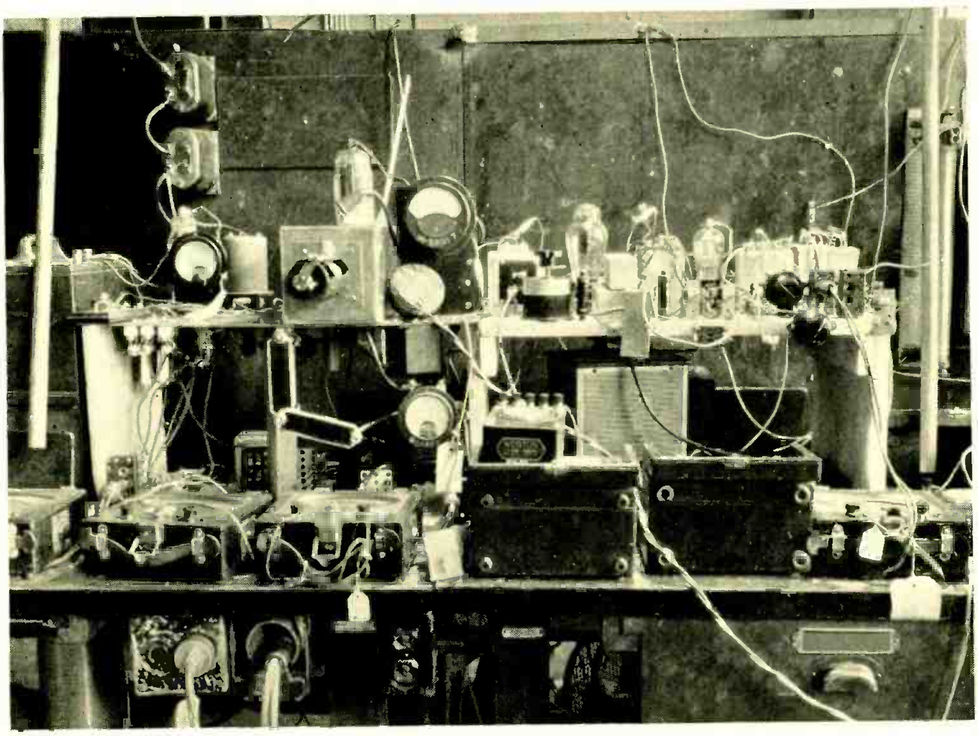
Fig. 5—A typical loss-frequency curve obtained with the new recorder

will be proportional to the difference between 60 cycles and the frequency of the rotor current. If the rotor frequency is less than 60 cycles the rotation will be in one direction, while if it is greater than 60 cycles, it will be in the other direction. The problem thus narrows down to providing for the motor a current whose frequency differs from 60 cycles in proportion to the departure of the brush from the position of equilibrium.

This is accomplished by a circuit that changes the frequency of a heterodyne oscillator in proportion to the displacement of the brush from the position of equilibrium. With the brush in the balanced position, the frequency of the oscillator is 60 cycles, but this frequency will change, becoming greater or less than 60 cycles, in proportion to the displacement of the brush from the position of equilibrium. A simplified schematic of the circuit is shown in Figure 2. The brush of the attenuator is connected to the grid of an amplifier-rectifier and the potential across the attenuator, with the brush in position of equilibrium, results in a rectified plate current which serves as the basic or equilibrium output. When, due to a change in frequency, the overall loss of the measuring circuit changes, the potential on the grid and the plate output will change proportionally. This rectified plate current passes through one winding of a three-coil inductor. The other two windings form part of the tuning inductance of the variable oscillator of the heterodyne group. The inductance of this three-coil unit is a function of the total magnetic flux in the core, which—in turn—varies with the current in the winding carrying the rectified plate current.

The fixed oscillator of the heterodyne group has a frequency of 15,000 cycles, and the variable oscillator, with equilibrium current flowing through the middle coil of the three-coil inductor, has a frequency of 15,060 cycles. The beat frequency output of the group is thus 60 cycles under balanced conditions, and as a result the Selsyn motor will not rotate. As the equilibrium position on the attenuator changes, however, the rectified current in the inductor will change, and as a result the frequency of the variable oscillator will depart from its basic frequency of 15,060 cycles. The resulting beat frequency to the Selsyn motor will differ correspondingly from 60 cycles, and the motor will rotate at a speed proportional to this difference.

As may be seen in Figure 3, the Selsyn motor moves the brush by an endless cord which is fastened to the brush, passes around a pulley at the far end of the attenuator, and makes several turns around a drum on the shaft of the motor. The construction of the attenuator itself is shown more clearly in Figure 4, while the complete recorder, mounted on a relay rack bay, is shown in the photograph at the head of this article. A typical transmission characteristic obtained with the apparatus is shown in Figure 5. Only about three minutes is required to make one such curve, and this speed permits transmission studies to be made which by manual methods would be far slower and more costly.



A typical first laboratory set-up of a radio transmitter

Social Implications of Research

Addressing the Harvard Tercentenary Conference on Arts and Sciences, on this subject, Dr. F. B. Jewett said: ". . . The purpose which the Tercentenary Committee had in mind could be accomplished by scrutiny of examples from almost any of the great modern industries which have developed on the foundation facts, techniques and methods of science. None of them, however, I think more completely exemplifies the present and prospective economic and social values of practical applications of science than does that part of electrical communication which we designate as telephony. Nor is there any other in which, so far as I am aware, the fundamental principles of the scientific method have been extended so greatly to control accurately, uniformly and continuously the operation of a vast human and material mechanism. This control is imperative if the service is to have that degree of reliability demanded by the requirements of a social and business society organized to a large extent on the assumption that satisfactory telephone service is always instantly available. . . .

"So far have we gone already in perfecting the adaptation of science to the art of telephony that most of us when we use the telephone are not even cognizant, except vaguely, perhaps, of the fact that our ability to talk freely wherever and whenever we wish is the result of an infinite amount of work by the men in the laboratory. . . . This taking-for-granted attitude on the part of the many is common in every technical application of science to our daily usage. From it and from its corollary—action of a social, political or economic character with little or no understanding of the underlying and controlling forces—come most of our problems of proper social control of these new things. One of the biggest, if not the biggest problem ahead of us, is the educational problem of teaching a vast population, which is becoming more and more dependent on the things of applied science, enough of their inherent possibilities and limitations so that they can operate the social controls without danger of wrecking the machinery.

"As one infinitesimal contribution to this educational problem and simply by way of illustrating in the field of telephony a few of the problems research men are solving every day in a multitude of industries, I shall give you a few demonstrations of things not normally observable when we use the telephone but which constitute some of the hidden factors I have mentioned. . . . " At this point Dr. Jewett made several comprehensive demonstrations of modern telephony covering long-distance calls, telephone conference service, experiments on a 1700-mile cable circuit which included distortion, noise currents and echoes, and privacy systems for radio-telephone circuits.

Dr. Jewett then introduced Homer Dudley, who demonstrated synthesized speech. Mr. Dudley explained that the equipment performed electrically the same operations as a human being mimicking instantaneously any speech sounds which he hears. His ears pick up the sounds; they are analyzed in his brain to obtain information as to their pitch, inflection, and peculiarities; then nerves, upon the basis of that information, set his vocal organs in motion to produce similar sounds. What this speech synthesizing equipment will ultimately mean Dr. Jewett did not attempt to predict; emphasizing, however, that it was another step in the fundamental researches which Bell Telephone Laboratories continually carries on into the characteristics of human speech.

Contributors to This Issue

AFTER receiving from California Institute of Technology the B.S. and M.S. degrees in chemistry, A. R. Kemp joined these Laboratories in 1918. For two years he supervised the work of the analytical laboratory. Since 1920 he has been mainly engaged in chemical research on rubber and allied materials used as insulation. He is now in charge of the organic division of the Chemical Research group.

K. W. PFLEGER received the degrees of A.B. and E.E. from Cornell University in 1921 and 1923 respectively, and joined the Department of Development and Research of the American Telephone and Telegraph Company in September of the latter year, coming to the Laboratories in 1934. During this entire time he has been in transmission development work, chiefly on problems pertaining to delay equalization, delay measuring, temperature effects in loaded-cable circuits, and telegraph theory.

T. SLONCZEWSKI has been a member of the Laboratories technical staff since he received the degree of B.S. in E.E. from the Cooper Union Institute in 1926. He was at first engaged in the development of alternating-current bridges but has recently devoted his attention to the study of oscillator circuits. This led to the design of the 100-kilocycle oscillator which was made to provide testing facilities in connection with the development of high-frequency mechanical filters. His experience with measurements where sweep methods were used dates back to 1928 when he participated in the development of such a circuit for measuring the reflection coefficient of filters and coils. He has also done graduate work at Columbia University during the time he has been with the Laboratories.

J. C. BAIN's association with radio dates back to 1918 when he entered the employ of the Marconi's Wireless Telegraph Company of London, England. In 1923 he resigned to join the radio department of the Cunard Steamship Company, serving on this Company's transatlantic liners for approximately six years. Since joining the Radio Development Department of these Laboratories in 1929, Mr. Bain has been engaged principally in the

A. R. Kemp

K. W. Pfleger

T. Slonczewski

J. C. Bain

Austin Bailey

T. A. McCann

preparation of information covering the installation of broadcasting and police radio systems. For the last three years he has worked on the mechanical design of radio equipment for aircraft as well as for other mobile applications.

AUSTIN BAILEY received the A.B. degree from the University of Kansas in 1915 and the Ph.D. degree in physics from Cornell University in 1920. After spending a year as Superintendent of the Apparatus Division of the Corning Glass Works and a year as Assistant Professor of Physics at the University of Kansas, he joined the Department of Development and Research of the American Telephone and Telegraph Company in 1922. In 1934 he was transferred to the Bell Telephone Laboratories where in the Transmission Development group his work has been largely concerned with ultra-high frequencies. While associated with the D. and R. his work in the field of radio was concerned primarily with long-wave transmission phenomena, on which he has published a number of papers. The first transatlantic telephone service was established in 1927, and it was in this connection that experiments were undertaken on teletypewriter transmission which led to the device described in this issue of the RECORD.

T. A. MCCANN, after graduating from high school, spent one year as a radio operator at sea and then spent two years at Denison University, Granville, Ohio. He then became a member of the staff at the New Brunswick, N. J., radio station of RCA. A year later, he went to Ohio State University and in 1925 graduated with the degree B.E.E., having spent an intervening summer in the engineering department of Western Union Telegraph Company. After graduation he joined the Department of Development and Research of the American Telephone and Telegraph Company, where he was engaged chiefly in developing teletypewriter equipment and regenerative repeaters and was associated with the application of teletypewriters to the transatlantic radio circuits. Since his transfer to the Laboratories with the D. and R. he has been engaged in the development of regenerative repeaters and teletypewriter facilities.