A Recording Transmission Measuring System For Telephone Circuit Testing

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A number of types of measurement are made on telephone circuits to determine their transmission performance, these measurements being made with manually operated devices. This paper describes a transmission measuring system which automatically records the results of many of these measurements.

THE making of transmission measurements on telephone circuits is essentially a delicate operation. However, with the aid of vacuum tubes and, more lately, copper-oxide rectifiers, devices have been developed for measuring the various important transmission characteristics of telephone circuits, including transmission losses and gains for single frequencies, speech volume and noise, all of these measurements being made with meters as are measurements of the performance of electric power systems.

There has now been developed an experimental model of a system not only for indicating but also for recording the results of transmission measurements on telephone circuits. It was developed particularly for the purpose of automatically plotting curves of transmission loss versus frequency, this characteristic of telephone circuits being a very important index of the ability of the circuit to transmit speech clearly. It is, however, also suitable for making various records of performance as a function of time, including transmission loss, speech volume and noise.

The essential elements of the automatic recording system are shown in Fig. 1 as they are used in making a transmission-frequency run on a telephone circuit. At one end of the circuit is an adjustable frequency oscillator which generates testing power, a sending panel for supplying this power to the circuit and adjusting it to the proper value and a synchronous motor for varying the oscillator frequency. At the other end is a receiving panel which amplifies the weak received testing power and converts it to direct current which causes the pointer of the recording meter to move. The meter is calibrated to record the transmission efficiency of the circuit directly in decibels. The heavily outlined parts are those used for recording work only, the remainder being parts already in use in the field in the making of ordinary transmission measurements.

The general operation is as follows: Constant testing power is supplied to one end of the circuit by the adjustable frequency oscillator, the frequency generated being varied continuously from one end of the range to the other by slowly turning the frequency control dial with the synchronous motor. While this takes place the recording meter at the other end of the circuit makes a record of the received power on a strip of paper, which is moved steadily by a synchronous motor, the resulting curve being a graph of the variation of the transmission efficiency of the circuit with respect to frequency. The purpose of the tuned circuit shown in Fig. 1 is to cause a mark to be made on the paper in the recording meter when a particular frequency is received. This mark serves as a reference point for applying a frequency scale to the record after the curve has been made.

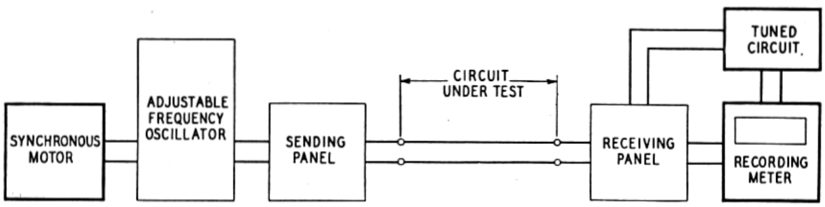

Fig. 1—Schematic arrangement of recording system.

If it is desired to obtain a record of transmission efficiency with respect to time, the same arrangement is used without the motor at the sending end, the oscillator frequency being fixed. The recording meter will then draw a line showing how the received power, and therefore the loss introduced by the circuit, changes with respect to time. If it is desired to record noise on the circuit instead of transmission loss the oscillator is disconnected from the circuit and the amplification at the receiving end increased until the very small noise currents are sufficient to cause readings on the meter. If the receiving apparatus is connected across a working telephone circuit it will serve as a recording speech volume indicator.

The oscillator, amplifier and other parts of the system have great stability and when left in continuous operation will maintain adjustments over long periods so that they may be connected to and used in the same manner as an ordinary voltmeter.

Figure 2 shows an experimental setup of the oscillator used at the sending end of a circuit and the recorder and associated parts at the receiving end. The motor-driven oscillator is at the left and the recorder at the right. Directly above the recording meter is the receiving panel which amplifies and rectifies the current received from the line. The tuned circuit associated with the frequency marking device is mounted on the rear of the panel below the meter.

The recording meter is a new design developed by the Weston Electrical Instrument Corporation in accordance with specifications drawn

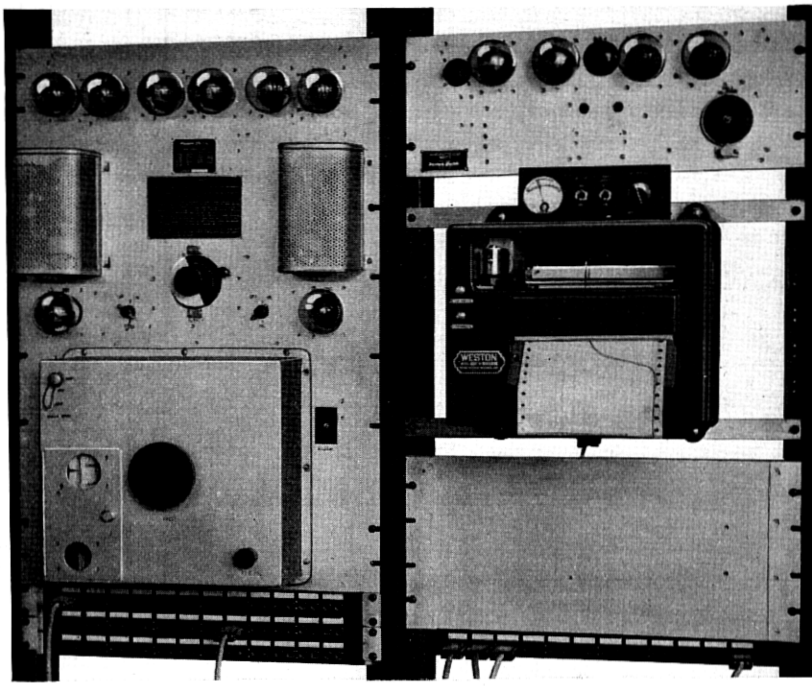

Fig. 2—Experimental setup of recording system.

up by Bell System engineers to meet the special needs of telephone circuit testing. It is extremely fast in operation, the moving system responding to fluctuating currents in about the same manner as the moving system of a fast d-c. voltmeter. Complete transmission frequency runs on circuits may be made in as short a time as one minute when the transmission loss is changing rapidly with frequency and in much less time with less rapid transmission loss variations. The ballistics of the moving system are such that the recorder may be used as a recording volume indicator although for this purpose the readings at some parts of the scale are not exactly the same as those of the nonrecording meters used in the standard volume indicators. Records of telephone circuit noise, which sometimes fluctuates in magnitude, can also be recorded. This high recording speed is made possible by making use of the fact that a record can be made on heat-sensitive paper without actual contact between the heat source and the paper and, therefore, without friction between the paper and the moving system which carries the heat source. Of particular importance is the fact that there is no static friction between these parts so that the power required to turn the moving system is only that necessary to overcome inertia, restoring spring force, damping and pivot friction, as is the case with an ordinary indicating meter.

Figure 3 illustrates the general principles of this recorder. Heat-sensitive paper is drawn over a straight bar which is at right angles to

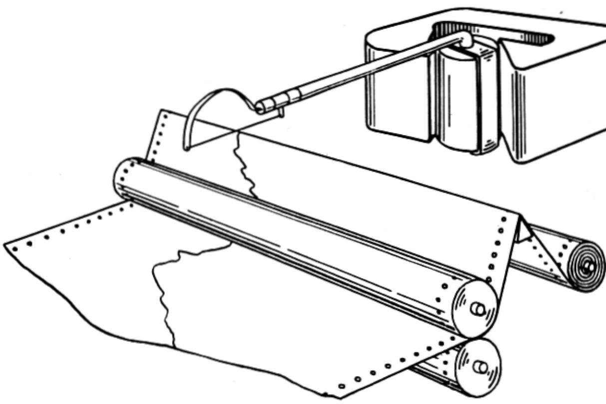

Fig. 3—Diagram illustrating recording principle.

the direction of paper movement, the bar being shaped so that only a line of paper is directly below the pointer of the moving system. A fine straight electrically heated wire is placed on the end of the pointer so that as the current through the moving system is varied the hot wire travels at approximately right angles to the line of the exposed paper and only a small spot of the paper is affected by the heat at any instant. With this arrangement the plot obtained has rectangular coordinates, which is a very desirable feature.

The heat-sensitive paper is a colored paper coated with white wax and before exposure is nearly pure white. The application of heat causes the wax to melt and be absorbed by the paper, making a distinct colored trace. The rapidity of action is dependent upon the amount of heat and the rate of movement of the heated wire with respect to the paper. The temperature of the wire is regulated to suit conditions; however, the maximum heat used is insufficient to char the paper even when it is not in motion. This method of recording is particularly satisfactory from a maintenance standpoint. A record is made almost the instant the current is turned on and there is no danger of failure of recording when the meter is not in continuous operation.

The reliability is so great that it is not necessary for the attendant making the test to see the recording meter while it is in use. Because of this and the stability of the associated sending and receiving apparatus, it should be possible to locate an instrument of this type at some central point in an office and have it used by testers some distance away. For such an installation it would of course, be necessary to have auxiliary circuits for enabling any tester to determine if the system is available for use, to indicate when a test has been completed and to enable the recording meter and oscillator to be started from remote points. Either the oscillator or the recording meter can be set in motion by the operation of a key and, if desired, each device can be made to stop automatically when the test has been completed.

Circuit characteristics, such as transmission efficiency, speech volume, and noise are all measured in terms of the unit of transmission—the decibel, referred to as the db—and the meters used in making these measurements are calibrated in db. An ordinary voltmeter or ammeter which has a uniform voltage or current scale will have a logarithmic db scale since current changes corresponding with db changes have a logarithmic relation. The logarithmic db scale is not suitable for maintenance work as some of the divisions are unnecessarily large and others too small to be read accurately. The range of the recording meter is about 26 db and the scale is divided into 2 db divisions. Ten of these divisions have been made approximately equal by a special design of the magnetic circuit of the instrument. In the conventional moving coil instrument the moving coil rotates in an airgap of uniform width and great effort is made to have the flux distribution in this gap uniform. In the recording meter the airgap is not constant but increases in width with the deflection of the coil. With suitable shaping of the pole faces of the permanent magnet and the iron core around which the moving coil turns, the magnetic flux distribution in the gap causes the angular movement of the coil to be approximately proportional to the current change expressed in db.

Figure 4 is a view of the moving system and the recording mechanism swung out of the case and shows the moving coil and the large magnet associated with it. It will be noted that a small magnet is mounted near the large one. This magnet induces eddy currents in a vane which is attached to an extension of the pointer, thereby acting as a brake to control the damping of the moving system. The ordinary meter with a uniform airgap does not need an auxiliary damping attachment as suitable damping can be obtained by eddy currents induced in the moving coil as it turns in the airgap. The non-uniform airgap gives a variable damping and the external damping device is provided to equalize this variation.

The heat-sensitive paper is also sensitive to friction and can be marked by pressure with a small wire, a characteristic which is utilized

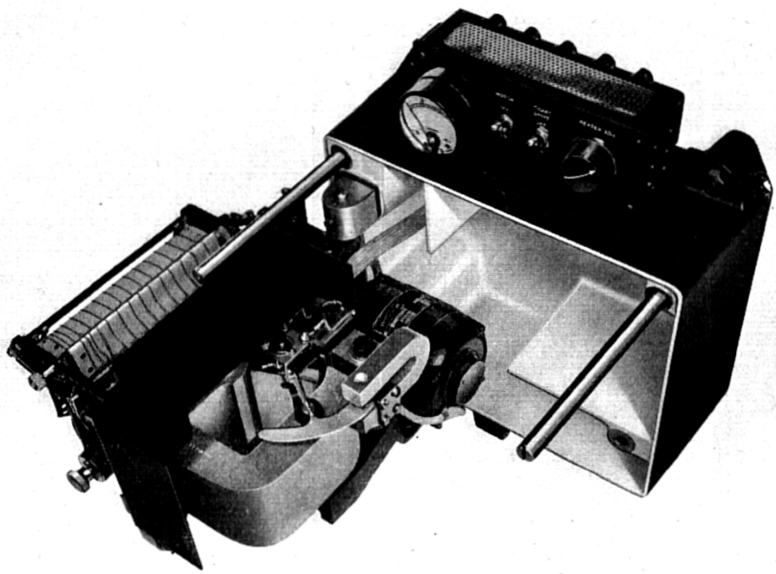

Fig. 4—Recorder mechanism showing moving system.

to make each recorder rule its own db scale as a record is made. Cheap plain unruled paper is used and a high accuracy of calibration is obtained by making the ruling devices adjustable. Fig. 5 shows the ruling devices which consist of loops of spring wire. While the paper used in the recorder is sensitive to both heat and friction it will stand handling without injury.

The paper is 6 inches in width. Two rates of paper movement are used in ordinary testing—10 inches per minute for transmission frequency measurements where speed is important and 6 inches per hour for long-period observations. The paper moving mechanism is made so that each curve can be torn off as soon as made, the paper coming out of a slot in the front of the case shortly after it has passed over the point of recording. The mechanism will accommodate a 400-foot roll of paper, which is sufficient for about 400 transmission frequency runs or for one month's operation at the slow speed. A new roll can be inserted in a very short time.

As previously stated, the deflection of the meter in db is plotted against frequency for some classes of measurements and against time for others. Since the same meter is used for many types of test it is

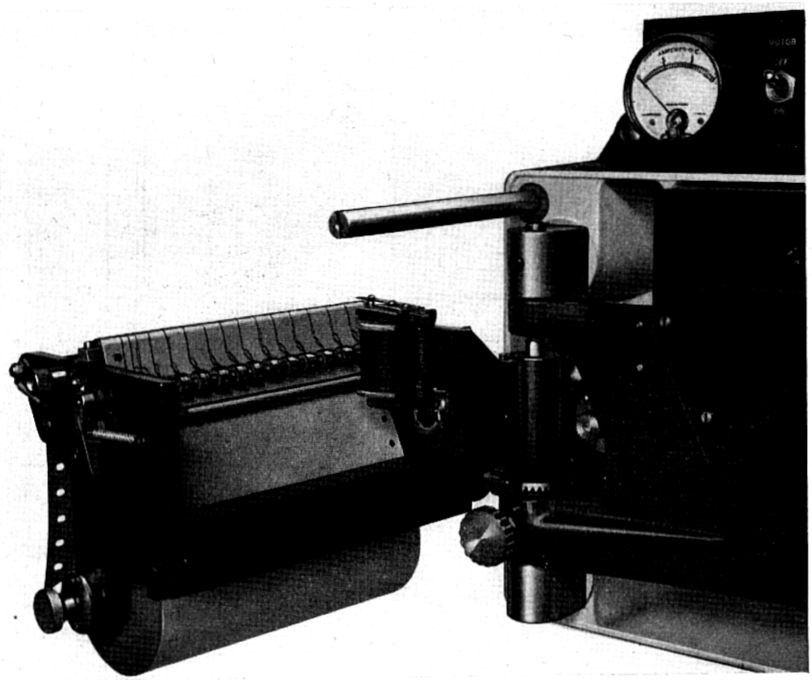

Fig. 5—Ruling and marking features of recorder.

preferable not to have the paper ruled for either frequency or time but to apply frequency or time markings after the record has been made. This is done by making reference marks on the margin of the paper as it goes through the recorder, and using them as indices to correlate the frequency or time and the record. As the paper passes over the bar, the marks are made by means of the electro-magnetic device shown in Fig. 5 at the right of the paper roll. As previously mentioned, when transmission-frequency characteristics are measured a tuned circuit causes a mark to be made when a particular frequency is received. Knowing the time frequency characteristics of the oscillator the entire frequency range can then be added by means of a rubber stamp. When time markings are desired the marking device may be operated by an external time clock. There is, of course, nothing in the design of the meter which would prevent using ruled paper in case this should be desirable.

The oscillator of the recording system is of the heterodyne type which uses a single dial for frequency adjustment, the frequency being varied continuously from one end of the range to the other as the dial is turned. When transmission-frequency curves are made a motor is connected to the dial, turning it at a uniform rate. The time-frequency scale of the oscillator is neither uniform nor logarithmic, as will be

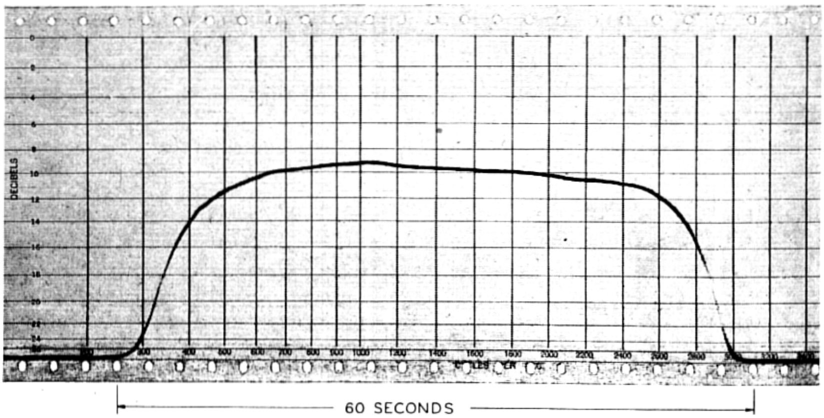

Fig. 6—Transmission frequency characteristic of message telephone circuit A.

noted in Figs. 6 to 8, being a compromise which gives sufficient space on the record to all parts of the range which are of particular interest.

A number of typical curves made by the recording system are shown in Figs. 6 to 12. Figures 6 and 7 are transmission-frequency characteristics of two telephone message circuits, each curve having been made in about one minute, using a paper speed of 10 inches per minute. Fig. 8, which is a transmission-frequency curve for a wide-band program circuit, was made in 30 seconds. Although a wide frequency range is covered by this curve, the absence of rapid transmission variations in the program circuit permitted a rapid change of the oscillator frequency.

Figures 9 and 10 were made with the slow rate of paper feed and are records of 24-hour continuous measurements on message telephone

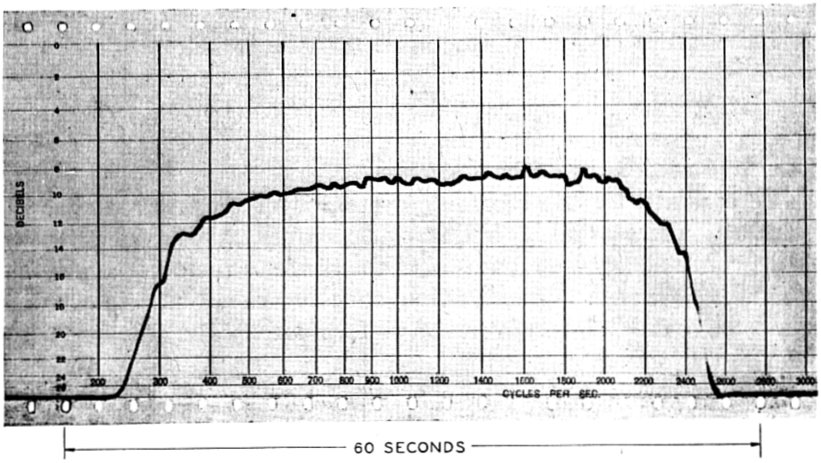

Fig. 7—Transmission frequency characteristic of message telephone circuit B.

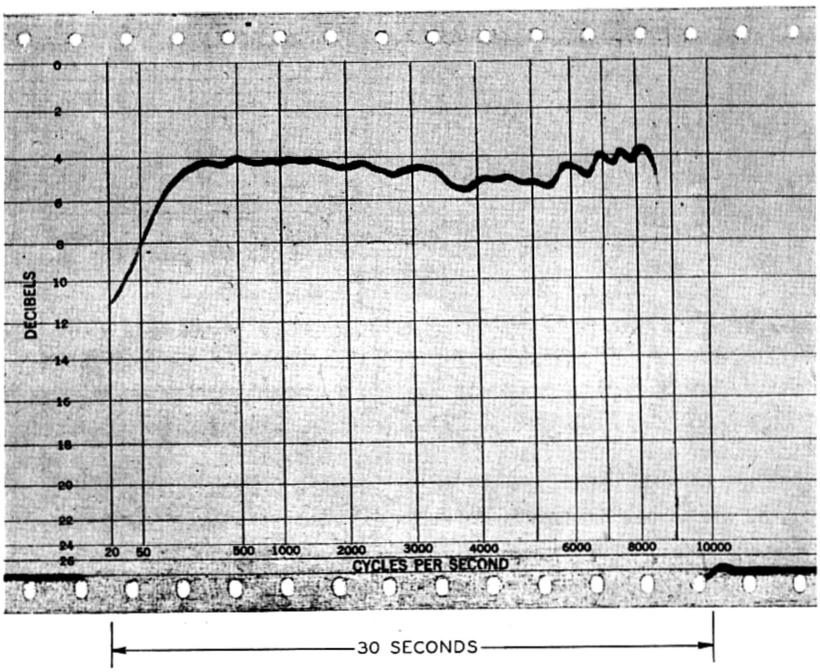

Fig. 8—Transmission frequency characteristic of program circuit.

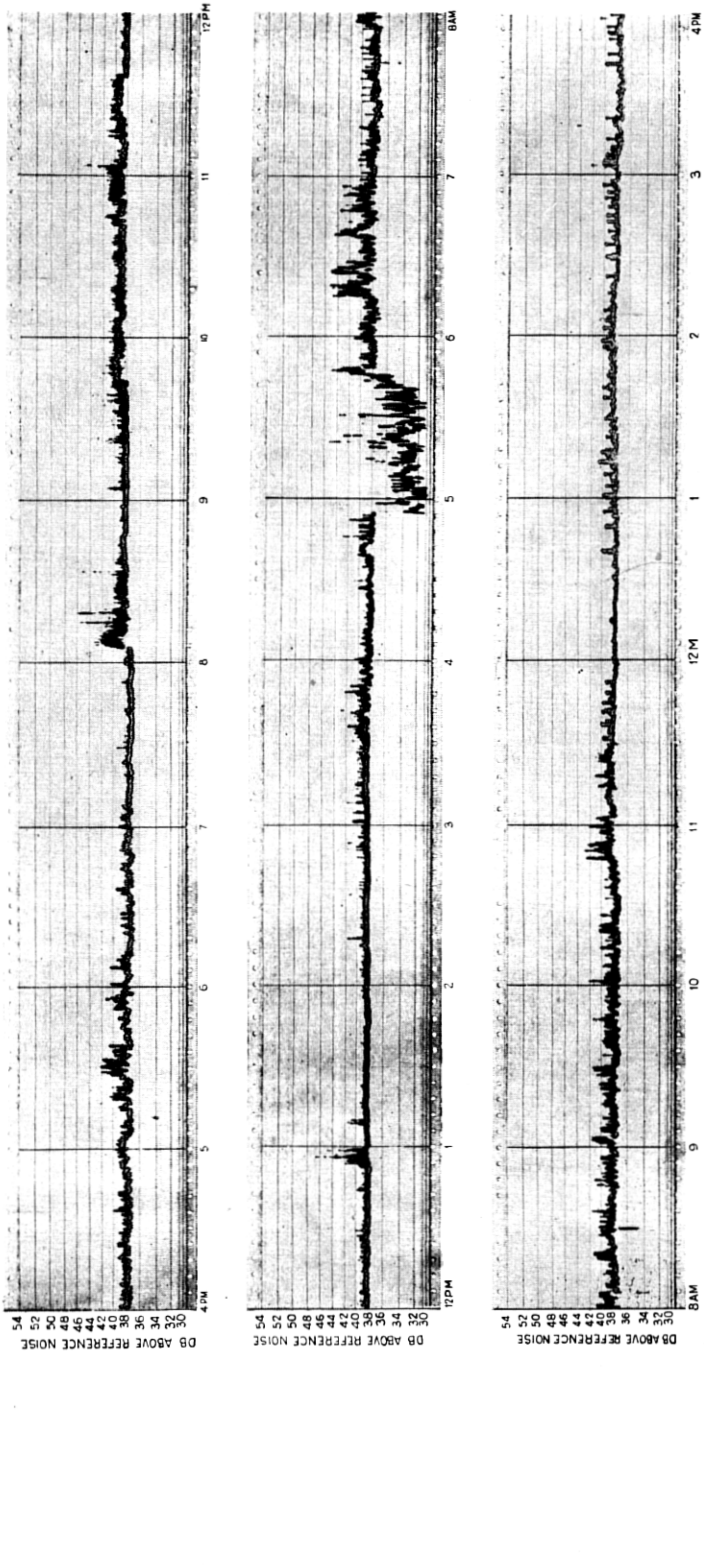

Fig. 9—24-hour record of noise on noisy open-wire phantom circuit.

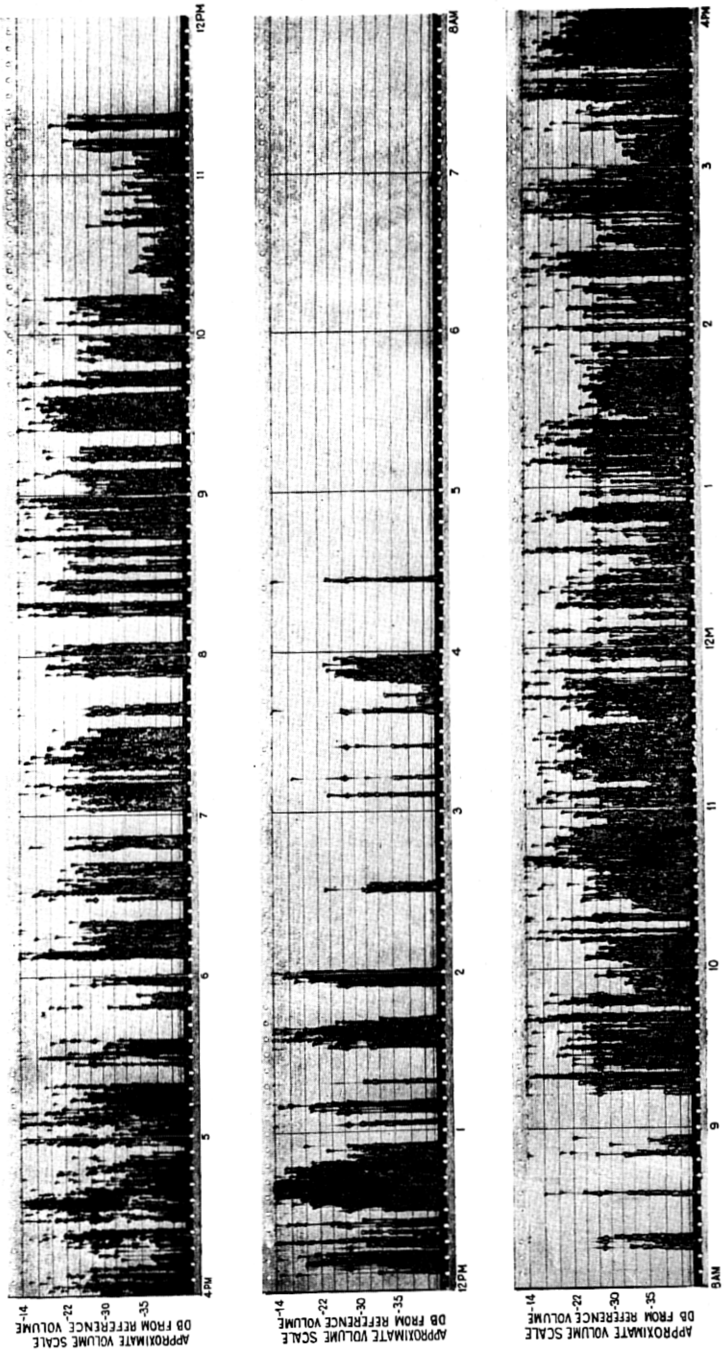

Fig. 10—24-hour volume indicator record on working telephone circuit

circuits. Figure 9 is a record of noise and Fig. 10 is a record of variations in speech volume on a working circuit. The speech volume record is of particular interest in showing graphically the variation of load on the circuit during the different periods of the day and also the extreme variations in the volume of different talkers. The recording system was bridged on one end of the circuit so that a difference of several db in volume level between the talkers at the two ends of the circuits is to be expected. Figure 11 is a short-period record of speech volume made at the high rate of paper feed.

It will be noted that the width of the mark made by the heated pointer is much greater in the case of the slow speed records than in the case of the high speed records. In the slow speed records illus-

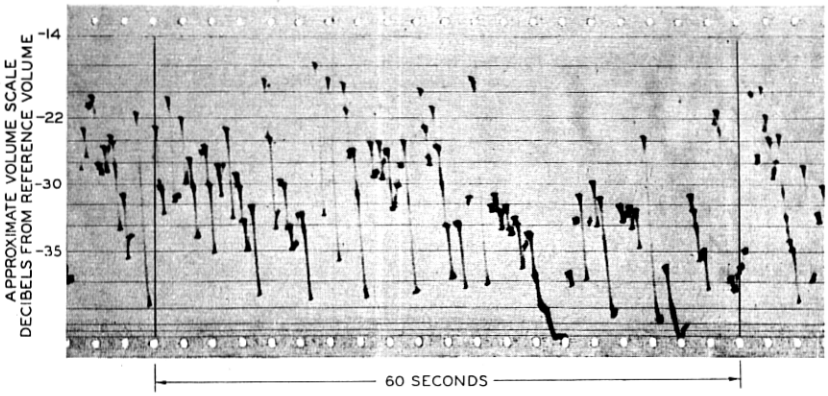

Fig. 11—Volume indicator record at high rate of paper movement.

trated the points of interest are the peaks which the pointer reaches frequently and the heat is adjusted so that a good record is made of these peaks. The movement of the pointer is so rapid that no trace is made between the peaks and the zero line. This feature is an advantage rather than a disadvantage since even with such a high speed recorder the movement of the pointer is slightly behind the electrical impulse which energizes it and for such tests as measurements of speech volume the record between the zero line and the peaks or between any two peaks would not be extremely accurate. The exact center of the broad line is directly under the heated wire. This point is clearly distinguishable in the broad trace made by slow speed records.

It is expected that recording transmission measuring systems will be of considerable value in locating intermittent troubles of very short duration which are not easy to locate with manual arrangements.

Fig. 12 is a record of the 1,000-cycle loss of a long four-wire cable circuit which was removed from service for purposes of trouble location. The small jogs in the curve were caused by the normal functioning of the automatic transmission regulators. The sudden change occurring at 8:50 a.m. was due to a trouble which momentarily decreased the transmission loss. The other large jog in the record was caused by an attendant making a routine adjustment. Evidently a trouble condition can not only be detected but located

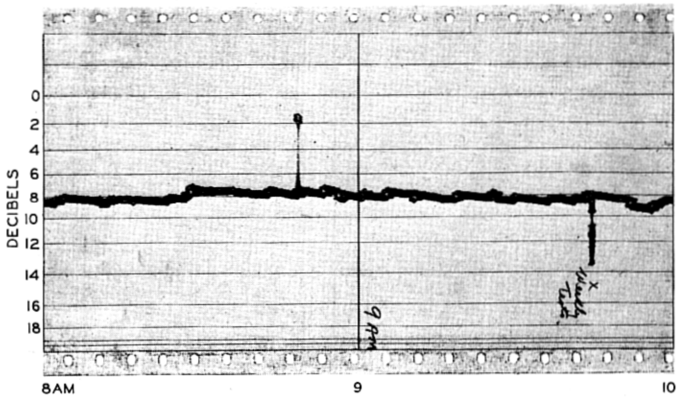

Fig. 12—Transmission loss—time record made on long four-wire cable circuit while locating a trouble.

by connecting transmission recorders at a number of different points along a circuit and making simultaneous records.

Transmission-frequency measurements on circuits and repeaters can be made with the recording system in less than one-tenth the time required with manually operated measuring apparatus. When the system has been completely developed and applied generally in the field, material time savings should result, particularly in the larger offices. Also, it is to be expected that the continuous records obtained with the recorders as compared to measurements at only a few points with manually operated apparatus will materially assist in disclosing abnormal circuit conditions.