The Testing of Telephone Transmitters.

A TELEPHONE circuit is composed essentially of a transmitter, a connecting link, and a receiver In practice the connecting link, consisting of the subscriber's line wires and the apparatus in the exchange or exchanges, as well as of the junction and trunk lines, is always subject to a certain amount of interference due to the coupling which may exist with various sources of electrical energy such as other telephone lines, power cables, and the like. This coupling causes disturbances in the link, appearing as noise in the receiver In modern circuits the coupling is reduced to a very small value but, since it cannot be entirely eliminated, line noise is always present and becomes more noticeable as the length of the line is increased. It is therefore of the greatest importance that the efficiency of the transmitter in converting sound into electrical energy should be high, since this governs the ratio of the volume of speech to the volume of noise produced in the receiver The transmitter must deliver to the line so much energy that the volume of the received speech in the worst case is both adequate for intelligibility and sufficiently above the noise level. Unless the energy delivered to the line be sufficient, amplification *en route* or the use of a more sensitive receiver will effect no improvement, as by such means both noise and speech level are raised without materially altering their ratio.

It follows that in consequence of the rapid development of long distance telephony during recent years attention has been directed to the question of increasing the efficiency of the transmitter and of improving its overall response to speech frequencies. So far as the latter problem is concerned, it has long been known that the most important frequencies from the point of view of maximum intelligibility of speech lie between 500 and 2500 cycles per second, and that the upper portion of this range is the more important. Very little improvement in articulation can be obtained by including all the frequencies below 500 cycles per second, although there is some gain in naturalness and volume, and little advantage is secured by including frequencies above 2500 unless the range is extended very considerably, say to 5000 or even 10,000 c.p.s. However, for various reasons connected with loading and balancing the cut-off of modern telephone circuits and repeaters is at about 2500 c.p.s., and any higher frequencies present in the output of the transmitter are therefore lost.

New types of transmitters which have recently been introduced show a marked improvement over earlier designs and have been adopted by most of the principal administrations. They reach a much higher standard as regards both volume and articulation, and their response within the desired frequency range is much more uniform. To maintain this standard in a commercially produced article is, however, a matter of no little difficulty Great accuracy is required in the manufacture and assembly of the component parts and every precaution must be taken to ensure that the filling of carbon granules is of the correct grade, accurate in quantity, and free from contamination. In this respect much has been achieved by improved methods of production but, despite

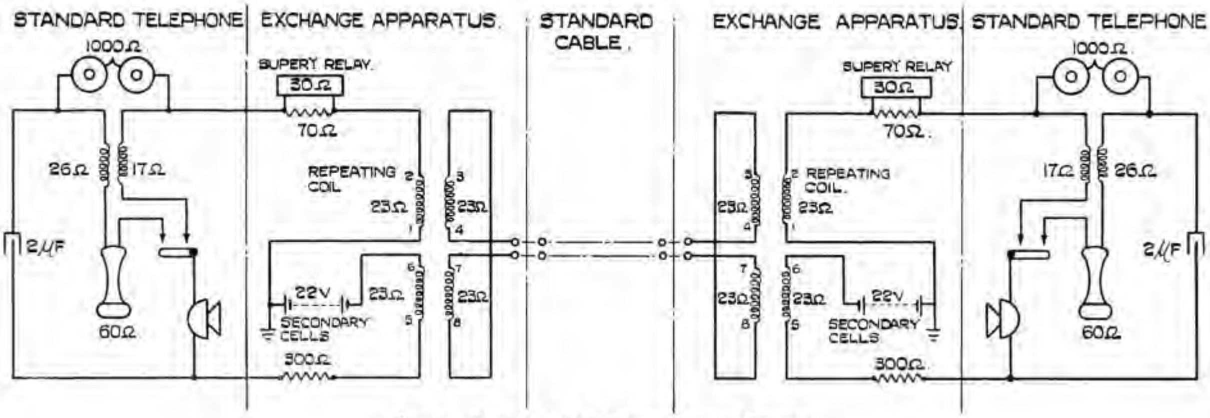

Fig. 1.—Standard C.B. Transmission Circuit.

the precision so attained, finished transmitters may show quite wide variations in efficiency which can only be determined by subjecting each specimen to careful examination and test. It follows that in order to guarantee uniformity the same precision is necessary in testing as in manufacture.

Of the numerous tests which are applied to a telephone transmitter in order to obtain a complete record of its performance, those from which its response curve is determined are of importance chiefly in the development stage. This characteristic is largely governed by mechanical design and will not vary widely between different samples of the same type. To ascertain the response to sound waves of different frequencies the output of the transmitter under test is compared with that given by a high quality condenser microphone whose characteristic is known. Readings are taken at a large number of frequencies within the range of interest, the tones being usually supplied by a loud-speaker of good design fed by an oscillator whose output can be accurately controlled. The tests are made in a room which is heavily padded to eliminate resonance as much as possible, and care is taken that the condenser microphone and the transmitter under test occupy similar positions in the sound field given by the loud-speaker

When the response curve has been determined tests for articulation are made. These require a trained team of observers and take up a large amount of time. The method employed is essentially as follows. One observer speaks a large number of meaningless test syllables into the transmitter under examination, while another observer at the distant end of the test circuit notes down the syllables received. The tests are then repeated with other callers and listeners. Finally a comparison is made between the syllables actually spoken and received, and the percentage correctly transmitted is recorded. To obtain reliable results a very large number of observations must be made.

Tests for volume are normally made by the "voice-ear" method. The circuit employed, shown in Fig. 1, consists of two subscribers' lines, each of 300 ohms resistance, joined by a junction in which there is a fixed length of approximately 30 miles of standard artificial cable and in which an additional length of standard cable may be inserted. The transmitter to be tested is compared with a similar one which has been very carefully calibrated and tested over a long period of time to ensure that it remains constant in use. The caller counts " one-two-three-four-five " into each transmitter in turn, at the same time operating

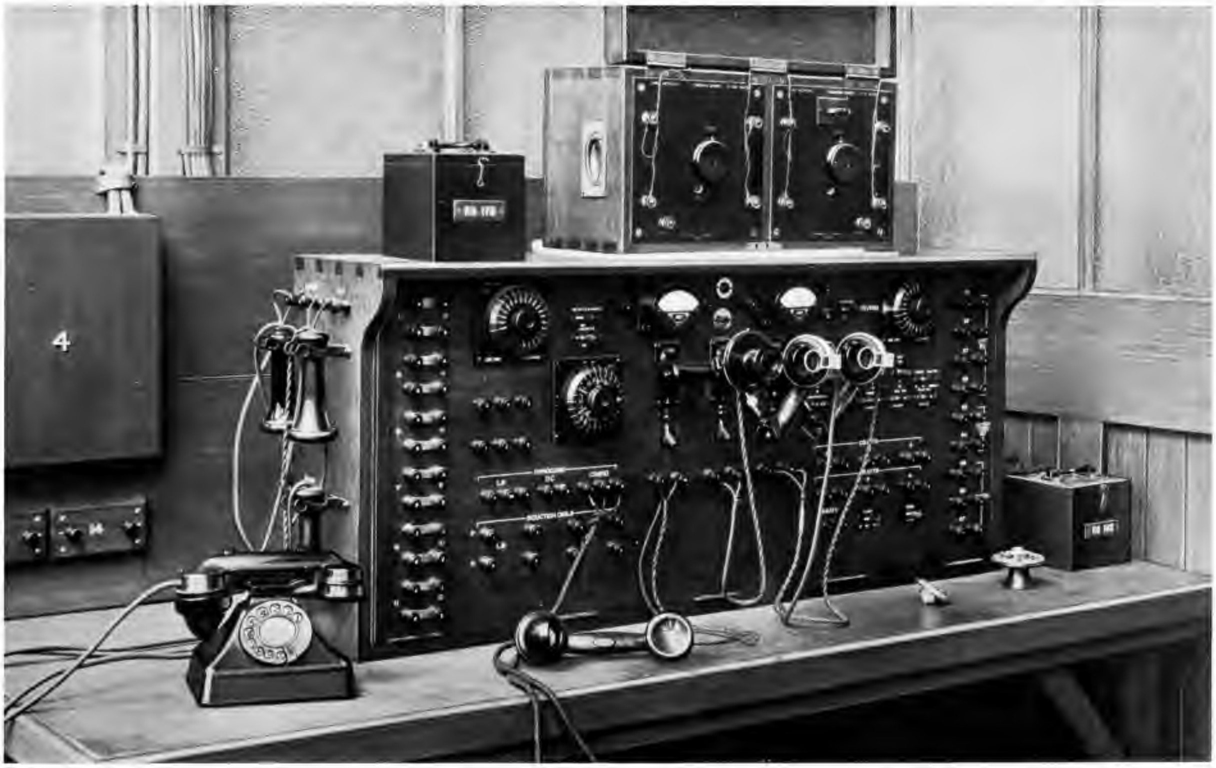

Fig. 2.—Sending end test set.

a key to switch the appropriate transmitter into circuit. The listener compares the volume received in the two cases and operates a buzzer to indicate the louder of the two. The caller then inserts artificial cable into the junction circuit of this transmitter and adjusts it until the listener is satisfied that the received volumes are equal. The test is then repeated with the caller and listener interchanged. With this method a degree of accuracy to within about 1 M.S.C. can be obtained by experienced observers.

In cases where observers do not agree, due either to insufficient experience or to variation in articulation characteristics between the standard and the transmitters being tested, a slightly different method of testing is employed. In this second method an exact balance is not attempted. The caller adjusts the variable cable so that the transmitter under test is first definitely better than the standard and then definitely worse, as indicated by the listener's signals. In order to do this the caller makes notes of the cable loading for or against the transmitter under test, and of the listener's signals for each loading. This is continued until consistent signals are given for a particular loading in both directions, *i.e.* better or worse. A final check is then given in both directions and if the signals are still in agreement, the point of balance is taken as being the mean of the two loadings for which consistent signals have been obtained.

When this method is employed the test is generally made with at least three observers, each observer acting in turn as caller and listener, so that the final balance point is the average of at least six sets of observations. The time taken precludes its use for ordinary routine testing, but it is useful in cases where difficulties arise as mentioned, and when a check test is considered desirable.

In making these tests a number of precautions must be taken. At the sending end the caller must take care to keep his voice at a uniform volume, and his lips at the same distance from the transmitter in each case. Fig. 2 illustrates a typical testing set as used at the sending end and shows two hand-combination transmitters and one of the solid back type in position for test. All the transmitter mouthpieces are fitted with guard rings which the caller's lips should just touch so as to ensure that the distance between the source of sound and transmitter is uniform. Unless this precaution is taken, variations of several miles of standard cable may be introduced.

The large box on the test set contains on the left the fixed standard artificial cable, normally set at 30 miles, and on the right the adjustable cable for equalising the volume from the two transmitters under comparison. The smaller boxes on the top and at the side contain calibrated sub-standards. The two upper dial switches adjust the resistance in the line loops and are normally set at 300 ohms for the tests described. The third dial switch enables the adjustable artificial cable to be inserted in the junction of either transmitter as required. It also controls by means of relays other switching operations when testing components other than transmitters. The voltmeter and ammeter are used for resistance tests as described below The complete set is arranged so that tests may be made on various components (induction coils, etc.) and also on complete telephone instruments.

To obtain reliable results it is advisable that the transmitter used as a standard should be of a similar type to the one under test. If the transmitters have different response curves their articulation characteristics will differ and it is found in practice that great difficulty will be experienced in estimating the balance. A listener will give different balances when the speaker is changed, while different listeners will again vary widely in their estimates.

The main requirement at the receiving end is that the listener should be out of earshot of the caller and that his surroundings should be very quiet. This can be assured by placing the receiving end test set in a silence cabinet, of which Fig. 3 shows a typical example. The walls, floor and roof are composed of several layers of various sound absorbing materials, while double doors are provided, also well insulated. Where there is any likelihood of sound transmission through the structure of the main building, it is necessary to protect the silence cabinet from vibrations transmitted through the floor This may be done by avoiding a rigid connection between the cabinet and the floor, the cabinet being supported by some material which will absorb the vibrations.

Fig. 4 shows the test set situated in the silence cabinet. For transmitter testing the only essentials are the receiver and the buzzer key, but for convenience an ordinary telephone to the sending end is provided and on the set shown provision is made for the testing of receivers and other components and complete instruments.

In addition to quiet external conditions for the listener, very quiet conditions on the testing circuit are required. The connecting lines should be run in screened cable and the 22-volt battery should not be used for the supply to any circuits which might be liable to cause extraneous noise.

Transmitter resistance is measured on the sending end test by means of the voltmeter and milliammeter seen in Fig. 2. The same connections are used as for the volume test, but the milliammeter is placed in series with the transmitter, and the voltmeter across both. The line resistance is adjusted to give 25 m.a. through the transmitter while the latter is spoken into in a normal voice, and the reading of the voltmeter taken. The "talking resistance" of the transmitter can then be calculated.

Fig. 3.—Typical silence cabinet.

Tests for "frying" are made by reducing the line loop at the sending end to zero, so as to give the maximum current through the transmitter, and listening on the receiver at the sending end. Transmitters for use in a handcombination are tested in various positions while mounted in a service instrument. Quiet conditions are again essential. For quantitative measurements a very sensitive valve voltmeter is employed to measure the voltage generated across the transmitter

A transmitter with a tendency to "pack" will generally be detected during the volume tests, but a further test for packing is made by speaking or humming quietly into the transmitter in a uniform tone and, by means of the associated receiver, observing any tendency towards loss of volume.

The liability of a transmitter to "howl" when mounted in a handcombination is ascertained by reducing the line resistance to zero and gently tapping the transmitter while the handcom is held in various positions and also placed on a flat surface.

By reason of the length of time necessary for the application of the foregoing series of tests, the procedure outlined is obviously confined to the laboratory The production of large quantities of transmitters for public service—an average factory order will amount to 50,000—involves the adoption of routine methods by which both preliminary inspection and final tests are carried out as rapidly as possible, yet with the precision which will ensure that every complete transmitter reaches the desired standard.

The procedure employed in applying the final tests during routine inspection of quantities consists of a double check. By means of equipment similar to that described, each transmitter, after examination at various stages of manufacture, is subjected to a comprehensive test for frying, packing, and volume. Out of each quantity assembled a percentage is also delivered to the laboratory,

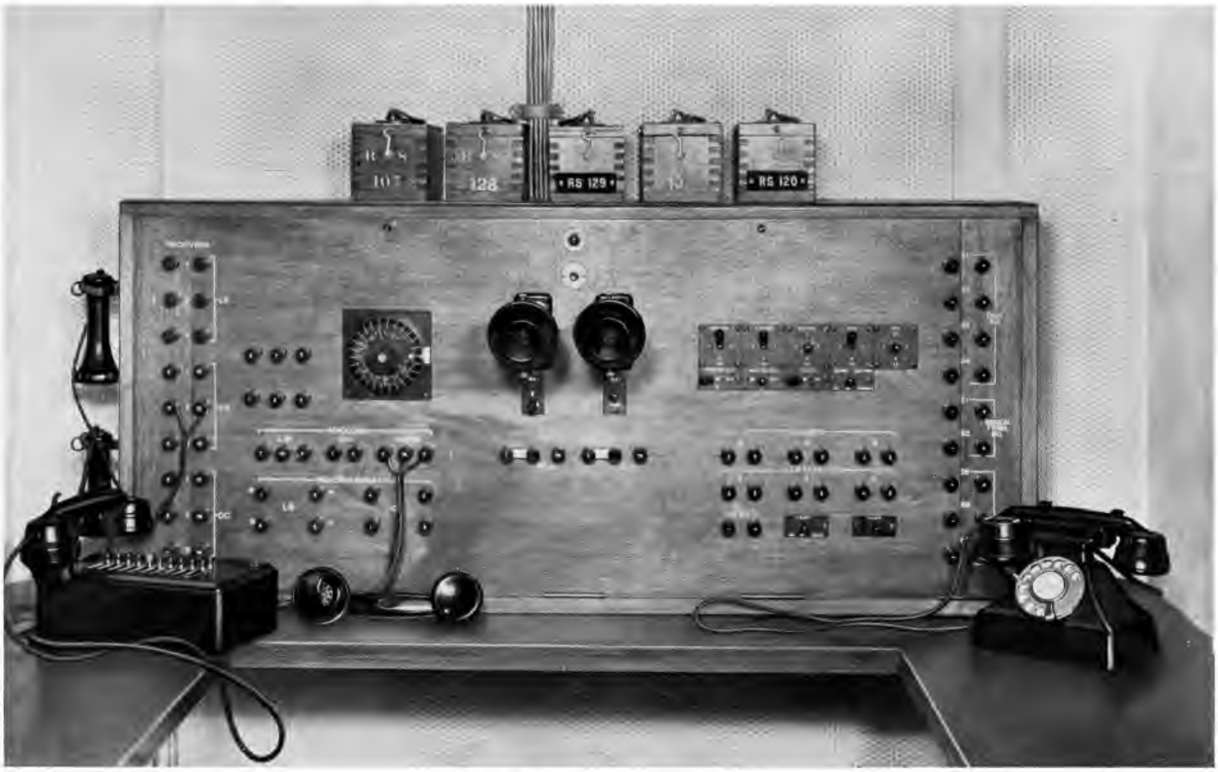

Fig. 4.—Receiving end test set.

where an entirely independent staff of observers makes similar tests, including those for resistance and articulation. The laboratory thus directly controls production, thereby ensuring in the finished article the efficiency laid down by specification.

The time taken by the voice-ear method of testing has led the British Post Office recently to develop a new equipment—the Telephone Instrument Tester—by means of which transmitters, receivers and complete telephone sets may be tested still more rapidly and with even greater precision. In this equipment the voice is replaced by a loud-speaker fed by an oscillator giving a complicated " wobble tone," and the ear is replaced by an amplifier-rectifier which gives readings in decibels relative to a standard. The oscillator proper has two valves with tuned anode circuits, one of which is adjusted to oscillate at 180 c.p.s. The tuning of the other circuit is effected by a motor-driven rotary condenser revolving at 300 r.p.m. and having a maximum and minimum capacity such that the frequency varies from 600 to 1600 c.p.s. each half-revolution. These two waves are simultaneously applied to the grid of a " mixer " valve, the voltage of the rythmic tone being twice that of the 180 cycle tone. In the anode circuit of the mixer valve is a filter which eliminates the 180 cycle wave, and the resultant wave is amplified and fed to the loud-speaker This tone then contains all frequencies from 600—180 to 1600 + 180 c.p.s., *i.e.* from 420 to 1780 c.p.s., neglecting harmonics.

The transmitter to be tested is held against a guard in the front of the loud-speaker, the current to the loud-speaker and the distance of the guard being so arranged that a sound pressure of 20 dynes/cm^2 is produced at the mouthpiece of a handcom. transmitter, and 30 dynes/cm^2 at that of a solid-back transmitter The transmitter is connected in the standard *C.B.* circuit shown in Fig. 1 except that the receiver is replaced by a 400 ohm resistance and the secondary of the repeating coil is closed by a 600 ohm resistance in place of the artificial cable. The input to the amplifier is connected across a very small fraction of this resistance (less than one ohm) and the amplified voltage is applied to the grid of a valve so biassed as to act as an anode bend rectifier A fraction of the voltage feeding the loud-speaker is likewise applied to the grid of a second detector valve as far as possible identical to the first. Connecting the anodes of these two valves is a *D.C* voltmeter and the whole is so adjusted that the voltmeter gives a mid-scale reading when a transmitter having a volume efficiency equal to the standard is being tested. The voltmeter scale is marked in decibels on each side of the central zero, the maximum reading on each side being 5 db, and means are provided for calibration. The Tester is calibrated daily by testing on it six transmitters whose efficiencies are known.

For receiver tests the same circuit is employed except that a 50 ohm resistance replaces the transmitter, and the input to the amplifier is tapped across the whole 600 ohms resistance instead of across only a fraction of it. The receiver, fitted with an "artificial ear," which is an acoustic filter giving similar damping to the average human ear, is held against the loud-speaker guard and acts, therefore, as a very insensitive transmitter Owing to the fact that the whole of the 600 ohms resistance is used when testing receivers and only a small fraction in the case of transmitters, approximately the same readings are obtained on the voltmeter scale in the two cases. The change from transmitter to receiver testing is made by throwing one key

Transmitter resistance is measured immediately after the volume test by throwing another key, the resistance being read on the same voltmeter Other keys make circuit changes such that local battery transmitters, operators' head sets, complete instruments, etc., can all be tested in their respective circuits with a minimum of trouble.

By using this equipment tests can be made at more than twice the rate possible with even the simplest voice-ear method and the accuracy is greater than is obtainable by any except the most careful and prolonged laboratory tests as described earlier On this account the new Tester certainly meets the requirements of both the manufacturer and the larger Administrations but, while the use of it is superseding other methods for routine purposes, the voice-ear method is likely to remain the final criterion of the performance of a transmitter in service.