INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE

(C. C. I. F.)

XVIIth PLENARY ASSEMBLY

GENEVA, 4-12 OCTOBER 1954

VOLUME IV

Recommandations and measurements concerning transmission quality

Telephone Apparatus

Published by the

INTERNATIONAL TELECOMMUNICATION UNION

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CONTENTS OF THE BOOK OF ANNEXES TO VOL. IV OF THE GREEN BOOK

FIRST PART

GENERAL RECOMMENDATIONS ON THE TRANSMISSION QUALITY OF AN OVERALL INTERNATIONAL TELEPHONE CONNECTION OR OF THE CONTINENTAL SECTION OF AN INTERNATIONAL INTERCONTINENTAL TELEPHONE CONNECTION

1.1 REFERENCE EQUIVALENTS

Practical limits for the reference equivalents between two subscribers, the reference equivalent of the national sending system and the reference equivalent of the national receiving system

In any international telephone connection between two subscribers situated within the same continent the reference equivalent between the two subscribers must not exceed 4.6 nepers or 40 decibels.

The reference equivalent of the national sending system (as considered from the ends of the international circuit) must not exceed 2.1 nepers or 18.2 decibels.

The reference equivalent of the national receiving system (as considered from the ends of the international circuit) must not exceed 1.5 nepers or 13 decibels.

If gain is introduced in the international exchange (for example by the insertion of a repeater to compensate for the attenuation in the circuit between the international exchange and the terminal local exchange), this gain will be included in the above-mentioned reference equivalents for the national systems.

If, in the case of certain connections, the nominal equivalent referred to above of the international circuit is reduced by a certain quantity in the international exchange concerned, this reduction will be considered as being equivalent to a corresponding gain made to the national systems.

Note 1. — Efforts should be made so that the maximum limit of 4.6 nepers for the reference equivalent between the two subscribers in any international call whatsoever, be an absolute upper limit, including therein variations of all kinds ; it should thus include both variations with time, and tolerances, with respect to their nominal values, of the reference equivalents of lines and apparatus.

In this connection, Administrations and Private Operating Companies must take account of the fact that it is possible for variations (within an interval of 0.35 nepers or 3 decibels) to occur in the values of reference equivalents measured at the C.C.I.F. Laboratory, but it is considered, for the time being, that no tolerance can be specified for the possible variations due to these causes in planning national telephone networks.

Note 2. — The limiting transmission conditions indicated above concern only the reference equivalent (4.6 nepers for the whole transmission system) and do not take any account of the transmission impairment due to the effects of noise or limitation of the band of frequencies effectively transmitted (see section 1.3 below).

Practical limits for the reference equivalent between two operators or between an operator and a subscriber

In an international telephone call, the reference equivalent between two operators or between an operator and a subscriber should not exceed the values contained in the following table :

Calls between two operators		Calls between an operator and a subscriber			
Reference equivalent of the connection between two operators		Reference equivalent of the connection between an operator and a subscriber situated at the same end of the international line		Reference equivalent of the connection between an operator and a subscriber situated at opposite extremities of the international line	
Subscriber's line disconnected	Subscriber's line connected	International circuit disconnected	International circuit connected	Subscriber's line disconnected	Subscriber's line connected
2.5 nepers ou 21.8 decibels	3.3 nepers ou 28.7 decibels	2.55 nepers ou 22.2 decibels	2.95 nepers ou 25.7 decibels	3.55 nepers ou 30.9 decibels	3.95 nepers ou 34.4 decibels

Note. — Administrations and Private Operating Companies can use various methods to assure themselves that the limits shown concerning the reference equivalents are not exceeded. For example, networks can be made representing the principal combinations of commercial subscriber's telephone equipment, subscriber's lines, junction lines and local and trunk exchange circuits ; each of these networks would represent a complete national sending system or a complete national receiving system which would be compared, in a voice-ear test, with the Master Reference System (S.F.E.R.T.) without distortion or with a Working Standard System which had previously been compared with the S.F.E.R.T. The operations can be restricted to the measurement of the reference equivalent of the subscriber's telephone apparatus under certain specified conditions ; to this value of reference equivalent is added the factory acceptance tolerance for the subscriber's telephone apparatus considered, the image attenuation (calculated or measured at 800 c/s) of the subscriber's lines, junction lines and circuits connecting this apparatus to the international exchange, and the composite attenuations (measured or calculated at 800 c/s on a pure resistance of 600 ohms) of the exchange circuits used in the connection between this equipment and the international exchange (including the circuit of the exchange serving the subscriber and that of the international exchange). In any case, however, it is necessary to check the results of these calculations by means of a voice-ear test carried out on the artificial units representing the most typical complete national sending and receiving systems.

1.2 TRANSMISSION PERFORMANCE RATINGS

a) Definitions of transmission performance rating and articulation reference equivalent (A.E.N.)

Articulation reference equivalent (A.E.N.) [Articulation Reference Equivalent (A.E.N.) (G.B.) Equivalent articulation loss (Am.)]

If articulation measurements are made alternately on a telephone system and on the *Reference system for the determination of A.E.N. (S.R.A.E.N.)* with different values of junction attenuation up to the point where values of articulation on both systems are substantially reduced, then the results of these tests may be presented in the form of curves showing the variation of sound articulation against attenuation. The value A_1 of the attenuation of the system under test and the value A_2 of the attenuation of the A.R.A.E.N. at a fixed value of 80% sound articulation can then be determined.

$(A_2—A_1)$ is by definition equal to the *articulation reference equivalent* abbraviated to A.E.N.

Transmission performance Rating, relative to S.R.A.E.N.

The loss (in decibels or nepers) which it is necessary to add to, or to remove from, the S.R.A.E.N. so as to give equal transmission performance when the equipment considered is used to replace the whole of the reference circuit or added to an appropriate part of it. For international planning this equality of transmission performance should be on the basis of articulation tests.

b) Calculation of the nominal transmission performance rating of a national sending or receiving system

The nominal transmission performance rating of a national sending or receiving system is the sum of the following quantities :

1. The nominal transmission performance rating of the local system (average value in service).
2. The nominal transmission performance rating of the connection between the local exchange and the international exchange (average value in service).

1. When it is desired only to check whether a national sending or receiving system satisfies the limits fixed for international service (§ *d* below) the transmission performance rating of the local system may be taken as the A.E.N. value for this system (see the note below).

The nominal transmission performance rating for the local system considered is then equal to the A.E.N. value (articulation reference equivalent) of the system comprising a typical telephone set (i.e. the average value in service for the type of telephone set considered) connected by means of an artificial line (representing the subscriber's line actually used) to a typical local exchange feeding bridge. This quantity is itself equal to the A.E.N. value determined at the C.C.I.F. Laboratory, reduced by a correction if the subscriber's line actually used is less unfavourable than that which was supplied to the C.C.I.F. Laboratory.

2. The average transmission performance rating relative to S.R.A.E.N. of the connection established between the local exchange and the international exchange is equal to the sum of the following numbers :

— the loss of the trunk circuits between the terminal trunk exchange and the international exchange, measured at 800 c/s, increased by the impairment due to bandwidth limitation (see § **1**.3 below) when these circuits present an attenuation distortion greater than that allowed by the C.C.I.F. recommendations (see section **1**.3.2 of the 1st Part of Vol. III of the *Green Book*).

— the average transmission performance rating for the junction circuits given by the following expression :

$$i = K \times L$$

where : i = average rating in decibels or nepers.
L = length of the junction circuit in kilometres,
K = a coefficient which depends on the type of junction circuit considered in nepers per kilometre or in decibels per kilometre (see Annex 1 of the *Book of Annexes* to Vol. III of the *Green Book*).

— the average insertion rating of each intermediate exchange. The rating corresponding to the insertion of an electrical circuit element, which, in conformity with C.C.I.F. recommendations effectively transmits the frequency band 300-3400 c/s, can be calculated by taking the arithmetic mean of the 4 values of insertion loss (or gain) of the element considered measured at 500, 1000, 2000, 3000 c/s and expressed in decibels or nepers. Until a more precise value (or more precise values) for this rating results from measurements which each Administration can carry out on this subject, a provisional value will be adopted of 1.0 decibel for each intermediate exchange included in the connection.

Note 1. — Circuit noise which remains within the limits fixed by the C.C.I.F. recommendations is not taken into consideration.

Note 2. — The composite attenuation of the lines which connect international exchanges to local exchanges should be such that the reference equivalent of the national sending system and that of the national receiving system remain within the limits compatible with good telephone transmission.

Note 3. — For future planning, the lines connecting international exchanges with local exchanges should be capable of transmitting effectively the band of frequencies from 300 to 3400 c/s.

The attenuation distortion of these lines should not appreciably increase that of the international circuit ; consequently, where the lines are loaded, a sufficiently high cut-off frequency should be chosen.

Note 4. — As for international planning, transmission performance rating can be evaluated by assessing the transmission performance by means of articulation measurements, the following considerations define the relationship between transmission performance rating and A.E.N. (for sending and receiving) for a commercial telephone system.

NOTE

Relationship between transmission performance rating and A.E.N. value (for sending and receiving) for a commercial telephone system

The variation of the reference equivalent of the sidetone path of a telephone set affects both the sending and receiving efficiencies of this set. The resultant effect on the " transmission performance rating " of a symmetrical telephone system, presenting the same conditions of subscriber's line and room noise at both ends, is approximately equal to the sum of the separate effects on sending and receiving. The A.E.N. measuring technique includes the direct measurements of the effect on receiving for the level of room noise used in the tests, since the effect at the receiving end is due to the masking of the received speech sounds by the room noise reaching the telephone receiver over the sidetone path.

However, the effect at the sending end is due to the fact that a variation of the reference equivalent of the sidetone path produces a variation of the subscriber's speech power. The measurement of A.E.N. values involves the use of a constant speech volume and, consequently does not take account of this effect.

In principle, corrections should be made to the measured A.E.N. values to take account of the effects which occur in service due to departure from the conditions specified for the determinations of these A.E.N. values. However, when it is only a question of evaluating the transmission quality of commercial telephone connections of which the characteristics correspond to the worst transmission quality allowed in service, the small differences which occur by reason of different sending end sidetone conditions can at present be neglected. It has been agreed to define arbitrarily and provisionally that the correction due to the effect of sidetone at the sending end is to be zero.

Administrations and Private Operating companies who wish to plan their national networks on the basis of transmission performance ratings will find in Annex 2 of the *Book of Annexes* to Vol. IV of the *Green Book* some indications of the corrections to be made to A.E.N. values to take account of sending end sidetone.

c) Determination of A.E.N. values

The reference system for the determination of A.E.N. values (S.R.A.E.N.) and the methods of determination of A.E.N. values of commercial telephone systems in the C.C.I.F. Laboratory are described in sections **3**.1.3 and **3**.1.4 below.

d) Limits for the transmission performance rating between two subscribers, the transmission performance rating of the national sending system and the transmission performance rating of the national receiving system

Rule: It is very desirable that, for 90% of international calls, the nominal total transmission performance rating from subscriber to subscriber should not exceed 49 decibels (5,65 nepers). Provisionally this limit may be subdivided in the following manner :

For 90% of international calls :

— the nominal transmission performance rating of the national sending system must not exceed 24 decibels (2.77 nepers),

— the nominal transmission performance rating of the national receiving system must not exceed 18 decibels (2.07 nepers).

It is assumed in the above that the transmission performance rating of the international circuit does not exceed 0.8 nepers or 7 decibels. This transmission performance rating is equal to the nominal equivalent of the circuit at 800 c/s (as defined in sections **1**.1 above), correction being made if necessary for impairment (see section **1**.3 below). This limit does not take account of the variations in the loss of the international circuit, with respect of its nominal value, as a function of time.

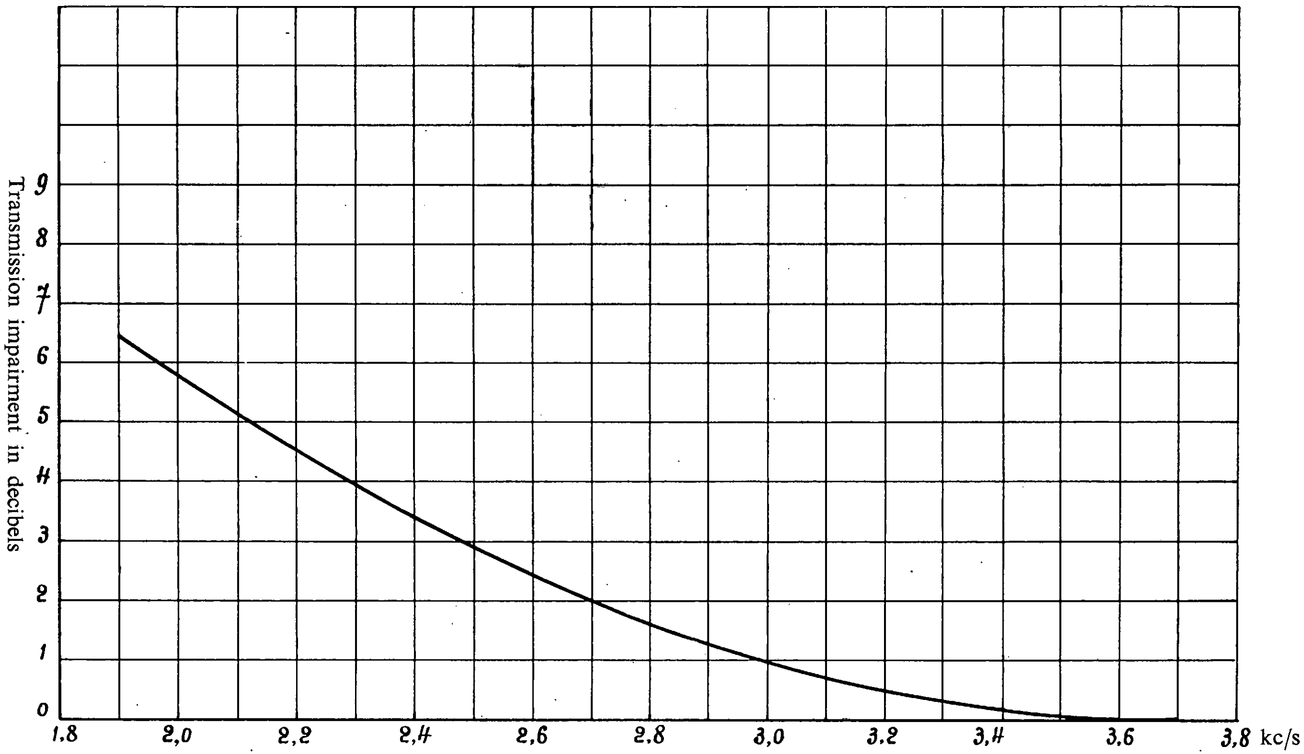
Note 1. — These limits (24 decibels and 18 decibels) for the national systems, at the sending and receiving ends, do not include the probable variations, as a function of time, of the losses of the trunk circuits which form part of the national system.

Note 2. — These limits apply to A.E.N. values deduced from values determined, for a local system, at the C.C.I.F. Laboratory as indicated in Section **3**.1.4 below, with, in particular, a room noise at the receiving end of 60 decibels for the commercial systems and an electrical background noise (of a psophometric e.m.f. of 2 millivolts) injected at the input to the receiving system of the S.R.A.E.N.

1.3 TRANSMISSION IMPAIRMENTS

a) Transmission impairment due to limitation of the frequency bandwidth effectively transmitted by the trunk circuit

Observations have been made in the United States of America of the repetitions during conversations and articulation measurements have been made in various national laboratories as well as in the C.C.I.F. Laboratory. The results obtained



The frequencies shown on the abscissa are the maximum frequencies effectively transmitted according to the definition adopted in the United States of America, i.e. those for which the attenuation is greater by 10 decibels than the attenuation at 1000 c/s.

FIGURE 1. — *Transmission impairment due to limitation of the frequency bandwidth effectively transmitted*

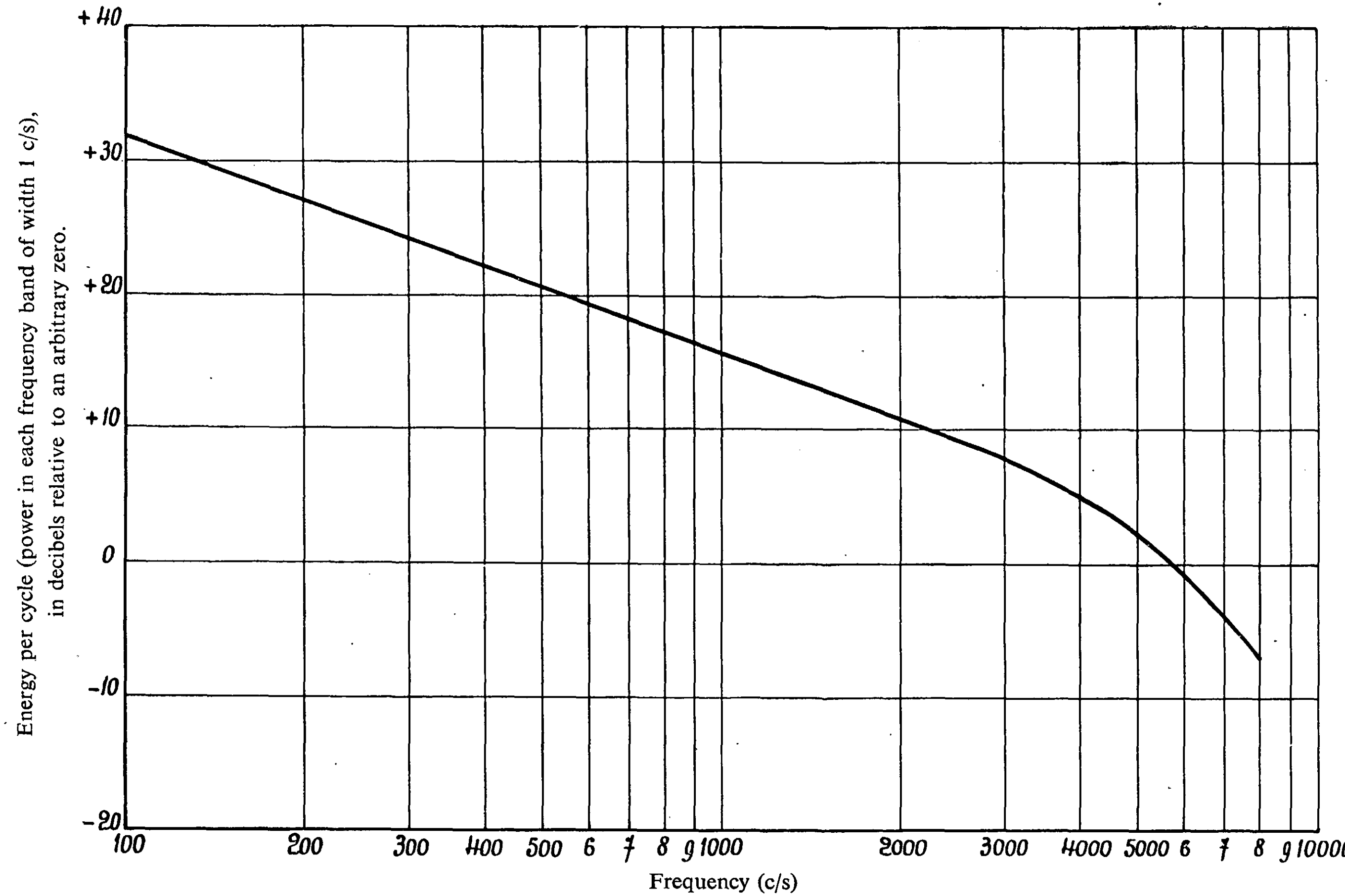


FIGURE 2. — *Power density spectrum of the room noise produced in the listening cabinet of the C.C.I.F. Laboratory*

This curve conforms to the mean power density spectrum of noise observed in locations where telephone sets are situated, published Hoth.

permit the mean curve given in Fig. 1 to be plotted showing the impairment due to limitation of the frequency bandwidth effectively transmitted by a trunk circuit.

The equation to this curve is $y = 2\ (3.7 - f)^2$, where y is the transmission impairment (in decibels) due to the limitation of the frequency bandwidth effectively transmitted, and f is the frequency (in kc/s) for which the loss of the circuit exceeds its loss at 1000 c/s by 10 decibels.

Note. — The impairment due to limitation of the band of frequencies effectively transmitted for a chain of national trunk circuits or for a connection between two international exchanges made up of several international circuits is not obtained by adding the individual impairments. It is necessary to consider the impairment for the circuit which transmits effectively the narrowest band of frequencies.

b) Transmission impairment due to circuit noise

This question is under study by the C.C.I.F. While awaiting the results of this study, it is pointed out that the Annex No. 3 of the *Book of Annexes* to Vol. IV of the *Green Book* gives some information on a method for evaluating the " transmission impairment due to circuit noise ".

c) Impairment due to room noise

The method of measuring A.E.N. values includes the effect of 60 db room noise * at the receiving end. For other cases, Annex 4 of the *Book of Annexes* to Vol. IV of the *Green Book* gives information on the method of evaluating the " impairment due to room noise " used in the United States of America.

1.4 GROUP DELAY

It is necessary in a continental call, to limit the delay between the two subscribers to a value provisionally fixed at 250 milliseconds. (Group delay measured at a frequency of about 800 c/s).

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* The power density spectrum of the room noise used in A.E.N. measurements is given in Figure 2. The following articles give information on room noise at locations where commercial telephone sets are located.

1. A Room-Noise Survey of Business Subscribers' Telephone Locations. *B.P.O. Research Report*, No. 8990 — 1935.
2. Room-Noise at Telephone Locations. D. F. Seacord, *Electrical Engineering*, Part 1, 58, 255, 1939.
3. Room-Noise Spectra at Subscribers' Telephone Locations. D. F. Hoth, *Journal of the Acoustical Society of America*, 12, 499, 1941.

To ensure this, the group delay on each of the sending or receiving national systems should not exceed 50 milliseconds, and that on the international circuit or the chain of international circuits should not exceed 150 milliseconds.

These figures represent maximum values ; for the establishment of the general plan of interconnection, however, values of 50 milliseconds will be taken for each of the national sending and receiving systems and 100 milliseconds for the two international circuits forming parts of the international call of transit type.

It is desirable, in an intercontinental call whenever economic conditions permit, to limit the group delay on the connection, within the European continent, from the subscriber to the terminals of the intercontinental circuit, to a value fixed provisionally at 100 milliseconds.

In this connection it is recommended that, for the future, high-velocity transmission circuits should be used in the principal routes of the international network.

Note. — The " group delay " with which we are concerned here is the derivative, with respect to the angular frequency ω, of the phase-shift (of the circuit or the chain of circuits) for the frequency f considered (angular frequency is 2π times the frequency f). This " group delay " is the time taken by a peak in the envelope of a group of two sinusoidal waves of angular frequencies very close together, ω and $(\omega + d\omega)$, to traverse the circuit (or the chain of circuits).

1.5 PHASE DISTORTION

In general, the phase distortion of international circuits and national trunk circuits (including their line equipment) should be such that the differences between the group delays do not exceed the following values * :

Permissible difference between the minimum value of group delay in the whole band of frequencies transmitted and that at:

	Lower nominal limit of the band of frequencies transmitted	Upper nominal limit of the band of frequencies transmitted
1. *In the case of a continental connection*		
On the international section of the connection	10 milliseconds	5 milliseconds
On each of the national sections	20 milliseconds	10 milliseconds
Or on the chain of connections	50 milliseconds	25 milliseconds
2. *In the case of an intercontinental connection*		
On the section from the subscriber to the beginning of the intercontinental circuit	30 milliseconds	15 milliseconds

* *Provisional recommendation.* — It is possible that these limits cannot be met in the case of connections of very great total length or where there are a large number of modulations or demodulations.

SECOND PART

RECOMMENDATIONS CONCERNING SUBSCRIBERS' STATIONS, LOCAL LINES AND JUNCTIONS, LOCAL EXCHANGES AND MANUAL TRUNK EXCHANGES

2.1 SUBSCRIBERS' LINES AND SETS

2.1.1 Conditions which should be satisfied by subscribers' stations used with international circuits rented temporarily for private purposes

The C.C.I.F. is at present studying the conditions imposed generally on the sensitivity of local sending and receiving telephone circuits. Until the results of this study become available, Administrations and Private Operating Companies should refer to the recommendation below which lays down the conditions which should be satisfied by subscribers' stations used with international circuits rented temporarily for private purposes.

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering,

That the sets connected to a rented international telephone communication channel should in no case be made generally available for public use and that the rented line should in no way be given over to a third party,

It is unanimously recommended,

That it is desirable for the rented circuits to terminate, at the subscriber's premises, in installations of which the equipment is forbidden to be used on these circuits except under the conditions set out in the rental agreement.

On the other hand considering

that connections set up over rented circuits should satisfy the same electrical conditions as commercial connections between subscribers,

It is unanimously recommended,

1. That it is desirable to recommend Administrations and Private Operating Companies to forbid, wherever possible, the use of microphones giving greater power output than that given by normal microphones and also the use of special receivers ;

2. That it is desirable to recommend Administrations and Private Operating Companies to reserve themselves the right to verify by means of volume meters, that the volume transmitted over rented telephone circuits does not reach an excessive level ;

3. That, where Administrations and Private Operating Companies authorize the use of receiving amplifiers, it is desirable that the gain given by this apparatus should be limited so that it is not possible for the user to overhear, by means of crosstalk, conversations on neighbouring circuits ;

4. That it would be desirable for the above recommendations to be applied to all telephone sets used on international connections as well as to all international telephone circuits.

2.1.2 Devices for recording messages or telephone conversations

The International Telephone Consultative Committee

Considering,

That only Administrations or Private Operating Companies are in a position to decide whether to allow in their respective networks devices for recording messages or telephone conversations ;

That where certain Administrations or Private Operating Companies have decided to permit these, they would be interested to know the essential technical clauses to be imposed upon such recording equipment ;

It is unanimously recommended :

That the essential technical characteristics that can be recommended for these devices for recording messages or telephone conversations are as follows :

The devices for recording messages or telephone conversations have three applications :

(a) Such a device can serve as an auxiliary in a telephone installation to record the conversation exchanged by the calling subscriber with his correspondent ;

(*b*) Such a device can also, in the absence of the called subscriber, record the message from the caller after indicating by means of a suitable phrase that the called subscriber is out but that the recording of the conversation is going to take place ;

(*c*) Such a device can be used on supervisors' desks in local or trunk telephone exchanges.

In order that such apparatus shall have no harmful effect on the plant and shall not adversely affect the transmission quality, it is desirable that it should comply with a certain number of conditions which are enumerated below ; the conditions which are mentioned are not general but apply to each particular method of use.

1. Input impedance. — The input impedance of the recording device, connected in parallel with a connection on which a conversation is taking place, should be high enough at all frequencies above 300 c/s to ensure that the insertion loss does not exceed 0.5 decibels for any amplitude of speech signal likely to occur during a conversation.

Whenever the recording device is, in the absence of the subscriber, substituted for the set, it should present an input impedance close to that of the subscribers' set for which it is substituted.

2. The recording device should be well balanced to earth so that its connection to the line shall not produce or agravate any noise disturbance on the telephone circuit ; furthermore the power supplies to the recorder should not produce any disturbance on the telephone circuit.

3. There should be sufficient margin between the background noise of this recording device and its overload point so that the weakest speech sound to be recorded should be at least 20 decibels above the background noise. Alternatively the recording device may contain a " volume compressor " which on the one hand, amplifies the very weak speech sounds so that they reach a level of 20 decibels above the background noise of the recording device but which, on the other hand, attenuates the very loud speech sounds so that they do not cause overloading during recording.

4. The recording device should reproduce a conversation recorded on a circuit of total reference equivalent, subscriber to subscriber, corresponding to an attenuation between subscribers sets of 29 decibels, with sufficient clarity considering the quality of telephone systems and with a subjective acoustic intensity comparable to that given by a telephone receiver connected to the same circuit.

5. In order to preserve secrecy of telephone conversations, a conversation recorded with the maximum possible gain should be quite unintelligible if the speech volume is lower than 55 decibels below reference volume.

6. If the recording device contains, after the amplifier, a listening arrangement to monitor the recording of the conversation when the subscriber is present,

it should, so as to avoid acoustic couplings in this listening arrangement, employ only a headband receiver, this being connected by means of a fixed pad so as to provide a subjective acoustic intensity at the most equal to that given by the receiver of the subscriber's telephone equipment connected to the line.

7. Where the recording device is such that, when the called subscriber is absent, it connects itself automatically in place of the subscriber's set, it is necessary for the device to send out a reply signal on being called and then to give a spoken announcement (film or disk for example) to make it known to the calling subscriber that his correspondent is absent but that a recorder is ready to take a message. This announcement should be sent out at a volume not exceeding values normally encountered in telephone conversations.

Note. — This point forms the subject of a new study by the 6th Study Group of the C.C.I.F.

8. In order to be able easily to disconnect the recording device when it is out of order and so avoid any possible disturbance to the conversation, it would be useful to provide a key to break both wires of the connecting circuit ; on the other hand, so as to limit any danger due to an insulation breakdown between the power supply circuits and the connecting wires, it is desirable to insert protectors in accordance with the normal practice in the countries concerned. Finally, to avoid giving rise to a calling signal at the exchange when the device is connected by means of the isolating key, it is necessary to insert in each leg of the circuit either a capacitor of appropriate maximum capacitance and designed so as to avoid distortion of automatic dialling impulses, on any other device with fulfils this purpose.

9. The general arrangement of recording devices should be conform to the general installation conditions in force.

2.1.3 Subscribers' telephone sets containing either loudspeaking receivers or microphones associated with amplifiers

This question is being studied by the C.C.I.F.

2.2 LOCAL LINES, JUNCTIONS AND LOCAL EXCHANGES

The C.C.I.F. is at present studying (in its 4th Study Group) the particular conditions which these network elements should satisfy in addition to the general conditions recommended in the 1st Part above.

2.3 MANUAL TRUNK EXCHANGES

2.3.1 Operators' positions

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering,

That it is necessary to reduce as much as possible the disturbance due to room noise as well as to the insertion losses due to operators' sets,

Unanimously recommends :

1. That the operators' sets used for international telephony should be provided with an arrangement allowing the microphone to be disconnected, this device being preferably a changeover key ;

2. That the operators' set while being used on an international telephone call should not cause, in the silent listening position (microphone out of circuit), an insertion loss greater than 0.05 nepers or 0.43 decibels at any frequency between 300 and 3400 c/s. To reduce this insertion loss sufficiently (while assuring the operator good enough reception), a suitable impedance can be introduced, in the silent listening position, in series with the operator's receiver, alternatively the connection between the operator's receiver and the telephone circuit can be made by means of a transformer of sufficiently high transformation ratio.

Note 1. — It is necessary to ensure that the speech signals of the operators do not overload the amplifiers or modulators of carrier systems. The operators' sets and associated equipment should be so designed that, under service conditions, the operators do not produce a speech volume greater than that of a subscriber situated very close to the trunk exchange considered. When Administrations or Private Operating Companies put any new type of operator's set into service they must check that this is still so.

Note 2. — On an international telephone call the operators' positions should, so far as the reference equivalent between two operators or between an operator and a subscriber, not exceed the limits specified in Section **1**.1 above.

2.3.2 Supervisor's desks

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Recommends unanimously :

1. That the equipment of the supervisor's desk should allow the supervisor who is using the desk :

(a) to listen on the circuits,

(b) to listen on the operators' sets,

(c) to listen on the order wires,

(d) to be connected with the section supervisors ;

2. That the desk should be provided with a clock ;

3. That the equipment of the desk and the circuit of the operators' sets should be such that no indication of any nature can reveal to an operator that she is being observed from the supervisor's desk.

4. That where the trunk operator calls a subscriber or an exchange by automatic routing, the supervisor's desk equipment should permit verification of correctness of the dialled impulses.

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering on the other hand,

That observation on a given circuit by the supervisor's desk is in general, of a prolonged character and that supervisor's desks at international terminal exchanges exercise this supervision simultaneously ; that, consequently, it is appropriate, from the point of view of insertion loss caused by observation, to be more severe in the case of observation on the part of the supervisor's desk than in the case of supervision by an operator,

Unanimously recommends :

1. That the insertion loss caused by observation on the part of the supervisor's desk of a circuit or of an operator's set should in no case exceed the value of 0.03 nepers or 0.26 decibels, at any frequency effectively transmitted by the trunk circuits (any frequency between 300 and 3400 c/s) ;

2. That it is, furthermore, desirable to reduce to as small a value as possible the insertion loss caused by observation, for example by using, if need be, an amplifier.

2.3.3 Arrangements for Conference calls

The arrangements for conference calls should satisfy the following provisional recommendation :

a) *Setting-up and supervision of conference calls*

Supervision and determination of chargeable time of a conference call should always be the responsibility of a special trunk operator attached to the exchange, of those at which the conference call equipments are installed, which, by agreement between the Administrations and Private Operating Companies concerned, is the master exchange ; on being requested to do so by this special trunk operator, the trunk operators at the exchanges concerned should be able swiftly to insert the conference call equipments either automatically or manually (if manual this plays no part in the operating procedure) ;

This special trunk operator has on her position the necessary means of calling individually the various trunk exchanges concerned, of receiving the clearing signals, of reconnecting to the circuits concerned, in the normal manner, the subscribers of the local network, and of supervising the conference call.

b) *Connecting equipment for interconnecting several long-distance international telephone circuits and several local circuits*

The connecting equipment for conference calls should permit interconnection of two-wire or four-wire circuits without any change in setting up the circuits ; the connecting equipment should equally permit two-wire or four-wire subscribers' lines to be connected to the international circuits :

The loss at the frequency of 800 c/s of two international circuits interconnected by means of the connecting equipment should not exceed 1.3 nepers or 11.3 decibels ;

The reference equivalent of a conference call between any two subscribers should not exceed the value prescribed for a normal call (see Section **1**.1 above) ;

The additional attenuation distortion introduced by the connecting equipment in the various paths should be as little as possible ;

The connecting equipment should not noticably reduce the stability of the interconnected circuits ;

Where special microphones or loudspeakers are used in the subscriber's sets, separate lines should preferably be used for sending and receiving and precautions should be taken against the effect of acoustic coupling between microphones and loudspeakers ;

The power output of the microphones and special amplifiers in the subscribers' stations should not exceed that given by the normal microphones of subscribers' sets in order to avoid overloading the repeaters in circuit ;

At any receiving position the power from any of the various sending positions should be roughly equal.

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THIRD PART

MEASURING METHODS AND APPARATUS

3.1 TRANSMISSION STANDARDS

3.1.1 Reference Systems for the determination of reference equivalents

Three types of system exist for the determination of reference equivalents. These three types should comply with the conditions indicated below and are denoted by the following titles :

I. Master Telephone Transmission Reference System (S.F.E.R.T.)

II. Telephone Transmission Reference Systems

III. Working Standards.

CONDITIONS WHICH SHOULD BE FULFILLED BY REFERENCE SYSTEMS FOR THE DETERMINATION OF REFERENCE EQUIVALENTS

I. *The Master Telephone Transmission Reference System (S.F.E.R.T.).* — This system is clearly defined in the documents kept by the Secretariat-General of the C.C.I.F. and at the C.C.I.F. Laboratory. Furthermore the duplicated document entitled " Draft of summary of instructions on the use and maintenance of the C.C.I.F. Laboratory ", gives some information on this system and on its conditions of use.

A schematic of the Master Telephone Transmission Reference System is given in Figures 3 and 4 below, and shows the arrangement of the sending and receiving systems into which fixed distortion networks can be switched at will, by means of switches C_1 and C_2.

II. *Telephone Transmission Reference Systems.* — Each system is composed of a sending system, an artificial line and a receiving system complying with the following conditions :

1. — *Sending system*

Definition of the Acoustic Input to the Microphone. — In order to simplify the definition of the reference system, it is useful to start with the sound pressure rather than with the acoustic power. For the sending system the ratio of the voltage delivered to the input of the artificial line of the reference system to the sound pressure on the diaphragm of the microphone is consequently chosen as the measure of efficiency. Hence it is necessary to fix the essential external dimensions of the microphone and the manner in which it is to be used (see below).

Figure 5 below shows the dimensions which define the " normal speaking distance " used for measuring reference equivalents with the S.F.E.R.T.

Method of measuring the Acoustic Input to the Microphone. — For the measurement of this sound pressure any of the known and reliable methods may be used (e.g. thermophone, Rayleigh disc, or compensation methods). The C.C.I.F. is studying the possibility of using also the method termed " reciprocity " for measuring the sensitivity of condenser microphones (see Section **3**.3.1 below).

The method at present used in the C.C.I.F. Laboratory is described in Annex 5 of the *Book of Annexes* to Vol. IV of the *Green Book.*

Maximum permissible Acoustic Input for which the Microphone is to be designed. — The maximum acoustic pressure depends upon the permissible non-linear distortion. It has been found that when the types of microphones and receivers mentioned below, together with suitable amplifiers, are used, no appreciable non-linear distortion is produced over the range of sound pressure normally occurring.

Output Impedance of the sending system. — In order to have all required corrections in a positive direction it is convenient to select 600 ohms (zero angle) as the output impedance of the sending system. A tolerance of ± 5 per cent and an angle not greater than $\pm 10°$ may be permitted over the frequency range 100 to 5000 c/s.

Adjustment of the sensitivity of the sending system. — The sensitivity of the sending system must be adjustable in steps of not more than 0.02 nepers or 0.2 decibels, between limits of -1 to $+1$ neper or -10 to $+10$ decibels.

Ratio between the Voltage and the Acoustic Pressure (taken respectively at the Output and Input of the sending system) defining the zero point of the Sending System. — The zero point of the sending system should approximate to that of commercial standard systems in general use. (See later, under **3**.1.2.A, " Normal adjustment of the S.F.E.R.T.")

Frequency Range over which this Ratio must remain Constant. Permissible Variations of the Ratio in this Frequency Range. — The variations of this ratio must not exceed ± 0.2 nepers or ± 2 decibels in the frequency range between 100 and 5000 c/s.

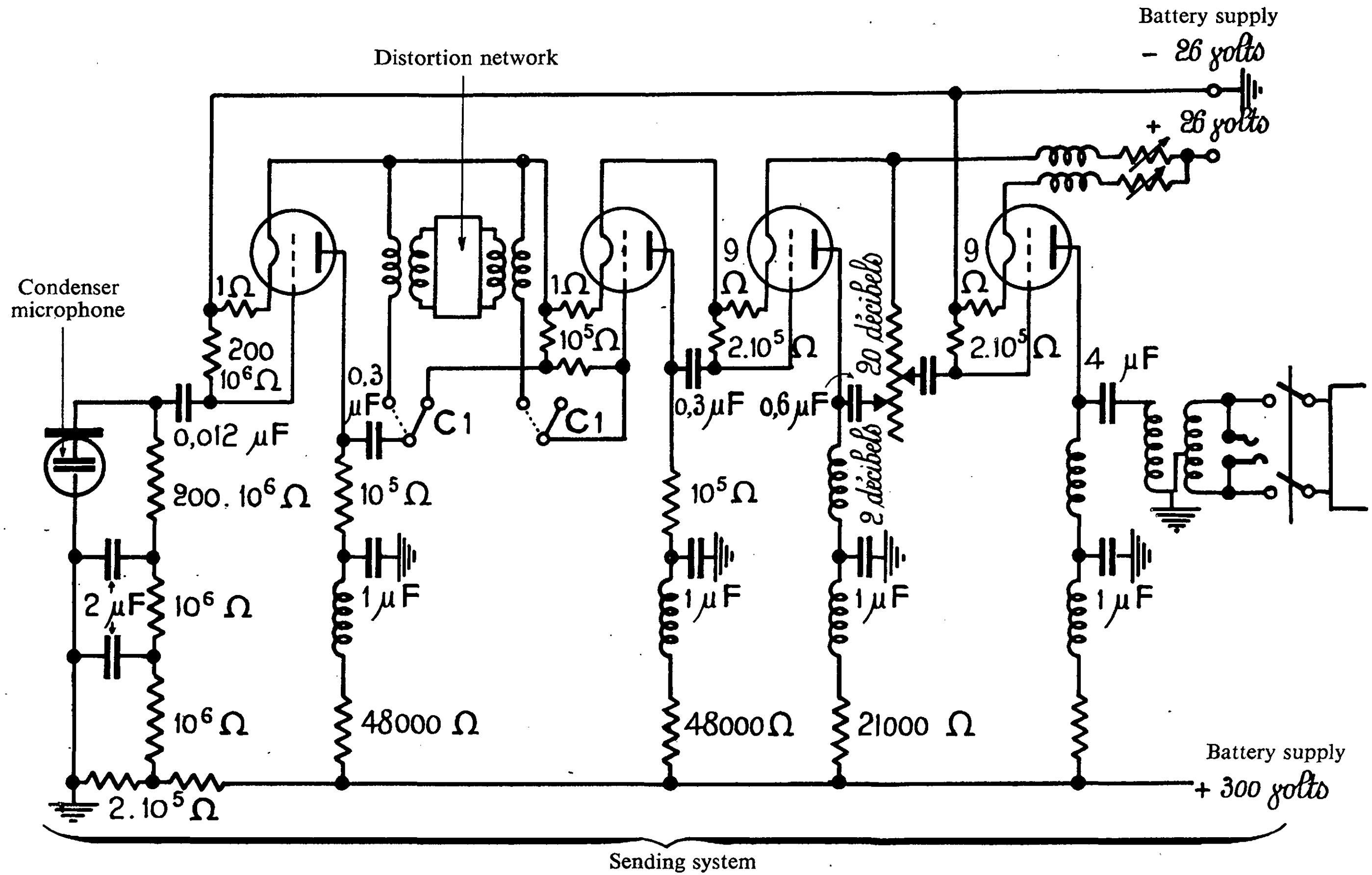


FIGURE 3. — *Schematic of the European Master Telephone Transmission Reference System (S.F.E.R.T.) Part 1*

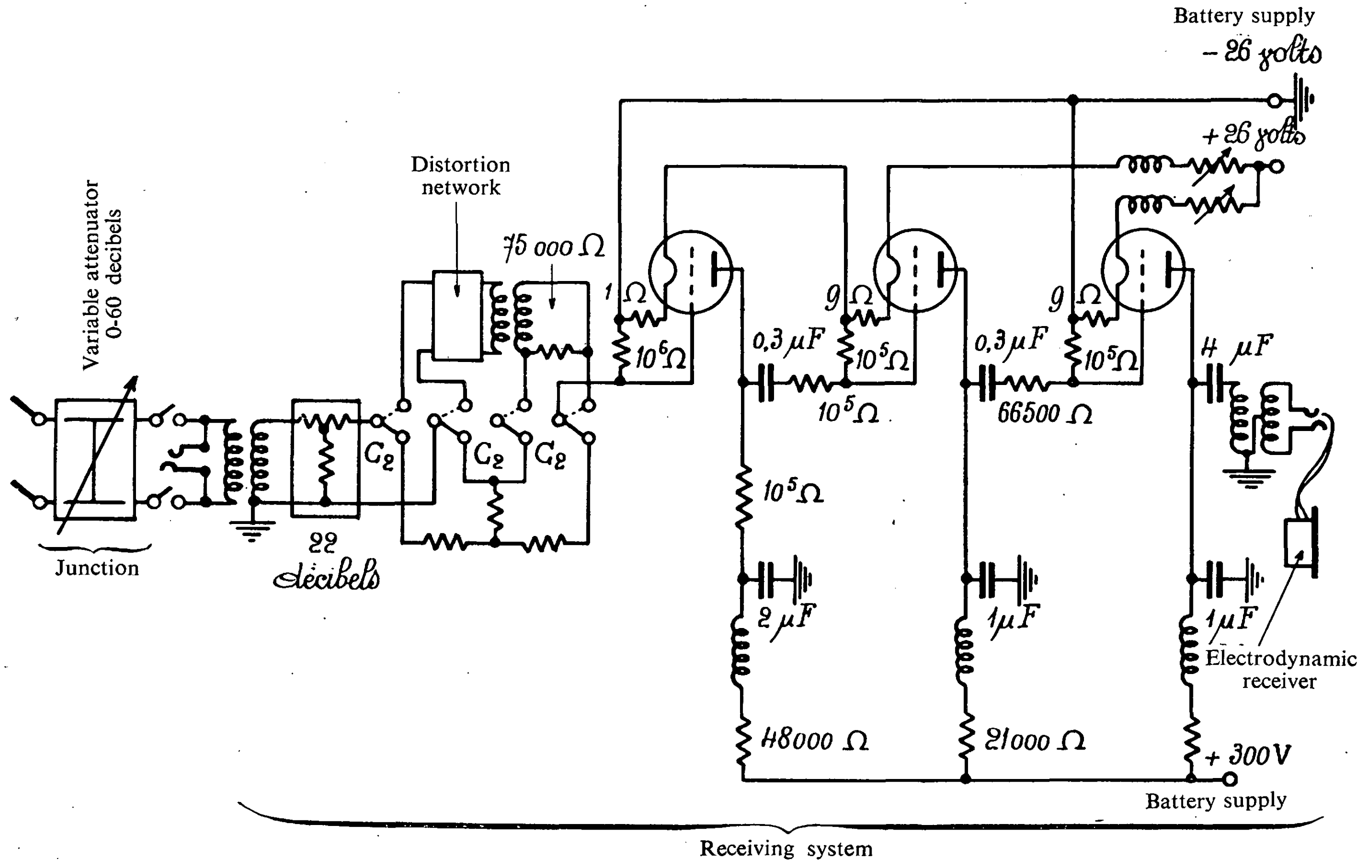
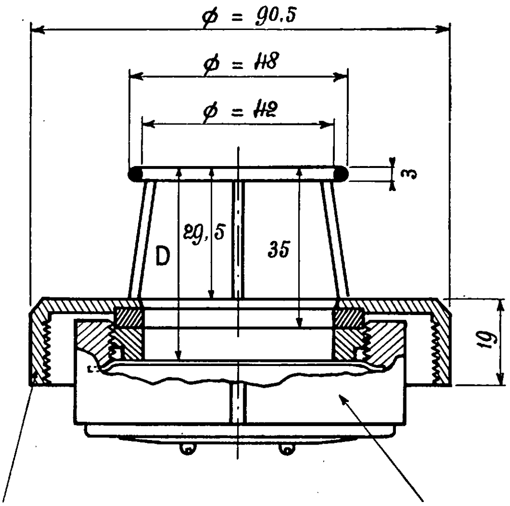


FIGURE 4. — *Schematic of the European Master Telephone Transmission Reference System (S.F.E.R.T.) Part 2*

Maximum permissible Non-Linear Distortion in the sending System: (a) *for the maximum pressure,* (b) *for a given fraction of this pressure.* — The maximum acoustic pressure on the microphone depends on the permissible non-linear distortion. Experience has shown that for sounds of normal intensity the use of the types of microphone and of receiver specified below and associated with suitable amplifiers, does not give rise to any harmful non-linear distortion.



Device for fixing the speaking distance

Condenser microphone of the S.F.E.R.T.

D = distance between the talkers' lips and the diagram of the microphone : 35 + 8.51 = 43.51
Dimensions in millimeters

FIGURE 5. — *The condenser microphone of the S.F.E.R.T. and the device for fixing the speaking distance*

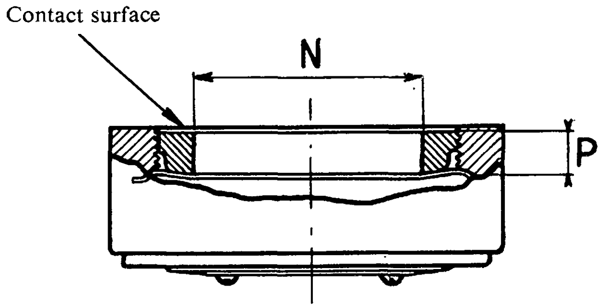
Design of a Sending System satisfying the required Conditions. — A sending system, consisting of a condenser microphone with stretched metallic diaphragm, and associated with a suitable amplifier, would satisfy the above conditions. Any other type of microphone equally well satisfying the above conditions would be acceptable. The essential dimensions of the condenser microphone are indicated in Figure 6. To compensate for the variations which may occur in the sending system a regulating device should be included in it.

2. — *Junction*

Characteristic Impedance of the Junction. — The junction must have a characteristic impedance of 600 ohms (zero angle). A tolerance $\pm 1\,\%$ in modulus and $\pm 2°$ in angle may be permitted over the frequency range 100 to 5000 c/s.

Adjustment of the Attenuation of the Junction. — The attenuation of the junction must be adjustable in steps of 0.02 nepers or 0.2 decibels between the limits 0-6 nepers or 0-60 decibels.

CROSS-SECTION OF THE CONDENSER MICROPHONE



Volume of the microphone cavity = 12.3 cm³

Dimensions in cm.

A	6, 667
B	2, 540
C	4, 7625
D	6, 670
L	0 400
N	4, 286
P	0. 851
Z	3, 968

FIGURE 6. — *Microphone*

CROSS-SECTION OF THE COUPLING DEVICE

Volume of coupler = 6 cm³

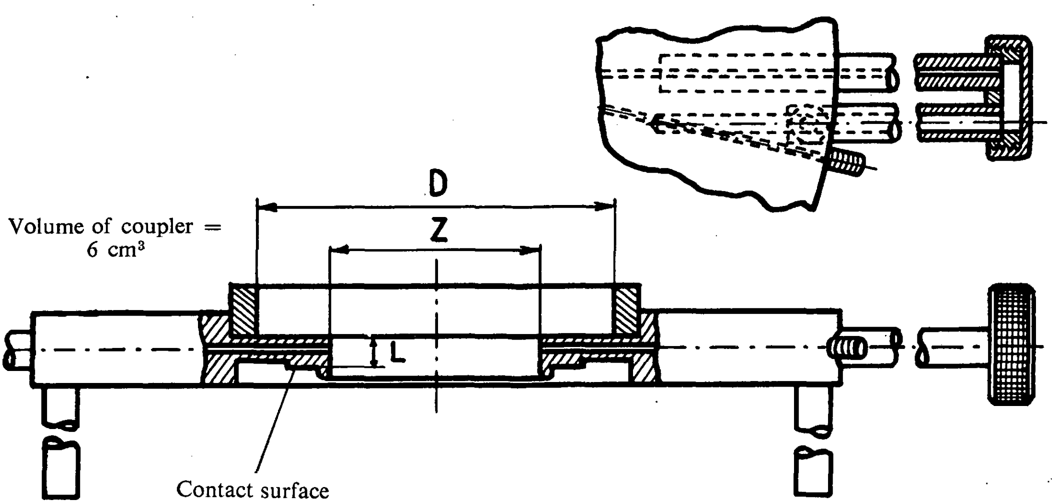


FIGURE 7. — *Coupling Device*

3. — *Receiving System*

Definition of the Acoustic Output furnished by the Receiver. — The sound pressure delivered at the end of a metallic acoustic coupler is regarded as a measure of the acoustic output. The essential dimensions of this coupler are given in figure 7. It is necessary to fix the essential dimensions of the receiver in the same way as for the microphone, and these are also given in figure 8.

SECTION OF ELECTRO-DYNAMIC RECEIVER, CONDENSER, MICROPHONE, AND ACOUSTING COUPLING DEVICE

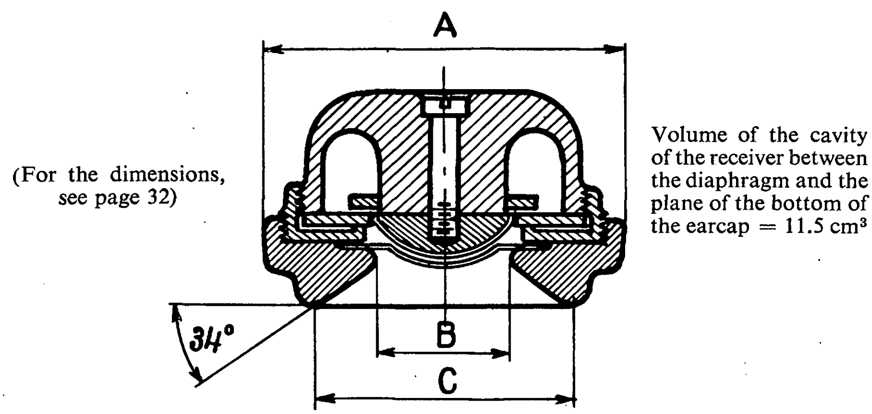


FIGURE 8. — *Receiver*

Method of Measuring the Acoustic Output of the Receiver. — The measurement of this sound pressure, as in the case of the transmitter, may be carried out by means of any of the known and reliable methods (in particular : calibration by means of a condenser microphone and the sound pressure compensation method).

The method at present used in the C.C.I.F. Laboratory is described in Annex 5 of the *Book of Annexes* to Vol. IV of the *Green Book.*

Input Impedance of the Receiving System. — The impedance of the receiving system must be 600 ohms (zero angle). A tolerance of $\pm 5\,\%$ on the modulus and $\pm 10°$ on the angle over the frequency range 100 to 5000 c/s may be permitted

Adjustment of the Sensitivity of the Receiving System. — The sensitivity of the receiving system must be adjustable in steps of not more than 0.02 nepers or 0.2 decibels between limits of -1 to $+1$ neper or -10 to $+10$ decibels.

Ratio between the Acoustic Pressure and the Voltage (taken respectively at the Output and Input of the receiving System) defining the zero Point of the Receiving System. — The sensitivity of the receiving system is determined by the ratio of the sound pressure in the acoustic coupler to the input voltage across the receiving system. The zero point of the receiving system should approximate to that of commercial standards in general use (see later, under 3.1.2.A " Normal adjustment of the S.F.E.R.T.").

Frequency Range over which this Ratio must remain Constant. Permissible Variations of the Ratio in this Frequency Range. — The variations of this ratio must not exceed ±0.4 nepers or ±4 decibels for frequencies lying between 300 and 3000 c/s or ±1 neper or ±10 decibels for frequencies between 100 and 5000 c/s.

Maximum Non-Linear Distortion permissible in the Receiving System. (a) *For Maximum Voltage,* (b) *for a given Fraction of this Voltage.* — The maximum voltage at the terminals of the receiving system depends on the permissible non-linear distortion. It has been found that for sounds of normal intensity the use of the types of receiver specified below, when associated with suitable amplifiers, does not give rise to any harmful non-linear distortion.

Design of a Receiving System Satisfying the required Conditions. — Any system satisfying the above conditions is admissible.

The earpiece of the receiver must have certain essential dimensions which are indicated in Figure 8. Also the volume of the cavity bounded by the receiver diaphragm, the walls of the earpiece and the plane of contact with the acoustic coupler must be approximately the same as indicated by the dimensions of this drawing.

III. *Working Standards.* — Working standards are systems which can be calibrated by voice-ear comparisons (telephonometric measurements) with a Telephone Transmission Reference System.

They consist of a sending system, a junction and a receiving system.

The sending and receiving systems should have characteristics similar to those of commercial telephone apparatus.

Although it may be more convenient to obtain working standards by choosing equipment of normal commercial types, different commercial types can be used.

To determine the relative equivalents of commercial telephone systems, essentially the following " Working Standards " are available :

(a) Working standards with subscribers' apparatus (S.E.T.A.B.).

(b) Working standards with electro-dynamic microphone and receiver (S.E.T.E.D.).

Note. — Various Working Standards have been used in the past : Working Standard with carbon microphone (S.E.T.A.C.), Working Standard with electro-dynamic microphone. Information on these systems together with their methods of use can be found in Volume IV of the *Yellow Book* (pp. 147-164). Use of these systems is no longer advised.

According to the definitions adopted by the C.C.I.F. for the reference equivalents of a system or of a part of a system (see the definitions given in the first part of this volume), when telephonometric measurements are made to determine a reference equivalent, the system or the part of the system being studied should be compared either with the S.F.E.R.T. without distortion or with a working standard which has already been calibrated against the S.F.E.R.T. without distortion, on condition that this working standard should either have no distortion or have distortion, so as to have similar characteristics from the point of view of distortion to those of the system or the part of the system being studied.

Administrations and private operating Companies who wish to set up a S.E.T.A.B. system are recommended to choose from their normal commercial equipment, items whose sensitivity (measured by comparison with one of the other working standards at their disposal) varies as little as possible : e.g. a variation of ±2 decibels relative to the mean value seems at present admissible.

These items selected for their stability can form working standards which should be calibrated frequently either against the S.F.E.R.T. without distortion or against a working standard which has already been calibrated against the S.F.E.R.T. without distortion.

The " S.E.T.A.B. " and " S.E.T.E.D. " working standards are described respectively in Appendixes I and II below.

Administrations and Private Operating Companies which do not possess a working standard which has itself already been compared with the S.F.E.R.T. can have the stability of their commercial apparatus checked either by the C.C.I.F. Laboratory in Geneva or by an Administration or Private Operating Company which does possess a working standard already itself compared with the S.F.E.R.T.

3.1.2 Calibration of reference systems for the determination of reference equivalents

A. — Normal adjustment of the S.F.E.R.T.

The characteristic curves of the microphone and receiver of the S.F.E.R.T. will be referred, respectively, to one volt per dyne/cm³ for the sending system, and one dyne/cm² per volt for the receiving system. The values, for the different frequencies to be considered, of the ratios of volts per dyne/cm² and of dynes/cm² per volt, proposed for characterising the normal adjustment of the sending and receiving systems, with and without distortion, and the values in dynes/cm² per dynes/cm² for the complete reference system containing a junction of zero decibels, are given in Tables I to V below. With each of these values is given the corresponding number of decibels relative to one volt per dyne/cm² for the sending system, to one dyne/cm² per volt for the receiving system, and to one dyne/cm² per dyne/cm² for the complete system.

The maximum permissible deviations of the characteristic curves of the reference system, and of its components, for any frequency must not exceed ±0.1 nepers or ±1.0 decibels from the values given in the tables attached (for frequencies between 100 and 5000 c/s.)

The arithmetic means of the values given in Tables I to V, for frequencies between 200 and 3600 c/s inclusive, will be taken as the specification for adjustment of the Master System without distortion, and for its components. In cases of any difference between the characteristic curves of the sending and receiving systems without distortion, and the values given in the attached tables, the setting of the potentiometer for each element will be changed by a quantity equal to the mean of the differences, in decibels, between the test results at the time considered, and the values given in the tables below (for frequencies given in these tables which are between 200 and 3600 c/s).

For the sending system and for the receiving system with the distortion networks the maximum permissible deviation for any frequency is the same as in the preceding case for components without distortion. To ensure that adjustment at any instant takes into account deviation with respect to the values given in the attached tables, the arithmetic mean in decibels of the deviations obtained for the three frequencies 800, 1100 and 1300 c/s will be taken.

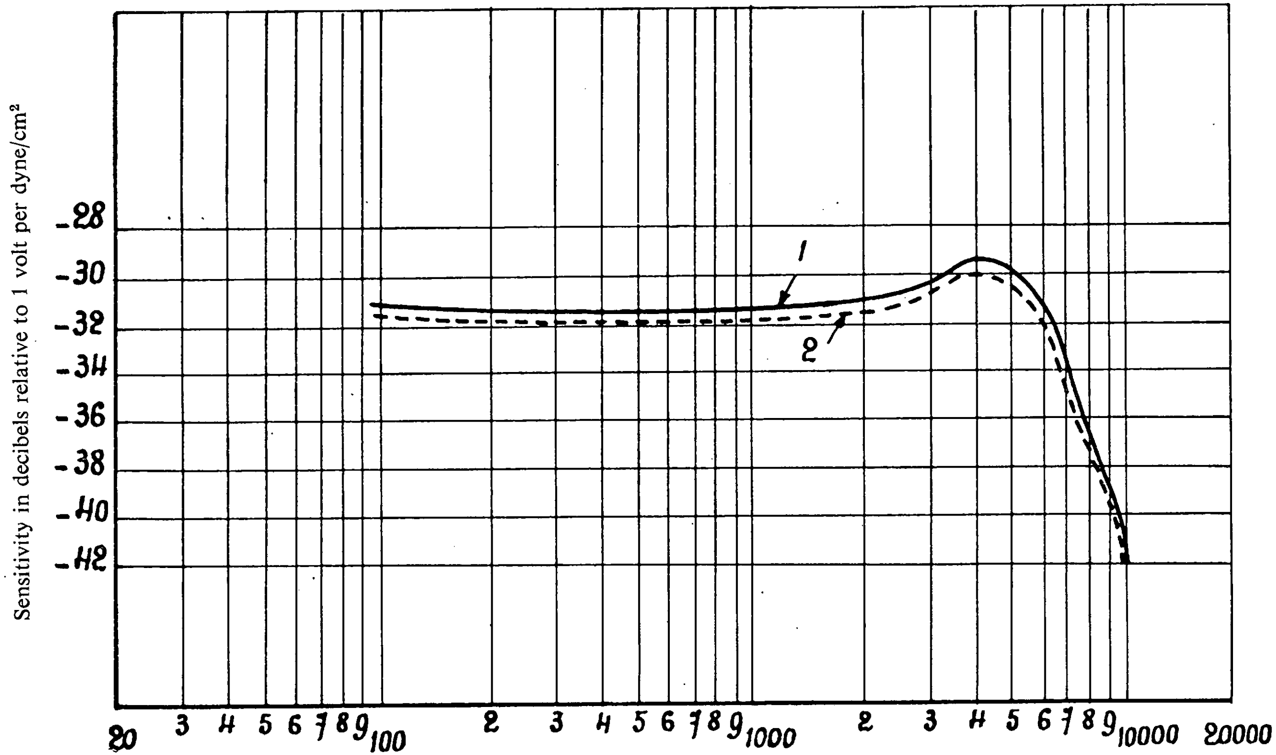
The characteristic curves in Figures 9 to 12 below furnish an illustration of the working of the sending and receiving systems of the S.F.E.R.T. (without and with distortion) ; the dotted curves numbered 2 represent the normal adjustment of the sending and receiving systems for the standard microphone No. 3824 and of the standard receiver No. 22 at the date these curves were drawn (January 1930).

Rules have been laid down for obtaining the characteristic curves of the S.F.E.R.T. and its components.

1. Characteristic curves of each condenser microphone and of the associated amplifier ;
2. Combination of the characteristic curve of one of the condenser microphones with that of the associated amplifier ;
3. Characteristic curves of each electro-dynamic receiver (moving-coil type) and of the associated amplifier ;
4. Combination of the characteristic curve of one of the electro-dynamic receivers with that of the associated amplifier ;
5. The characteristic curves obtained with one of the condenser microphones and one of the electro-dynamic receivers, when the distorting networks are inserted in the corresponding amplifiers.

For these purposes all the data concerning the characteristic curves should be expressed in decibels, and referred to one volt per dyne/cm^2 for the microphones, and to one dyne/cm^2 per volt for the receivers. Further, the test results will be given for one of the condenser microphones with four thermophones.

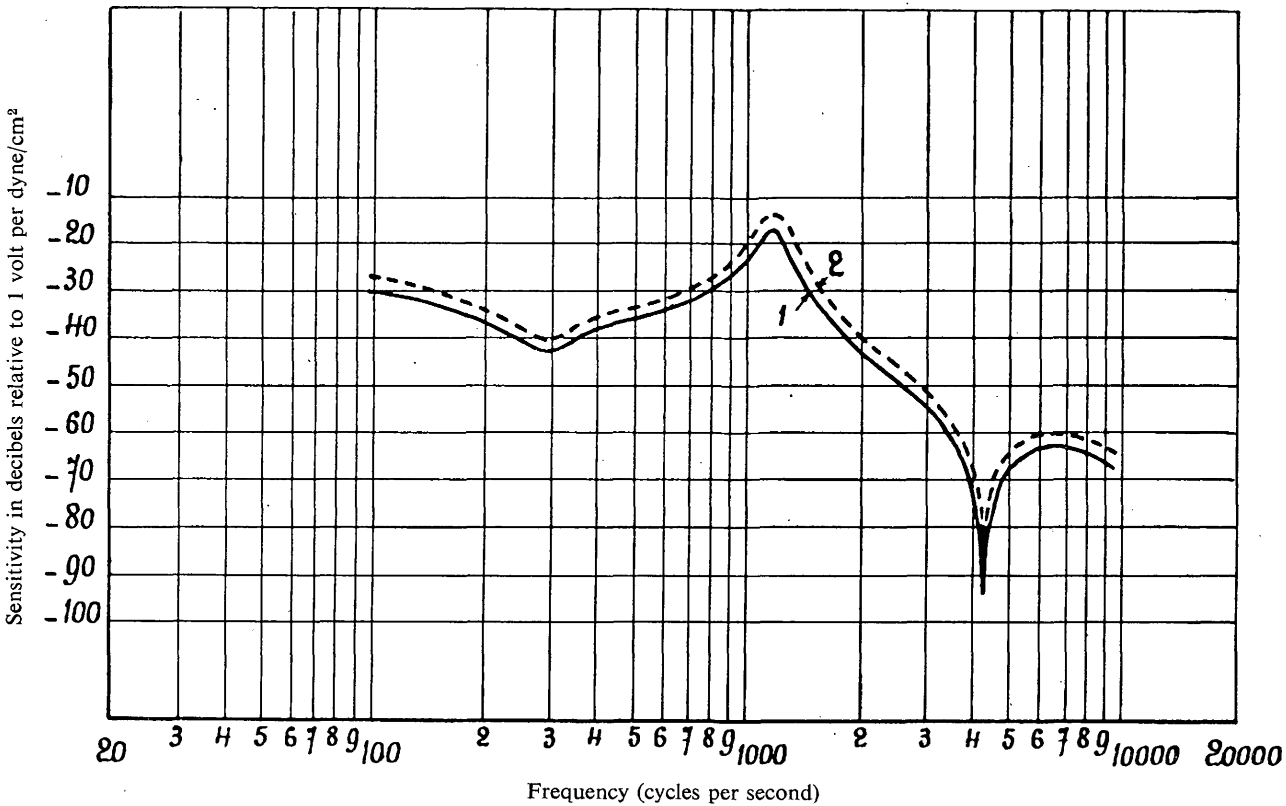
In order to reduce the noise in the Master System to a negligible quantity, periodic measurements are also made of the noise produced by the elements of the S.F.E.R.T. This procedure is also followed in order to determine the noise which may be produced by the condenser microphone under operating conditions.



Frequency (cycles per second)

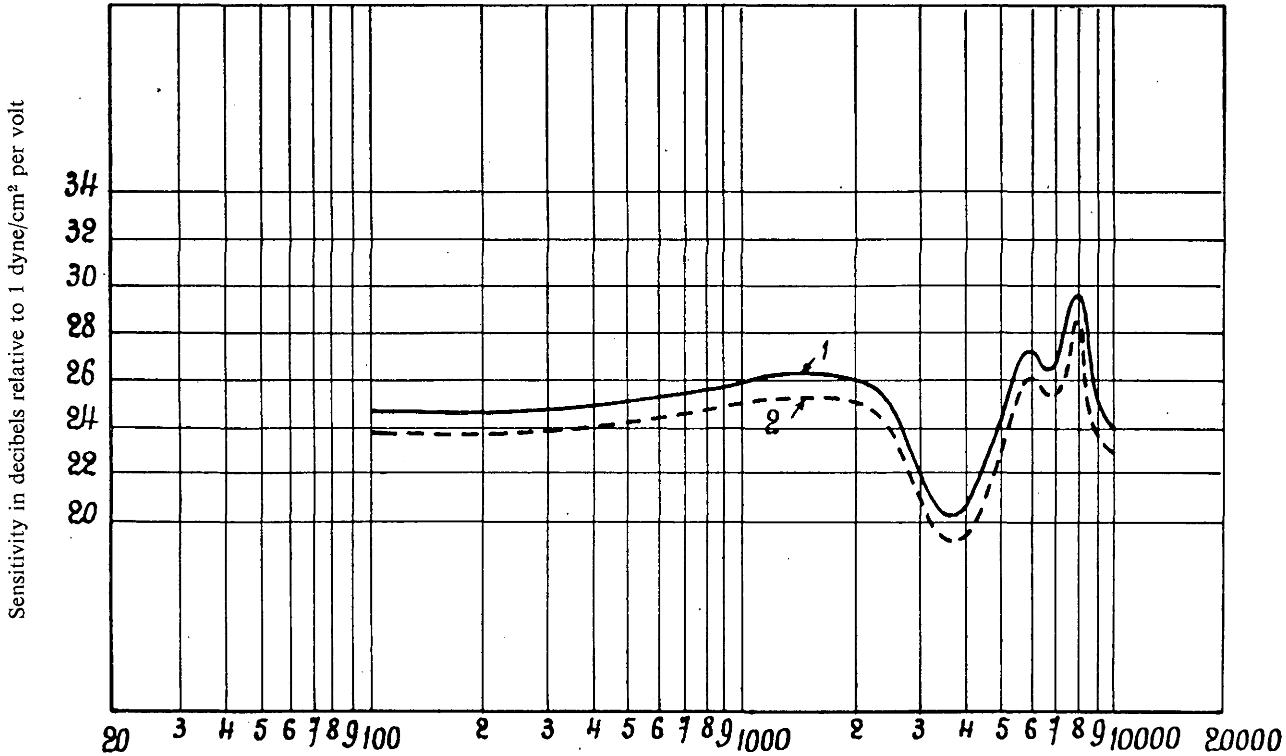
Curve 1. — Dials set to zero
Curve 2. — Dials set at 0.4 decibels

FIGURE 9. — *Characteristic curve of the sending system (without distortion) of the S.F.E.R.T. Standard Microphone No. 3824*



Curve 1. — Dials set to zero
Curve 2. — Dials set at +2.3 decibels

FIGURE 10. — *Characteristic curve of the sending system (with distortion) of the S.F.E.R.T. Standard Microphone No. 3824*



Curve 1. — Dials set to zero
Curve 2. — Dials set at −1.0 decibels

FIGURE 11. — *Characteristic curve of the receiving system (without distortion) of the S.F.E.R.T. Standard Receiver No. 22*

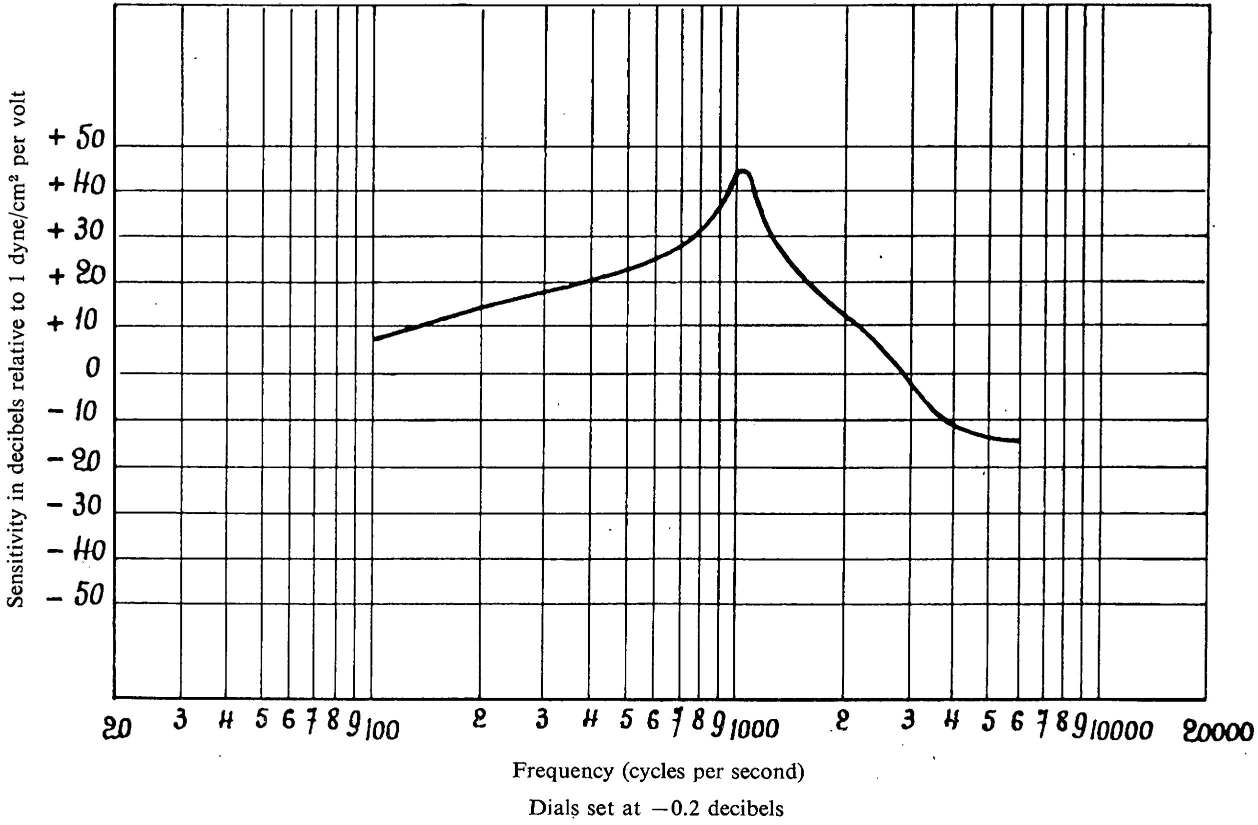


FIGURE 12. — *Characteristic curve of the receiving system (with distortion) of the S.F.E.R.T. Standard Receiver No. 22*

TABLE I

Characteristic Values which define normal adjustment of the Distortionless Sending System of the S.F.E.R.T.

Frequency	Volts per dyne/cm²	Decibels *	Frequency	Volts per dyne/cm²	Decibels *
100	0.0272	−31.3	1 800	0.0263	−31.6
200	0.0272	−31.3	2 100	0.0269	−31.4
300	0.0260	−31.7	2 400	0.0269	−31.4
400	0.0257	−31.8	2 700	0.0275	−31.2
500	0.0253	−31.9	3 000	0.0284	−30.9
600	0.0253	−31.9	3 300	0.0294	−30.6
700	0.0253	−31.9	3 600	0.0305	−30.3
800	0.0253	−31.9	4 000	0.0323	−29.8
900	0.0257	−31.8	5 000	0.0337	−29.4
1 000	0.0257	−31.8	6 000	0.0309	−30.2
1 100	0.0257	−31.8	7 000	0.0229	−32.8
1 200	0.0257	−31.8	8 000	0.0165	−35.7
1 300	0.0260	−31.7	9 000	0.0121	−38.4
1 500	0.0263	−31.6	10 000	0.0092	−40.7

Frequency range	Average value in volts per dyne/cm²	Average value in decibels
500-2500 c/s	0.0259	−31.7
200-3600 c/s	0.0266	−31.5

* Decibels referred to 1 volt per dyne/cm².

TABLE II

Characteristic Values which define normal adjustment of the Distortionless Receiving System of the S.F.E.R.T.

Frequency	Dynes/cm² per volt	Decibels *	Frequency	Dynes/cm² per volt	Decibels *
100	16.4	24.3	1 800	17.6	24.9
200	17.4	24.8	2 100	17.8	25.0
300	17.6	24.9	2 400	16.2	24.2
400	17.2	24.7	2 700	14.7	23.3
500	17.0	24.6	3 000	13.3	22.5
600	16.8	24.5	3 300	12.3	21.8
700	16.8	24.5	3 600	11.1	20.9
800	16.8	24.5	4 000	10.5	20.4
900	16.8	24.5	5 000	12.3	21.8
1 000	17.0	24.6	6 000	17.2	24.7
1 100	17.0	24.6	7 000	14.5	23.2
1 200	17.2	24.7	8 000	14.5	23.2
1 300	17.2	24.7	9 000	14.5	23.2
1 500	17.2	24.7	10 000	10.9	20.7

Frequency range	Average value in dynes/cm² per volt	Average value in decibels
500-2500 c/s	17.03	24.6
200-3600 c/s	16.28	24.2

* Decibels referred to 1 dyne/cm² per volt.

Table III

Characteristic values which define normal adjustment of the complete S.F.E.R.T. without Distortion and with 0 Decibels in Circuit

Frequency	Dynes/cm² per dyne/cm²	Decibels *	Frequency	Dynes/cm² per dyne/cm²	Decibels *
100	0.446	−7.0	1 800	0.462	− 6.7
200	0.474	−6.5	2 100	0.479	− 6.4
300	0.458	−6.8	2 400	0.435	− 7.2
400	0.441	−7.1	2 700	0.404	− 7.9
500	0.431	−7.3	3 000	0.378	− 8.4
600	0.426	−7.4	3 300	0.362	− 8·8
700	0.426	−7.4	3 600	0.338	− 9.4
800	0.426	−7.4	4 000	0.338	− 9.4
900	0.431	−7.3	5 000	0.415	− 7.6
1 000	0.436	−7.2	6 000	0.531	− 5.5
1 100	0.436	−7.2	7 000	0.332	− 9.6
1 200	0.441	−7.1	8 000	0.239	−12.5
1 300	0.446	−7.0	9 000	0.175	−15.2
1 500	0.452	−6.9	10 000	0.100	−20.0

Frequency range	Average value dynes/cm² per dyne/cm²	Average value in decibels
400-2500 c/s	0.441	−7.1
200-3600 c/s	0.429	−7.3

* Decibels referred to 1 dyne/cm² per dyne/cm².

Table IV

Characteristic Values of the Sending System with Distortion Network No. 1

Frequency	Volts per dyne/cm²	Decibels *	Frequency	Volts per dyne/cm²	Decibels *
100	0.0618	−24.2	1 800	0.0169	−35.5
200	0.0275	−31.2	2 100	0.00977	−40.2
300	0.0090	−40.9	2 400	0.00610	−44.3
400	0.0143	−36.9	2 700	0.00408	−47.8
500	0.0204	−33.8	3 000	0.00299	−50.5
600	0.0263	−31.6	3 300	0.00202	−53.9
700	0.0316	−30.0	3 600	0.00133	−57.6
800	0.0390	−28.2	4 000	0.000611	−64.3
900	0.0483	−26.3	4 400	0.0000751	−82.5
1 000	0.0741	−22.6	5 000	0.000531	−65.5
1 100	0.139	−17.1	6 000	0.00104	−59.7
1 160	0.185	−14.6	7 000	0.00100	−60.0
1 200	0.182	−14.8	8 000	0.000824	−61.7
1 300	0.118	−18.6	9 000	0.000684	−63.3
1 500	0.039	−28.2	10 000	0.000575	−64.8

* Referred to 1 volt per dyne/cm².

TABLE V

Characteristic Values of the Receiving System with Distortion Network No. 1

Frequency	Dynes/cm² per volt	Decibels *	Frequency	Dynes/cm² per volt	Decibels *
100	2.79	8.9	1 200	43.5	32.8
200	5.4	14.6	1 300	24.0	27.6
300	7.8	17.8	1 500	12.0	21.6
400	10.4	20.3	1 800	5.93	15.5
500	13.3	22.5	2 100	3.39	10.6
600	17.4	24.8	2 400	2.07	6.3
700	22.5	27.0	2 700	1.259	2.0
800	29.3	29.3	3 000	0.813	− 1.8
900	44.5	33.2	4 000	0.248	−12.1
1 000	96.3	39.7	5 000	0.133	−17.5
1 060	150.0	43.5	6 000	0.100	−20.0
1 100	116.3	41.3			

* Decibels referred to 1 dyne/cm² per volt.

B. — NORMAL VOCAL POWER FOR TELEPHONOMETRIC MEASUREMENTS

The volume indicator termed " Volume Indicator " used in the C.C.I.F. Laboratory is connected at the output of the sending system of the S.F.E.R.T. The dial of this volume indicator should be set at −16 decibels and the operator speaks at the microphone of the sending system of the S.F.E.R.T. using such a vocal power that the needle of the measuring instrument reaches the mark. This vocal power is the " normal vocal power for telephonometric measurements ". The " volume (of speech sounds) " corresponding to this " normal vocal power " is the " normal volume for telephonometric measurements ".

C. — COMPARISON OF REFERENCE SYSTEMS WITH THE MASTER REFERENCE SYSTEM AND THE NECESSARY INTERVALS OF TIME BETWEEN SUCH MEASUREMENTS

As a reference system complying with the above mentioned conditions may differ from the Master System, the first calibration should be made in the C.C.I.F. Laboratory using the complete sending and receiving systems (including the amplifiers) of the system to be calibrated. This first calibration will indicate whether subsequently it will be sufficient to calibrate only the microphone and receivers of the reference system by comparison with those of the Master System.

D. — INITIAL COMPARISON OF WORKING STANDARDS WITH THE S.F.E.R.T. OR WITH A REFERENCE SYSTEM

Every working standard, before being put into service, should be compared either with the Master Reference System (distortionless S.F.E.R.T.) or with a reference system which has itself been compared with the distortionless S.F.E.R.T.

This comparison is intended to define the transmission qualities of a component of the Working Standard as compared with the corresponding component of the S.F.E.R.T. It indicates in transmission units (nepers or decibels) the amount by which the respective sending or receiving system of the Working Standard is worse or better relative to the sending or receiving system of the S.F.E.R.T.

The method of testing used is the following :

The tests are carried out by telephonometric comparison (voice and ear tests), substituting the component to be compared (sending or receiving system) for the corresponding component of the S.F.E.R.T. An artificial line of adjustable loss, in series with the more efficient system, enables the efficiencies of the two systems to be made equal.

The circuit diagrams showing the general method of calibrating the sending and receiving systems of the Working Standard with the S.F.E.R.T. are shown in Figures 13 and 14 respectively.

The method of comparison employed in the C.C.I.F. Laboratory is based on tests (elementary balances, see later) by only two operators (one operator speaking and one listening) and the use of three distortionless attenuators with characteristic impedances of 600 ohms at zero angle.

The first attenuator is set to a value of 24 decibels (or 2.8 nepers) at the C.C.I.F. Laboratory (in any case the value of this attenuator should be greater than 15 decibels (or 1.8 nepers) in order :

1. To adjust the current in the receiving systems to a value such that the best conditions for comparative listening tests are obtained ;

2. To prevent electrical interaction effects between the sending and receiving systems.

The second attenuator introduces a " hidden " attenuation because its value is unknown to the listening operator.

The third attenuator, called a " balancing attenuator " is adjusted by the listening operator and is to enable equality of sounds to be obtained.

A combination of three keys (See Figures 13 and 14) which can be operated simultaneously, provides the switching necessary for telephonometric comparisons.

A volume indicator (the Volume Indicator of the S.F.E.R.T.) enables the speaking operator to maintain the " normal volume for telephonometric tests " as defined above under B. The reference equivalents of the transmitting and receiving systems of the Working Standard considered are obtained from the average of a certain number of telephonometric tests called " Elementary Balances ".

To make an elementary balance, the following procedure is adopted :

a) *Tests on a Sending System* (Figure 13)

Each elementary balance is carried out by two operators.

The speaking operator (P) having adjusted the hidden loss to a certain value (known only to himself) speaks conventional phrases alternately into each microphone. In the C.C.I.F. Laboratory the conventional phrase is as follows : Paris-Bordeaux-Le Mans-St. Leu-Léon-Loudun.

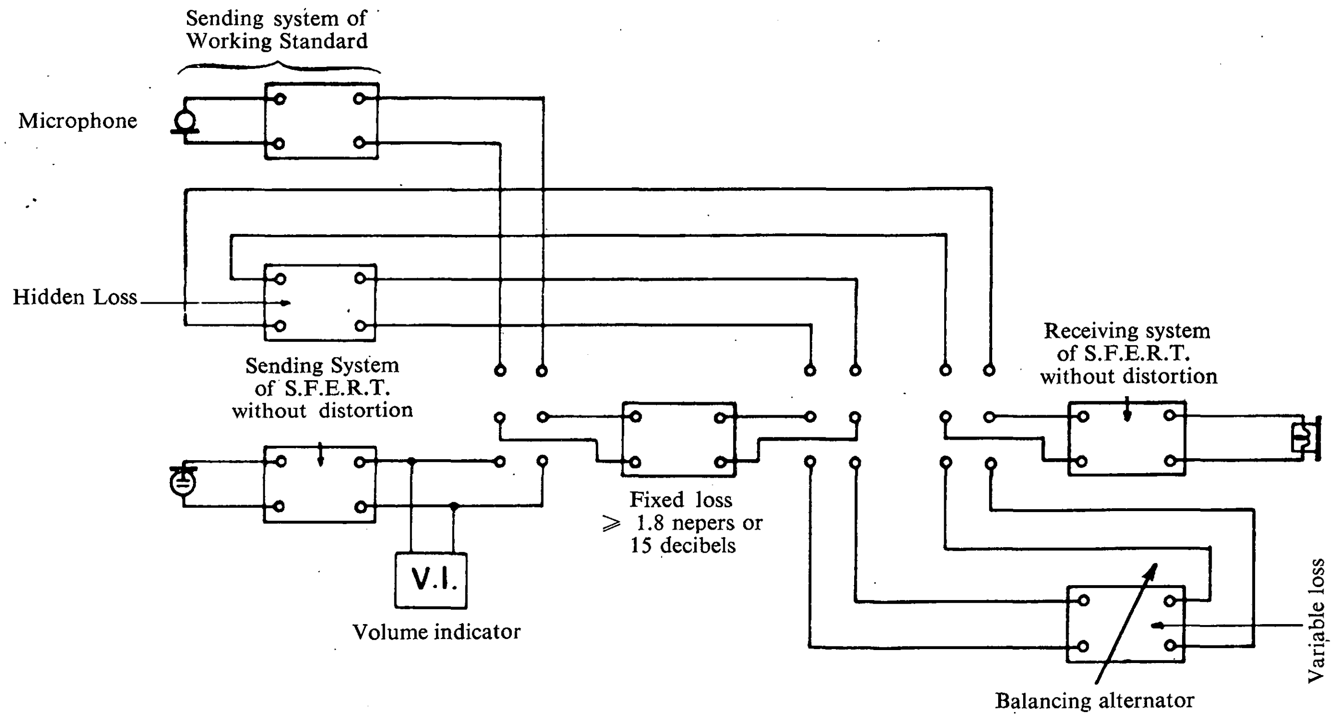


FIGURE 13. — *Comparison for sending of a Working Standard with the S.F.E.R.T.*

Note. — For information ; the C.C.I.F. Laboratory adjusts the fixed loss to the value of 24 decibels (or 2.8 nepers)

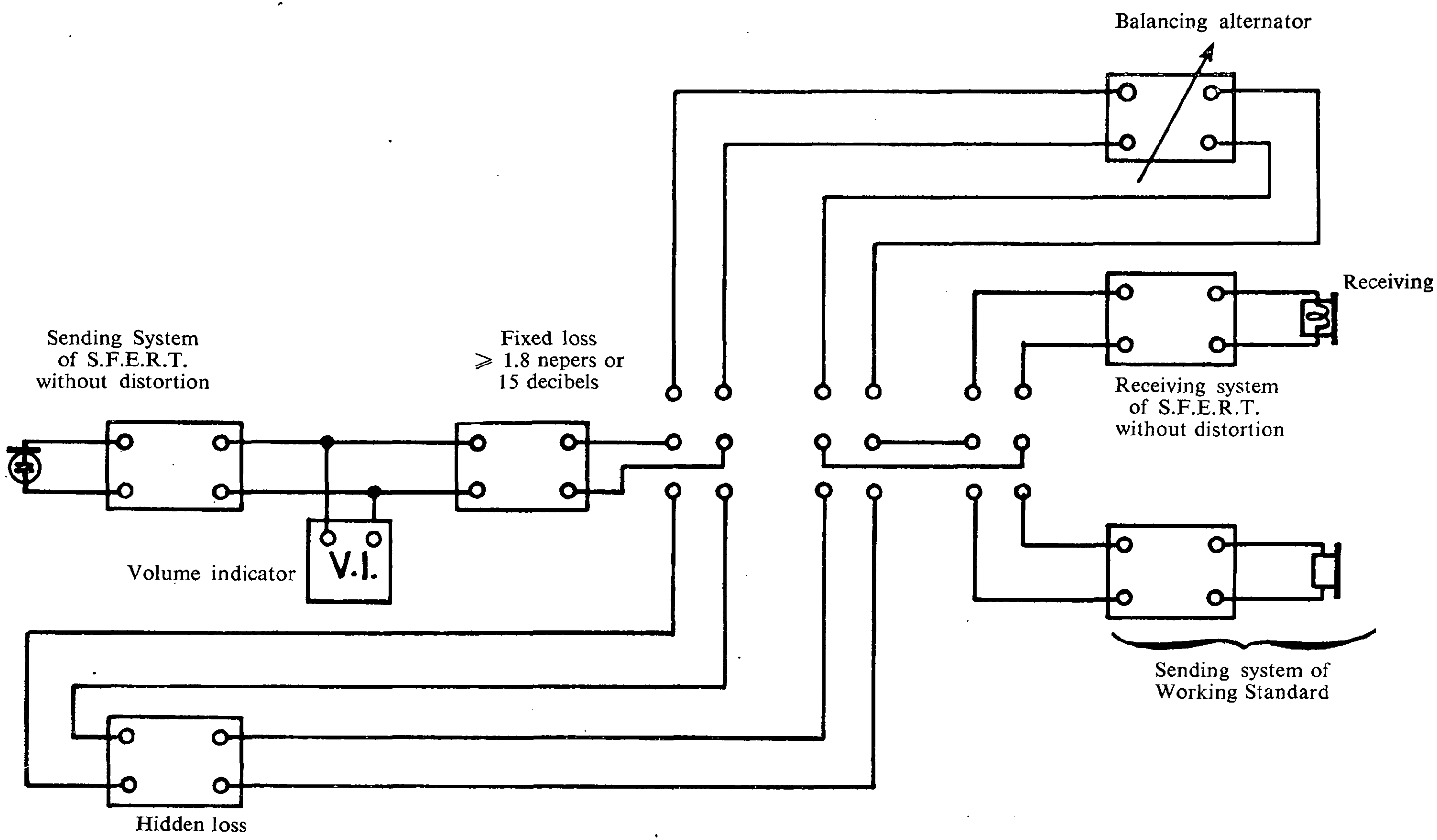


FIGURE 14. — *Comparison for receiving of a Working Standard with the S.F.E.R.T.*

Note. — For information ; the C.C.I.F. Laboratory adjusts the fixed loss to the value of 24 decibels (or 2.8 nepers)

The operator (P) endeavours to speak in a normal tone at a normal conversational speed and to preserve the " normal volume for telephonometric tests ". He operates the keys simultaneously so that the necessary connections are made according to the microphone employed. The listening operator (E) adjusts the balancing attenuator, of which he has control, to obtain equality of sound intensity for the two sets of positions of the keys.

b) *Tests on a Receiving System* (Figure 14)

Each elementary balance is made by two operators. The speaking operator (P) having adjusted the hidden loss to a certain value (known only to himself) repeats, in a normal tone and at a normal conversational speech, while preserving the " normal volume for telephonometric tests ", the conventional phrases into the microphone of the S.F.E.R.T. sending system. He operates the keys putting the S.F.E.R.T. receiving system and the Working Standard receiving system successively into circuit with the S.F.E.R.T. sending system. The operator (E) listens with the two receivers (S.F.E.R.T. receiver and the receiver of the Working Standard under test) successively. He also adjusts the balancing attenuator so as to obtain equality of sound intensity with each of the two receivers.

Each series of telephonometric tests consists of a certain number of elementary balances. The number of elementary balances which makes up a series of tests is at least six ; it is normally twenty at the C.C.I.F. Laboratory with a normal crew of five operators and can be increased whenever considered necessary.

The test results are recorded on calibration forms as shown below (Forms E and F) which are delivered to the various Administrations and Private Operating companies ; these forms give the following information :

1. Number and specification of the equipment tested.
2. Date or dates of tests.
3. Value of the reference equivalent.
4. Standard deviation.
5. Quality of the sound with respect to the S.F.E.R.T. as indicated below.

When the sound balance has been obtained in a voice test, the listening operator compares the quality of the sound of the apparatus under test with the quality of the sound of the Reference System. He records the result of this comparison in the " Remarks " column of the forms. The scale of comparison is as follows :

Comparison :	Abbreviation entered in the column " Remarks "
Shrill	A (shrill)
Equal	=
Deep	G (deep)

Form E

C.C.I.F. Laboratory

Test Form No. ...

Reference equivalent of the *sending* system of the working standard

Microphone No. ...

Mean reference equivalent :
Standard deviation :
Working Resistance :
Quality :
Date of Tests :
Remarks :

Form F

C.C.I.F. Laboratory

Test Form No. ...

Reference equivalent of the *receiving* system of the working standard

Receiver No. ...

Mean Reference Equivalent :
Standard deviation :
Quality :
Date of Test :
Remarks :

(c) *Microphone Resistance Tests*

The resistance test of the microphone is carried out during the voice test by means of the voltmeter-ammeter method. The voltmeter and ammeter employed are of the damped type.

Several observations are made while speaking into the microphone under test, and the resistance value taken is the mean of those obtained during the tests.

Note. — Values of reference equivalent supplied by the C.C.I.F. Laboratory are the means of the elementary balances. At the same time mention is made in the Reports giving the results of the error likely to affect these measurements when account is taken of the possible variations from one crew to another or of one combination of operators to another.

E. — Periodic Calibration of Standard Equipment by the C.C.I.F. Laboratory

It is necessary periodically to compare standard equipment with the international telephonometric basis formed by the S.F.E.R.T. without distortion or with a reference system itself calibrated with respect to the distortionless S.F.E.R.T The recommendations concerning the despatch of equipment to the C.C.I.F. Laboratory are given in Section 3.1.6 below.

APPENDIX I

Rules concerning the composition of Working Standards with subscriber's equipment (S.E.T.A.B.)

Working Standards with subscriber's equipment consist of a sending system, an attenuator and a receiving system. The sending and receiving systems consist respectively of subscriber's sets of a commercial type associated with a subscriber's line and a feeding bridge. The feeding current should be low enough to avoid any risk of damage to or instability of the microphone.

The attenuator connected between the sending and receiving systems should have a minimum loss of 1.8 nepers (15 decibels) and an impedance of 600 ohms.

The system should be complete with a volume meter to enable the vocal power used during telephonometric tests to be maintained.

It is, of course, essential for the microphones and receivers to satisfy certain conditions to enable them to be considered as standards. Administrations and Private Operating Companies who have not already done so may therefore send to the C.C.I.F. Laboratory six handsets which are declared to have been stable during preliminary tests extending over a period of six months.

The C.C.I.F. Laboratory will first carry out a preliminary articulation test to assess the quality of the apparatus ; then it will conduct at intervals of two months five measurements of sending and receiving reference equivalent in order to check the stability of the apparatus.

After these preliminary measurements the C.C.I.F. Laboratory will choose, from the six items of the same type which have been sent there, three items which will serve as sending standards and three items which will serve as receiving standards. It will proceed to the calibration of the standard apparatus thus selected under the following conditions :

1. Determination of the sending and receiving reference equivalents. For each measurement at least 40 elementary balances will be made in order to obtain reliable values of reference equivalents.

2. Articulation measurements. The mean value of articulation for the three microphones selected will be measured together with that for the three receivers selected.

The technical conditions for this measurement will be defined by agreement between the Administration or Private Operating Company concerned and the C.C.I.F. Laboratory.

APPENDIX II

Description of a Working Standard having electro-dynamic microphone and receiver (S.E.T.E.D.)

Even in a working standard with modern instruments (S.E.T.A.B.), the stability obtainable is less than is desirable and there remains the necessity of calibrating the standards by periodical comparison with the S.F.E.R.T. or another system of greater stability.

A working standard has therefore been designed to use a moving coil microphone and receiver furnishing a high quality circuit with stable characteristics.

The system has been designed for high quality speech because it is considered that the standard with which commercial systems are compared should always be better in performance than the commercial systems tested ; there is also another reason, namely the provision of a stable system with which to compare commercial systems on an articulation basis since this seems likely to become the basis of transmission planning instead of planning on the loudness basis of reference equivalents.

The new working standard is provided with means for absolute calibration of its microphones and receivers. It is sufficiently simple to be installed in many laboratories, and will serve as a primary standard on the spot, making it seldom necessary for those that have this working standard to send transmitters and receivers elsewhere for calibration.

The S.E.T.E.D. Working Standard comprises :

1. A rack with 19 inch panels of the following dimensions :

6 ft ½ in. high
2 ft 9 in. wide
2 ft deep

On this rack are mounted a vu-meter ; a microphone amplifier and its equalizer ; a control panel which contains an attenuator ; a filter ; push buttons and relays to change the test circuit and jacks for external connections ; a receiver amplifier with equalizer and a mains operated power unit. This weighs 405 kg altogether.

2. Standard piezoelectric quartz microphone for objective calibration of the transducers (microphones and receivers).

3. Moving coil microphone and receiver.

4. Accessories.

The Working Standard includes a volume meter of the vu-meter type for the adjustment of the vocal power of the talker and also as an indicating voltmeter for objective calibrations.

An oscillator for calibration over the range 100 to 5000 c/s is required; this is not included as part of the equipment.

The moving coil microphone is of a special type designed for close-talking. It is substantially protected against the effects of breath moisture.

To standardise the lip position a ring gauge is fitted to the microphone, which is mounted on an adjustable stand.

The frequency characteristic of the microphone and its equaliser is such that the ratio of its output voltage to the sound pressure at the speaker's lip position is constant over the working frequency range.

The receiver is furnished with an equaliser such that the ratio of the sound pressure in a human ear to the voltage across the input of the equaliser varies as a function of frequency according to the " ortho-telephonic " response curve.

The gain of the amplifiers is adjustable so as to obtain normal values of 62.1 decibels for the microphone amplifier and 17.5 decibels for the receiver amplifier.

The calibration of an amplifier is carried out by comparing its gain against the loss of a pad of fixed resistors using a single-frequency signal from an external oscillator and the volume indicator as a meter indicating equality. The amplifier has generous negative feedback and there is ordinarily no need to specify stabilised mains supply.

A band pass filter, 300-3400 c/s is introduced to restrict the transmission to a band similar to that of an ordinary telephone circuit. This is necessary because the new Working Standard in fact transmits a wide frequency band extending from 50-9000 c/s and is in this form unsuitable for comparison with circuits of narrow band width.

The piezoelectric quartz microphone used for calibration is described below. The moving coil microphone calibration consists of a direct comparison between its output voltage and that of the quartz crystal assembly, which is not frequency dependent. The moving-coil receiver is calibrated by measuring the voltage fed to it in order to excite the quartz crystal assembly to a constant output voltage, i.e. to produce a constant sound pressure.

The quartz crystal is associated with a three-stage battery-operated pre-amplifier followed by the 62.1 db amplifier already mentioned. The volume meter is used throughout the calibrations to indicate equality of voltage only.

The gain-frequency characteristic of the pre-amplifier is automatically eliminated from the calibration because the calibrating signal is injected directly in series with the crystal element. The only " unknown " in the system is therefore the piezoelectric activity, and this can be calculated from the physical dimensions and first principles.

The standardization of the pre-amplifier, calibration of microphone and receiver and setting up of other combinations of circuits are made easily by a pushbutton which operates the appropriate relays. These relays are fitted with platinum contacts in all circuits which carry speech currents. Other pushbuttons operate the other relays necessary to set up the test circuits, adjust the gains of the amplifiers and to set up the complete circuit as required for tests based on comparisons of volume or for A.E.N. measurements.

In the microphone and receiver calibrations, the attenuator is connected in the circuit limb containing the transducer under test. This attenuator is used to bring the two readings of the volume meter to equality so that the attenuator settings are a direct measure of the electro-acoustic calibration in question.

Some features of the acoustic calibrations are :

1. The relationship between the sound pressure applied to the crystal microphone and its output voltage is independent of frequency and temperature.

2. The acoustic medium is air at the pressure and temperature of normal operation.

3. A few measurements have been made to ascertain the extent to which the moving coil microphone and receiver and the calibration equipment are affected by temperature. The entire calibrating equipment and moving coil microphone and receiver were raised from 16° to 40° C. The microphone sensitivity fell generally about 0.7 db. The receiver sensitivity was practically unchanged except for an octave either side of the diaphragm resonance frequency, the maximum change being a fall of under 2 db. Both calibrations returned to their original values when the apparatus was restored to room temperature.

4. The acoustic couplers are small enough to secure uniformity of sound pressure.

5. The calibration measurements are repeatable to ±0.5 db (or better in the middle range).

6. The receiver coupler is in the form of an artificial ear having an acoustic impedance compounded of stiffness and acoustic resistance terms.

7. The microphone is calibrated at constant pressure independent of frequency. This calibration curve is related to the free field response mentioned earlier by means of a correction depending on the geometry ; the correction is established once for all by means of a free field calibration measured with an artificial mouth in a room of controlled acoustics

The S.E.T.E.D. working standard has been designed with a view to its use as a reference system for articulation tests.

It may also be employed with loudness balancing for the determination of reference equivalents.

In both cases appropriate circuits can be set up for determining the relative equivalent (or the A.E.N. value) of a commercial telephone system for receiving, sending or for the complete system.

The reference equivalents of the S.E.T.E.D. for sending and receiving obtained by direct determinations made in the C.C.I.F. Laboratory are as follows :

The sending reference equivalent of the S.E.T.E.D. is 3.3 db better than the S.F.E.R.T., the receiving reference equivalent of the S.E.T.E.D. is 1.1 db better than the S.F.E.R.T.

The A.E.N. values have also been determined by comparison with the A.R.A.E.N. for the complete system, for the sending system and for the receiving system :

The sending A.E.N. is 3.3 $\pm$ 1.9 db better than the A.R.A.E.N.

The receiving A.E.N. is 10.2 $\pm$ 2.3 db better than the A.R.A.E.N.

The overall A.E.N. of the complete system is 17.3 db better than the A.R.A.E.N.

The S.E.T.E.D. is provided with arrangements at the input of the receive amplifier to allow noise to be injected or sidetone to be provided but the values of A.E.N. given above have been determined with airborne room noise which was used with the A.R.A.E.N. at the period when these tests were made.

Calibration of the S.E.T.E.D. depends upon the quartz crystal microphone which uses the direct piezoelectric effect in a stack of X-cut quartz crystal (see Figure 15) ; one face of each crystal element is exposed to sound pressure, the opposite face is securely attached to a massive block. This ensures that the driven face is stiffness controlled up to the resonant frequency of the combined mechanical system (estimated at 20 kc/s). Six similar crystal elements are stacked with alternately poled electric faces adjacent. The advantage over a single rectangular block of the equivalent size is that the source impedance is lower. This facilitates design of the valve input stage. An incidental advantage is a small improvement in the signal to noise when the limiting factor is thermal noise in the associated grid leak resistor.

It is imperative in using the direct action principle with quartz to ensure that the acoustic drive is limited to a single surface. At the same time the crystal assembly must be free from mechanical constraints so that its sensitivity can be calculable from first principles. The design adopted meets these requirements, a non-hardening compound being used to seal an airgap between the crystal and the surrounding metal. This prevents the access of sound to the side faces of the crystal assembly without constraining the motion.

The crystal having been very carefully selected and prepared, it is possible to calculate the microphone sensitivity on the reasonable assumptions of crystal homogeneity and of simple compressional stress parallel to the Y = axis which is uniform and equal throughout the crystal to the applied acoustic pressure.

i.e. $$\frac{e}{p} = \frac{4\pi L_1 d_{21}}{n K_{11}} \times 300$$

where e = open circuit e.m.f. in volts between adjacent crystal interfaces;
p = sound pressure in dynes per cm^2;
n = number of crystal sections;
K_{11} = dielectric constant of quartz in direction of X-axis (4.55);
L_1 = dimension of crystal stack parallel to X-axis (in cms.) (See Figure 15);
d_{21} = piezoelectric constant of quartz relating compressional stress parallel to Y-axis to polarisation parallel to X-axis. The units are e.s.u. charge per dyne ($6.9 \times 10_{-8}$).

It is seen that the quantity $\frac{e}{p}$ is independent of frequency, so that the frequency response is truly flat. This gives the microphone its useful character as a standard.

The source impedance of generated e.m.f. is a capacitance where

$$C = \frac{1}{9 \times 10^{11}} \cdot \frac{n^2 K_{11} a}{4\pi L_1} \text{ farads}$$

where a = area of the part of the crystal face (perpendicular to the X-axis) covered by metal, slightly less than the area $L_2 L_3$ of the crystal face.

Upper limits to the sensitivity $\frac{e}{p}$ and to C are set by the following requirements:

1. The resonant frequency of crystal system must be higher than highest frequency in use (this determines L_2).
2. The linear dimensions of the exposed face must be small compared to the wavelength of the sounds in air (this determines L_1 and L_3).

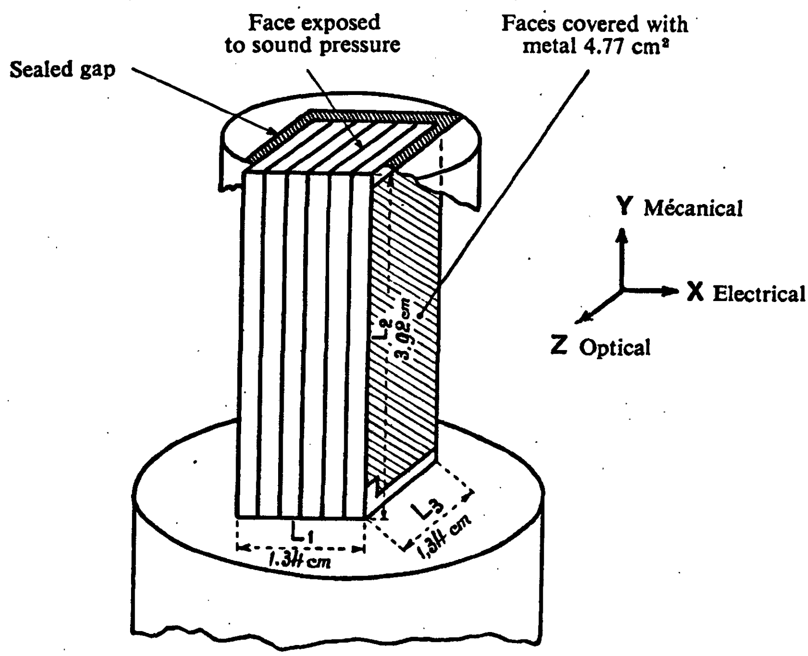


FIGURE 15

The values adopted are

$$L_2 = 3.92 \text{ cm}$$
$$L_1 = L_3 = 1.34 \text{ cm}$$
$$a = 4.77 \text{ cm}^2$$
$$n = 6$$

from which the sensitivity is calculated at

$$20 \log_{10} \left(\frac{e}{p}\right) = -97.9 \text{ db rel. 1 volt per dyne/cm}^2$$

and the capacitance C = 51.5 pF.

Response of the preamplifier is maintained down to about 100 c/s by using a 100 megohm grid leak resistor and Type 155 amplifying pentode input stage with underrun heater, having an input capacitance about 4 pF. The exact circuit constants however are unimportant because they are eliminated in the inject calibrating method, which introduces a known e.m.f. directly in series with the crystal.

Secondary calibrations of the quartz microphone have been made using probe microphones coupled to it by a specially designed fixture. The 3 probe microphones used had been compared directly with primary standards. The deduced quartz microphone sensitivities were −98.2 −98.0 and −98.4 db rel. 1 V per dyne/cm², compared to −97.9 db from calculation.

3.1.3 Reference system for the determination of A.E.N.

A. — Reference system for the determination of A.E.N. (S.R.A.E.N.)

The reference system for the determination of A.E.N. is a system consisting of the following elements :

— Reference equipment for the determination of A.E.N. (A.R.A.E.N.) (described in detail in § B below).

— A band-pass filter cutting off at 300 and 3400 c/s.

— A device allowing " electrical background noise " (Hoth spectrum) to be injected at the input of the receiving system (point M in Figure 16) at a psophometric e.m.f. of 2 mV.

The schematic diagram of the S.R.A.E.N. is given in Figure 16 below.

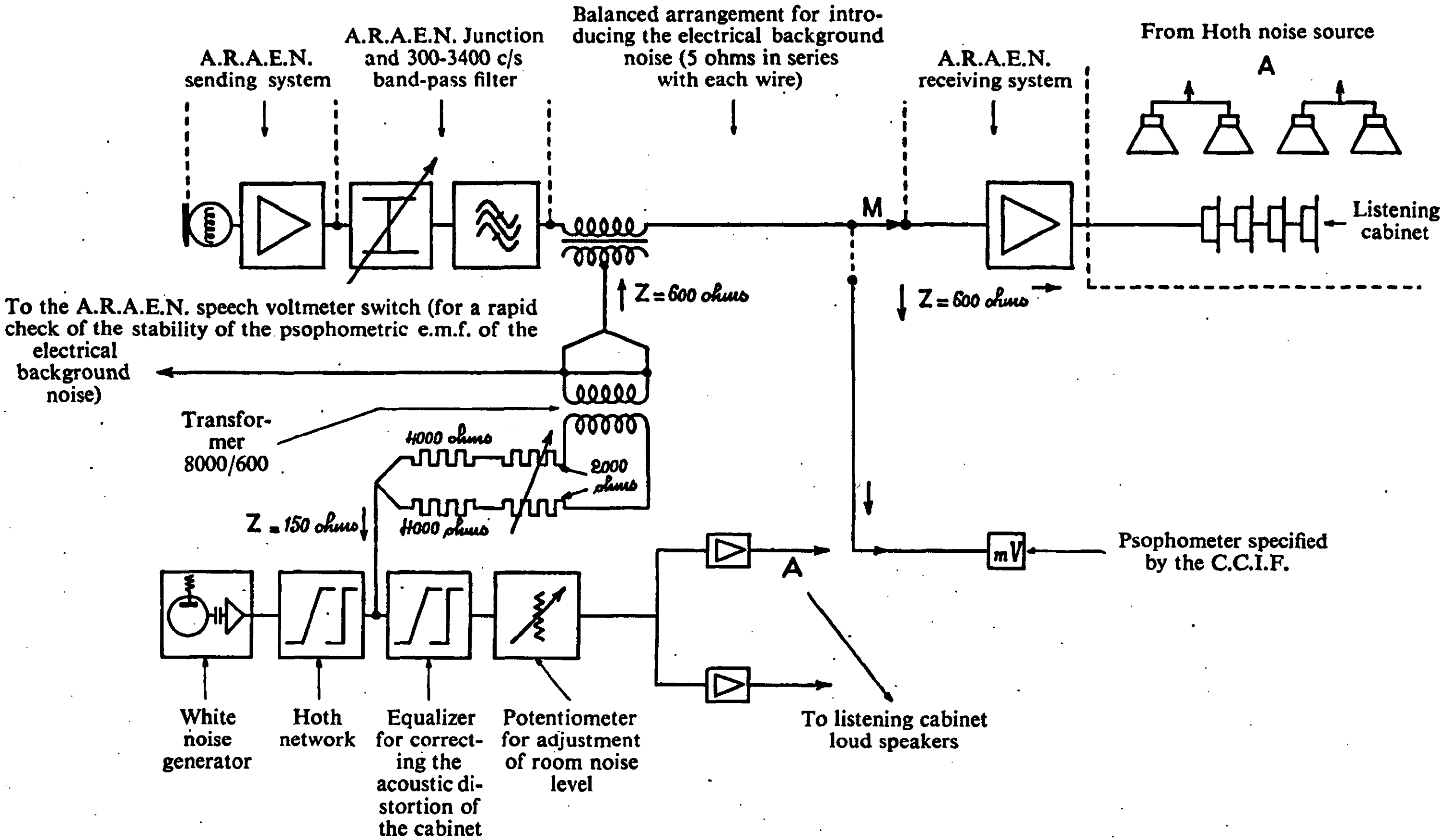


FIGURE 16. — *Schematic diagram of the S.R.A.E.N. including the arrangement for injecting the " electrical background noise " into the A.R.A.E.N., and the measurement of the psophometric voltage of this noise*

B. — Reference Apparatus for the determination of A.E.N. (A.R.A.E.N.)

B.1. — *General*

The A.R.A.E.N. comprises three main parts :

1. The transmission path proper, subdivisible into sending end, junction and receiving end.

2. Centralised apparatus for the supply of room noise and intercommunication facilities.

3. Calibration equipment arranged to facilitate the proper maintenance of the Reference System.

The transmission path incorporates a moving coil microphone, send and receive amplifiers, junction attenuators and four moving coil receivers. There is a junction filter having a transmission characteristic similar to that of an average carrier channel (4-kc/s carrier spacing). This filter can be inserted either in the transmission path of the A.R.A.E.N. or in the test telephone circuit. The complete transmission path, when the filter is switched out of circuit, is designed to reproduce the transmission characteristics of a free field air path, one metre long, the air path being assumed to be used with monaural listening. Normal settings of the send and receive amplifiers are such that these characteristics are reproduced with 30 db non-reactive attenuation in the junction.

Room noise is produced, as a continuous-spectrum sound, by amplifying the random fluctuations of the anode current of a gas-filled triode. The spectrum is adjusted to the average observed at telephone locations.

Calibrated probe-tube microphones are provided as secondary standards for use :

(a) with an artificial ear for observing the performance of the moving coil receivers, and

(b) with a closed coupler for observing the performances of the microphones.

Rayleigh Disks and a Standing Wave Tube are provided as a primary standard and used to calibrate the probe-tube microphones. An oscillator, milliameters and ancillary equipment complete the electro-acoustic testing gear.

This system is completely defined in documents held by the C.C.I.F. Secretariat and the C.C.I.F. Laboratory, furthermore the duplicated document entitled : " Draft summary of instructions for the use and maintenance of the C.C.I.F. Laboratory " gives a shortened description of the equipment and its method of use.

B.2. — *Transmission path.*

This transmission path consists essentially of the items whose characteristics are given in the table below and which are interconnected according to the arrangement in Figure 17 by means of the Junction Switching Panel.

Item	Performance Characteristics
Microphone S. T. & C. 4021 E	Attenuation distortions +2.5 db ; 80-6000 c/s. (Equalised to still closer limits by separate equaliser circuit.)
Microphone Amplifier	Input Impedance : High as compared with 20 ohm microphone. Output Impedance : 600 +50 ohms over range 80-600 c/s. A fixed value of gain is provided. Gain without feedback : 68 db. Gain with feedback 47 +0.2 db over range 80-600 c/s. Max. noise level at output (input closed with 20 ohms) : −82 db rel. to 1 volt across 600 ohms.
Send (or receive) Amplifier	Input and output Impedances : 600 +50 ohms. Gain without feedback : 100 db. Max. gain with feedback : 64 db. Attenuation distortion : +0.3 db over range 50-6000 c/s. Range of gain control : 48 db (in 0.2 db steps).
Telephone Receiver S. T. & C. 4026 A	Attenuation distortion (on real ear) +5 db over range 80-6000 c/s (before equalization).

B.3. — *Equipment for supply of room noise and intercommunication circuit*

This equipment of which Figure 18 shows connexions in schematic form, comprises :

1. A source of noise (gas-filled triode) ;
2. Power amplifiers for feeding loudspeakers ;
3. A sound level meter, which can be switched to the various listening points ; and
4. Loudspeaking telephone equipment to facilitate intercommunication between members of the testing crew.

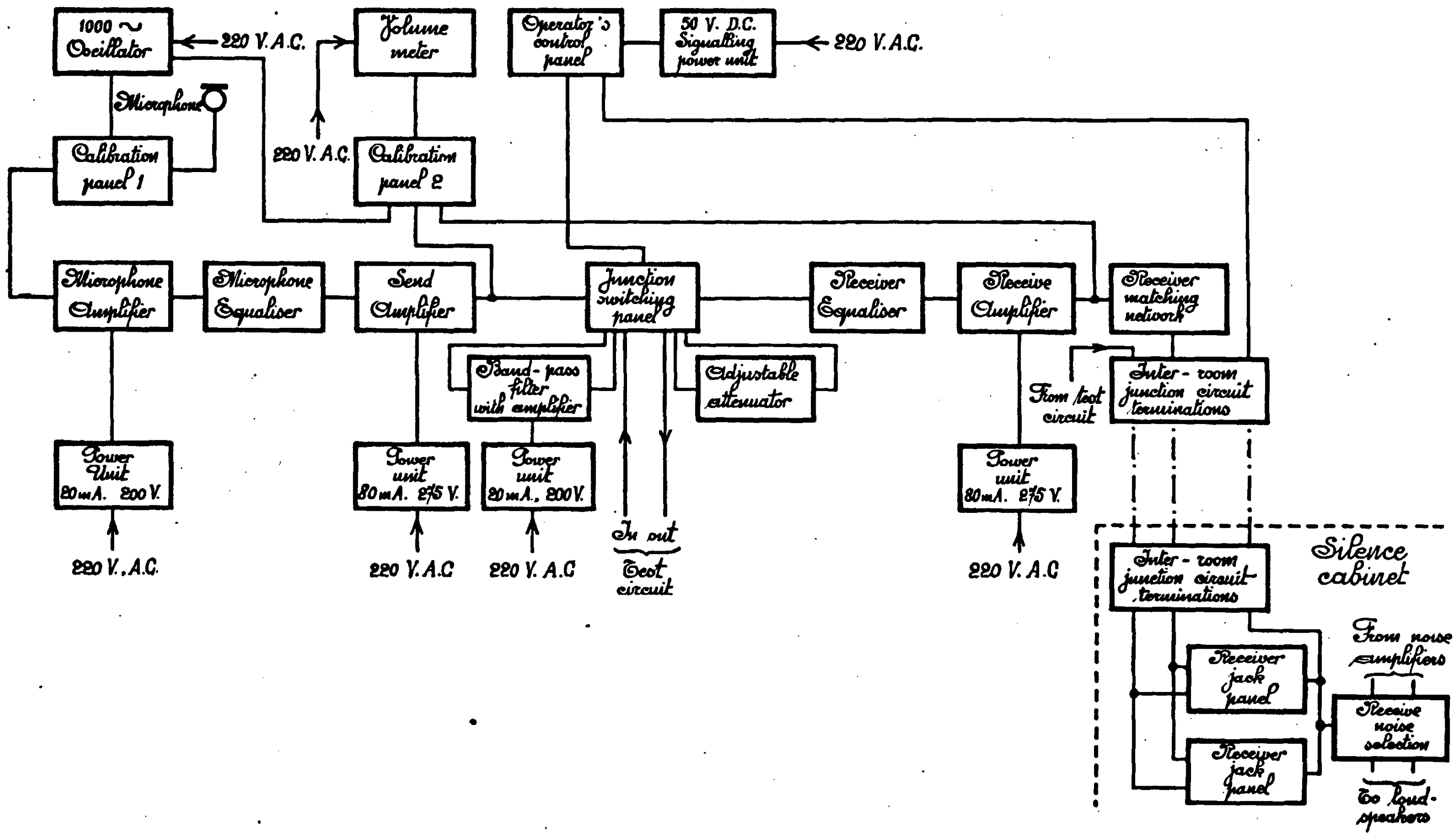
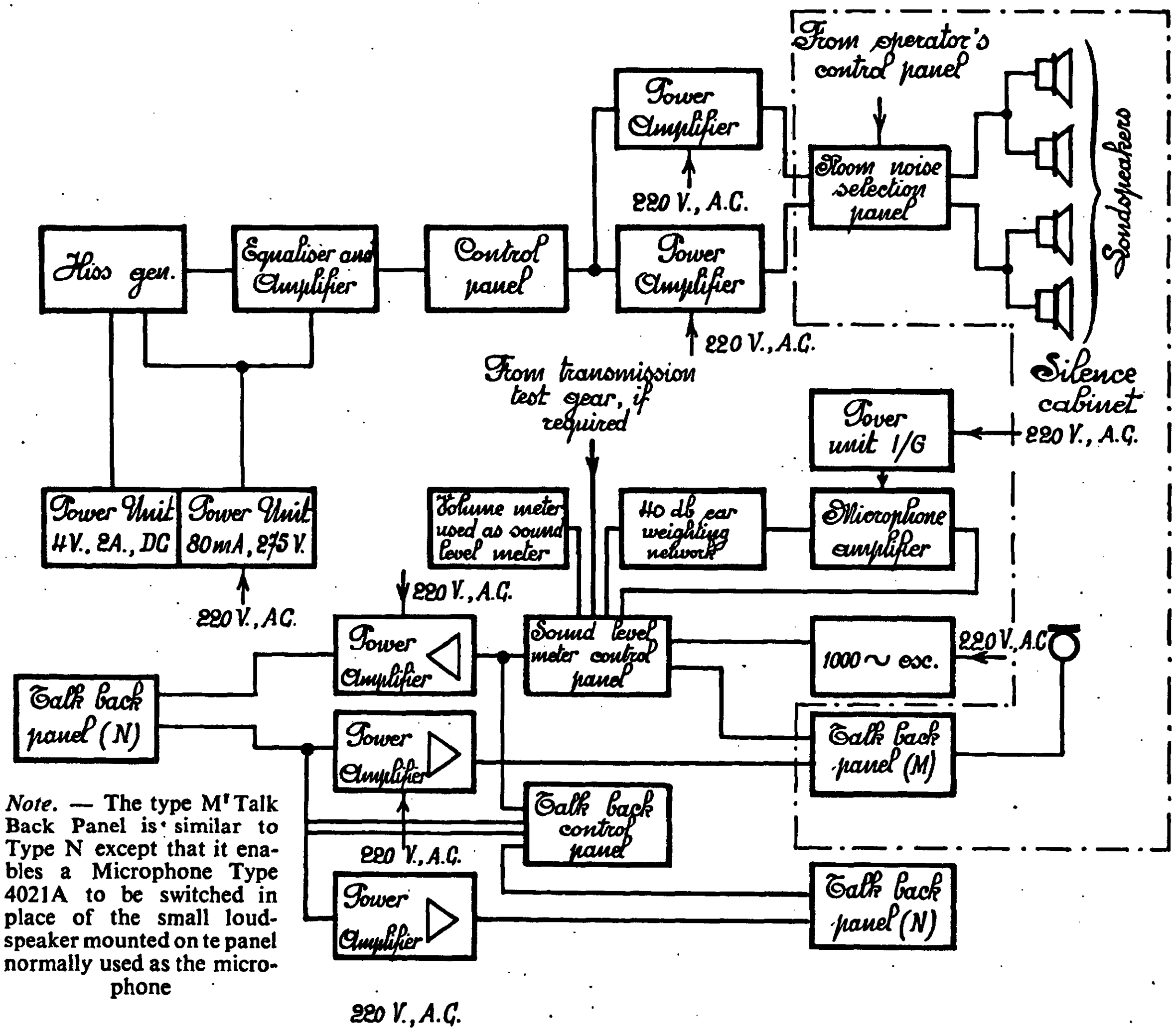


FIGURE 17. — *Schematic diagram of the Reference Equipment for the determination of A.E.N.*



Note. — The type M' Talk Back Panel is similar to Type N except that it enables a Microphone Type 4021A to be switched in place of the small loudspeaker mounted on te panel normally used as the microphone

FIGURE 18. — *Noise generation, level measurement and talk back equipment*

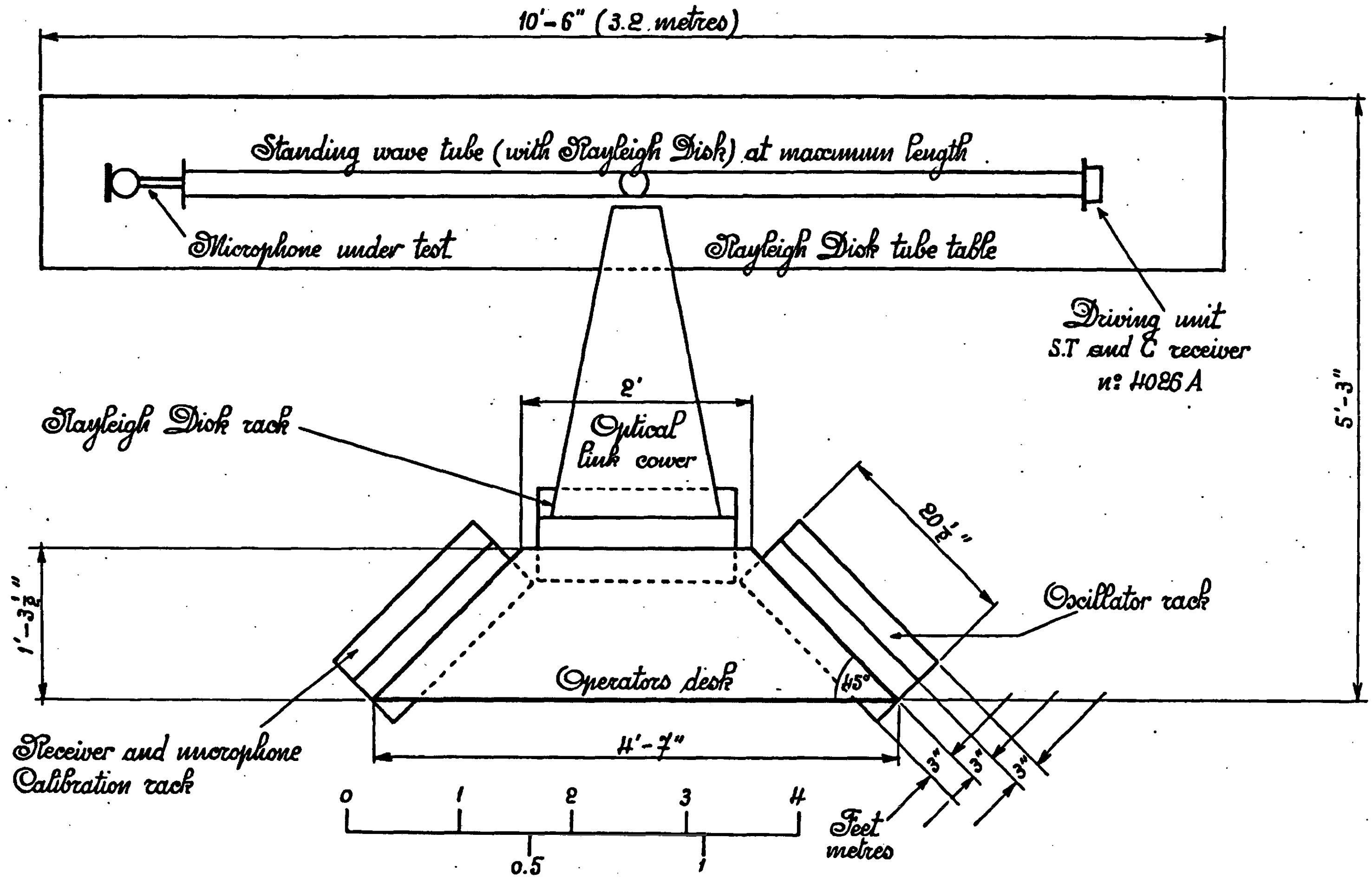


FIGURE 19. — *Plan of microphone and receiver calibration equipment A.R.A.E.N.*

B.4. — *Calibration Equipment*

The general arrangement of the electro-acoustic gear is shown in Figure 19. The method of using this equipment at the C.C.I.F. Laboratory is described in Annex 5 of the *Book of Annexes* to Vol. IV of the *Green Book.*

The Rayleigh disk is suspended into the centre of the standing wave tube and optical means are provided at the operator's desk for observing its angular deflection (from which sound pressures at the end of the tube can be calculated). The probe of the microphone under test is inserted in a hole in a plate closing one end of the standing-wave tube ; the other end is closed by a moving-coil receiver fed from an oscillator at the operator's right hand. The output of the probe-tube microphone is read on a meter mounted in front of the operator.

Calibration of the probe-tube microphone is effected by adjusting the frequency of the oscillator to produce a stationary wave in the tube to give simultaneous maxima of the deflection of the Rayleigh disk and of the output of the microphone. At any one setting of the length of the standing-wave tube, frequencies for calibration can be used which are those of the fundamental mode of resonance in the tube (about 100 c/s) and any odd harmonic thereof. To obtain calibration points at other frequencies it is necessary to alter the length of the tube ; means are provided for doing so, but it will not be necessary to use this facility for routine checks of the sensitivity of the probe-tube microphones.

The rack on the left of the operator's desk contains equipment for checking the sensitivities of the microphones and receivers of the Reference System (A.R.A.E.N.) against a calibrated probe-tube microphone. The main items of equipment for this work are :

Probe-tube Microphone. — For calibration of this Reference System two microphones and one amplifier and equalizer are provided ; the equalized frequency characteristic of the probe-tube microphone and amplifier is substantially flat from about 80 to 6000 c/s.

Artificial Ear. — A device for presenting to a telephone receiver an acoustical load equivalent to that of a real ear, and permitting the measurement of sound pressure at a specified point therein by means of a probe-tube microphone.

Closed Coupler. — A small cylindrical chamber closed at one end by a moving-coil receiver (the source of sound) and at the other by the microphone under test, with means for admitting the tip of a probe-tube microphone for measuring the acoustic pressure. A microphone calibration at constant pressure under specified conditions of test can thus be obtained which is sufficient for detecting any change of sensitivity of the microphone.

A high grade moving coil milliameter and a thermocouple milliameter are associated with the equipment as primary and secondary standards (respectively) for electrical measurements and arrangements are provided for switching the different items of electrical equipment to facilitate routine calibrations.

Note. — It is sometimes convenient when using a Reference Telephone System for Articulation Testing to make records of the operator's speech to assist training in correct pronounciation. A recording equipment suitable for use in conjunction with the microphone and receivers of the A.R.A.E.N. exists and has been sent to the C.C.I.F. Laboratory. This equipment should not be regarded as forming a specific part of the Reference System.

B.5. — *Theoretical efficiency of the complete A.R.A.E.N.*

The construction of the A.R.A.E.N. is such that, in the standardised position of the microphone (defined below, the whole system included between the talker's mouth and the listener's ear, represents from the acoustical standpoint, the equivalent of a one metre air path. Thus the A.R.A.E.N. represents that portion included between a point situated at 13.25 inches (about 33 cm) from the talker's lips (the position of the centre of the microphone) * and the head of the listener; the latter situated at a point one metre from the talker's lips.

Neglecting the effect upon the sound field caused by the obstruction effect of the listener's head the difference in acoustic pressure between these two points is theoretically:

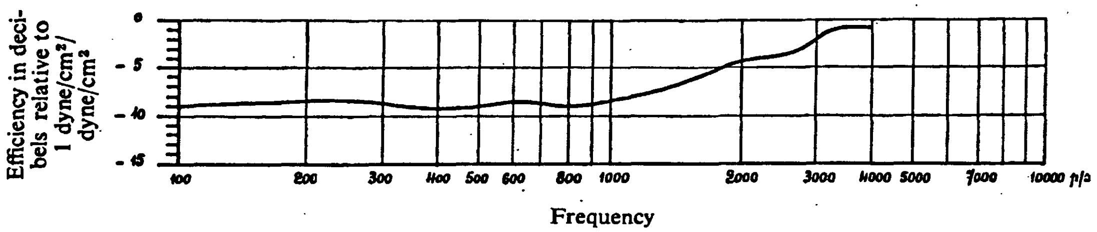
$$20 \log_{10} \frac{39.37}{13.25} = 20 \log_{10} \frac{100}{33.5} = 9.5 \text{ decibels.}$$

Taking into account the obstruction effect caused by the listener's head according to the curve *b* of figure 20 below the following values are obtained:

Frequency	Pressure increase due to obstruction effect	Theoretical loss
100 Hz	0 db	9.5 db
300 Hz	0 db	9.5 db
1 000 Hz	1 db	8.5 db
2 000 Hz	4.6 db	4.9 db

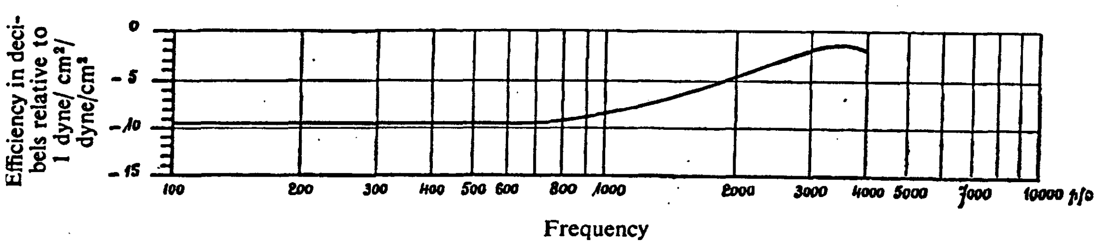
Efficiency of the A.R.A.E.N. sending end. — The efficiency of the sending end of the A.R.A.E.N. has been fixed at a value permitting the control of the speaking level by means of a specified speech voltmeter (see Section 3.2.2 below) connected to the output of the sending system. The speech voltage applied to the input of the junction and read on this speech voltmeter is one volt when the operator speaks at the "A.R.A.E.N. reference vocal level" (see section 3.1.4 below). Under these conditions the acoustic pressure applied to the diaphragm of the microphone is 1 dyne/cm².

* The rim of the baffle plate of the microphone is situated at 12 inches (1 foot) from the talker's lips.



a) Overall working characteristic of the ARAEN taken with microphone type 4021E No. 1284 and a typical receiver type 4026A, the band pass filter being out of circuit *.

Adjustement { Send amplifier " normal "
Junction : 30 db
Receive amplifier " normal " +1 db



b) Characteristic of transmission in free air over a distance of 1 metre-" conversation distance ", account taken of the distortion of the acoustic field caused by the presence of the listener's head (theoretical definition of the frequency characteristic of the A.R.A.E.N. set up in accordance with the adjustments shown above).

FIGURE 20. — *A.R.A.E.N.*

Efficiency of the A.R.A.E.N. receiving end. — The efficiency of the receiving end has been determined conventionally such that the condition indicated above (for the " air to air " efficiency of the A.R.A.E.N.) is complied with for a junction attenuation equal to 30 decibels.

The table below gives the values of acoustic pressure (in decibels relative to 1 dyne/cm²) produced by a receiver when a level of −30 decibels relative to 1 volt is applied to the input of the receiving system i.e. when an acoustic pressure of 1 dyne/cm² is applied to the microphone.

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* *Note.* — The effect of the filter is to cause a sharp cut off below 300 and above 3400 c/s ; between these frequencies the loss introduced is less than −0.5 db.

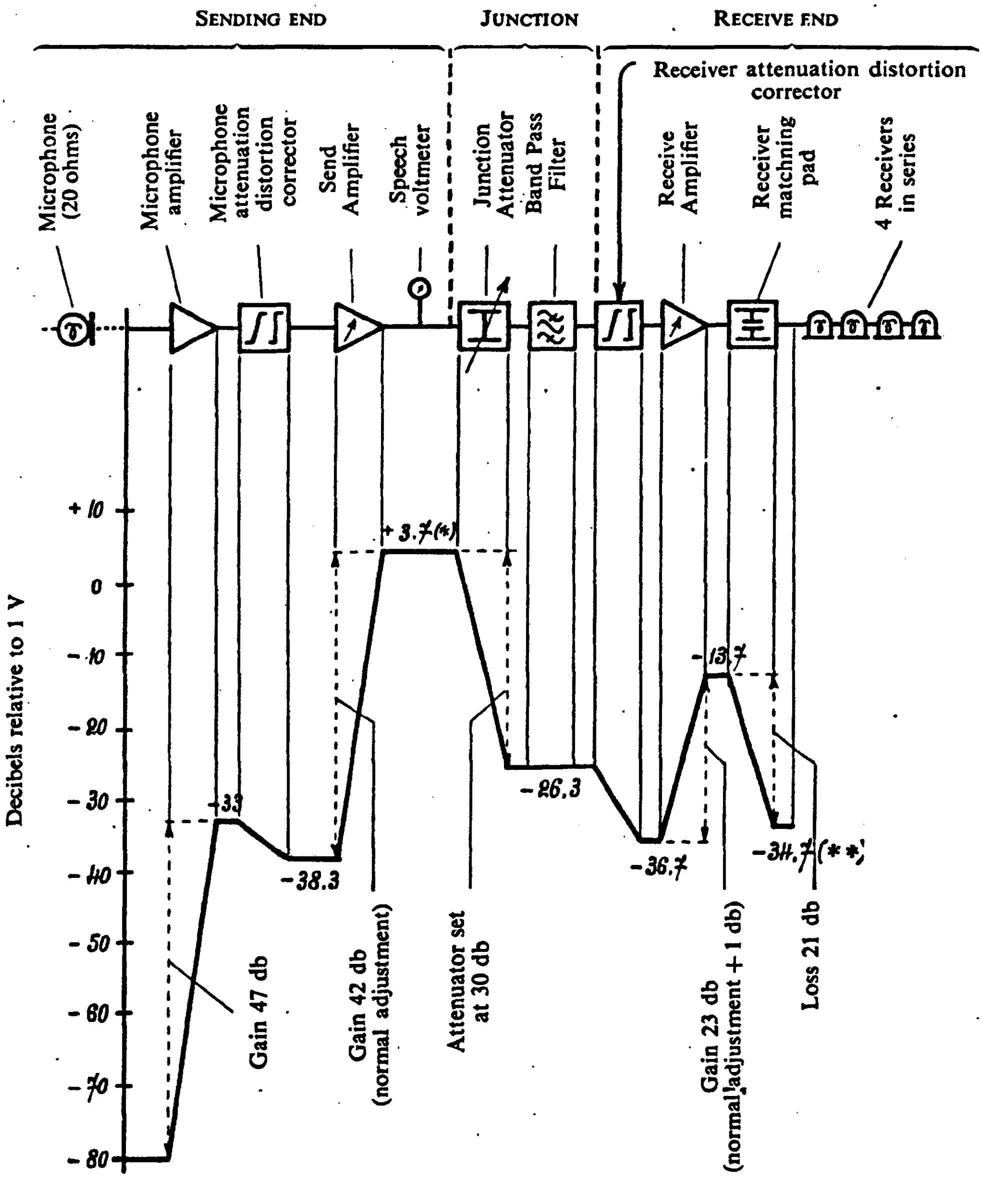


FIGURE 21. — *Diagram showing the levels at various points in the A.R.A.E.N. when a pure tone at —80 db relative to 1 V is applied to the microphone sockets, in the following conditions of adjustment.*
Send amplifier: normal
Receive amplifier: normal + 1 db
Junction attenuator: 30 db

* The speech volume is 0 db (relative to 1 V) at this point when the microphone is connected and the talker speaks at the reference vocal level for the A.R.A.E.N.

** With tolerance of
(±1.5 db if the band pass filter is in circuit
(±1.0 db if the band pass filter is not in circuit

Frequency	Voltage at the input of the receiving system (output of the junction)	Total loss of the electrical part of the receiving system	Voltage applied to one receiver	Average receiver efficiency	Acoustic pressure produced by one receiver
c/s	db relative to 1 volt	db	db relative to 1 volt	db relative to 1 dyne/cm²/volt	db relative to 1 dyne/cm²
100	−30	25.8	−55.8	46.0	−9.8
300	−30	25.2	−55.2	46.1	−9.1
1 000	−30	19.5	−49.5	41.2	−8.3
2 000	−30	15.4	−45.4	41.4	−4.0

The following table shows the comparison of the theoretical and actual values of overall attenuation of the A.R.A.E.N.

Frequency	Overall attenuation of the A.R.A.E.N.		
	Theoretical value	Actual value	Actual value corrected to take account of the position of the probe in the artificial ear *
c/s	db	db	db
100	9.5	9.8	9.8
300	9.5	9.1	9.1
1 000	8.5	8.3	8.3
2 000	4.9	4.0	4.3

* This correction is necessary because the value of pressure taking account of the presence (in the acoustic field) of the listener's head is referred to the external opening of the ear canal, whilst in the artificial ear the probe of the microphone is placed at the lower part of the artificial ear cavity ; the region corresponding to the external opening of the real ear canal is close to the upper part of the artificial ear cavity. This correction becomes very important at the high frequencies. The differences between the measured values (corrected in this way) and the theoretical values are due to small variations in the frequency characteristics of the receivers.

In practice, for the adjustment of the gain of the sending and receiving amplifiers, account must be taken of the differences in the frequency characteristics of the individual microphones and receivers. The C.C.I.F. Laboratory is in possession of the necessary documentation for the calculation of these corrections from the small changes in sensitivities of the microphones and receivers as obtained during calibration measurements. Figure 21 gives a diagram showing the levels at various points in the A.R.A.E.N. when normally adjusted.

C. — Description and adjustment of the S.R.A.E.N.

The Articulation Reference System (in short denoted by S.R.A.E.N.) is made up of the following elements :

— the A.R.A.E.N. ;
— a 300-3400 c/s band pass filter ;
— an arrangement for introducing the " electrical background noise ".

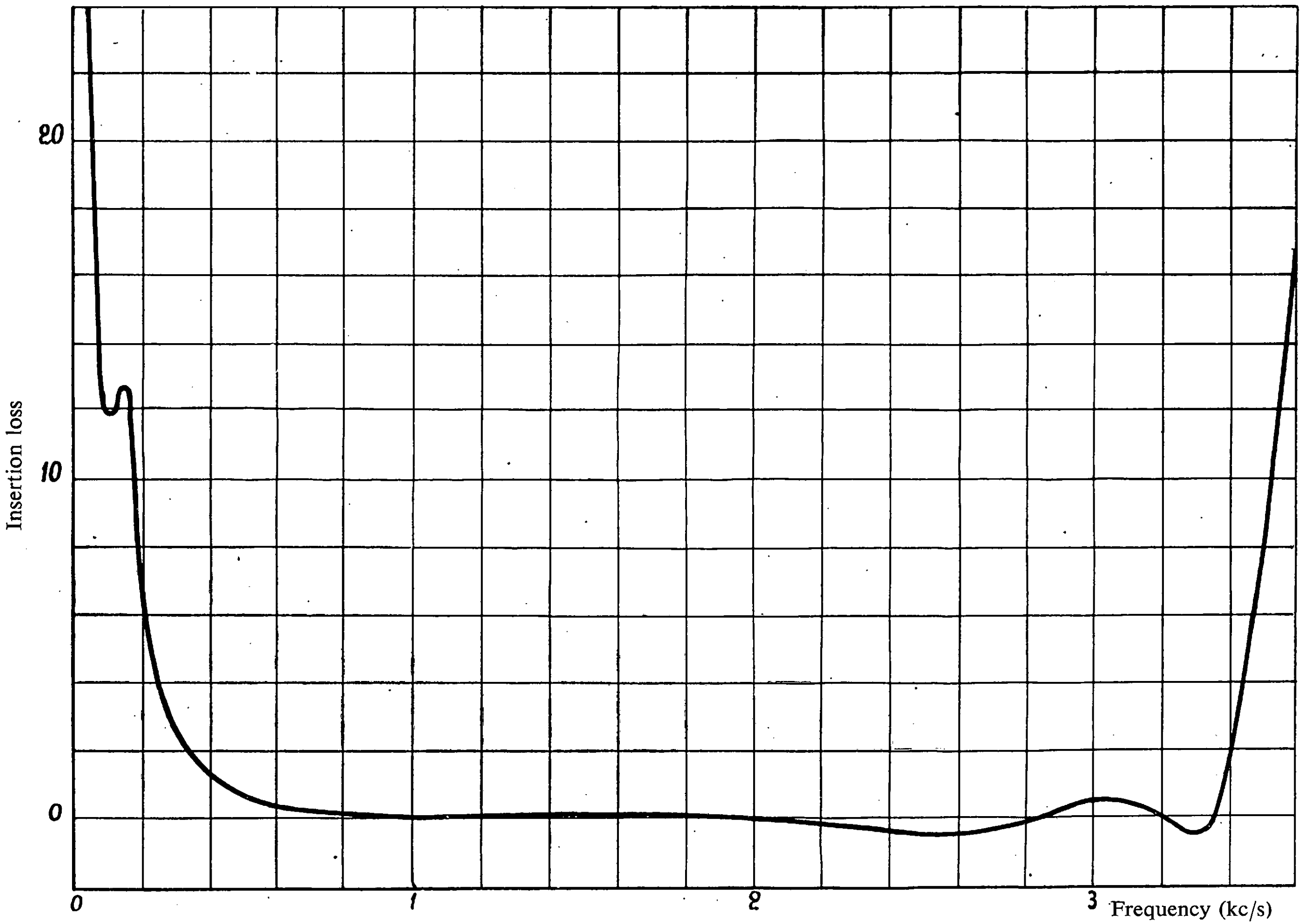


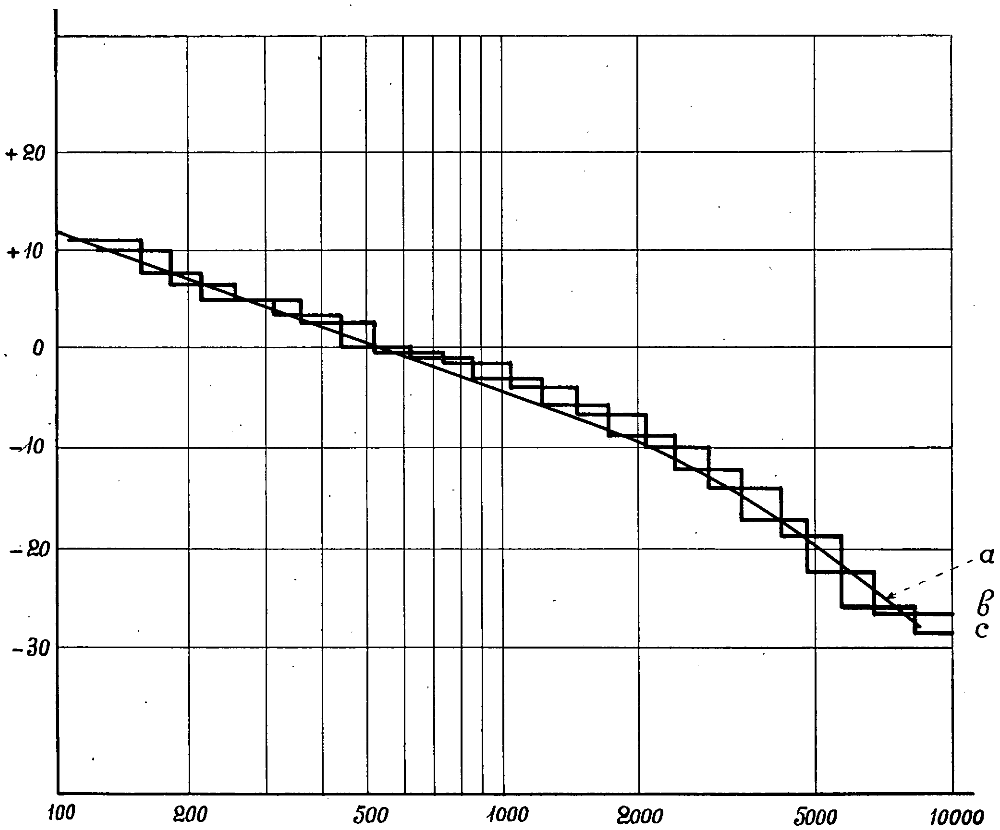
FIGURE 22. — *Insertion loss (between 600 ohms terminations) of the 300-3400 c/s band pass filter*

C.1. — *A.R.A.E.N.*

The A.R.A.E.N. is described in Chapter B above.

C.2. — *300-3400 c/s Band Pass filter*

The band pass filter has cut-off frequencies of 300 and 3400 c/s ; it stimulates the transmission characteristics of a typical carrier system telephone channel. The insertion loss is within the limits ±0.5 db in the band 300 to 3400 c/s. For frequencies above 3400 c/s the insertion loss increases to reach at least 30 db at 4000 c/s and remains above this value for all frequencies above 4000 c/s.



a ———— Mean power density spectrum of noises observed at subscriber's telephone stations (published by Hoth).

b ———— Typical power density graph of the electrical background noise injected
c ———— at the input of the A.R.A.E.N. receive end (obtained at the C.C.I.F. Laboratory with two sets of half-octave filters.

FIGURE 23. — *Power density spectrum of the " electrical background noise " injected at the input of the A.R.A.E.N. receive end.*

C.3. — *Electrical background noise*

An electrical background noise is injected at the input of the receive end of the A.R.A.E.N. having the Hoth spectrum and at a psophometric e.m.f. of 2 mV measured at this point with the commercial telephone circuit psophometer specified by the CC.I.F. Figure 23 gives the mean power density spectrum observed at subscriber's telephone stations (Hoth spectrum) (curve *a*) together with typical graphs *b* and *c* obtained at the C.C.I.F. Laboratory with two sets of half octave filters.

Note. — Administrations and Private Operating Companies can consider the use of other working standards for the determination of A.E.N. values, these systems being capable of being calibrated by comparison with the S.R.A.E.N.

3.1.4 Measurement of A.E.N. of a commercial telephone system (sending and receiving) by comparison with the S.R.A.E.N.

I. — INTRODUCTION

The present recommendation applies to the routine tests carried out in the C.C.I.F. Laboratory for the determination of A.E.N. values of commercial telephone systems sent to that laboratory by recognised Administrations and Private Operating Companies.

The term " experiment " is used in what follows to designate the whole of the operations carried out on a given type of telephone system and includes :

(a) measurements of reference equivalent (sending and receiving) preceding the articulation test to check the good working order of the systems and to allow, if necessary, a later check of their stability.

(b) articulation tests in which the systems indicated in Table 5 below are compared :

Circuit No.	Send end	Receive end	Noise at receive end
1	A.R.A.E.N.	A.R.A.E.N.	Electrical background noise
2	commercial	A.R.A.E.N.	Electrical background noise
3	A.R.A.E.N.	commercial	60 db room noise (Hoth spectrum)

Circuit 1. — " Articulation Reference System " i.e. the complete S.R.A.E.N. (with the 300-3400 c/s band pass filter in the junction and the electrical background noise (see Section 3.1.3 above).

Circuit 2. — The commercial sending end connected to the receiving end of the A.R.A.E.N. through the junction attenuator of the A.R.A.E.N. and the same band pass filter.

Circuit 3. — The sending end of the A.R.A.E.N. connected to the commercial receiving end through the junction attenuator of the A.R.A.E.N. and the same band pass filter.

Note. — The extreme terminals of the A.R.A.E.N. (i.e. the microphone and the four receivers are placed in special cabinets to shield them from any external interference; the interior walls of these cabinets have received appropriate acoustical treatment.

II. — Conditions of measurement

Telephone systems used

For a given type of commercial subscriber's telephone system forming the subject of an experiment, the Administration or Private Operating Company concerned must supply five telephone systems each including :

— a subscriber's telephone set
— a feeding network representing the feeding bridge,
— a subscriber's artificial line representing the most unfavourable line conditions that that Administration or Private Operating Company *normally* allows in international telephone calls.

During reference equivalent measurements or articulation tests, the subscribers' sets are fed according to the information supplied by the Administration or Private Operating Company concerned.

II.1. — *Talking distance*

The talking distance used for the measurement of a sending A.E.N. value is determined by the mean values of the following parameters (defined on pages 146 and 151 below Section **3**.4.2, § *c*).

$$\alpha = 22° \qquad \beta = 12°54' \qquad \delta = 13.6 \text{ cm}$$

The Administration or Private Operating Company concerned must then supply at the same time as the five subscribers' telephone sets a total of two guard rings for this " speaking distance " as well as two guard rings for the measurement of the reference equivalents : The values of the parameters defining this latter " speaking distance " are indicated on page 151 and are reproduced here :

$$\alpha = 15°30' \qquad \beta = 18° \qquad \delta = 14 \text{ cm}$$

II.2. — *Vocal power to be used during the tests*

The vocal power used will be the reference vocal level for A.R.A.E.N. — The reference vocal level for A.R.A.E.N. is that vocal power which produces, at a point 33.5 cm directly in front of the lips of the talker, an acoustical speech pressure for each of the three syllables " Can-Con-By " of the carrier phrase (used in

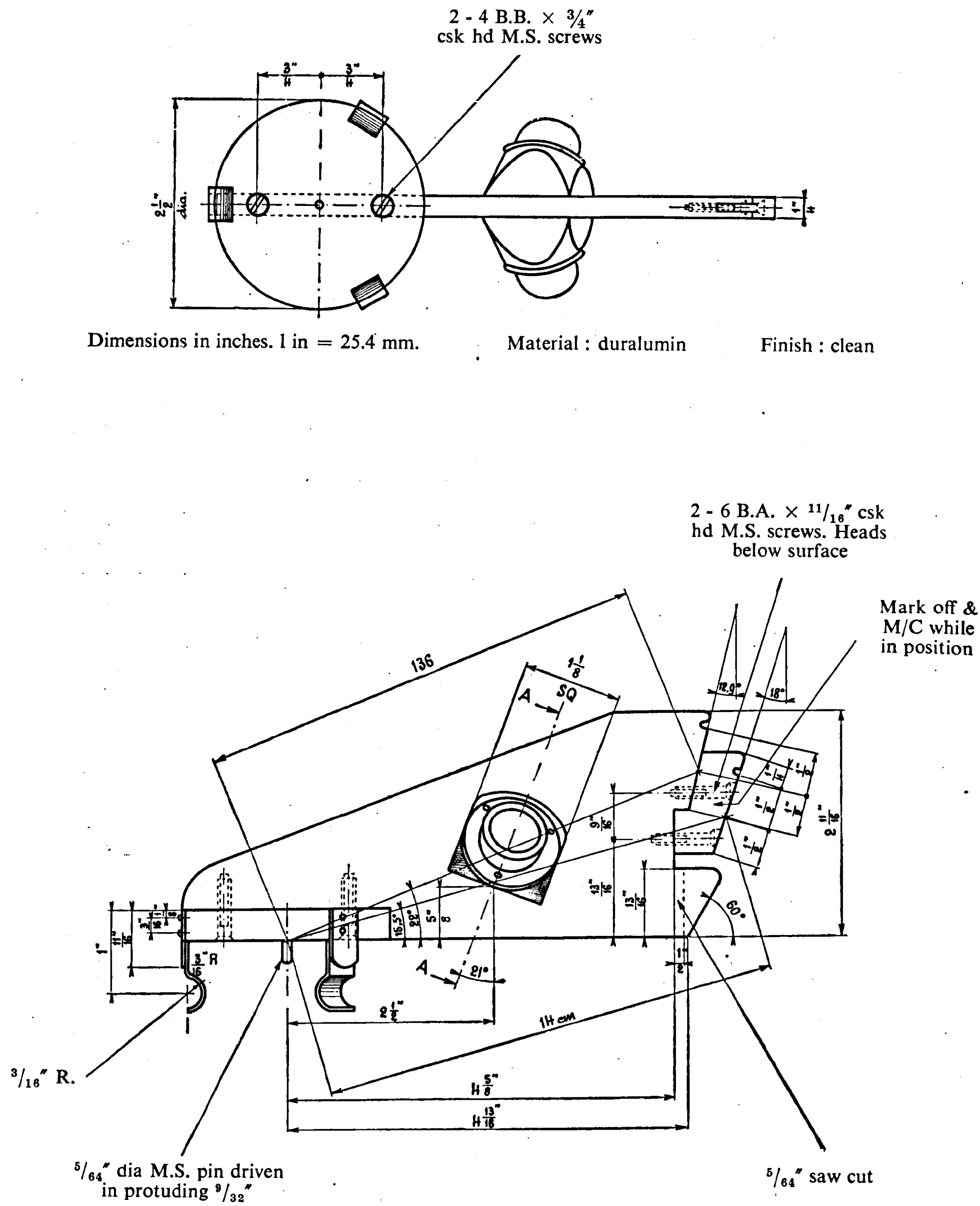


FIGURE 24. — *Type of gauge used for setting the handsets in articulation tests at the C.C.I.F. Laboratory*

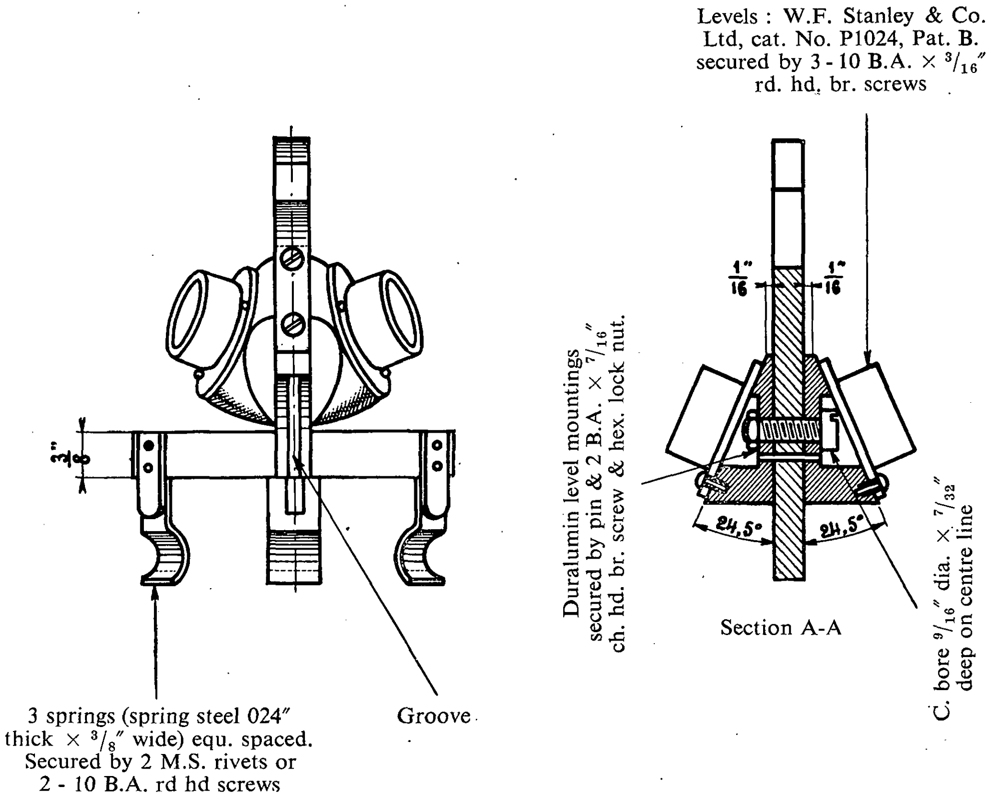


FIGURE 24 (Contd.)

articulation tests), a deflection of the needle of the indicating instrument of the specified speech voltmeter (see section 3.2.2 below) connected to a specified microphone and amplifier system equal to that obtained when an acoustic pressure of 1 dyne per cm² at 1000 c/s is continuously applied at this same point.

II.3. — *Mounting of the telephone handsets*

With the above values of α, β and δ, it is possible to determine the position of a guard ring which fixes the position of the talker's mouth relative to the handset. The plane of this ring will be perpendicular to the plane of symmetry of the handset and the centre of the guard ring will be situated in that plane of symmetry.

Its position is defined by the following geometrical construction carried out in the plane of symmetry of the handset. An origin is taken at the centre of the receiver ear cap. From this origin a straight line is drawn forming an angle α with the plane of the surface of the earcap and in the plane of symmetry of the handset and having a length δ. The point thus determined is the centre of the guard ring and should coincide with the centre point of the lips.

The intersection of the plane of this ring with the plane of symmetry of the handset will be a straight line perpendicular to the direction of speaking as just defined, i.e. that the perpendicular to this straight line will form an angle β with the intersection of the plane of the receiver with the plane of symmetry of the handset.

The position of the guard ring is thus determined and fixed with respect to the handset.

All that remains is to fix the position in space of the guard ring during the articulation tests. It is assumed that the operator will talk in such a manner that the plane of symmetry of his face will be vertical. The centre of the guard ring will be in this plane and the plane of the guard ring will be perpendicular to it.

Apart from this it has been decided (as a convention) that the plane of the guard ring will be vertical.

The Administration or Private Operating Company concerned is requested to supply a setting gauge for each type of handset such that when fixed on the receiver ear-cap the plane of symmetry of the gauge being coincident with that of the handset, the indications marked on the gauge determine the correct position of the guard ring relative to the handset as has been defined above. In addition this gauge must be fitted with a spirit level placed so that the plane of the guard ring is vertical when the air bubble is within the central outlined area. By way of example Figure 24 below shows a gauge used at the C.C.I.F. Laboratory for one particular type of handset.

Note. — The position of the guard ring with respect to the handset is determined uniquely for A.E.N. measurements by the conditions defined above. Provisionally, for each type of handset, it would be desirable to define a gauge which will determine the position of the whole (handset and guard ring) such that the two following conditions will be satisfied simultaneously :

1. The plane of the guard ring is vertical.

2. The position with respect to the vertical of the plane of the diaphragm of the microphone capsule is as nearly as possible the same as it would occupy during normal conversation.

II.4. — *Preliminary treatment of the microphone before each talk*

Before each talk and after the handset has been fixed in its support in the appropriate manner, the feeding current is applied and the microphone is rotated gently, once forward and once back, about 3/4 of a circle and is then fixed in position while avoiding any mechanical shock.

II.5. — *Use of the handsets during the experiment*

The five handsets of each type of system will be numbered 1, 2, 3, 4 and 5, this numbering being at random.

Throughout the tests the operators will use the handsets in accordance with Table A below irrespective of the type of telephone system considered :

TABLE A*

No. of the Sending Handset	Listening Position 1	2	3	4
	No. of the Receiving Handset			
1	5	4	3	2
2	1	5	4	3
3	2	1	5	4
4	3	2	1	5
5	4	3	2	1

* The tables applicable to all experiments that are designated by letters and tables which must be " randomized " between one experiment (on one type of system) and another are designated by numbers.

As has been explained the handsets are numbered 1 to 5 but it should be understood that in the case of Circuit 1 (see Introduction) these numbers do not apply and should be disregarded. In the case of Circuit 2 these numbers serve to indicate the handset used by the talker. In the case of Circuit 3 these numbers indicate the group of handsets used by the four simultaneous listeners with the following convention : 1 represents the use of Handset No. 5 at Position 1, Handset No. 4 at Position 2, etc. as is clearly shown in Table A above.

Previous to any testing, a transmitter capsule and a receiver capsule will be allocated to each handset. There will be no permutation of these capsules during the tests.

II.6. — *Logatoms and carrier phrase to be used*

Logatoms will be used which have been made up in the following manner :

(a) The sounds are taken from the table given in the Note below.

(b) Each logatom is composed of an initial consonant (or consonance), a vowel and a final consonant (or consonance). (A consonance comprises a group of consonants such that the whole logatom can still be pronounced as a single utterance.)

(c) Each sound forming part of a logatom is drawn at random from among all those appropriate to that particular part of the logatom (that is to say, from the sounds of the corresponding column of the table of the Note 1 below).

(d) It is not considered necessary that the set of lists of logatoms should be balanced in pairs from the point of view of their difficulty.

The following (Esperanto) carrier phrase will be used :

KAN KON BAJ . . . . OLSO
(English equivalent : CAN CON BY . . . ALSO)

the logatoms being inserted in place of the stops. This phrase has been chosen for the following reasons.

All the vowel sounds of this phrase are long ones, giving a large deflexion to the needle of the voltmeter. The last sound preceding the logatom is phonetically a vowel and the first sound following the logatom is a vowel.

The phrase being meaningless it is natural to stress all the syllables equally.

This carrier phrase is to ensure that the vocal level remains constant throughout the tests ; to achieve this the talker should ensure that each of the three syllables CAN, CON, BY produces on the indicating instrument of the speech voltmeter of A.R.A.E.N. a deflexion of the needle just to the zero mark, this mark corresponding to reference vocal level for the A.R.A.E.N. The talker, following the sensatory impression thus obtained, will endeavour to pronounce the logatom at the normal vocal level so adjusted.

Enunciation of each logatom should be confined to only those sounds which constitute the logatom without the addition of any other parasitic vowel.

Remark 1. — The use of a carrier phrase implies that the voltmeter is used during the whole time of talking.

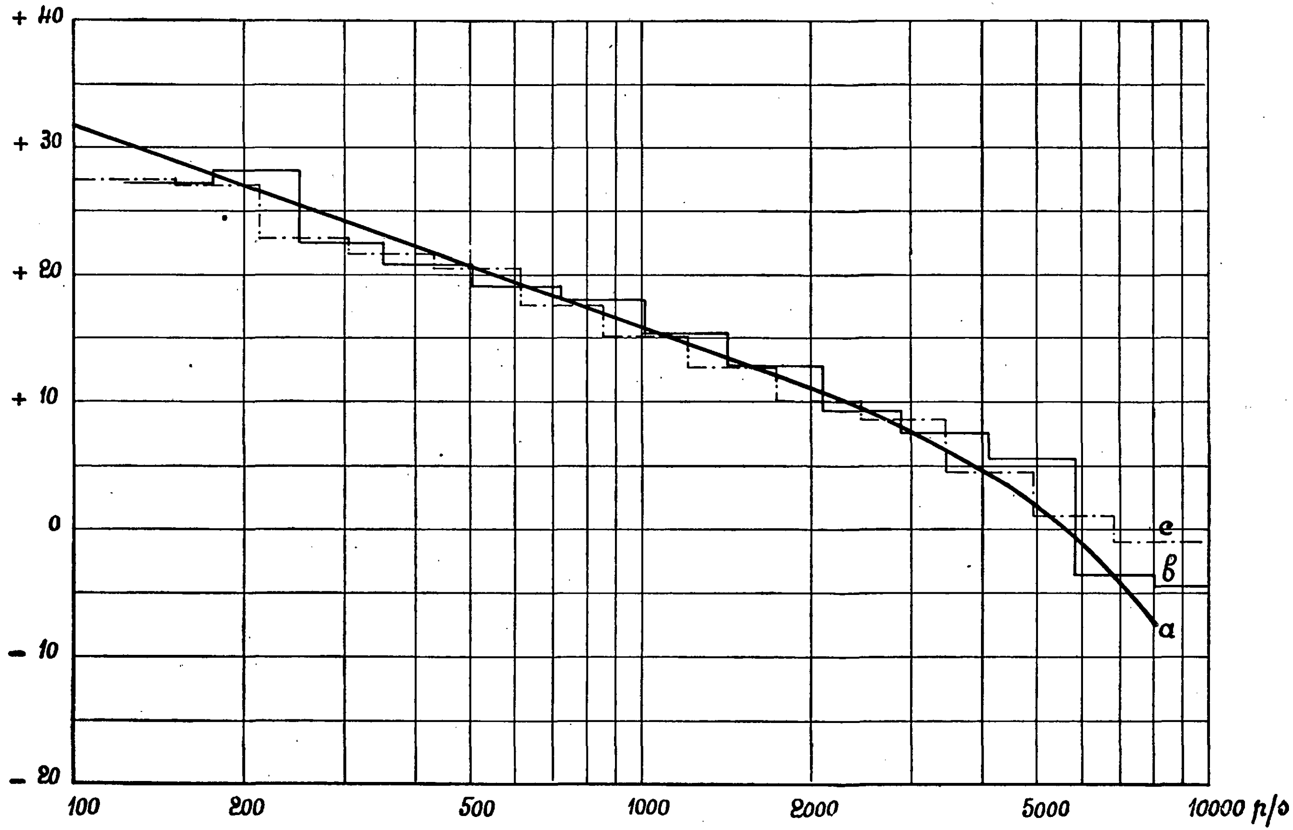
Remark 2. — About 4000 logatoms will be kept, each written on a separate card, and the lists of logatoms will be made up from this pool by drawing the cards at random.

Remark 3. — The listeners will write out in capital letters the logatoms received (there will be enough time for this when a carrier phrase is used).

Table of consonants (or consonances) and vowels to be used for the construction of logatoms in Esperanto symbols, for international measurements of articulation made with the A.R.A.E.N.

Initial consonants or consonances			Intermediate vowels	Final consonants or consonances			
B		SP	A	B	LN	P	Ŝ
BL	K	ST	E	C	LP	PT	T
BR	KL	SV	I	Ĉ	LT	R	V
C	KR	Ŝ	O	D	LV	RB	Z
Ĉ	L	ŜL	U	F	M	RD	
D	M	ŜM		FT	MB	RG	
DR	N	ŜN		G	MD	RK	
F	P	ŜP			MP	RM	
FL	PL	ŜT		K		RN	
FR	PR	ŜV		KS	MS	RS	
G	R	T		KT	N	RT	
GL	S	TR		L	ND	S	
GN	SK	V		LB	NK	SK	
GR	SL	Z		LD		SM	
Ĝ	SM			LK	NS	SP	
H	SN			LM	NT	ST	

Note. — The consonants, consonances and vowels above are written in Esperanto.



a ——— Mean power density spectrum of noise observed at telephone subscribers' stations (published by Hoth)

b ——— Typical graphs obtained at the C.C.I.F. Laboratory with two sets of filters.

c -·-·-·- Typical graphs obtained at the C.C.I.F. Laboratory with two sets of filters.

FIGURE 25. — *Power density spectrum of room noise produced in the listening room of the C.C.I.F. Laboratory*

Power per cycle per second (power in each frequency band of 1 c/s width), in decibels relative to an arbitrary zero

Remark 4. — Each member of the crew will correct the logatoms written by another member.

Note. — The sounds to be used in the construction of the logatoms are given in the table of page 74.

II.7. — *Noise at the receiving end*

For *sending* A.E.N. measurements on a commercial telephone circuit an " electrical background noise " is injected at the input of the A.R.A.E.N. receive end having a psophometric e.m.f. of 2 mV measured with the commercial telephone circuit psophometer specified by the C.C.I.F. Figure 16 above gives a schematic diagram of the circuit for introducing the " electrical background noise at the input of the A.R.A.E.N. receive end and Figure 23 above gives the power density spectrum of this noise.

For measurements using a *commercial receiving circuit* (the case of Circuit 3, see Introduction above), a room noise is used at the receiving end only. This room noise should have a power density spectrum corresponding to that published by Hoth and reproduced in Figure 25 which also shows the spectral distribution of a typical room noise measured in the listening cabinet of the C.C.I.F. Laboratory ; graphs *b* and *c* represent respectively the results of measurements on this noise made with two sets of half octave filters.

The acoustic intensity will be 60 db above a reference point defined by 2.10^{-4} dyne/cm^2 at 1000 c/s in a free progressive wave ; this acoustic intensity will be measured with the American sound level meter equipped with weighting network A (Standard Z.24.3.1944 of the American Standards Association, translated (into French) in the Annex 17 of the *Book of Annexes* of Volume IV of the *Green Book*).

Note. — Before the XVIIth Plenary Assembly of the C.C.I.F., the C.C.I.F. Laboratory determined A.E.N. values in all cases (sending and receiving) with room noise at the receiving end ; the present method introduces, with respect to the values previously measured, a difference of —2 decibels in the receiving transmission performance rating of a commercial telephone circuit.

II.8. — *Junction*

The junction used throughout the tests comprises a band-pass filter 300-3400 c/s. and a variable distortion-less attenuator (the junction of the A.R.A.E.N.). This junction has always the same composition whetever the system, S.R.A.E.N. or commercial, under test.

III. — Measurements of the reference equivalents

Measurements of reference equivalents will be carried out for each of the five sending and receiving ends of the type of commercial system considered, immediately preceding the execution of the articulation tests. These measurements will be carried out by the use of the S.F.E.R.T. according to the usual practice of the C.C.I.F. Laboratory. For the sending ends these measurements will be made using the guard ring specified for reference equivalent measurements.

Note. — It may be said that in general the " experiment " considered will consist of a single replication of articulation tests and will consequently last about a week (see sub-section 3.1.5 below) : this being so a single set of measurements of reference equivalent should be sufficient. If, on the contrary, it appears necessary to carry out a second replication on a given type of commercial telephone system, and as this replication may take place some weeks or even months after the first, a repeat will be made of the set of reference equivalent measurements before the supplementary replication with the object of verifying the stability of the 5 telephone sets subjected to experiment.

IV. — Articulation tests

The measurements carried out on a commercial telephone system are described below.

The order of execution of the tests, the method of their execution as well as the analysis and presentation of the results will remain the same for all types of system but the values of junction attenuation together with the randomization of test conditions will be different for each " experiment " carried out on a particular type of commercial telephone system.

Tests of sound articulation as a function of junction attenuation will be made in taking five values of attenuation for the junction of the circuit measured. These values will be denoted respectively by x_1, x_2, x_3, x_4 and x_5 db. The mid value i.e. x_3 of the junction attenuation will correspond approximately (within 5 db) to the final value of $x_{0 \cdot 8}$ (the attenuation corresponding to a sound articulation of 80%). The symbol x_1 corresponds with the smallest value of attenuation and the symbol x_5 with the greatest. The intervals between two consecutive values of attenuation will be constant, this interval being fixed at 5 db. * In Table No. 3 below the values of junction attenuation are indicated by the letters *a*, *b*, *c*, *d*, and *e* and these symbols are allocated at random independently for each of the Circuits 1, 2 and 3 tested during an " experiment " (see Introduction). Table 1 below gives an example of the allocation these symbols to the numerical values x_1, x_2, x_3, x_4, and x_5 of the attenuation for an experiment with one type of system.

Table 1 *

Telephone circuits	a	b	c	d	e
1	x_2	x_5	x_4	x_1	x_3
2	x_3	x_5	x_1	x_2	x_4
3	x_1	x_3	x_5	x_2	x_4

* See the note at the foot of Table A, page 73.

* Experience has shown that for certain types of modern commercial telephon system this value of 5 db is too great ; in this case the C.C.I.F. Laboratory will make the measurements with smaller intervalls between consequtive junction attenuation settings (e.g. 4 decibels).

In order to avoid trial and error methods in the determination of the mid-value of junction attenuation x_3 for a given system, a measurement will be made of the sound articulation with two attenuations one of which corresponds to a sound articulation greater than 80% (shown as x' in Table 2) and the other corresponding to a sound articulation of less than 80% (shown as x''). These tests will be known as " preliminary tests ".

IV.1. — *Preliminary tests*

The preliminary tests will be carried out in accordance with Table No. 2 below.

Each operator read 25 logatoms (75 sounds) for each of the attenuation values and for each circuit tested.

The determination of the mid-value x_3 of the junction attenuation values for each circuit will be made as follows : on a paper graduated with two linear scales, the values of junction attenuation x' and x'' will be set out on the abscissa and the average values of sound articulation (after transformation according to the logistic function (as indicated in Appendix I below) obtained at these two values of attenuation, will be set out on the ordinate. The value of x_3, corresponding as nearly as possible to a sound articulation of 80%, will be determined from the straight line joining those two points and this value will be used for the final tests.

TABLE 2

Programme for the preliminary articulation tests for an " experiment " on one type of commercial telephone system

Talker	Listeners showing position in listening cabinet				Symbol indicating value of junction attenuation	Numbers of the telephone circuits		
	1	2	3	4				
A_1	B_5	C_4	D_3	E_2	*a*	3	2	1
B_2	C_1	D_5	E_4	A_3	*b*	1	3	2
C_3	D_2	E_1	A_5	B_4	*a*	2	1	3
D_4	E_3	A_2	B_1	C_5	*b*	1	2	3
E_5	A_4	B_3	C_2	D_1	*a*	1	2	3
A_1	B_5	C_4	D_3	E_2	*b*	3	1	2
B_2	C_1	D_5	E_4	A_3	*a*	3	2	1
C_3	D_2	E_1	A_5	B_4	*b*	3	1	2
D_4	E_3	A_2	B_1	C_5	*a*	2	3	1
E_5	A_4	B_3	C_2	D_1	*b*	1	3	2

Relation between the symbols *a* and *b* and the value of junction attenuation

Telephone circuit	*a*	*b*
1	x'	x''
2	x''	x'
3	x'	x''

The suffix to the letters A, B, C, D and E indicates the number of the handset to be used by the operator A, B, C, D or E. The order of the tests is given by following each of the three columns marked " Numbers of the telephone circuits " in succession from top to bottom.

IV.2. — *Final articulation tests*

The plan of execution of the final sound articulation tests is established by use of the method known as the Graeco-Latin Square. A square has been chosen at random from the whole range of possible Graeco-Latin squares following the procedure given in Annex II below. A typical Graeco-Latin square is shown below. (For convenience the Greek Letters have been replaced by numbers.

	Columns				
Rows	*a*1	*b*2	*e*5	*c*3	*d*4
	*d*2	*e*3	*c*1	*a*4	*b*5
	*e*4	*a*5	*d*3	*b*1	*c*2
	*c*5	*d*1	*b*4	*e*2	*a*3
	*b*3	*c*4	*a*2	*d*5	*e*1

The columns of this square represent the different talkers and the rows represent the " groups " of tests. The tests are carried out in groups, all the tests of " Group 1 " being completed before beginning the tests of " Group 2 " these being entirely completed before beginning the tests of " Group 3 " and so on.

The letters *a*, *b*, *c*, *d* and *e* represent the values of the junction attenuation, the numbers 1, 2, 3, 4 and 5 represent the numbers allocated to the handsets used at the sending end or to the set of four handsets in use at the receiving end. The plan of the programme of an experiment on a typical commercial telephone system may be put in the form of Table 3 below :

TABLE 3

Talker		" A "	" B "	" C "	" D "	" E "
Listeners		BCDE	CDEA	DEAB	EABC	ABCD
Group	1	*a*1	*b*2	*e*5	*c*3	*d*4
	2	*d*2	*e*3	*c*1	*a*4	*b*5
	3	*e*4	*a*5	*d*3	*b*1	*c*2
	4	*c*5	*d*1	*b*4	*e*2	*a*3
	5	*b*3	*c*4	*a*2	*d*5	*e*1

Within the 25 cells of the Graeco-Latin square of this table it is necessary :

— to distribute the three circuits independently at random for each cell. (The numbers of these circuits are then written in each square from top to bottom.)

— in each cell and for each system to insert the numerical value of junction attenuation (x_1, x_2 ... or x_5) taking account of both the letter symbol (*a*, *b* ... or *e*) representing the value of attenuation allocated to this cell and the relation between these symbols and the numerical values x_1, x_2 ... or x_5. This relation is given only for the " experiment " cited as an example in Table of § IV

The complete plan of the articulation test thus established is shown in Table 4 below.

The order of execution of the tests is obtained by taking first " Group 1 " and reading along each line in succession. When all the tests of " Group 1 " are finished the tests of " Group 2 " are taken in the some order and so on.

The number written in each cell at the side of the letter symbol giving the value of junction attenuation indicates, according to the circuit considered, either the number of the handset used at the sending end or the set of four receivers used at the receiving end.

Table A (see § II.5) indicates how these handsets are to be allocated.

Note. — This Table A is applicable for all " experiments ", i.e. whatever type of commercial system is being tested).

TABLE 4

Talker	" A "	" B "	" C "	" D "	" E "
Listeners	BCDE	CDEA	DEAB	EABC	ABCD
Group 1	*a*1 $3/x_1$ $2/x_3$ $1/x_2$	*b*2 $2/x_5$ $3/x_3$ $1/x_5$	*e*5 $3/x_4$ $1/x_3$ $2/x_4$	*c*3 $1/x_4$ $2/x_1$ $3/x_5$	*d*4 $3/x_2$ $1/x_1$ $2/x_2$
Group 2	*d*2 $3/x_2$ $1/x_1$ $2/x_2$	*e*3 $1/x_3$ $3/x_4$ $2/x_4$	*c*1 $1/x_4$ $2/x_1$ $3/x_5$	*a*4 $1/x_2$ $3/x_1$ $2/x_3$	*b*5 $2/x_5$ $3/x_3$ $1/x_5$
Group 3	*e*4 $2/x_4$ $3/x_4$ $1/x_3$	*a*5 $3/x_1$ $2/x_3$ $1/x_2$	*d*3 $3/x_2$ $1/x_1$ $2/x_2$	*b*1 $2/x_5$ $1/x_5$ $3/x_3$	*c*2 $3/x_5$ $2/x_1$ $1/x_4$
Group 4	*c*5 $3/x_5$ $2/x_1$ $1/x_4$	*d*1 $1/x_1$ $3/x_2$ $2/x_2$	*b*4 $3/x_3$ $2/x_5$ $1/x_5$	*e*2 $2/x_4$ $3/x_4$ $1/x_3$	*a*3 $2/x_3$ $1/x_2$ $3/x_1$
Group 5	*b*3 $3/x_3$ $1/x_5$ $2/x_5$	*c*4 $1/x_4$ $2/x_1$ $3/x_5$	*a*2 $1/x_2$ $2/x_3$ $3/x_1$	*d*5 $1/x_1$ $3/x_2$ $2/x_2$	*e*1 $2/x_4$ $1/x_3$ $3/x_4$

Taking account of the indications of Table 4 the following Table 5 has been set up in order to illustrate, for the first groups of tests only, the order of execution of the tests and the conditions fixed for each " talk ".

It is to be noted that in Table 5 the receivers of the reference system are not shown since it is understood that when tests are made on a telephone circuit which involves the use of the reference system receiving end (in the example quoted Circuits 1 and 2) the four receivers of that system will not be permuted.

TABLE 5

	Talker	Sending handset	Circuit and value of junction attenuation	Position 1	Position 2	Position 3	Position 4
				Listeners and receiving handsets			
" Group " No. 1	Talker rotation A	–	$3/x_1$	B 5	C 4	D 3	E 2
	B	2	$2/x_5$	C –	D –	E –	A –
	C	–	$3/x_4$	D 4	E 3	A 2	B 1
	D	–	$1/x_4$	E –	A –	B –	C –
	E	–	$3/x_2$	A 3	B 2	C 1	D 5
	A	1	$2/x_3$	B –	C –	D –	E –
	B	–	$3/x_3$	C 1	D 5	E 4	A 3
	C	–	$1/x_3$	D –	E –	A –	B –
	D	3	$2/x_1$	E –	A –	B –	C –
	E	–	$1/x_1$	A –	B –	C –	D –
	A	–	$1/x_2$	B –	C –	D –	E –
	B	–	$1/x_5$	C –	D –	E –	A –
	C	5	$2/x_4$	D –	E –	A –	B –
	D	–	$3/x_5$	E 2	A 1	B 5	C 4
	E	4	$2/x_2$	A –	B –	C –	D –

According to the indications shown in this table, the articulation tests are then carried out in the following way : an operator reads 25 logatoms at the specified vocal level, these being inserted in the carrier phrase, the other four operators of the crew in the listening cabinet listen with the receivers of the telephone circuit under test. Such a test is known as a " talk ".

(See in Table B below the operations performed by an operator during the course of a " talk ".)

At the end of each talk, the operator who has just spoken is replaced by another operator and so on until there has been a complete rotation of the five operators in the talking position. This set of five talks constitutes a " rotation ". At the end of each rotation the operators proceed to the scoring of the lists of logatoms, each list of received logatoms being scored by an operator other than the writer.

TABLE B

Measurements of articulation (final tests)

Order of operations performed by an operator during a ' talk '			
At the sending end		At the receiving end	
1	Set up the test conditions viz : *a)* Commercial system (type of circuit under test, adjustment of feeding battery voltage, adjustment of the position of the handset on its stand, adjustment of the distance between the guard ring of the commercial microphone and the rim of the baffle plate of the A.R.A.E.N. microphone), or : *b)* Reference system (check of the speaking distance).	1	Each operator to put in circuit the handset allocated to him for this test.
2	Preparatory treatment of the microphone.	2	To write down the logatoms heard over the system under test.
3	Set up the required room noise		
4	Read a list of 25 logatoms inserting them in the carrier phrase and retaining the specified vocal level.		

IV.3. — *Number of talks per " experiment "*

It is understood in the present programme that each " experiment " carried out on a commercial telephone system will consist of a single sequence. A statistical analysis of these tests (by the method described in Appendix 1 below) will show whether there is need to carry out one or more complementary sequence to determine the A.E.N. values (sending and receiving) for this type of system with the desired precision.

Table 5 which gives the whole of the " talks " carried out for a " group " contains three talker rotations. The whole of the five groups of tests shown in Table 4 constitutes a sequence. Thus a sequence includes five groups of tests or fifteen talker rotations or in other words seventy five talks.

IV.4. — *Number of sounds received per experiment for each value of junction attenuation and for each telephone system*

In one talk an operator reads 25 logatoms and the four operators in the listening cabinet receive a total of $25 \times 4 = 100$ logatoms (300 sounds) per talk thus making a total of $300 \times 75/3 = 7500$ received sounds per telephone circuit per sequence. The number of sounds received for each value of attenuation is then :

$$7500 : 5 = 1500 \text{ sounds.}$$

Consequently 7500 sounds will be received per telephone system and per experiment if *the experiment consists of a single sequence.* If the statistical analysis of the result of such an experiment shows that this number of received sounds is insufficient a further sequence will be considered.

V. — INSCRIPTION AND CLASSIFICATION OF THE RESULTS

Throughout the articulation tests made during an experiment the four forms below will be used for the inscription and classification of the results.

Form A

Articulation score sheet. — Each listener will write on this form the logatoms which he hears. The sounds making up each logatom are to be written in capital letters in the first column by the listener. Later another crew member, carrying out the correction of the list, writes in the second column the correct sound wherever a sound has been incorrectly received. Examples are given in the Form A reproduced below ; the first logatom is wholly correct, in the case of the second the initial consonant was understood to be ' M '. whereas it was ' N ' and for the third the vowel was understood to be ' O ' whereas it was ' A ' and the final consonant understood to be ' FT ' instead of ' S '.

Form B

Articulation test sheet. — With the exception of the last six columns a set of these forms is completed before each sequence. The appropriate columns are completed from the programme of the " talks " (Table 5 above) with the object of giving complete details for each talk. Before each talk the details of execution of that talk should be verified to ensure that they are all in agreement with the indications shown on this sheet.

Form C

Articulation. Test summary sheet. — One of these forms will be made out for each telephone circuit tested (i.e. 3 Forms C per type of system) and each one will contain all the results given in the final column of the articulation test sheets (Form B). These results will be arranged in accordance with the Graeco-Latin square used for that experiment.

As the experiment proceeds the test results will be entered into these summary sheets so that an indication is given of the progress of the experiment.

Form D

Articulation test summary sheet for one type of commercial telephone system. — On this sheet (one sheet being used for one type of telephone system) are written the totals, summed over the three circuits for the rows (groups), the columns (talkers) and for the attenuation values.

When the experiment is finished the three Forms C corresponding to Circuits 1, 2 and 3 are completed as well as the Form D corresponding to the three circuits as a whole ; the statistical analysis of the test results may then be proceded with.

Form A

Articulation score sheet

.... db

Type of telephone system .... Replication ....

Circuit No. .... Talk No. ....

Talker .... Microphone current ....

Listener .... Date ....

No. of Group and talker rotation .... List No. ....

74	1	G U V	— — —	26	49
73	2	M A G	N — —	27	48
72	3	V O F T	— A S	28	47
71	4			29	46
70	5			30	45
69	6			31	44
68	7			32	43
67	8			33	42
66	9			34	41
65	10			35	40
64	11			36	39
63	12			37	38
62	13			38	37
61	14			39	36
60	15			40	35
59	16				
58	17				
57	18				
56	19				
55	20				
54	21				
53	22				
52	23				
51	24				
50	25				

FORM B

Articulations test sheet

Type of telephone system .... Replication No. ....

Date ....

Names of operators				
A	B	C	D	E

No. of group and talker rotation	Talk No.	Talker	Sending handset	Listening positions N° 1 Listener Handset	N° 2 Listener Handset	N° 3 Listener Handset	N° 4 Listener Handset	Telephone circuit	Junction attenuation db	No. of Sounds correctly received Positions 1	2	3	4	Total of sounds correctly received for each talk	Transformed total
	1	A	–	B 5	C 4	D 3	E 2	3	x_1						
	2	B	2	C –	D –	E –	A –	2	x_5						
1/1	3	C	–	D 4	E 3	A 2	B 1	3	x_4						
	4	D	–	E –	A –	B –	C –	1	x_4						
	5	E	–	A 3	B 2	C 1	D 5	3	x_2						
	6	A	1	B –	C –	D –	E –	2	x_3						
	7	B	–	C 1	D 5	E 4	A 3	3	x_3						
1/2	8	C	–	D –	E –	A –	B –	1	x_3						
	9	D	3	E –	A –	B –	C –	2	x_1						
	10	E	–	A –	B –	C –	D –	1	x_1						
	11	A	–	B –	C –	D –	E –	1	x_2						
	12	B	–	C –	D –	E –	A –	1	x_5						
1/3	13	C	5	D –	E –	A –	B –	2	x_4						
	14	D	–	E 2	A 1	B 5	C 4	3	x_5						
	15	E	4	A –	B –	C –	D –	2	x_2						

Form C

Articulation test summary sheet
(transformed results)

Type of telephone system .... Replication No. ....

Telephone circuit .... Date ....

<table>
<tr><th rowspan="2">Groups</th><th colspan="5">Talkers</th><th rowspan="2">Group totals (rows)</th></tr>
<tr><th>“A”</th><th>“B”</th><th>“C”</th><th>“D”</th><th>“E”</th></tr>
<tr><td>1</td><td>*</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Talker totals</td><td>“A”</td><td>“B”</td><td>“C”</td><td>“D”</td><td>“E”</td><td>Grand total
..............................</td></tr>
<tr><td>Attenuation totals</td><td>x_1 db</td><td>x_2 db</td><td>x_3 db</td><td>x_4 db</td><td>x_5 db</td><td rowspan="2">Linear
..............................</td></tr>
<tr><td>Handset totals</td><td>(1)</td><td>(2)</td><td>(3)</td><td>(4)</td><td>(5)</td></tr>
</table>

* Indicate in each cell : the junction attenuation ;
the number of the handset used.

The term “ linear ” is given by :

$$(-2)\,(T_{B_1}) + (-1)\,(T_{B_2}) + 0(T_{B_3}) + 1(T_{B_4}) + 2(T_{B_5})$$

FORM D

Articulation Test Summary Sheet
Results summed over all three circuits

Type of telephone system .... Replication No. ....

Date ....

Totals per :	Groups	1	2	3	4	5
	" Talker "	" A "	" B "	" C "	" D "	" E "
	Groups Attenuation	x_1	x_2	x_3	x_4	x_5
				Grand total		
				Linear :		

VI. — STATISTICAL ANALYSIS OF THE RESULTS

The results of the articulation test results for an " experiment " will be analysed by the method of " polynomial coefficients " described in the Appendix 1 attached.

VII. — PRESENTATION OF THE RESULTS AND OF THE STATISTICAL ANALYSIS

For each type of telephone system the articulation results together with their statistical analysis will be presented in the following manner :

Values of A.E.N. for sending and receiving for a typical commercial telephone system and the results of the statistical analysis of the tests

Commercial telephone system ....

Sending A.E.N. : 14.7 ± 1.2 db worse than A.R.A.E.N.
Receiving A.E.N. : 14.2 ± 1.4 db worse than A.R.A.E.N.
Value of $x_{0.8}$ for Circuit 1 (A.R.A.E.N. complete) 60.6 db

Error mean square			228
Statistical significance of certain factors :			
(C)	Talkers	No	
(E)	Groups	No	
(AE)	Circuit Group interaction	No	
(F_2)	Sending handsets	No	
(F_3)	Groups of receiving handsets	No	
(AC)	Circuit Talkers interaction	No	
(AB′)	Circuit Regression line slope interaction	Yes	(4252.5)
(B-B′)	Dispersion about regression lines	No	
	Slopes of regression lines b_1		−8.508
	b_2		−5.972
	b_3		−4.920

Note 1. — The numerical values quoted in this example correspond to the "experiment" analysed in Appendix 1.

Note 2. — When a factor is show as significant, the value of its mean square is shown in brackets in the table above.

VIII. — Electrical checking of the working condition of commercial telephone systems and the reference system

Daily tests

A check of the correct functioning of the reference system as well as of the commercial telephone systems will be made before each rotation.

Reference system. — For these check measurements the operators will conform to Section D of the " Instructions for operators of the C.C.I.F. Laboratory ".

Briefly these checks consist of the :

(a) check of the calibration of the vocal level indicator.
(b) check of the sending end of the reference system.
(c) check of the receiving end of the reference system.
(d) check and adjustment to the value of 60 db of the room noise in the listening cabinet by the A.R.A.E.N.* sound level meter.

* From time to time the C.C.I.F. Laboratory will check the room noise level with the American Sound Level Meter.

Commercial telephone system. — Check of the whole electrical portion of each complete telephone system at a frequency of 1000 c/s using for this purpose the " tele tests " section of the general test panel of the electrical measuring equipment supplied with the A.R.A.E.N.

This arrangement permits the microphone of the sending subscriber's set to be replaced by an a.c. generator of given e.m.f. and of impedance equal to the mean impedance of the microphone capsule of this set and to measure the p.d. across the receiver of the receiving telephone system situated in the listening cabinet. The schematic diagram of this measurement is given in Figure 26.

The measured value of the voltage VS across the terminals of the telephone receiver has no absolute meaning ; it is merely a value to allow a check to be made of the good order of the complete telephone system.

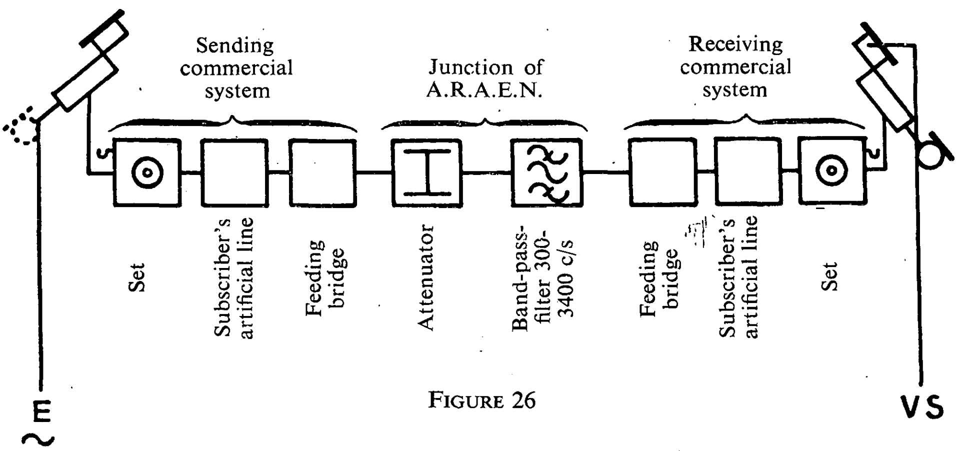


FIGURE 26

APPENDIX 1

Method of statistical analysis of experimental articulation test results and the determination of A.E.N. values for a subscriber's commercial telephone system

INTRODUCTION

This method of analysis is termed " Analysis by the Polynomial Coefficients Method ".

This Appendix contains a brief description of an analysis of experimental results of an articulation test.

The procedure to be followed in such an analysis consists of two stages :

1. Separation and estimation of the errors.
2. Determination of the value of junction attenuation corresponding to a sound articulation of 80% (in order to deduce the A.E.N. value).

I. — SEPARATION AND ESTIMATION OF THE ERRORS

An example of a statistical analysis, using this method, is given below in order to illustrate the different steps that this analysis involves. The experimental data corresponding to the calculation that appears below are taken from Test No. A15/51 carried out by the Research Branch of the British Telephone Administration.

When the observations have been completed the results must be arranged according to the Graeco-Latin square which was used for the design of the experiment. In the example considered the telephone circuit denoted by Circuit 1 is the S.R.A.E.N., that is to say, the A.R.A.E.N. together with the 300-3400 c/s. Band Pass Filter (i.e. the " system R " used by the C.C.I.F. Laboratory). Circuit 2 consists of a commercial sending end connected to the receiving end of the A.R.A.E.N., Circuit 3 consists of the A.R.A.E.N. sending endconnected to a commercial receiving end. These last two circuits also include the 300-3400 c/s. Band Pass Filter.

The Tables 1, 2 and 3 give the results for the " talks " for each telephone circuit.

TABLE 1

Circuit 1

Group (Row)	" Talker "				
	" A "	" B "	" C "	" D "	" E "
1	65 db	60 db	50 db	70 db	55 db
	66	60	74	27	73
	59	37	71	4	70
	43	66	75	26	70
	65	66	74	32	69
	233	229	294	89	282
2	55 db	50 db	70 db	65 db	60 db
	71	70	20	52	53
	73	72	35	45	69
	52	72	37	52	67
	70	71	42	61	62
	266	285	134	210	251
3	50 db	65 db	55 db	60 db	70 db
	74	57	66	56	19
	72	58	64	54	45
	68	62	71	54	43
	71	62	58	63	47
	285	239	259	227	154
4	70 db	55 db	60 db	50 db	65 db
	24	67	55	72	48
	40	65	56	74	47
	18	70	63	70	53
	44	74	70	72	57
	126	276	244	288	205
5	60 db	70 db	65 db	55 db	50 db
	67	30	37	57	72
	66	5	49	65	73
	50	46	53	63	74
	63	36	53	64	73
	246	117	192	249	292

TABLE 2

Circuit 2

Group (Row)	"Talker" "A"	"B"	"C"	"D"	"E"
1	45 db (1) 68 66 45 61 240	35 db (2) 70 68 68 72 278	55 db (5) 19 51 56 55 181	40 db (3) 68 67 68 67 270	50 db (4) 48 52 55 50 205
2	50 db (2) 52 61 40 55 208	55 db (3) 39 41 52 55 187	40 db (1) 60 61 68 69 258	45 db (4) 57 58 63 62 240	35 db (5) 70 72 69 69 280
3	55 db (4) 52 49 33 54 188	45 db (5) 59 57 68 62 246	50 db (3) 43 45 54 62 204	35 db (1) 71 67 68 68 274	40 db (2) 67 60 69 61 257
4	40 db (5) 73 71 67 72 283	50 db (1) 60 52 60 62 234	35 db (4) 70 69 73 74 286	55 db (2) 32 28 43 54 157	45 db (3) 69 72 72 65 278
5	35 db (3) 73 68 63 71 275	40 db (4) 66 60 68 72 266	45 db (2) 56 59 67 60 242	50 db (5) 44 43 49 48 184	55 db (1) 32 35 39 29 135

TABLE 3

Circuit 3

Group (Row)	" Talker "				
	" A "	" B "	" C "	" D "	" E "
1	45 db	50 db	40 db	55 db	35 db
	(1)	(2)	(5)	(3)	(4)
	59	47	69	40	72
	63	53	60	61	71
	65	55	68	45	69
	58	56	62	28	69
	245	211	259	174	281
2	35 db	40 db	55 db	45 db	50 db
	(2)	(3)	(1)	(4)	(5)
	68	64	57	60	61
	69	64	39	64	58
	67	68	64	55	59
	67	72	41	60	52
	271	268	201	239	230
3	40 db	45 db	35 db	50 db	55 db
	(4)	(5)	(3)	(1)	(2)
	65	67	74	60	63
	69	65	68	67	48
	61	70	71	56	37
	55	66	66	60	32
	250	268	279	243	180
4	55 db	35 db	50 db	40 db	45 db
	(5)	(1)	(4)	(2)	(3)
	61	73	64	68	67
	39	69	55	73	53
	48	69	64	62	63
	44	73	40	60	57
	192	284	223	263	240
5	50 db	55 db	45 db	35 db	40 db
	(3)	(4)	(2)	(5)	(1)
	62	45	54	66	71
	54	36	61	72	69
	63	34	65	69	65
	51	61	52	66	62
	230	176	232	273	267

The totals calculated for each talk for the set of listeners as shown in the three preceding tables are transformed by means of Table 2 below. The results after transformation are set down on Form C as in Tables 4, 5 and 6 and at the sametime totals are calculated for each Group (row), for each " Talker " (Column), for each Attenuation and, where appropriate, for each handset.

TABLE 4

Circuit 1

Row Group	" Talker "					Row Total
	" A "	" B "	" C "	" D "	" E "	
1	65 db 562	60 db 559	50 db 695	70 db 457	55 db 638	2911
2	55 db 603	50 db 647	70 db 489	65 db 542	60 db 582	2863
3	50 db 647	65 db 568	55 db 592	60 db 557	70 db 503	2867
4	70 db 484	55 db 622	60 db 574	50 db 659	65 db 538	2877
5	60 db 576	70 db 478	65 db 529	55 db 579	50 db 679	2841
Column total	2872	2874	2879	2794	2940	Grand total 14 359
Attenuation total	50 db 3327	55 db 3034	60 db 2848	65 db 2739	70 db 2411	Linear −2127

* See page 111.

TABLE 5

Circuit 2

Row Group	"Talker" "A"	"B"	"C"	"D"	"E"	Row Total
1	45 db (1) 569	35 db (2) 627	55 db (5) 521	40 db (3) 610	50 db (4) 538	2865
2	50 db (2) 541	55 db (3) 525	40 db (1) 591	45 db (4) 569	35 db (5) 632	2858
3	55 db (4) 526	45 db (5) 576	50 db (3) 538	35 db (1) 618	40 db (2) 589	2847
4	40 db (5) 641	50 db (1) 563	35 db (4) 651	55 db (2) 505	45 db (3) 627	2987
5	35 db (3) 620	40 db (4) 603	45 db (2) 571	50 db (5) 523	55 db (1) 490	2807
Column Total	2897	2894	2872	2825	2876	Grand total 14 364
Handset Total	(1) 2831	(2) 2833	(3) 2920	(4) 2887	(5) 2893	Linear
Attenuation total	35 db 3148	40 db 3034	45 db 2912	50 db 2703	55 db 2567	−1493

TABLE 6

Circuit 3

Row Group	"Talker" "A"	"B"	"C"	"D"	"E"	Row Total
1	45 db (1) 575	50 db (2) 543	40 db (5) 592	55 db (3) 516	35 db (4) 635	2861
2	35 db (2) 612	40 db (3) 606	55 db (1) 535	45 db (4) 568	50 db (5) 559	2880
3	40 db (4) 580	45 db (5) 606	35 db (3) 629	50 db (1) 573	55 db (2) 520	2908
4	55 db (5) 529	35 db (1) 644	50 db (4) 553	40 db (2) 598	45 db (3) 569	2893
5	50 db (3) 559	55 db (4) 518	45 db (2) 561	35 db (5) 616	40 db (1) 605	2859
Column Total	2855	2917	2870	2871	2888	Grand total 14 401
Handset Total	(1) 2932	(2) 2834	(3) 2879	(4) 2854	(5) 2902	Linear
Attenuation total	35 db 3136	40 db 2981	45 db 2879	50 db 2787	55 db 2618	−1230

From these three tables a fourth Table 7 is prepared (Form D) containing the sums over all three circuits for Groups (rows), " Talkers " (Columns) and Attenuations.

TABLE 7

Results summed over Circuits 1, 2 and 3

Row Totals (Groups)	(1) 8637	(2) 8601	(3) 8622	(4) 8757	(5) 8507	Grand total
Column Totals (Talkers)	" A " 8624	" B " 8685	" C " 8621	" D " 8490	" E " 8704	43 124
Attenuation totals	x_1 9611	x_2 9049	x_3 8639	x_4 8229	x_5 7596	Linear −4850

The quantity denoted by the term " linear " (in Tables 4, 5, 6 and 7) is required for the determination of the slope of the curve representing the change of test results after transformation as a function of the junction attenuation. It is calculated by the summation of the products of each attenuation total (TB) by the appropriate polynominal coefficient. In the case of five values of attenuation these coefficients are respectively : −2, −1 ; 0, + 1, + 2.

Hence for Circuit 1 :

$$[-2\ (3327)] + [-1\ (3034)] + 0\ (2848) + 1\ (2739) + 2\ (2411) = -2127$$

The following step is an analysis of variance of the experimental data assembled in the four preceding tables (4, 5, 6 and 7). Before proceding to the analysis an explanation is given of the symbols that will be used. For each circuit the following factors may be separated : Attenuations (B), " Talkers " (C), Groups (E) and where appropriate the sending handsets or the sets of receiving handsets (F). The letter in brackets after each factor serves to distinguish this factor. The factor represented by the differences between the telephone circuits is called Circuits, and is denoted by (A). These five factors correspond to the principal effects but it is necessary to consider in addition the three interaction effects denoted by (AB), (AC) and (AE). These interaction effects represent the degree to which the effects (B), (C) and (E) are different in the case of tho separate circuits. Finally an estimate of the random experimental error is obtained ; this being known as Error.

Each of the factors corresponding to a principal effect appears in the design with a certain number of values, or levels, for example, there are five Attenuations (B), five " Talkers " (or five levels of C), etc. There are consequently the same number of Attenuation totals, " Talker " totals, etc. and these totals are denoted by $T(B)_{i,j}$, $T(C)_{i,j}$, etc., the first suffix indicating the level of that factor and the second indicating the circuit to which the total applies. For example :

$$T(B)_{2\times 3} = 2981, \qquad T(C)_{4\times 2} = 2825, \qquad T(E)_{3\times 1} = 2867.$$

The totals after summation over all the circuits are denoted in the same way but with the second suffix omitted, e.g. $T(B_3) = 8639$. The grand totals for each circuit are denoted by G_1, etc... and the grand total after summation over all circuits by G.

The individual transformed scores within each circuit are collectively termed y_l, etc. according to the circuit to which they apply (it is not necessary to distinguish between the individual values of y_j).

Finally the number of levels of (B) is given the symbol a (a = the number of Attenuation values per Circuit) and the number of individual values of y which contribute to each Attenuation total is given the symbol r. The number of Circuits is called q.

The analysis of variance requires the computation of several sums of squares which will now be indicated. Each circuit is first treated separately. The sum of squares for each main effect is denoted by S(B), S(C), etc...

For each Circuit

$$S(B) = \sum_i \frac{T(B)^2_{i,j}}{r} - \frac{G^2_j}{ar}$$

Similarly S(C), etc... is obtained by replacing T(B) by T(C), etc... The second term remains the same for any given circuit. The denominator of the first term is equal to the number of individual values of y which contribute to each of the totals concerned, in this case 5 for each of the sums S(B), S(E), S(C) and S(F). In designs other than the Graeco-Latin Square the divisor may not be the same for all these factors..

$$S\,(B)_1 = \frac{3327^2 + 3034^2 + 2848^2 + 2739^2 + 2411^2}{5} - \frac{14\,359^2}{5 \times 5}$$

$$= 8\,340\,046 - 8\,247\,235 = 92\,811.$$

$$S\,(C)_1 = \frac{2872^2 + 2874^2 + 2879^2 + 2794^2 + 2940^2}{5} - \frac{14\,359^2}{5 \times 5}$$

$$= 8\,249\,387 - 8\,247\,235 = 2152.$$

$$S\,(E)_1 = \frac{2911^2 + 2863^2 + 2867^2 + 2877^2 + 2841^2}{5} - \frac{14\,359^2}{5 \times 5}$$

$$= 8\,247\,758 - 8\,247\,235 = 523.$$

$$\text{Error} = \text{Sum of square for } y_1 - \frac{G_1^2}{5 \times 5} - S\,(B)_1 - S\,(C)_1 - S\,(E)_1 = 4028.$$

In addition to these sums of squares, that for linear regression of y on attenuation is required. This quantity is given by the following expression in the case of five levels of attenuation :

$$S(B')_1 = \frac{[-2T(B)_{1 \times 1} - 1T(B)_{2 \times 1} + 1T(B)_{4 \times 1} + 2T(B)_{5 \times 1}]^2}{10\ r}$$

The quantity in the bracket is given in the four tables above under the term " linear ". The sum of squares representing the dispersion of the observed attenuation means about the best-fitting straight line is given by $S(B)_1 - S(B')_1$.

Circuit 1

$$\frac{G_1^2}{25} = 8\ 247\ 235$$

Factor	Degrees of freedom	Sums of squares
$(B)_1$	4	92 811
$(C)_1$	4	2 152
$(E)_1$	4	523
Error Circuit 1	12	4 028
$(B')_1$	1	90 483
$(B)_1 - (B')_1$	3	2 328

The number of degrees of freedom for each of the main effects is one less than the number of levels of that effect. The number of degrees of freedom for the error is given by subtracting the number of degrees of freedom for all the appropriate factors from the total number of data per circuit less one, i.e. : $25 - 1 - 4 - 4 - 4 = 12$.

The same procedure is then adopted with the other circuits giving results as in the tables below.

Circuit 2

$$\frac{G_2^2}{25} = 8\ 252\ 980$$

Factor	Degrees of freedom	Sums of squares
$(B)_2$	4	45 120
$(C)_2$	4	666
$(E)_2$	4	3 663
$(F)_2$	4	1 234
Error Circuit 2	8	1 209
$(B)'_2$	1	44 581
$(B)_2 - (B')_2$	3	539

Circuit 3

$$\frac{G_3^2}{25} = 8\ 295\ 552$$

Factor	Degrees of freedom	Sums of squares
$(B)_3$	4	30 606
$(C)_3$	4	448
$(E)_3$	4	351
$(F)_3$	4	1 196
Error Circuit 3	8	1 140
$(B')_3$	1	30 258
$(B)_3 - (B')_3$	3	348

It should be noted that the presence of the (F) effect reduces the number of degrees of freedom Error to 8 in the case Circuits 2 and 3.

The next step is to calculate the main effects (B), (C) and (E) for the summations over all circuits. This is done in the same was as for the individual circuits, except that all the divisors are increased by multiplying by 3, the number of Circuits over which summation has taken place. The general rule for determining a divisor is that it is equal to the number of individual unit data over which summation has taken place to obtain the totals which are being squared.

$$\text{Thus :} \quad \frac{G^2}{3\times5\times5} = 24\ 795\ 725$$

$$S(B) = \frac{9611^2 + 9049^2 + 8639^2 + 8229^2 + 7596^2}{3\times5} - 24\ 795\ 725$$

$$= 157\ 855$$

$$S(C) = 1\ 872$$

$$S(E) = 2\ 138$$

S(B′) is also obtained as before except that the divisor becomes $10\times3\times5$

$$S(B') = 156\ 817$$

The next stage is the calculation of the interaction sums of squares and this is best performed by assembling in a table all the sums of squares already calculated ; the interaction sums of squares are then obtained by subtraction.

Factor	Circuit 1	Circuit 2	Circuit 3	Summation over all circuits	Interaction (AB), (AC), (AE), and (AB′)
(B)	92 811	45 120	30 606	157 855	10 682
(C)	2 152	666	448	1 872	1 394
(E)	523	3 663	351	2 138	2 399
Error	4 028	1 209	1 140	—	—
(B′)	90 483	44 581	30 258	156 817	8 505
(B) – (B′)	2 328	539	348	—	—

The interaction sums of squares are obtained by subtracting the value in the fifth column from the sum of the values in the second, third and fourth columns.

Thus : 92 811 + 45 120 + 30 606 – 157 855 = 10 682

Factor	Degrees of freedom	Sum of squares	Mean square	Variance ratio
(A)	2	42	21	0,092
(B)	4	157 855	39 464	173.2 †††
(AB)	8	10 682	1 335.25	5.86 †
(C)	4	1 872	468	2.05
(E)	4	2 138	534.5	2.35
(AC)	8	1 394	174.25	0.76
(AE)	8	2 399	299.9	1.32
$(F)_2$	4	1 234	308.5	1.35
$(F)_3$	4	1 196	299	1.31
Error	28	6 377	227.75	—
(B′)	1	156 817	156 817	688.4 †††
(AB′)	2	8 505	4 252.5	18.67 ††
(B) – (B′)	9	3 215	357.2	1.56
$(B')_1$	1	90 483	90 483	397.2 †††
$(B')_2$	1	44 581	44 581	195.7 †††
$(B')_3$	1	30 258	30 258	132.8 †††

The pooled error can be obtained from this table by adding together the error sums of squares for the three circuits and in the same way can be calculated the pooled dispersion about the three linear regression lines by adding together the sums of squares for (B) — (B′).

These results together with the two sums of squares for (F) can now be assembled all together and tested against the pooled error mean square. This testing for significance is described later.

In the above table the sum of squares for (A) is obtained by subtracting $\frac{G_2}{75}$ from the sum of the corresponding quantities for the three circuits separately, i.e.

$$8\,247\,235 + 8\,252\,980 + 8\,295\,552 - 24\,795\,725 = 42$$

The number of degrees of freedom for (A) is, as given by the rule, one less than the number of circuits. The number of degrees of freedom for the interaction effects is given by multiplying together the numbers of degrees of freedom for the corresponding main effects. The number of degrees of freedom for pooled quantities is given by adding the numbers of degrees of freedom for the quantities which have been pooled.

The mean squares are given by dividing the sum of squares for each factor by the corresponding number of degrees of freedom. The variance ratio is the mean square divided by the mean square for error.

The significance of each factor can now be tested by the magnitude of the variance ratio. Tables are available which give the critical values of variance ratio for 5%, 1% and 0.1%* levels of significance as functions of the numbers of degrees of freedom for the factor being tested and for the error against which the factor is being tested. An extract of such a table is attached at the end of this appendix (Table 1). When the variance ratio exceeds the critical value for the 5% level but does not exceed that for the 1% level the factor is said to be " significant " and this is denoted in the above table by †. When the 1% level is exceeded but not the 0.1% the factor is said to be " highly significant "; this is denoted by ††. When the 0.1% level is exceeded the term " very highly significant " is applied and the fact is denoted by †††.

The interpretation of this table enables a critical examination of the reliability of the experiment to be made. Some experience must be gained before the full use can be made of the information which the analysis of variance table yields. The most important use of such a table is to decide whether or not the experiment should be repeated. Some guidance on this decision is now given.

1. The magnitude of the error mean square will indicate whether the results have achived the normal degree of consistency. Values in excess of 500 are rare.

2. The significance or not of (E) indicates whether the results have remained stable between the five groups which have been executed in succession. If (E) were significant and it were noticed that the row totals of the table giving the summations over all three circuits successively increased from Row 1 to Row 5, it would suggest that a practice effect was present. In such a case a repeat of the experiment should certainly be carried out. If the (AE) interaction were also significant, it would indicate that the practice effect was either confined to only one or two circuits or was unequal for the three circuits.

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* The critical value variance ratio at the 5% level of significance is that value which, if a great number of experiments were carried out, would be exceeded on an average of five times in every hundred by chance variations alone as a result of the limited amount of data available in each experiment. It could also be said that the factor is " significant at the 5% level ".

3. When either of the (F) effects is significant it denotes that the set of five handsets is not homogeneous and that caution must be exercised in extending any conclusions from the measurements to all handsets of the same type. There would be no point in repeating the experiment using the same five handsets but it would be useful to obtain another set of five and then to repeat the experiment.

4. It is very important to note whether the (AC) interaction is significant or not because its significance would mean that the results which have been obtained for comparisons between the three circuits, i.e. A.E.N. values, are to a certain extent peculiar to the particular crew in use. That is, if the confidence limits are based on the value of the error mean square obtained, they may not include the true A.E.N. value applicable for any crew trained in the same manner and employing the same technique. There is again no point in repeating the experiment immediately with the same crew. The results can, however, be presented without being misleading by employing the (AC) mean square and its number of degrees of freedom for estimating the confidence limits which will, thereby, be somewhat broader.

5. If (B′) is very highly significant it shows that the mean slope of the three regression lines of y on x has been estimated with satisfactory precision. Unless this slope is precisely estimated the final results in the form of $x_{0.8}$ values will have confidence limits so wide that they are quite useless.

6. The (AB′) interaction is frequently, but not always, significant. When it is not significant it shows that a common value may be taken for the slope of the three regression lines ; advantage can be then taken of the fact to calculate the two A.E.N. values without first calculating the three $x_{0.8}$ values, but this will not be done in what follows for the sake of keeping the form of presentation of the results uniform. When the (AB′) interaction is significant it shows that different slopes apply for the three regression lines ; the very high significance of $(B')_1$, $(B')_2$ and $(B')_3$ will show that the three slopes have been separately estimated with sufficient precision. Unless the three variance ratios of these exceed (about) 64 the results will not be sufficiently precise ; indeed certain approximations in estimating the confidence limits which are used below will not be valid.

7. (B)—(B′) gives a measure at the dispersion of the observed points about the three regression lines. If this is not significant is shows that use of a linear regression line was justified. If significant it may be evidence of significant curvature but this could best be investigated by plotting the regression lines and inspecting them visually ; sometimes curvature is due to the choice of a set of attenuation values extending too far into the high articulation region.

II. — Determination of $x_{0.8}$ values and A.E.N. values

The next step to be described is the calculation of the $x_{0.8}$ values for the three circuits. The linear regression coefficients, b_1, b_2, b_3 are given by dividing the sums of products termed " linear " in each of Tables 4, 5 and 6 above by 50 I. I is the interval in decibels between consecutive values of junction attenuation. In this case where $I = 5$ db we have :

$$b_1 = \frac{-2127}{250} = -8.508$$

$$b_2 = \frac{-1493}{250} = -5.972$$

$$b_3 = \frac{-1230}{250} = -4.920$$

Now $x_{0.8}$ is given by the expression :

$$x_{0.8} = \bar{x} + \frac{569.3 - \bar{y}}{b}$$

where 569.3 is the value of y corresponding to 0.8 sound articulation,
$\bar{x}$ is the mean attenuation (or middle value) and
$\bar{y}$ is the mean value of y for the particular circuit.

Circuit 1

$$x_{0.8} = 60 + \frac{569.3 - \frac{14\,359}{25}}{-8.508}$$
$$= 60 + \frac{-5.1}{-8.508}$$
$$= 60.60 \text{ db.}$$

Circuit 2

$$x_{0.8} = 45 + \frac{569.3 - \frac{14\,364}{25}}{-5.972}$$
$$= 45 + \frac{-5.3}{-5.972}$$
$$= 45.89 \text{ db.}$$

Circuit 3

$$x_{0.8} = 45 + \frac{569.3 - \frac{14\,401}{25}}{-4.920}$$
$$= 45 + \frac{-6.7}{-4.920}$$
$$= 46.36 \text{ db.}$$

The sending A.E.N. value is obtained by calculating the difference between the $x_{0.8}$ values for Circuits 1 and 2, namely :

60.60 −45.89 = 14.71 db worse than A.R.A.E.N.

The receiving A.E.N. value is obtained from the difference between the $x_{0.8}$ values for Circuits 1 and 3, namely :

60.60 −46.36 = 14.24 db worse than A.R.A.E.N.

When the (AB′) interaction is not significant, as has already been explained, a common slope may be taken. This would be given by the expression :

$$b = \frac{\text{Sum of products for linear regression given in the table of summation over circuits}}{150\, I}$$

(The figure would be −4.850 in this example if the interaction had been not significant.)

If this common value of b is used in the expression for $x_{0.8}$ it is obvious that the A.E.N. values can be calculated directly without introducing the quantity 569.3 and with somewhat less arithmetic. This procedure is, however, not recommended because it is usually of some interest to know the $x_{0.8}$ values (especially that of Circuit 1) as well as the A.E.N. values.

III. — Calculation of confidence limits

Provided that the slopes of the three regression lines have been estimated with good precision (see § I) and that the value of y does not differ much from 569.3 (or, what is the same thing, x does not differ much from $x_{0.8}$, say by not more than 5db), the following approximate formula may be used for $V(x_{0.8})$.

$$V(x_{08}) = \frac{V_o}{25\, b^2}$$

Circuit 1

$$V(x_{0.8}) = \frac{227.75}{25\,(-8.508)^2} = 0.126\ (\text{db})^2$$

Circuit 2

$$V(x_{0.8}) = \frac{227.75}{25\,(-5.972)^2} = 0.255\ (\text{db})^2$$

Circuit 3

$$V(x_{0.8}) = \frac{227.75}{25\,(-4.920)^2} = 0.368\ (\text{db})^2$$

The variances of the two A.E.N. values are given by adding together the variances of the two $x_{8.0}$ values used in calculating the respective A.E.N. values.

Thus,

$$V(\text{Sending A.E.N.}) = 0.126+55\ 2.0 = 0.381\ (\text{db})^2$$

and

$$V(\text{Receiving A.E.N.}) = 0.126+0.368 = 0.494\ (\text{db})^2$$

The corresponding confidence intervals are calculated from these variances in the usual way, namely :

$$\text{Confidence interval} = \pm\, t\sqrt{V}$$

where t depends on the number of degrees of freedom for V_o (in this case 28, corresponding to $t = 2.05$ for 95% confidence). The confidence intervals are therefore as follows :

$x_{0.8}$	Circuit 1	±0.73 db
	Circuit 2	±1.03 db
	Circuit 3	±1.24 db
A.E.N.	Sending	±1.26 db
	Receiving	±1.43 db

In the case where the (AC) interaction is significant the above procedure is modified by the use of the (AC) mean square instead of the error mean square with a corresponding change of the number of degrees of freedom for t (the confidence intervals would in such cases generally be much wider). Only experience will show whether this is likely to be a common occurrence.

Randomized Blocks Design
(2 Attenuation values per Circuit)

(This design is not described in such detail as has been devoted to the Graeco-Latin Square Design.)

In this design " Talkers " are used as blocks and the two attenuation values for each circuit are taken as treatments and allocated at random to all the blocks. Although the C.C.I.F. 9th Series of tests has not actually been arranged in this way it is permissible to use part of the results for illustration of the analysis.

Analysis of variance. — The individual scores are first assembled as follows (one circuit only will be given in full in Table 9 below) :

TABLE 9

Circuit 2 $\left(\frac{\text{III}}{\text{R}}\right)$ *(1st Replication)*

Attenuation	" Talker "				
	" A "	" B "	" C "	" D "	" E "
23 db	64	73	65	70	70
	64	63	68	68	71
	54	69	68	75	68
	61	65	68	72	61
	243	270	269	285	270
37 db	34	62	38	54	40
	30	41	51	62	59
	18	58	62	36	54
	42	57	60	52	41
	124	218	211	204	194

The other circuits (Circuit 1 will be taken as R/R of the 9th Series of Tests with the same vocal level as the commercial circuits ; Circuit 3 will be taken as R/III) are assembled in the same way and the totals for each talk transformed as before. The transformed data are then arranged as in the following table.

TABLE 10

						Sum
Circuit 1						
39 db.	591	614	608	635	606	3 054
52 db.	540	551	564	565	542	2 762
Sum	1 131	1 165	1 172	1 200	1 148	5 816
						linear
						−292
Circuit 2						
23 db.	573	610	608	647	610	3 048
37 db.	482	549	543	538	530	2 642
Sum	1 055	1 159	1 151	1 185	1 140	5 690
						linear
						−406
Circuit 3						
24 db.	575	622	606	598	566	2 967
38 db.	527	525	543	541	538	2 674
Sum	1 102	1 147	1 149	1 139	1 104	5 641
						linear
						−293
Summation over circuits 1 to 3						
x_1	1 739	1 846	1 822	1 880	1 782	9 069
x_2	1 549	1 625	1 650	1 644	1 610	8 078
Sum	3 288	3 471	3 472	3 524	3 392	17 147
						linear
						−991

The results of the analysis of variance are given in the following table.

TABLE 11

Factor	Degrees of freedom	Sum of Squares	Mean Square	Variance Ratio
(A)	2	1 631	815	3.82
(B) = (B′)	1	32.736	32.736	1.54
(AB) = (AB′)	2	858	429	2.01
(C)	4	5.648	1.412	6.63 †
(AC)	8	1.646	206	0.97
(BC)	4	565	141	0.66
(ABC) = error	8	1.704	213	—

Estimation of $x_{0.8}$. — The $x_{0.8}$ values may be estimated in a similar manner to that adopted for the previous design. The only difference is in the values of the divisors because there are here only two attenuation values per circuit.

Circuit 1

$$b = \frac{-292}{1 \times 5 \times 13} = -\ 4.49$$

$$x_{0.8} = 45.5 + \frac{569.3 - \dfrac{5816}{10}}{-4.49} = 45.5 + \frac{-12.3}{-4.49} = 48.24 \text{ db}$$

Circuit 2

$$b = \frac{-406}{1 \times 5 \times 14} = -\ 5.80$$

$$x_{0.8} = 30 + \frac{569.3 - \dfrac{5690}{10}}{-5.80} = 30 + \frac{0.3}{-5.80} = 29.95 \text{ db}$$

Circuit 3

$$b = \frac{-293}{1 \times 5 \times 14} = -\ 4.19$$

$$x_{0.8} = 31 + \frac{569.3 - \dfrac{5641}{10}}{-4.19} = 31 + \frac{5.2}{-4.19} = 29.76 \text{ db}$$

Estimation of confidence intervals. — The confidence intervals may also be estimated as before.

Circuit 1

$$V(x_{0.8}) = \frac{213}{(-4.49)^2 \times 5 \times 2} = 1.05$$

$$95\% \text{ confidence interval} = \pm 2.31 \sqrt{1.05} = \pm 2.37 \text{ db}$$

Circuit 2

$$V(x_{0.8}) = \frac{213}{(-5.80)^2 \times 10} = 0.63$$

$$95\% \text{ confidence interval} = \pm 2.31 \sqrt{0.63} = \pm 1.84 \text{ db}$$

Circuit 3

$$V(x_{0.8}) = \frac{213}{(-4.19)^2 \times 10} = 1.22$$

$$95\% \text{ confidence interval} = \pm 2.31 \sqrt{1.22} = \pm 2.55 \text{ db}$$

Crossover Design

This design, like the 2-point Randomized Blocks Design, assumes that a linear relationship between transformed articulation means and attenuation values, has already been verified. Five attenuation values are used for each circuit but only two out of the five " talkers " are used at each attenuation value. The arrangement is such that the slope of the regression line is estimated as precisely as possible but departures from it can be tested only with reduced precision. The observations are conducted in two groups and, if one group is completed before the other is commenced, any trend in the performance of the crew can be detected. In the first group the attenuation values for each circuit are allocated, one to each " talker ", independently at random. The second group is derived from the first by arranging that the " Talker " who used x_1 of any particular circuit in Group 1 uses x_5 of that same circuit in Group 2 ; the " Talker " who used x_2 in Group 1 uses x_4 in Group 2 of the same circuit ; the " Talker " who used x_3 in Group 1 uses x_3 of the same circuit also in Group 2. The design is given its name from the manner in which the attenuation values are crossed over between the two groups.

Analysis of variance. — The scores for the individual listeners are first assembled and summed over the four simultaneous listeners. These sums are then transformed as before. The assembly of the scores is not given here but only the transformed values arranged in such a way as to illustrate the form of the design and to facilitate the analysis of variance. The arrangement is very similar to that of the Graeco-Latin Square Design except that there are two groups instead of five.

TABLE 12

Circuit 1						
Group 1	65 db	50 db	55 db	45 db	60 db	Sum
	480	595	576	612	552	2 815
2	45 db	60 db	55 db	65 db	50 db	
	669	544	590	480	605	2 888
Sum	1 149	1 139	1 166	1 092	1 157	5 703
Attenuation totals	45 db	50 db	55 db	60 db	65 db	linear
	1 281	1 200	1 166	1 096	960	−746
Circuit 2						
Group 1	45 db	40 db	30 db	35 db	50 db	Sum
	515	594	614	553	532	2 808
2	35 db	40 db	50 db	45 db	30 db	
	659	628	528	538	627	2 980
Sum	1 174	1 222	1 142	1 091	1 159	5 788
Attenuation totals	30 db	35 db	40 db	45 db	50 db	linear
	1 241	1 212	1 222	1 053	1 060	−521

TABLE 12 *(Contd.)*

Circuit 3						
Group 1	40 db 581	35 db 605	45 db 575	50 db 549	55 db 510	Sum 2 820
2	50 db 558	55 db 505	45 db 585	40 db 583	35 db 641	2 872
Sum	1 139	1 110	1 160	1 132	1 151	5 692
Attenuation totals	35 db 1 246	40 db 1 164	45 db 1 160	50 db 1 107	55 db 1 015	linear −519
			Summation over Circuits 1 to 3			
Group totals 1	.	.	.	.	.	8 443
Group totals 2	.	.	.	.	.	8 740
	1	2	3	4	5	
" Talker totals	3 462	3 471	3 468	3 315	3 467	

Grand total . . . . . . = 17 183
Linear . . . . = −1 786

From Table 12 the necessary sums of squares for the analysis can be calculated giving the result shown in Table 13 below.

TABLEAU 13

Factor	Degrees of freedom	Sum of Squares	Mean Square	Variance Ratio
(A)	2	552	276	0.37
(B′)	1	53.163	53.163	71 †††
(AB′)	2	1.702	851	1.14
(C)	4	3.088	772	1.03
(E)	1	2.940	2.940	3.94
(AC)	8	3.872	484	0.65
(AE)	2	820	410	0.55
Error	9 −3 = 6	4.493	748	—

In the above table the number of degrees of freedom for the error has been reduced by three because it was necessary to fit three " missing " values to enable existing data to be used for the example.

The analysis of variance given above would indicate, from the relatively large value of error variance, an unsatisfactory experiment which ought to be repeated. Values in excess of about 500 are unusual in the experience of the British Post Office and of the C.C.I.F. laboratory. In spite of the unsatisfactory conclusion from the analysis of variance the values of $x_{0.8}$ and their confidence limits will be estimated below merely to illustrate the method.

Estimation of $x_{0.8}$. — The three circuits are identical to those used to illustrate the Graeco-Latin Square Design, in fact they are from the same experiment.

The $x_{0.8}$ values are obtained as before.

Circuit 1

$$b = \frac{-746}{10\times 2\times 5} = -7.46$$

$$x_{0.8} = 55 + \frac{569.3 - \frac{5703}{10}}{-7.46} = 55 + \frac{-1.0}{-7.46} = 55.13 \text{ db}$$

Circuit 2

$$b = \frac{-521}{100} = -5.21$$

$$x_{0.8} = 40 + \frac{569.3 - \frac{5788}{10}}{-5.21} = 40 + \frac{-9.5}{-5.21} = 41.82 \text{ db}$$

Circuit 3

$$b = \frac{-519}{100} = -5.19$$

$$x_{0.8} = 45 + \frac{569.3 - \frac{5692}{10}}{-5.19} = 45 + \frac{0.1}{-5.19} = 44.98 \text{ db}$$

Estimation of confidence intervals. — The confidence intervals are obtained as before.

Circuit 1

$$V(x_{0.8}) = \frac{748}{(-7.46)^2\times 2\times 5} = 1.34$$

$$95\% \text{ confidence interval} = \pm 2.45\sqrt{1.34} = \pm 2.48 \text{ db}$$

Circuit 2

$$V(x_{0.8}) = \frac{748}{(-5.21)^2\times 2\times 5} = 2.74$$

$$95\% \text{ confidence interval} = \pm 2.45\sqrt{2.74} = \pm 4.07 \text{ db}$$

Circuit 3

$$V(x_{0.8}) = \frac{748}{(-5.19)^2\times 2\times 5} = 2.79$$

$$95\% \text{ confidence interval} = \pm 2.45\sqrt{2.79} = \pm 4.10 \text{ db}$$

TABLE 1

Table of critical values of variance ratios

(Allowing for 28 degrees of freedom in the error mean square)

Significance	Degrees of freedom for the factor considered				
	1	2	4	8	9
5 %	4.20	3.34	2.71	2.29	2.24
1 %	7.64	5.45	4.07	3.23	3.11
0.1 %	13.5	8.9	6.3	4.7	4.5

TABLE 2

Table for the transformation of articulation test results

n = the sum of the numbers of sounds correctly received by four listeners

Logistic transformation $y = 500+100\times \text{arg. th}\left(\frac{2n}{300} - 1\right)$

The maximum value of n for 4 operators is 300.

n	0	1	2	3	4	5	6	7	8	9
100	465	466	467	468	468	469	470	470	471	472
110	473	473	474	475	475	476	477	478	478	479
120	480	480	481	482	482	483	484	485	485	486
130	487	487	488	489	489	490	491	491	492	493
140	493	494	495	495	496	497	497	498	499	499
150	500	501	501	502	503	503	504	505	505	506
160	507	507	508	509	509	510	511	511	512	513
170	513	514	515	515	516	517	518	518	519	520
180	520	521	522	522	523	524	525	525	526	527
190	527	528	529	530	530	531	532	532	533	534
200	535	535	536	537	538	538	539	540	541	542
210	542	543	544	545	546	546	547	548	549	550
220	551	551	552	553	554	555	556	557	558	559
230	559	560	561	562	563	564	565	566	567	568
240	569	570	571	573	574	575	576	577	578	579
250	580	582	583	584	585	587	588	589	591	592
260	594	595	597	598	600	601	603	605	606	608
270	610	612	614	616	618	620	622	625	627	629
280	632	635	638	641	644	647	651	655	659	664
290	668	674	679	686	695	704	715	730	750	786

APPENDIX 2

Formation and randomization of Graeco-Latin Squares

A Latin Square consists of p letters arranged in p rows having p letters in each ; each row and each column contains each letter once only. An example of a five - by - five Latin Square is as follows.

A	B	C	D	E
B	A	E	C	D
C	D	A	E	B
D	E	B	A	C
E	C	D	B	A

There are actually 161,280 different five-by-five Latin Squares but one can be chosen from this number by suitably randomizing one (chosen at random) of only 56 standard five-by-five squares. The standard squares are given by Fisher & Yates *(Statistical Tables for Biological, Agricultural & Medical Research,* Oliver & Boyd, Third Edition, 1948).

The randomization procedure is also described therein.

A Graeco-Latin Square consists of two superposed Latin Squares, one of Roman letters and the other of Greek letters, such that each row and each column contains each Roman letter once only and each Greek letter once only and, in addition, every possible combination of a Roman letter and a Greek letter occurs once only. An example is given below in which the lower case letters denote the Roman letters and the numbers denote the Greek letters.

a1	b2	c3	d4	e5
b3	c4	d5	e1	a2
c5	d1	e2	a3	b4
d2	e3	a4	b5	c1
e4	a5	b1	c2	d3

The formation of Graeco-Latin Squares for use in the designs of experiments is carried out by randomizing the above square in the following manner. Permute all rows except the first, permute all columns and allocate the letters (both Roman and Greek) at random to the particulars which they relate. The permutation is done at random either by marking cards, shuffling them and drawing them one at a time, by drawing numbered balls from a bag or by the aid of a table of random numbers. The second method is perhaps the most convenient as well as being quite reliable. For the purposes of illustration random numbers will be used.

The last four rows of the above Graeco-Latin Square numbered 1, 2, 3, 4. An extract from a table of random numbers is as follows :

5, 3, 4, 4, 0, 9, 4, 2, 7, 2, 0, 0, 4, 1, 8, 6.

The digits 1, 2, 3, 4 occur for the first occasion in the following order : 3, 4, 2, 1, so that the square is rewritten with its last four rows in this order.

a1	b2	c3	d4	e5
d2	e3	a4	b5	c1
e4	a5	b1	c2	d3
c5	d1	e2	a3	b4
b3	c4	d5	e1	a2

The columns can be randomized similarly by using another sequence of random numbers. These might be as follows :

1, 6, 9, 0, 8, 2, 6, 6, 5, 9, 8, 3, 6, 2, 1, 1, 6, 4, 1, 1.

Taking the digits 1, 2, 3, 4, 5 in the order in which they first occur we find : 1, 2, 5, 3, 4. The columns are therefore permuted in this order giving :

a1	b2	e5	c3	d4
d2	e3	c1	a4	b5
e4	a5	d3	b1	c2
c5	d1	b4	e2	a3
b3	c4	a2	d5	e1

Suppose now that the letters are to represent the five attenuation values 30, 35, 40, 45 and 50 bd. Another sequence of random numbers is :

4, 1, 4, 7, 1, 0, 2, 5, 6, 2, 9, 7, 0, 5, 3, 1.

Taking the digits 1, 2, 3, 4, 5 in the order in which they first occur we obtain : 4, 1, 2, 5, 3. The attenuation values when placed in this order become : 45, 40, 35, 50, 40 so that " a " represents 45 db, " b " represents 30 db, etc... If the numbers represent handsets, it is likely that they will have already been numbered in an effectively random fashion. (That is they have not been numbered in any such systematic way as giving the least sensitive one the lowest and the most sensitive one the highest number.)

If an effectively random numbering has been given no further randomizing is required for the numbers. The Graeco-Latin Square then becomes :

45	30	40	35	50
(1)	(2)	(5)	(3)	(4)
50	40	35	45	30
(2)	(3)	(1)	(4)	(5)
40	45	50	30	35
(4)	(5)	(3)	(1)	(2)
35	50	30	40	45
(5)	(1)	(4)	(2)	(3)
30	35	45	50	40
(3)	(4)	(2)	(5)	(1)

In this square the numbers in brackets represent the handsets.

In this form the square may be used for a single circuit in the design of an experiment. The complete randomizing procedure must be repeated for each new experiment.

3.1.5 Cost of determining (at the C.C.I.F. Laboratory) the A.E.N. values (for sending and receiving) of one commercial telephone circuit

These costs are determined on the basis of the number of hours of work by the C.C.I.F. Laboratory ; the rate per hour for the crew (of five male or female technical operators) of the C.C.I.F. Laboratory is evaluated periodically in Swiss francs (excluding general running expenses of the C.C.I.F. Laboratory other than lighting and heating).

The numbers of hours required for the A.E.N. measurements on one commercial telephone circuit are as follows :

1. Measurement of the A.E.N. for sending : 28 hours.
2. Measurement of the A.E.N. for receiving : 28 hours.
3. Measurement of the A.E.N. for a complete telephone circuit : 35 hours.

3.1.6 Recommendations to Administrations or Private Operating Companies concerning the forwarding of commercial telephone circuits to the C.C.I.F. Laboratory for articulation or reference equivalent measurements

Introduction

The instructions given in the *Yellow Book*, Volume IV, page 159, Note, relating to the despatch, by the various Administrations or Private Operating Companies, of telephone equipment for calibration or use in the series of tests by the C.C.I.F. Laboratory are not sufficiently complete ; these instructions were made when the C.C.I.F. Laboratory was in Paris and the measurements made by the Laboratory were principally of reference equivalents.

Because the C.C.I.F. Laboratory has been transferred from Paris to Geneva, and will be expected to carry out, in addition, measurements of A.E.N., it is necessary to provide supplementary information for Administrations and Private Operating Companies.

When sending commercial telephone circuits to the C.C.I.F. Laboratory for A.E.N. measurements, Administrations and Private Operating Companies are asked to follow the instructions below.

1. — *Equipment required to enable the A.E.N. to be measured*

Administrations and Private Operating Companies which desire A.E.N. measurements to be made are requested to send the C.C.I.F. Laboratory five complete commercial telephone circuits (the same type of set, the same types of transmitter and receiver capsules) consisting of the items listed below.

Quantity	Item	Remarks
5	Subscriber's sets	Without handsets
5	Handsets	
5	Subscriber's artificial lines	
5	Feeding bridges	Marked with the battery voltage
4	Guard rings	2 for reference equivalent measurements and 2 for A.E.N. measurements (See Section 3.1.4, § II.1)
1	Setting gauges for handsets	See Section 3.1.4, § II.3
	Spares	For all parts of the circuit

2. — *Form of the equipment for A.E.N. or reference equivalent measurements*

All the separate component parts of a telephone circuit should be provided with terminals and cords for making connections, and these should be readily accessible so as to facilitate the interconnection of the items. A convenient arrangement is with the components mounted on loose panels. Otherwise if, for example, the subscriber's set is provided in its commercial form, all the contacts such as dial and switch hook contacts must be strapped out with soldered connections.

The handsets should be equipped with transmitter and receiver capsules ; these should have impedance and sensitivity values which are close to the average values found for that type of set.

The handset should be fitted with a cord approximately three feet long with its free end suitable for terminating on small screw terminals 3 mm diameter (app. 6 B.A.) (such as are to be found in telephone type plugs).

It is desirable that some container should be provided for storage and protection of the handsets.

3. — *Sealing of equipment before despatch*

The Administration or Private Operating Company may if it desires place seals on the equipment sent to the C.C.I.F. Laboratory. At the same time it must be noted that the equipment (particularly the handsets) are submitted to a great deal of handling and, in the experience of the C.C.I.F. Laboratory, ordinary wax seals are insufficient. A suitable type of seal, locking together parts which could be separated, is provided by means of a small screw with its head below the external surface of the equipment. The head of this screw is covered with a small wax seal (flush with the outside surface) thus preventing the screw from being removed except intentionally.

4. — *Spare Parts*

To avoid interruptions in the tests, as a result of a fault in some part of a telephone circuit, it is necessary to supply the Laboratory with some spare parts, e.g. condensers and resistors as may be used in the subscriber's line, etc.

5. — *Diagrams*

To enable the equipment to be set up and to facilitate the clearance of any faults, a complete set of circuit diagrams should be sent to the Laboratory. It would be useful to indicate the numbering and name of each part of the telephone circuits, in particular for the subscriber's set, the transmitter capsule and the receiver capsule.

6. — *Packing of the equipment*

For the protection of the equipment during transit, it is necessary to pack the items in special cases. It is left to Administrations to choose that form of packing which seems best to them.

7. — *Method of despatch of equipment for A.E.N. or reference equivalent measurements*

When sending any equipment to the C.C.I.F. Laboratory the following instructions should be complied with :

7.1 *(a)* Choose a shipping agent in the place of despatch and another at Geneva. A list of shipping agents willing to undertake the customs formalities will be furnished on application by the Secretariat of the C.C.I.F., Maison des Congrès, Place Chateaubriand, Geneva.

(b) Affix to each package a label bearing the following :

" X... (name of shipping agent in Geneva), Genève, Appareils à livrer au Laboratoire du C.C.I.F., Maison des Congrès, Place Chateaubriand, Geneva. Pour retour à l'expéditeur après étalonnage par le Laboratoire ".

(c) Send by express, carriage paid, through international transit to Geneva addressed to the Director of the C.C.I.F., Maison des Congrès, Place Chateaubriand, Geneva, and settle, at the place of despatch (country of the Administration or Private Company concerned) all shipping costs as far as the C.C.I.F. Laboratory, including the charges made by the shipping agent in Geneva.

Before despatch an advice should be sent to the Secretariat of the C.C.I.F. indicating the name and address of the shipping agent in Geneva, the detailed description of the equipment sent and its exact value so that the C.C.I.F. can send the shipping agent in Geneva a declaration for the import of equipment into Switzerland without customs charges. In particular it is necessary to indicate in the description whether certain parts of the equipment are made of precious metals, and to give all the information necessary for the various customs formalities.

The equipment will be returned by the Laboratory after calibration in the packing cases belonging to the Administration or Operating Company concerned via the shipping agent in Geneva who will take it from the C.C.I.F. Laboratory and will deal with its despatch from the C.C.I.F. Laboratory to the place from which it was originally sent.

The Administration or Private Operating Company concerned will pay at the place of arrival (country of the Administration or Orivate Operating Company concerned) all the costs of returning the calibrated equipment, carriage forward, including the charges of the shipping agent in Geneva.

7.2 When the equipment is taken as hand luggage, the accompanying passenger should avoid any treatment which might cause its efficiency to be affected, such as violent shocks or leaving the cases near heating pipes, etc.

The accompanying passenger can carry with him the detailed description referred to above. On arrival at Geneva he should leave the equipment with the Customs to be called for, whence it will be collected by the staff of the Laboratory under a general authorization given by the Swiss authorities to the Director of the C.C.I.F.

7.3 When the bulk and weight of the equipment to be sent to the Laboratory does not exceed the limits allowed by the postal service, Administrations or Operating Companies can use this means, despatch being carriage paid (including delivery to the premises of the C.C.I.F. Laboratory). In this case an exact inventory of the contents of the parcels should be sent to the C.C.I.F. Laboratory who will make the necessary arrangements to collect the equipment from the customs.

3.2 OBJECTIVE MEASURING APPARATUS

3.2.1 **Artificial voices. Artificial mouths. Artificial ears**

Experiments directed towards replacing the human mouth in telephonometric measurements, for example by gramophone records associated with a loudspeaking telephone receiver or by a loudspeaking telephone receiver fed with a mixture of frequencies, have not yet reached the stage at which an internationally specified mechanical arrangement could be agreed which would allow the human mouth to be safely replaced. Also at the present stage it is considered essential that all telephonometric measurements at the C.C.I.F. Laboratory should continue to be made with the human mouth and ear. Nevertheless it is desirable to study the problem of designing apparatus for telephonometric measurements such that with its aid in the future, it should be possible for all these measurements to be made without recourse to the human mouth and ear.

In order to guide Administrations and Private Companies in this study, the original articles concerning the problem of the artificial ear are indicated in the bibliography below.

Meanwhile, it goes without saying that Telephone Administrations and Private Companies can, if they wish, use in the future devices which they may have been able to construct for large scale testing of telephone apparatus supplied by manufacturers, provided that the results obtained with these devices are in satisfactory agreement with results obtained by applying the human mouth and ear measuring method.

Note 1. — The plenary assembly at Copenhagen in 1936 considered that it would be of interest to deal separately with the design on the one hand, of an artificial speech source (words recorded on a gramophone record or a mixture of pure tones having the same effect as the human voice) and, on the other, of apparatus for producing a defined acoustic field according to certain specified conditions which will reproduce artificially a human mouth. The term " artificial voice " may be used for the former and " artificial mouth " for the latter.

Note 2. — Until the International Standardisation Organization or the International Electrotechnical Commission standardises an artificial ear for general use the XVIIth Plenary Assembly of the C.C.I.F. (Geneva 1954) recommends the provisional adoption of a " reference artificial ear " which will be used by the Telephone Administrations and Private Companies which participate in the work of the C.C.I.F. as well as the C.C.I.F. Laboratory. The dimensions of the coupler which forms this " reference artificial ear " are given in the Appendix below.

Note 3. — The general question of artificial voices, mouths and ears continues to be studied by the C.C.I.F.

Note 4. — Annexes 7 to 10 of the *Book of Annexes* to Volume IV of the *Green Book* describe for the sake of information the artificial mouths and ears used by the Administrations of France, Federal Germany and Great Britain.

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APPENDIX

Provisional reference artificial ear recommended by the C.C.I.F.

Until a standard artificial ear is generally adopted, the C.C.I.F. recommends the use of a provisional " reference artificial ear ".

The object of this decision is simply to permit comparison between the results of objective measurements made on telephone receivers in the C.C.I.F. Laboratory and in the national laboratories. Since it is a provisional decision, the simplest procedure is to take as a reference artificial ear one that has the simplest construction and which has been the subject of a detailed specification. It is therefore proposed to adopt the artificial ear used in the United States of America and in many other countries of the world by telephone Administrations and by manufacturers. It is pointed out that with this artificial ear, certain precautions must be taken in the application of telephone receivers with a very small ear-cap.

The exact dimensions of the reference artificial ear used in the C.C.I.F. Laboratory are defined in Figure 27 where it will be found that no indication has been given of the slope of the inclined surfaces against which the ear-cap of the telephone receiver being measured is applied. Administrations who wish to do so may, without objection, alter this slope to ensure a better fit on this artificial ear, for the receiver that they use. All the dimensions which determine the volume of air included between the artificial ear itself and the plane of separation from the telephone receiver having been fixed, the total volume included between, the artificial ear itself and the receiver ear-cap of course varies according to the type of receiver employed and is not maintained at the constant value of 6 cm^3 laid down in the American Standard Z.24.9.1949. By way of information those passages of that standard which are not in contradiction with the definition of the artificial ear used by the C.C.I.F. are reproduced in Annex 6 of the *Book of Annexes* to Vol. IV of the *Green Book*.

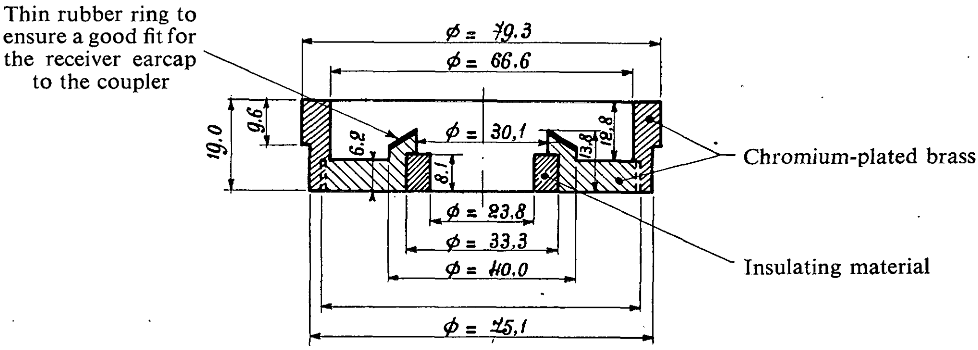

FIGURE 27. — *C.C.I.F. Reference Artificial Ear*

Note. — All dimensions are expressed in millimeters.

3.2.2 Volume meters

The C.C.I.F. considers that, in order to ensure continuity with previous practice, it is not desirable to modify the specification of the " Volume Indicator " which forms part of the S.F.E.R.T. nor of the volume meter of the A.R.A.E.N. employed at the C.C.I.F. Laboratory.

Furthermore other devices used at present in practice are described in Annexes 13, 14 and 15 of the *Book of Annexes* to Volume IV of the *Green Book.* The table below gives the principal characteristics of various measuring devices used for keeping a watch on the volume or peak values during telephone conversations or radio broadcast transmissions.

Note. — In Annexes 11 to 15 of the *Book of Annexes* to Volume IV of the *Green Book* are found descriptions of the following devices.

1. Volume Indicator — S.F.E.R.T. volume indicator.
2. A.R.A.E.N. Volume Meter or Speech Voltmeter.
3. Volume Meter standardized in the United States of America, termed the " vu-meter ".
4. Modulation Meter used by the British Broadcasting Corporation.
5. Maximum Amplitude Indicator Type U21 used in the Federal German Republic.

Comparative tests with different types of volume meters

A note which appears on pages 270 to 293 of Volume IV of the *White Book* of the C.C.I.F. (Budapest, 1934) gives some information on the results of preliminary tests conducted at the S.F.E.R.T. Laboratory to compare the Volume Indicator with different impulse indicators.

The results of comparative tests made in 1952 by the British Administration appears in Annex 16 of the *Book of Annexes* to Volume IV of the *Green Book.*

TABLE

Principal characteristics of various measuring devices used for keeping a watch on the volume or peak values during telephone conversation or radio broadcast transmissions

Type of apparatus	Rectifier characteristic *(Note 1)*	99% rise time (milliseconds)	Integration period (milliseconds) *(Note 2)*	Time to return to zero (value and definition)
British Speech Voltmeter Type 3 identical to the A.R.A.E.N. volume meter	2	230	110 (approx.)	Equal to the integration period
Vu-meter (United States of America)	1.0 to 1.4	300	165 (approx.)	Equal to the integration period
Volume meter of the " Volume Indicator " type S.F.E.R.T.-C.C.I.F.	2	about 400 to 650	200	Equal to the integration period
Peak Indicator for radio broadcast transmissions used by the British Broadcasting Corporation (B.B.C. Peak Programme Meter)	1	about 12	4	3 seconds for the reading to decay 26 db
Maximum amplitude indicator used in the Federal German Republic (Type U21)	1	about 80	5 (approx.)	1 or 2 seconds from 100% to 10% of the deflexion when continously applied

Note 1. — The number which appears in this column is the exponent n in the expression $[V_{(out)} = V^{n}_{(in)}]$ applicable for each half cycle.

Note 2. — The integration period has been defined by the C.C.I.F. as the " minimum period during which a sinusoidal alternating voltage must be applied to the terminals of the apparatus for the needle of the indicating instrument to reach within 0.2 nepers or about 2 db of the deflexion which would be obtained if the same voltage were applied indefinitely ". A logarithmic ratio of 2 db corresponds to a percentage of 79.5% and a ratio of 0.2 nepers to a percentage of 82%.

3.2.3 Psophometers (Apparatus for the objective measurement of circuit noises)

A. Psophometer for commercial telephone circuits

The C.C.I.F.,

Considering

That, since the psophometer for commercial telephone circuits was specified (Directives concerning the protection of communication lines against the interfering effects of electric power lines, Rome Edition, 1937, revised at Oslo, 1938), considerable progress has been made in the construction of telephone subscriber's apparatus, especially so far as the smoothness of the sensitivity-frequency characteristic is concerned,

That the " Joint Subcommittee on development and research of the Edison Electric Institute and the Bell Telephone System " (*Engineering Report* No. 45) has carried out numerous tests to determine the curve to be prescribed for the psophometer filter network in order to take account of the improved characteristics of subscribers' telephone equipment,

That numerous tests and measurements made in the course of the last few years show that the electro-acoustic characteristics of the subscribers' telephone equipment used in Europe are very similar to those of American equipment and that, consequently, it is unnecessary to repeat in Europe similar tests to those described by the Joint Subcommittee,

Unanimously recommends

That the weights attributed to different frequencies in the weighting network of the psophometer used for measurements at the terminals of a commercial trunk telephone circuit should be those in the table below. (See also the curve given in Figure 28 below), the underlined values only in the table should be considered as specifying the psophometer filter network and should be taken into consideration for check tests of the apparatus ; the other values, obtained by interpolation, are given to facilitate any calculations.

By convention, the numerical values are determined by attributing the value 1,000 to the frequency 800 c/s. The logarithmic weighting values are obtained by attributing the value corresponding to 0 nepers or 0 decibels to the frequency 800 c/s.

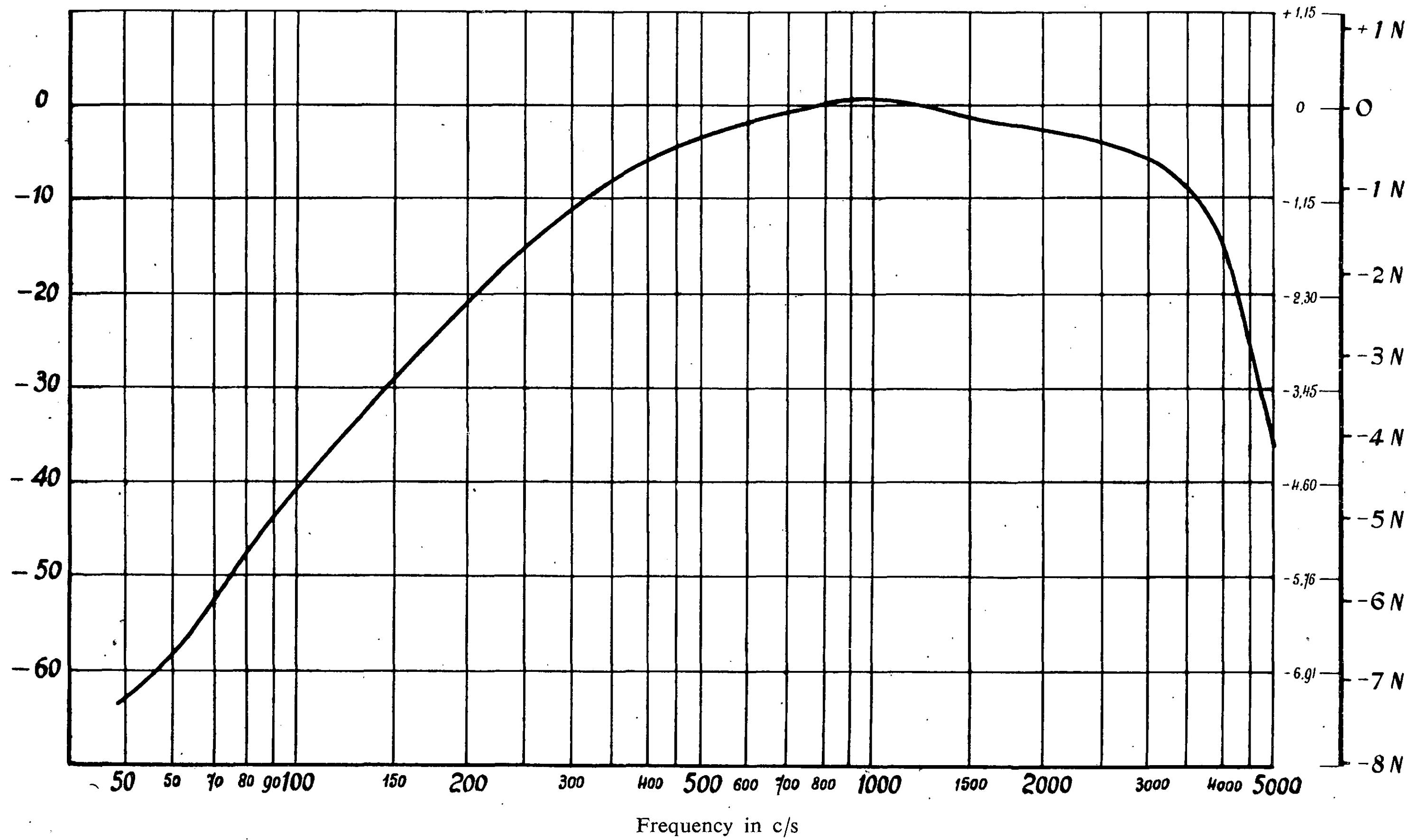

FIGURE 28. — *Characteristic curve of the psophometer filter network used for measurements at the terminals of a commercial trunk telephone circuit*

Table of commercial telephone circuit psophometer weighting coefficients

Frequency c/s	Weight			
	Numerical Value	Numerical Value Squared	Value in decibels	Value in Nepers
16.66	0.056	0.003136	−85.0	−9.79
50	0.71	0.5041	−63.0	−7.25
100	8.91	79.3881	−41.0	−4.72
150	35.5	1 260.25	−29.0	−3.34
200	89.1	7 938.81	−21.0	−2.42
250	178	31 684	−15.0	−1.73
300	295	87 025	−10.6	−1.22
350	376	141 376	− 8.5	−0.98
400	484	234 256	− 6.3	−0.73
450	582	338 724	− 4.7	−0.54
500	661	436 921	− 3.6	−0.41
550	733	537 289	− 2.7	−0.31
600	794	630 436	− 2.0	−0.23
650	851	724 201	− 1.4	−0.16
700	902	813 604	− 0.9	−0.10
750	955	912 025	− 0.4	−0.046
800	1 000	1 000 000	0.0	0.000
850	1 035	1 071 225	+ 0.3	+0.034
900	1 072	1 149 184	+ 0.6	+0.069
950	1 109	1 229 881	+ 0.9	+0.103
1 000	1 122	1 258 884	+ 1.0	+0.115
1 050	1 109	1 229 881	+ 0.9	+0.103
1 100	1 072	1 149 184	+ 0.6	+0.069
1 150	1 035	1 071 225	+ 0.3	+0.034
1 200	1 000	1 000 000	0.0	0.000
1 250	977	954 529	− 0.20	−0.023
1 300	955	912 025	− 0.40	−0.046
1 350	928	861 184	− 0.65	−0.075
1 400	905	819 025	− 0.87	−0.100
1 450	881	776 161	− 1.10	−0.126
1 500	861	741 321	− 1.30	−0·150
1 550	842	708 964	− 1.49	−0.172
1 600	824	678 976	− 1.68	−0.193
1 650	807	651 249	− 1.86	−0.214
1 700	791	625 681	− 2.04	−0.234
1 750	775	600 625	− 2.22	−0.255
1 800	760	577 600	− 2.39	−0.275
1 850	745	555 025	− 2.56	−0.295
1 900	732	535 824	− 2.71	−0.311
1 950	720	518 400	− 2.86	−0.329
2 000	708	501 264	− 3.00	−0.345
2 050	698	487 204	− 3.12	−0.359
2 100	689	474 721	− 3.24	−0.373
2 150	679	461 041	− 3.36	−0.386
2 200	670	448 900	− 3.48	−0.400
2 250	661	436 921	− 3.60	−0.414
2 300	652	425 104	− 3.72	−0.428
2 350	643	413 449	− 3.84	−0.442
2 400	634	401 956	− 3.96	−0.456

Table of commercial telephone circuit psophometer weighting coefficients (Contd.)

Frequency c/s	Weight			
	Numerical Value	Numerical Value Squared	Value in decibels	Value in nepers
2 450	626	390 625	− 4.08	−0.470
2 500	617	380 689	− 4.20	−0.484
2 550	607	368 449	− 4.33	−0.499
2 600	598	357 604	− 4.46	−0.513
2 650	590	348 100	− 4.59	−0.528
2 700	580	336 400	− 4.73	−0.544
2 750	571	326 041	− 4.87	−0.560
2 800	562	315 844	− 5.01	−0.576
2 850	553	305 809	− 5.15	−0.593
2 900	543	294 849	− 5.30	−0.610
2 950	534	285 156	− 5.45	−0.627
3 000	525	275 625	− 5.60	−0.645
3 100	501	251 001	− 6.00	−0.691
3 200	473	223 729	− 6.50	−0.748
3 300	444	197 136	− 7.05	−0.812
3 400	412	169 744	− 7.70	−0.886
3 500	376	141 376	− 8.5	−0.979
3 600	335	112 225	− 9.5	−1.09
3 700	292	85 264	−10.7	−1,23
3 800	251	63 001	−12.0	−1.38
3 900	214	45 796	−13.4	−1.54
4 000	178	31 684	−15.0	−1.73
4 100	144.5	20 880.25	−16.8	−1.93
4 200	116.0	13 456	−18.7	−2.15
4 300	92.3	8 519.29	−20.7	−2.38
4 400	72.4	5 241.76	−22.8	−2.62
4 500	56.2	3 158.44	−25.0	−2.88
4 600	43.7	1 909.69	−27.2	−3.13
4 700	33.9	1 149.21	−29.4	−3.38
4 800	26.3	691.69	−31.6	−3.64
4 900	20.4	416.16	−33.8	−3.89
5 000	15.9	252.81	−36.0	−4.14
> 5 000	< 15.9	< 252.81	< −36.0	< −4.14

Note 1. — If for the planning of certain telephone transmission systems calculations are to be made on a basis of the psophometric weighting values and it then appears useful to adopt for frequencies above 5000 c/s more precise values than those given in the above table, the following values may be adopted.

5 000 to 6 000	< 15.9	< 252.81	< −36.0	< −4.14
> 6 000	< 7.1	< 50.41	< −43.0	< −4.95

Permissible tolerances

The following permissible tolerances are :

50 to 300 c/s	±2 decibels or ±0.23 nepers
300 to 800 c/s	±1 decibel or ±0.12 nepers
to 800 c/s	0 decibels or 0 nepers
800 to 3 000 c/s	±1 decibel or ±0.12 nepers
3 000 to 3 500 c/s	±2 decibels or ±0.23 nepers
3 500 to 5 000 c/s	±3 decibels or ±0.35 nepers

Note 2. — During the XVIth Plenary Assembly (Florence 1951), the C.C.I.F. considered that it would be extremely undesirable to make any modifications in the weighting table or to the specification of the psophometer for as long a period as possible, for example for ten years.

Measurements at the terminals of a subscriber's telephone receiver. — The psophometer which was standardized by the XVIth Plenary Assembly of the C.C.I.F. for relatively stable circuit noise measurements, consists, for use at the end of an international telephone circuit (see above), of a filter network which takes account of the characteristics of a fairly modern type of telephone set used in the United States of America together with the mean characteristics of the national telephone network of that country. According to American practice, if it is desired to use this psophometer at the terminals of the telephone receiver, it is adapted for this purpose by removing that part of the filter network which takes account of the characteristics of the commercial telephone circuits. It seems unnecessary to have recourse to such a modification in Europe since the characteristics of telephone sets used in Europe cover a wide range. Choice of a single characteristic for the filter network which would result from a modification of this kind would probably be as arbitrary as would be the use, without modification, for measurements at the terminals of the telephone receiver, of the psophometer with filter network specified by the XVIth Plenary Assembly of the C.C.I.F. for measurements at the terminals of a commercial trunk telephone circuit (see above).

When only comparative measurements are needed, the psophometer specified by the XVIth Plenary Assembly of the C.C.I.F. can very well be used, without modification, as a voltmeter of which the characteristics have been arbitrarily fixed, to make measurements at the terminals of the subscriber's telephone receiver.

For studies of a fundamental nature, Administrations may very well wish to use filter network specially chosen to be appropriate for the studies concerned.

Essential clauses of a model specification for the provision of a psophometer for commercial telephone circuits

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering on the one hand,

That the design of a psophometer for commercial telephone circuits which will permit measurements to be made at frequencies lower than 40 c/s and particularly 16 $^2/_3$ c/s, would present construction difficulties and would result in a heavy and cumbersome instrument,

That the need to use the instrument at these frequencies would arise frequently,

That, when these frequencies are encountered, it seems possible that the instrument could be used as it stands with the addition of a suitable correcting network ;

Considering on the other hand,

That the provisional essential clauses of a model specification for a psophometer for commercial telephone circuits (see Recommendation No. 6, *Yellow Book*, Volume II) appears to be in insufficient detail so far as measurement of voltages of these types are concerned,

That it would seem proper to provide a check test to this effect,

That, nevertheless, by reason of the variety of designs of psophometers, it would seem impossible to recommend uniform testing clauses but it would seem useful to draw attention to this point,

Unanimously recommends

That it is advisable that psophometers for commercial telephone circuits should conform to the following conditions * :

1. *Graduation.* — The psophometer should be so graduated that, for each sensitivity provided, it gives by direct reading (or after multiplication by a factor defined by the sensitivity setting) the exact value of the voltage when a voltage at 800 c/s is applied to the input of the psophometer.

2. *Sensitivity.* — The psophometer should enable a clear reading to be obtained when a voltage at 800 c/s of at least 0.05 millivolts is applied to the input. It should also permit a direct reading of voltages at least up to 100 millivolts without the use of external potentiometer devices.

3. *Measurements.* — For every measuring range and under every condition of use of the instrument, for each sensitivity and for each frequency applied separately, the readings should be equal to the product of the applied voltage and the weighting coefficient for that frequency, divided by one thousand.

When the applied voltage consists of a number of different frequency components, the reading on the indicating instrument should be equal to the square root of the sum of the squares of the readings corresponding to the individual components applied separately.

To check that this condition is satisfied, it is possible to use, for example, the following procedure. Two sinusoidal voltages are applied successively at different frequencies which are not harmonically related and which give the same deflexion on the needle of the indicating instrument ; the resultant of these two voltages is then applied by means of an arrangement which allows them to be

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* *Note.* — During the XVIth Plenary Assembly (Florence 1951), the C.C.I.F. considered that it would be extremely undesirable to make any further modifications to the specification of the psophometer for as long a period as possible, for example for ten years.

attenuated equally and adjusted so as to restore the deflexion previously obtained. The loss introduced should be equal to 3 decibels or 0.35 nepers with a tolerance of ±0.5 decibels or 0.05 nepers.

The test should be made using different pairs of frequencies, some close together and others well apart. It should be repeated at different deflections of the needle of the psophometer.

4. *Linearity.* — When the periodic voltage waveform applied is peaky so that the peak value is much greater than the effective value, the corresponding weighted voltage measurement should be as much as possible free from any error caused by overloading the amplifier or other parts. It is possible to check whether this source of error has been eliminated by one of the following methods given as examples.

First Method. — A voltage is applied to the psophometer at a frequency of the order 2000 c/s in 5 millisecond pulses separated from each other by 20 millisecond intervals of silence. When the applied voltage is decreased from a value corresponding to the highest whieh can be measured by the apparatus, the readings should be proportional to the applied voltage with a tolerance of ± 5% (or ± 0.5 decibels or ± 0.05 nepers).

Second method. — The British Telephone Administration has adopted the following rule.

The psophometer contains a d.c. indicating instrument preceded by a square-law rectifier. The instrument is so graduated that Condition 1 is satisfied.

For a sinusoidal voltage of given frequency and for a fixed adjustment of the gain controls, the operating current of the indicating instruments should be proportional to the square of the voltage applied to the psophometer for values of this voltage between 0.4 to 2.5 times that required to produce a full-scale deflexion with a tolerance of ± 10% corresponding to an error in reading of about ± 5% (or ± 0.5 decibels or ± 0.05 nepers).

The following method of check is adopted : between the rectifier and the indicating instrument is inserted a network such that a known fraction of the rectified current passes through this instrument whilst the impedance presented to the rectifier remains the same as is presented to it by the indicating instrument when this is directly connected. By these means the deflexion can be brought back to a value lower or equal to the maximum fo the scale graduations and thus check that the condition is satisfied.

Third Method. — Another convenient recognised test in the case of a psophometer containing a d.c. indicating instrument preceded by a square-law rectifier consists of carrying out the test described by in 3. but applying a voltage having two sinusoidal components with values equal to 0.4 ; 1 ; 1.5 ; 2 and 2.5 times that corresponding to the full deflexion of the indicating instrument. The deflexion is reduced to a value equal to or less than the full scale by using a reducing network such as was involved in the description of the second method.

5. *Dynamic characteristic.* — The dynamic characteristic of the psophometer should be such that a noise of duration of the order of 0.15 to 0.25 seconds produces the same deflexion as a continuous noise, whilst noises of shorter duration produce proportionately smaller deflexions. This period is that which seems necessary for the noise to be entirely heard.

6. *Input impedance.* — The input impedance of the psophometer should be as large as possible over the whole frequency band 15 to 5000 c/s. In particular it should be at least 6000 ohms from 40 to 5000 c/s.

The impedance between the two terminals connected together and the case of the psophometer should be as high as possible at all frequencies from 15 to 5000 c/s. In particular it should be greater than 200,000 ohms at 800 c/s.

7. *Balance.* — The balance of the psophometer with respect to the case should be such that the application between the mid-point of a 600 ohms resistor connected to the input terminals and the case (Figure 29) of a voltage of 200 volts at 50 c/s, or 3 volts at 500 c/s or 10 volts at 800 c/s does not give a reading greater than 0.1 millivolt.

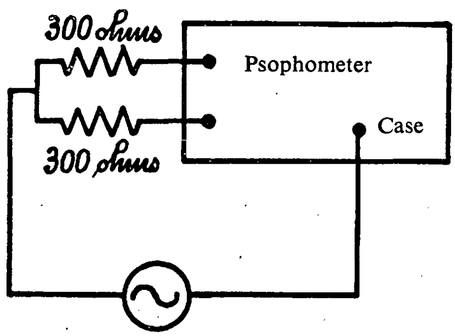

FIGURE 29

8. *Freedom from the effect of external fields.* — The apparatus should be free from the effects of external magnetic and electric fields even when used in the vicinity of power plant. In this respect it is necessary to note that external fields can affect the apparatus either in front of or after the range control (potentiometer) and accordingly the effects of these fields may or may not depend upon the setting of the range control.

The psophometer together with the boxes containing the power supplies should be screened ; the various external connections should be made with twisted and screened conductors. It is desirable to provide terminals so that all parts of the apparatus and their boxes can be earthed while the psophometer is in use.

Note. — As an example the British Telephone Administration carried out the following tests :

(a) A magnetic field of 0.01 oersted (alternating field at 300 c/s) is produced by means of a square coil of dimensions as follows :

— length of side, 40″ ;

— cross section not greater than 1 sq. inch consisting of n turns and carrying a current I amperes such that $nI = 0.84$. The psophometer under test is placed at the centre of this coil and its sensitivity is adjusted to that value for which an applied voltage of 0.2 millivolts would give the greatest deflection on the measuring instrument. Under these conditions the magnetic field should not produce a deflection greater than 0.04 millivolts.

(b) The magnetic field is then made 0.05 oersteds corresponding to $nI = 4.2$. Under these conditions for any sensitivity of the psophometer other than that mentioned under *(a)* the needle of the measuring instrument should not reach full scale.

9. *Adjustment.* — When the amplifier is not sufficiently stable an appropriate adjustment should be provided so as to maintain the amplifier gain at the desired value with an error less than ±5%.

10. *Construction.* — No inconvenience should be experienced in practice due to the effect of mechanical vibration.

The characteristics of the psophometer should be as stable as possible under practical conditions of use, i.e. in spite of transport, temperature variation etc.

The apparatus should be transportable and its weight reduced as much as the above conditions permit.

B. Psophometer used on radio broadcasting circuits

The general form as well as the principal characteristics given above for the psophometer used on commercial telephone circuits are applicable also for the

Table 2

Specification of the characteristic curve for the filter network of the psophometer used on a radio broadcasting circuit

(See curve in Figure 30 below)

Frequency c/s	Weighting coefficient	
	Nepers	Decibels
60	−3.70	−32.2
100	−3.00	−26.1
200	−2.00	−17.3
400	−1.01	− 8.8
800	−0.22	− 1.9
1 000	0	0
2 000	+0.61	+ 5.3
4 000	+0.94	+ 8.2
5 000	+0.97	+ 8.4
6 000	+0.94	+ 8.2
7 000	+0.84	+ 7.3
8 000	+0.59	+ 5.1
9 000	−0.03	− 0.3
10 000	−1.12	− 9.7

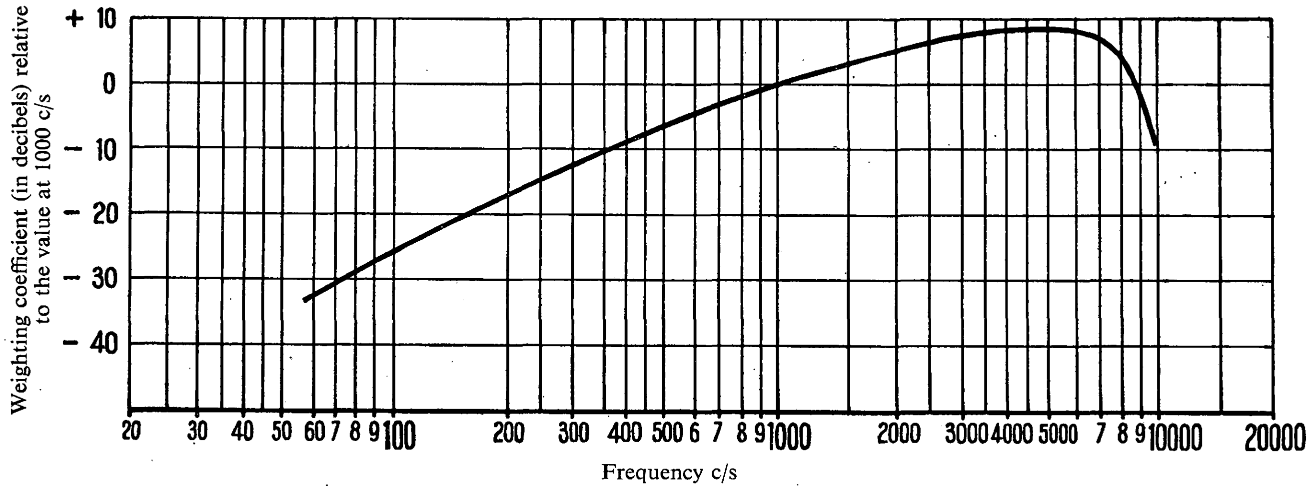

FIGURE 30. — *Characteristic curve of the filter network for the psophometer used for measurements on radio broadcasting circuits*

psophometer used on radio broadcasting circuits except for the data on the filter network which, in this case, should provisionally have a characteristic curve as in Table 2 above.

The weighting coefficients corresponding to the various frequencies have been determined from appreciation tests of the disturbing effect of noise when music is present. It is to be understood that the weighting coefficients are provisional and that new appreciation tests should be made taking account not only of the effect mentioned but also of the disturbing effect of noise during the silent periods of a musical transmission.

It should be noted, by way of information, that the Special International Committee on Broadcasting Interference (C.I.S.P.R.) is studying similar problems but from a slightly different viewpoint.

The weighting coefficients given by Table 2 provide merely a provisional objective to be attained and for the present no tolerances can be specified for the design of the filter network having the corresponding characteristic curve.

3.2.4 Apparatus for the objective measurement of room noise *

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering,

That the objective room noise measuring equipment at present designed and whose essential characteristics are given, among others, in the articles quoted in the bibliography below, possess certain common features ; thus all the devices comprise a microphone, an amplifier associated with a filter network, a detector and indicating device whose dynamic characteristics are analogous to those recommended by the C.C.I.F. for volume indicators (see above under **3.2.2**) ;

That appreciable differences remain between the various types of equipment namely the reference zero and the number of characteristic curves to be used for the measurements (these being always the curves of equal sound sensation) ;

That it has not so far been possible to specify exactly all the essential characteristics of room noise measuring equipment ;

Considering on the other hand,

That these questions are at present being studied by the International Electrotechnical Committee,

Recommends unanimously,

That it would be desirable for the International Electrotechnical Committee to study standardization of the essential characteristics of equipment for the objective measurement of room noise and obtain as soon as possible international agreement on this question.

* The attention of the 11th Study Group of the C.C.I.F. (Vocabulary Committee) is drawn to the fact that the term " sonometer " is inappropriate as a term to denote the apparatus described in this section.

Note. — Until international standardization is achieved, the C.C.I.F. has provisionally adopted, as the specification of equipment for the objective measurement of room noise, the specification given in Standard Z.24.3.1944 of the American Standards Association (Sound level meter for measurement of noise and other sounds). This specification forms the subject of Annex 17 of the *Book of Annexes* to Volume IV of the *Green Book.*

Bibliography

The essential characteristics of equipment for the objective measurement of room noise used by the American Telephone and Telegraph Company forms the subject of Standard Z.24.3.1944 " American Standard Sound Level Meters for measurement of noise and other sounds ", adopted on 28th July 1944 by the American Standards Association and used by the C.C.I.F. as the provisional specification (see above). Also given by way of information are the following references :

1. American tentative standards for sound level meters for measurement of noise and other sounds. *Journal of the Acoustical Society of America,* **8** (1936), p. 147.
2. C.G. Churcher et A.J. King. — The performance of noise meters in terms of the primary standard. *Journal of the Institution of Electrical Engineers,* **82** (1937), p. 57.
3. A.H. Davis. — An objective noise meter for the measurement of moderate and loud, steady and impulsive noises. *Journal of the Institution of Electrical Engineers,* **83** (1938), p. 249.
4. A.J. King, R.W. Gulke, C.R. Maguire et R.A. Scott. — Objective noise meter reading in phone for sustained noises with special reference to engineering plant. *Journal of the Institution of Electrical Engineers,* **88**, part 2 (1941), p. 63.

3.2.5 Other equipment

For equipment which can be generally used for electrical measurements with steady state alternating currents, see the *Book of Annexes* to Volume III of the *Green Book.*

3.3 OBJECTIVE ELECTRO-ACOUSTICAL MEASUREMENTS

3.3.1 Measurement of the absolute sensitivity of a sending or receiving system.

For such measurement, in general one of the following methods can be used :

(a) *Thermophone method.*

The principle and description of this method appears in the following articles :

H.D. Arnold & I.B. Grandall. — *Physical Review,* vol. 10 (1917), p. 22.

E.C. Wente. — *Physical Review,* vol. 19 (1922), p. 333.

S. Ballantine. — *Journal of the Acoustical Society of America,* vol. 3 (1932), p. 319.

Application of this method at the C.C.I.F. Laboratory for the absolute calibration of the S.F.E.R.T. is described in Annex 5 of the *Book of Annexes* to Volume IV of the *Green Book.*

(b) *Rayleigh disk method*

The principle and description of this method appears in the following articles :

W. König. — *Annalen der Physik*, vol. 43 (1891), p. 43.

E.J. Barnes & W. West. — *Journal of the Institution of Electrical Engineers*, vol. 65 (1927), p. 871.

W. West. — *Acoustical Engineering* (Pitman edition, London), chapter XI (1932)

R.A. Scott. — *Proceedings of the Royal Society A*, vol. 183 (1945), p. 296.

W. West. — *Proceedings of the Physical Society B*, vol. 62 (1949), p. 437.

Application of this method at the C.C.I.F. Laboratory for the absolute calibration of the A.R.A.E.N. is described in Annex 5 of the *Book of Annexes* to Volume IV of the *Green Book.*

(c) *Compensation method and electrostatic actuator method*

The principles and descriptions of these methods appear in the following articles :

E. Gerlach. — *Wiss. Veröff. Siemens-Konzern*, vol. 3 (1923), p. 139.

M. Grützmacher & E. Meyer. — *Elektrische Nachrichten Technik*, vol. 4 (1927), p. 203.

S. Ballantine. — *Journal of the Acoustical Society of America*, vol. 3 (1932), p. 219.

(d) *Reciprocity method for the calibration of condenser microphones*

The principle and description of this method appears in an article by R.K. Cook published in the *Journal of Research of the National Bureau of Standards* (Washington), Volume 25, page 489 (November 1940). Some complementary details are given in Annex 18 of the *Book of Annexes* to Volume IV of the *Green Book.*

The physical basis of this method is given in the following books and articles :

W. Voigt. — *Lehrbuch der Kristallphysik.* B.G. Teubner, Leipzig (1910).

Rayleigh. — *The Theory of Sound.* Macmillan & Co., London (1896).

S. Ballantine. — *Proceedings of the Institute of Radio Engineers*, vol. 17 (1929), p. 929.

H. Osterberg & J.W. Cookson. — *Review of Scientific Instruments*, vol. 6 (1935), p. 347.

S. Ballantine. — *Journal of the Acoustical Society of America*, vol. 3 (1932), p. 319.

L.J. Sivian. — *Bell System Technical Journal*, vol. 10 (1931), p. 96.

D.A. Keys. — *Philosophical Magazine*, vol. 46 (1923), p. 999.

W.R. MacLean. — *Journal of the Acoustical Society of America*, vol. 12 (1940), p. 140.

3.3.2 Measurements on subscriber's telephone equipment

1. — *Measurement of attenuation distortion of a telephone set*

The curve of the variation of the absolute sensitivity of a piece of telephone equipment (sending or receiving system) as a function of frequency does not supply complete information on the manner in which this equipment reproduces the human voice or music, although such a curve may often be called " the frequency characteristic ".

However, the curve of variation of the absolute sensitivity of telephone equipment as a function of frequency gives useful indications from the point of view of the transmission of speech. On the other hand, for the transmission of pieces of music, in the absence of a precise criterion of the quality of transmission (corresponding to articulation, or repetition rate, in commercial telephony) such curves should be sufficient to enable the quality of the terminal equipment used (microphone or loudspeakers) to be appreciated.

For obtaining sensitivity-frequency characteristics several modern commercial instruments are available which fall into two categories :

(a) Recording devices which enable the frequency characteristics of telephone equipment to be drawn automatically. One of the methods termed " Audiograph method " is described in Annex 19 of the *Book of Annexes* to Volume IV of the *Green Book.*

(b) Devices which employ a cathode ray tube and which allow the frequency characteristic of equipment to be rapidly displayed.

Some information concerning such types of device is given in Section **3.6** below, as well as in Annexes 21 and 22 of the *Book of Annexes* to Volume IV of the *Green Book.*

2. — *Measurement of non-linear distortion of telephone equipment and of microphone noise.*

Whilst the non-linear distortion of telephone receivers is in general negligible, microphones (and particularly carbon microphones of the type generally used in commercial telephone equipment) show considerable non-linearity : the relationship between the variation of microphone resistance and the acoustic pressure on the diaphragm, is not linear. This non-linearity becomes more important as the variation of resistance in relation to the total resistance of the microphone increases, i.e. when the microphone is more sensitive. Furthermore, there are two supplementary effects :

1. The microphone is insensitive to acoustic pressure lower than a certain value (threshold of excitation) ;
2. The mechanical inertia of the carbon granules (delay in establishing electrical contact between the granules) is, because of the various states of agitation of the carbon under the influence of acoustic waves, not the

same for all frequencies (for example ; slow beats between two sounds are in general favoured in reproduction by a carbon microphone.

Microphone noise is directly related to non-linearity. When non-linear distortion is measured, harmonic distortion as well as the variation of sensitivity with amplitude can be measured. As an example of such measurements reference can be made to a contribution of the Federal Germany Republic described in Annex 20 of the *Book of Annexes* to Volume IV of the *Green Book.*

3. — *Objective measurement of reference equivalent (sending and receiving) and of sidetone reference equivalent.*

(a) So far as the objective measurement of reference equivalent (sending and receiving) of subscriber's telephone equipment is concerned, attention may be drawn to the equipment used by the Administrations of the Federal German Republic and Switzerland which are described in Annexes 21 and 22 of the *Book of Annexes* to Volume IV of the *Green Book.*

(b) So far as the objective measurement of the sidetone reference equivalent of subscriber's telephone equipment is concerned, there is no objective method to be recommended, this whole question being studied by the C.C.I.F.

3.4 SUBJECTIVE VOICE-EAR MEASUREMENTS

3.4.1 Measurement of speech volume

The volume indicator should be used in accordance with the details given in Annex 11 of the *Book of Annexes* to Volume IV of the *Green Book.* The dial of the equipment should be set at "—16 decibels" when the "normal vocal power for telephonometric measurements" is to be used.

3.4.2 Measurement of reference equivalents and relative equivalents

a) MEASUREMENT OF TRUE REFERENCE EQUIVALENTS

This measurement consists of a comparison by voice and ear with the Master Telephone Transmission Reference System (S.F.E.R.T.) ; such a measurement is called a "telephonometric measurement".

This comparison may be direct, and in that case gives the reference equivalent of the complete system, or of the sending system, or of the receiving system considered. But generally, only working standards are compared directly with the S.F.E.R.T., before they are put in service, and then from time to time for checking. Consequently the reference equivalent of a system or part of a system is usually determined indirectly, that is to say, the reference equivalent of the system (or part of the system) is determined by means of an auxiliary system (working standard system) whose own reference equivalent has been previously determined by direct comparison with the Master Reference System.

(b) Measurement of relative equivalents

The working standard systems used at present being either of the carbon microphone type (S.E.T.A.B.) or of the electrodynamic microphone and receiver type (S.E.T.E.D.), the special precautions to be taken when making a telephonometric measurement are given below, especially in the measurement of the relative equivalent of a handset type equipment. Two methods of measurement are given as examples.

α) *Use of a Working Standard System of the S.E.T.A.B. type*

The telephonometric measurement to be made for determining the relative equivalent of a system or part of a system by comparison with a working standard having a carbon microphone (S.E.T.A.B.) can be made in one of the two following methods :

α.1 *Method termed " Two operator, hidden loss method ".*

The method is based on the simultaneous use of two adjustable attenuators ; one of these (balancing attenuator) serves the purpose of equalising the sound intensities at the receiving end ; the second attenuator (hidden loss attenuator) can be adjusted arbitrarily, before the test and unknown to the listening operator, in order to modify the apparent sensitivity of one of the instruments compared.

The results must be expressed as : x transmission units (nepers or decibels) " better " (M) or " Worse " (P) than the S.F.E.R.T., taking account of the reference equivalent of the S.E.T.A.B.

The particulars given below refer to setting up details, and are given only as examples.

α.1.1 *Comparison of a sending system with a standard sending system*

The schematic diagram together with the necessary switching arrangements for this comparison are shown in Figure 31.

To carry out an elementary balance a first operator " A " adjusts the hidden loss attenuator to a certain value ; he then talks alternately into microphones (1) and (2) repeating successively into each, one of the following conventional phrases, chosen so as to contain each of the principle vowel sounds :

Berlin, Hamburg, München, Koblenz, Leipzig, Dortmund (used in Germany).

One, two, three, four, five (used in Great Britain).

Joe took father's shoe bench out
She was waiting at my lawn } (used in the United States of America)

Paris, Bordeaux, Le Mans, Saint-Leu, Leon, Loudun (used in France and at the C.C.I.F. Laboratory).

He maintains, when talking, the " normal volume for telephonometric measurements " defined above " Transmission Standards ", § IV-3.1.2.B and places his lips so that they are approximately tangential to the plane of the circle

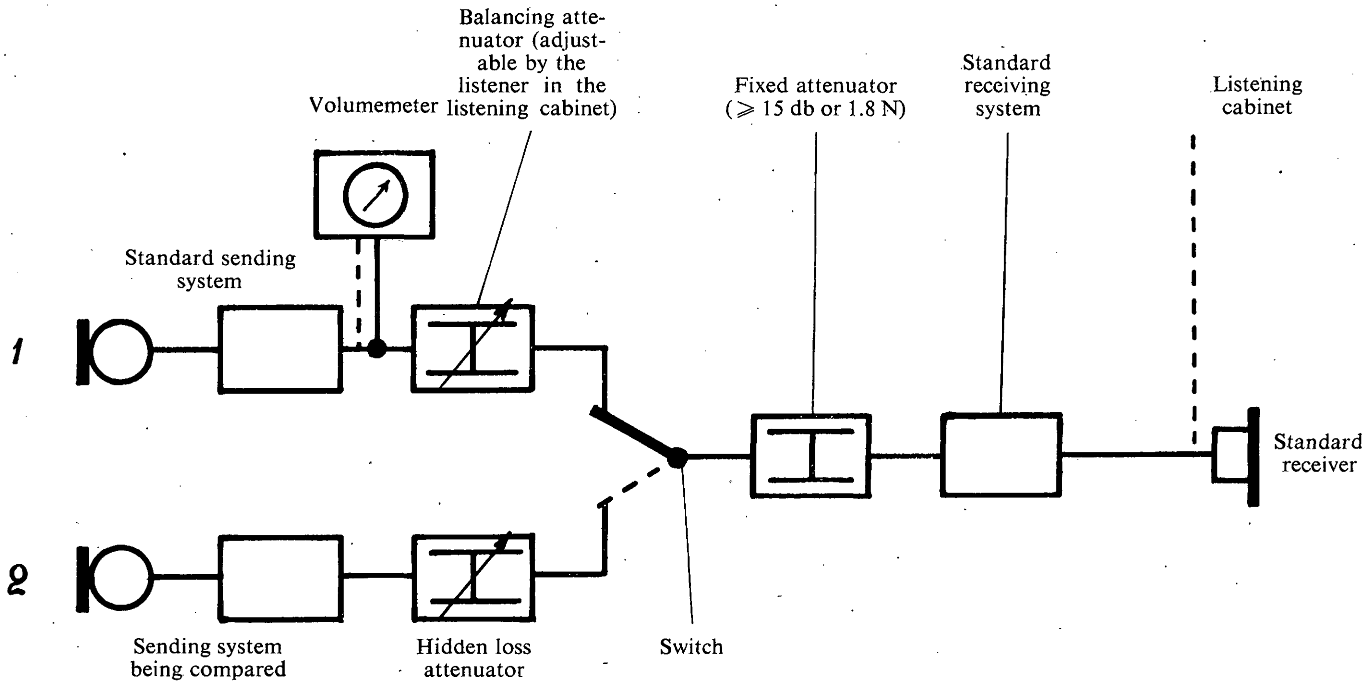

FIGURE 31. — *Comparison of a sending system with a standard sending system (Method termed "Two operators, hidden loss method")*

which bounds the guard ring *. At the same time he operates the switch in appropriate manner for controlling the switching system.

A second operator " B " receives, in a single receiver, the signals from the two microphones compared. He compares them by ear and adjusts the balancing attenuator so as to obtain the same sound intensity.

To enable the listening operator to follow the respective positions of the key, it is advisable to use a lamp the lighting circuit of which is controlled synchronously by the key. When glowing, it indicates that the balancing attenuation is inserted in the listening circuit. When the balance is thus obtained, the test is completed, and it is sufficient to record the readings of the two attenuators, and to interpret them according to the example given below.

α.1.2 *Comparison of a receiving system with a standard receiving system*

The schematic diagram together with the switching arrangements necessary for this comparison are shown in Figure 22.

To make an elementary balance a first operator " A " adjusts the hidden loss attenuator to a certain value, then talks into the standard microphone (always the same one) repeating the same conventional phrase at regular intervals and with " normal volume for telephonometric measurements "; (see above). He operates the key synchronously in order to obtain the appropriate circuit connections.

A second operator, " B " holds the two receivers in one hand, and places them alternately to his ear (in the position which gives the loudest signal) in step with the switching of the key. He then adjusts the balancing attenuator so as to obtain equality of sound from the two receivers. If the operator " B " cannot obtain equality of sound, i.e. when the system compared is more sensitive than the standard system, he asks operator " A " (by means of some type of signalling system, as, for instance, a suitable audible signal) to change the respective positions of the hidden loss and balancing attenuators.

A lamp the circuit of which is controlled synchronously by the key, indicates to operator " B " that the balancing line is inserted in the listening circuit, and also gives him the periodicity of the switching.

The reference equivalent (or relative equivalent) cannot be obtained by only one test. It is obtained from the mean of a sufficiently large number of elementary balances made according to the method described above. The minimum number of tests is six, and twelve should, normally, be made. When three operators are available, they can be grouped in six different ways, and it will then be necessary to make only one, or preferably two, tests for each possible combination of operators.

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* The position of the guard ring is defined on page 150 below.

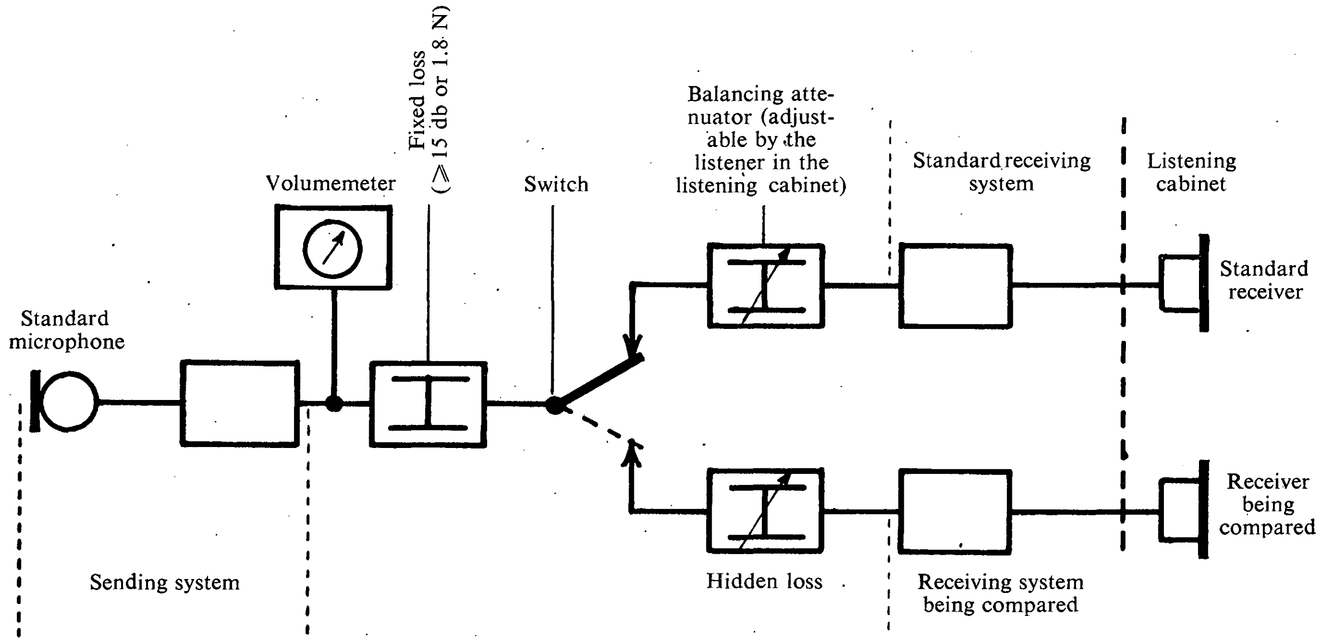


FIGURE 32. — *Comparison of a given receiving system with a standard receiving system (Method termed " Two operator, hidden loss method ")*

It is recommended that the test results be recorded on special sheets, on which are written the values of the hidden loss and balancing attenuation used during each elementary test, together with the mean values which indicate the final results of the telephonometric measurements. The table below gives an example of the recording of a telephonometric measurement conducted at the Laboratory with a crew of five.

System (type of telephone system tested) *Date:* ....

Operators			
1	....	4	....
2	....	5	....
3	....		

Reference equivalent (or relative equivalent) for sending (or receiving)

Measuring conditions (details of feeding bridge, with or without subscriber's line, voltage of feeding supply and value of microphone current)

Test No. ....

Listener

Talker	1			2			3			4			5			Total	Talker mean
	s	eq	r	s	eq	r	s	eq	r	s	eq	r	s	eq	r		
1				8	12	+4	9	6	−3	5	7	+2	5	7	+2	+ 5	+1.2
2	10	11	+1				6	10	+4	10	8	−2	7	11	+4	+ 7	+1.7
3	4	9	+5	4	9	+5				6	6	0	2	4	+2	+12	+3.0
4	8	16	+8	9	15	+6	9	7	−2				10	12	+2	+14	+3.5
5	6	13	+7	3	7	+4	9	7	−2	9	11	+2				+11	+2.7
Total			+21			+19			−3			+2			+10	49	
Listener mean		+5.2			+4.7			−0.7			+0.5			+2.5			

Reference equivalent +2.45 db (or 2.45 db Worse)
Standard deviation of the mean : ....

Simbols
- " s " denotes the hidden loss
- " eq " denotes the setting of the balance attenuator
- " r " denotes the result of the comparison (" eq " – " s ")

When it is desired to determine the reference equivalent of a sending (or receiving) system by means of a comparison measurement with a sending (or receiving) working standard system (whose reference equivalent has been determined at the C.C.I.F. Laboratory), it is necessary to take account of the value of reference equivalent of this sending (or receiving) standard system. The reference equivalent of a sending (or receiving) system is then determined from the test results in the following manner, e.g. :

Uncorrected mean result	−5.0 (5 db Better)
Reference equivalent of the working standard system	+1.3 (1.3 db Worse)
Reference equivalent of the system under test	(−5.0) + (+1.3) = −3.7 db or (3.7 db Better)

α.2 *Method termed " Three operator, without hidden loss, method "*

This method requires positions for three operators :

(a) Sending position ;

(b) Receiving position (where the telephonometric comparisons are made) ;

(c) Balancing position.

The sending and receiving positions are identical with those already described, the only difference between the two methods being in the number and positions of the attenuators. The comparison method employing three operators requires, in effect, only one adjustable attenuator in addition to the fixed attenuator. This is adjusted by operator " C ", who occupies the balancing position and receives signals from operator " B " at the receiving end. The hidden loss attenuator is replaced by direct metallic connections.

The method of operations is as follow :

α.2.1 *Comparison of a sending system with a standard sending system* (Figure 33)

Operator " C " adjusts the balancing attenuator to a preliminary value a_1, he then signals by lamp, by buzzer, or verbally to operator " A " that he may begin talking. The latter repeats into the two microphones alternately the conventional phrase adopted once for all, maintaining the normal volume for telephonometric measurement defined above (**3**.1.2.B). Operator " B " receives, on a receiver standard, the signals produced successively by the two microphones. A luminous indicator, controlled by the general switching system, indicates to him the microphone being spoken into at any instant (No. 1 or No. 2). If the sound intensity corresponding to Microphone 2 is less than the sound intensity corresponding to Microphone 1 (standard), " B " presses the signalling button marked

" P " (worse). A luminous signal (lighting of a lamp on the cap of which is marked the letter P) together with, if necessary, a buzzer signal, indicates to Operator " C " the first decision. A signal of the same type is also used to inform Operator " A " that he may stop talking. Operator " C " records immediately the test result in a table in the form :

a_1 P

The number a_1 can be entered in either of two columns. In the first, it indicates that the attenuation was introduced into the circuit at the same time as the standard, with the effect of attenuating the standard ; inserted in the second column, it indicates that the attenuation was introduced into the circuit at the same time as the test apparatus, with the effect of increasing the attenuation of the latter.

In the opposite case, if the sound intensity corresponding to Microphone No. 2 is greater than the sound intensity corresponding to Microphone No. 1 (standard), Operator " B " presses the signalling button marked " M " (better). A luminous signal (lighting of a lamp on the cap of which is marked the letter " M "), accompanied by a buzzer signal if necessary, then appears in front of Operator " C ". If the test result corresponds to an exact balance, operator " B " presses a third button controlling the circuit of a third lamp, which is used for signalling exact balance.

The balancing operator " C " then sets the balancing attenuator at a second value a_2. He then signals to Operator " A ", that he may resume talking. The result of this measurement will be a second decision, for instance M, signifying that the microphone compared appears to be better than the standard, when the latter is in series with an attenuation of a_2 units ; Operator " C " records the corresponding information in the form :

a_2 M

He then adjusts the attenuation, at his discretion, to new values in order to diminish the interval between the two values for which the balancing result changes its sign. When successive intervals (forming a convergent series) have determined, if not the number corresponding to an exact equality of the sound impressions, at least two values a and a' differing at the most by one or two decibels, or by 0.1 or 0.2 nepers, and for which one of the two instruments appears better or worse then the other, the test is considered as finished. Operator " C " at the control position signals the end of the test to the other two operators " A " and " B ", and a new balance can then begin.

A single determination of equality cannot be considered sufficient to denote balance, and must be confirmed by at least two decisions (M and P) enclosing it.

In order to facilitate scrutiny of the results, it is convenient to arrange the individual test results in such a way that they show clearly the position of the balance attenuator on the one hand (standard or test side) and on the other hand the corresponding decision given by the listener.

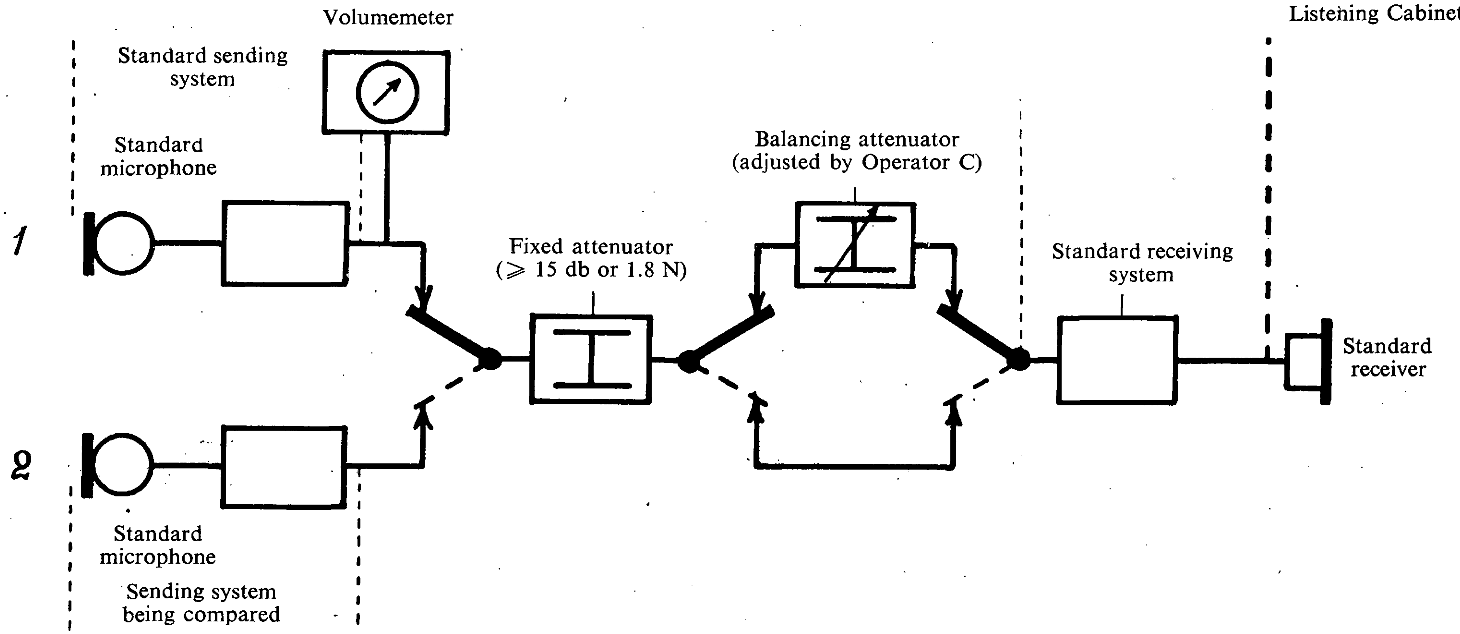


FIGURE 33. — *Comparison of a sending system with a standard sending system (Three operator, without hidden loss, method)*

The table below is an example of such an arrangement. The uncorrected result of the balance is either the number corresponding to the exact balance of the telephonometric estimations (when the exact balance has been obtainable, and confirmed, by enclosing values), or the mean of the two most adjacent numbers, one with the letter " M " (better) and the other with " P " (worse). The mean is then recorded, followed by the letter " P " or " M " according to whether the larger of the two numbers on either side of it is placed in the column marked " standard " or " instrument ".

The uncorrected test result for a series of six balances is the mean of the results of the six elementary balances. The net result of the telephonometric measurement or series of six balances is equal to the uncorrected result corrected for the reference equivalent of the standard. The final result, instead of being followed by the letter " M " or " P ", can be prefixed by the sign − or +.

Test of Sending System ....

Standard sending system used for Comparison No. ....

A-B (Talker) (Listener)			B-C			C-A		
Attenuation			Attenuation			Attenuation		
Standard Side	Instrument Side		Standard Side	Instrument Side		Standard Side	Instrument Side	
6		M	1		P	1		M
0		P	5		M		3	P
3		M	3		M		1	P
1		P	1		P	1		M
2		M	2		M		0	P
						1		M
Mean 1.5 P			Mean 1.5 P			Mean 0.5 P		
B-A			**C-B**			**A-C**		
Attenuation			Attenuation			Attenuation		
Standard Side	Instrument Side		Standard Side	Instrument Side		Standard Side	Instrument Side	
0		P		2	P	4		M
2		M	3		M		2	P
1		P	0		M	2		M
2		M		1	P	0		M
				0	M		1	P
Mean 1.5 P			Mean 0.5 M			Mean 0.5 M		

Uncorrected mean result	0.7 P
Reference equivalent of Standard	5.0 P
Reference equivalent of the instrument tested	5.7 P or + 5.7

α.2.2 Comparison of a receiving system with a Standard Receiving system

The operating method is similar to that for comparing two sending systems ; the only difference is, naturally, in the switching arrangement, which changes the receiving system instead of the sending system. For the general arrangement of the results the same instructions should be followed.

β) *Use of the S.E.T.E.D. Type Working Standard*

The S.E.T.E.D. can be used for measuring the reference equivalent of any sending (or receiving) system, particularly of systems normally employed in telephone service.

The method of comparison employed can be either of the two methods previously described.

Note. — In the past, the C.C.I.F. recommended use of working standards either with a carbon microphone (S.E.T.A.C.) or with an electromagnetic microphone (S.E.T.E.M.). Administrations and Private Operating Companies who still use these working standards will find information concerning them in Volume IV of the *Yellow Book* (Paris 1949), pp. 254 to 266.

(c) Precautions to be taken during Telephonometric Measurements

Volume to be observed. — The speech volume produced during telephonometric measurements is of great importance in the conduct of such measurements as it influences the absolute and relative sensitivities of the equipment (especially in the case of carbon microphones). This volume must correspond to the " normal power for telephonometric measurements " employed in the S.F.E.R.T. Laboratory and determined as shown above (see above § B of Section 3.1.2).

It is necessary to adjust this volume by means of a volume indicator whose needle is in view of the talker and which is connected at the input of the fixed junction attenuator (which has an input impedance of 600 ohms). This volume indicator must have been compared with the S.F.E.R.T. Volume Indicator, at the same time as its associated working standard (or with another volume indicator of the same type having itself already been compared with the S.F.E.R.T. Volume Indicator).

Packing Effect. — To prevent packing of carbon microphones under test, it is recommended that the microphone case be tapped lightly before each test.

Contact Resistance. — In order to reduce to a minimum the effect of contact resistances, it is recommended that good quality spring blades be used, exerting sufficient contact pressure.

The contact points must be made of a suitable metal, for example, silver and gold, or platinum, several springs being in parallel to provide a single connexion when the contact points are made of silver and gold.

It is, moreover, necessary to check frequently the electrical contacts of the plugs and of the switching system, by measuring the transmission equivalent of the electrical part of the system at at given frequency, for instance, 1000 c/s and with a very small current.

Position of the lips with respect to the microphone. — Not only is it necessary to use the normal volume for telephonometric measurements but it is also essential that the position of the lips with respect to the microphone should be rigously defined. In the case of a fixed microphone the operator when speaking must place his lips so that they are approximately tangential to the plane of the external opening of the microphone, and maintain this position throughout the test. To this end, a device termed a " guard ring " consisting of a circular ring of 2.5 cm diameter may be fitted to the microphone mouthpiece by means of a light attachment, and fixed so that the plane of the microphone opening is tangential to the plane of the lips when the operator applies his lips to the ring while talking. In any case, the front of the microphone must be inclined backwards, making an angle of 20° with the vertical.

In the case of a handset telephone, a " guard ring " conforming to the details below must always be used.

In the first place from measurements made on the heads of a large number of individuals, the characteristic head dimensions of an average subscriber have been determined together with the position in which he holds the handset to his ear during a telephone conversation. Such measurements have been made in various countries by means of an instrument termed a " Device for measuring the dimensions of the head ".

This device is shown in Figure 34. It consists of a telephone receiver to which is applied a complex voice frequency tone and to which is fixed a system of graduated scales. The device is held in the plane passing through the centres of the ears and of the mouth, the individual placing the receiver to his ear as he would normally do. The distance d_1 between the centre of the ear and the line of the lips and the distance d_2 of the displacement of the centre of the mouth are rear on the scales. By means of the abac (Figure 35) the following data are deduced :

1. The distance δ between the centre of the ear and the centre of the mouth.
2. The angle α between the plane of the earpiece of the telephone receiver and the straight line from the centre of this earpiece to the centre of the mouth.

The distance l between the mid-points of telephone receivers earpieces if placed against the two ears respectively is also measured (distance between the centres of the ears). The angle β is computed ; the intersection of the plane of the telephone earpiece placed against the ear and the plane through the centres of the ears and the centre of mouth defines one straight line ; β is the angle between this line and the " direction of speech ". The " direction of speech " is the straight line formed by the intersection of the median plane of the head with a plane through the centres of the ears and the centre of the mouth.

The value of β is obtained from the formula :

$$\beta = \arcsin \frac{l}{2\,\delta} - \alpha$$

The C.C.I.F. recommends the following values for α, β and δ in the case of reference equivalent measurements.

$$\alpha = 15° \, 30'$$
$$\beta = 18°$$
$$\delta = 14 \text{ cm.}$$

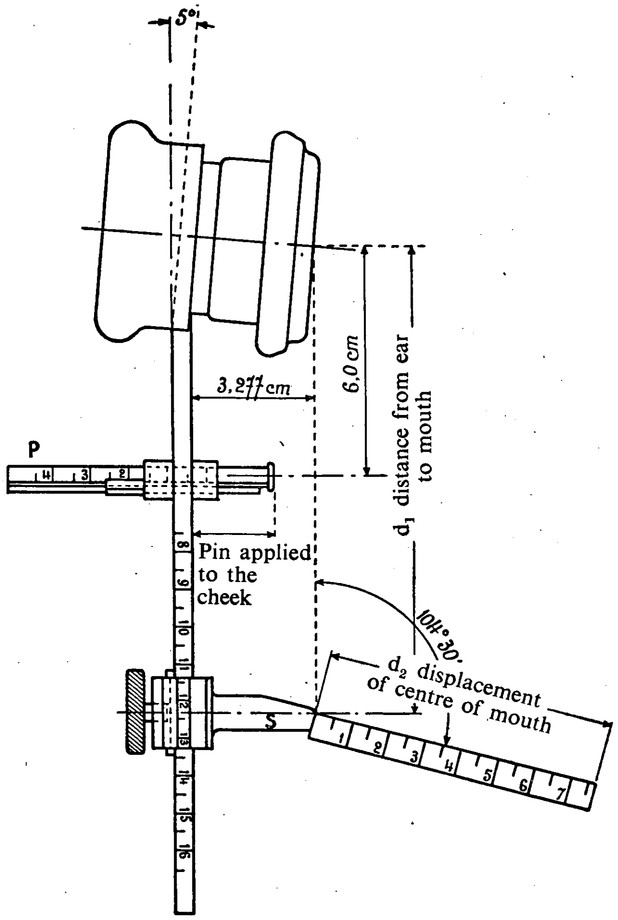


FIGURE 34. — *Device for measuring the dimensions of the head*

These figures are the most probable values observed in the United States. Although other measurements of the dimensions of heads of subscribers have given slightly different values, it is desirable to keep the above values for the sake of world-wide standardisation and also because, on the basis of these values, much information concerning the reference equivalents of commercial telephone instruments has already been determined.

Using the above values of α, β and δ, it is possible to determine the position of a guard ring to fix the position of the mouth of the operator who is talking into a handset. The plane of the guard ring will be at right angles to the plane of symmetry of the instrument and its centre will be located in that plane.

Its position will be defined by the following geometrical construction in the plane of symmetry of the handset. The mid-point of the earpiece of the receiver is taken as the origin. From this origin a straight line is drawn making an angle α with the intersection of the plane of the earpiece of the receiver and the plane of symmetry of the handset and a distance δ is marked off along this line. The point, thus determined, is the centre of the guard ring, which should coincide with the mid-point of the lips.

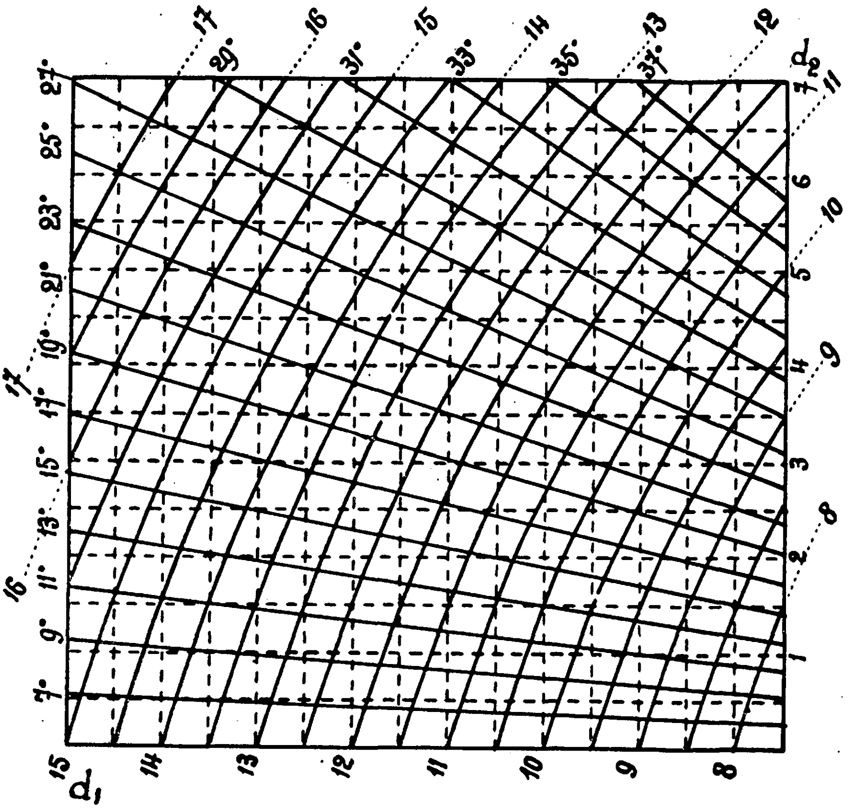


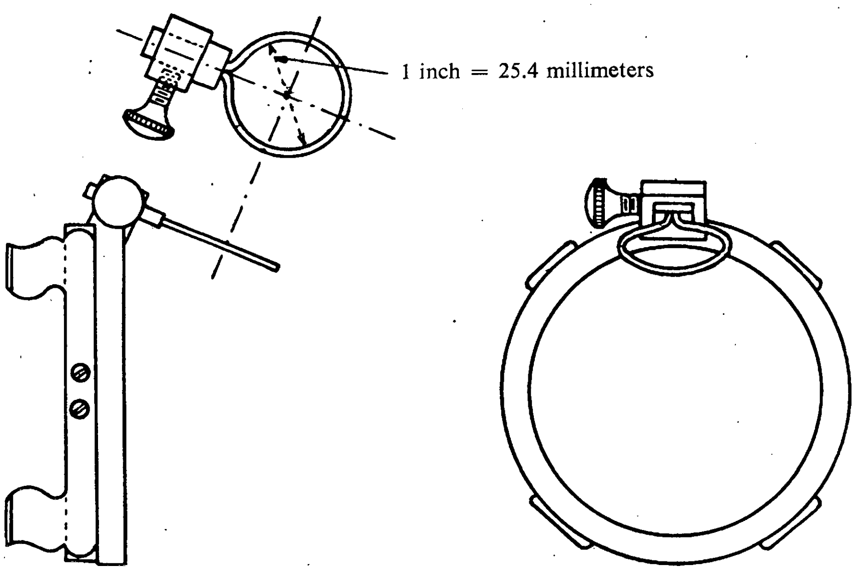
FIGURE 35. — *Abac used with the device for measuring the dimensions of the head*

d_1 Distance between the centre of the ear and the line of the lips (cm)
d_2 Displacement of the centre of the mouth (cm)
15-15, 14-14, etc... Distance δ in cm
7°, 9°, etc... Angle α in degrees

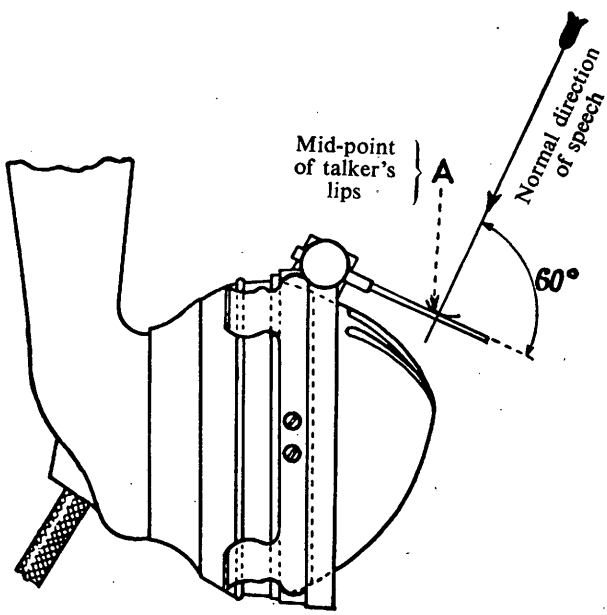
The intersection of the plane of this ring with the plane of symmetry will be a straight line, perpendicular to the direction of speech above defined ; i.e. the perpendicular to this straight line will make an angle β with the intersection of the plane of the receiver.

The position of the guard is thus completely determined and fixed with respect to the instrument.

It then remains to determine the position of the guard ring in space during telephonometric measurements. It is assumed that the operator talks in such



1. *Example of guard ring for tests of handsets*



2. *Attachment of guard ring to a handset*

FIGURE 36

a manner that the median plane of his face is vertical. The centre of the ring will be in that plane and the plane of the ring will be perpendicular to it.

It remains to determine the inclination of the ring with respect to the horizontal plane. This is taken as 45°, which corresponds to a normal posture during conversation, the head being inclined forward slightly.

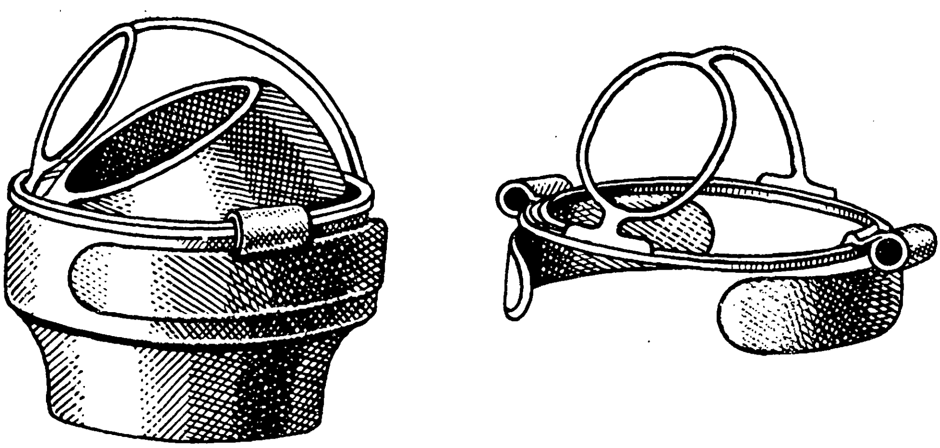
It should be noted that the position of the guard ring, thus defined, has been fixed without reference to the inclination of the diaphragm of the microphone and does not necessarily correspond to the best operating conditions of the latter.

If, when the handset is in the position described above, the receiver is near the operator's ear, care must be taken to ensure that the volume remains constant. In fact, with the volume meter connected to the standard, when the operator speaks into the handset he is inclined to vary his speech intensity on account of sound heard in the receiver by sidetone. This inconvenience is most likely to occur in instruments without an anti-side tone circuit.

In order to avoid this trouble the receiver of the handset should be disconnected and must not be placed on the operator's ear ; in addition, in the test arrangement a similar receiver should be inserted in place of the disconnected receiver which should be placed face downwards on the table so as to present an impedance similar to that of the receiver held to the ear.

It is essential that the guard ring and its mounting should be of light construction in order not to cause any disturbance in the acoustic field in front of the microphone. It is equally important that the pressure on the microphone case should not interfere with the mechanical and electrical properties of the microphone.

A device similar to that shown in Figure 36 and Figure 37 is recommended.



Attachment of guard ring to a handset

Perspective sketch of the guard ring

FIGURE 37. — *Guard ring used by the American Telephone and Telegraph Company for tests of handsets*

NOTE ON MEASUREMENTS OF REFERENCE EQUIVALENTS

It is necessary to draw a very clear distinction between, on the one hand, measurements required in the design and development of commercial telephone equipment to satisfy service conditions as well as possible and, on the other hand, the exchange between Administrations and Private Operating Companies of numerical data which enable different types of equipment to be compared, so far as reference equivalents are concerned, considered as one of the factors which affect transmission quality.

In the first case it is necessary to measure the sending and receiving sensitivities of the equipment over a wide range of variation of either the position of the subscriber's mouth with respect to the microphone or of the volume used or even of the feeding current value.

In the second case it is sufficient to give for each item a value of sending and receiving reference equivalent corresponding to a conventional position of the mouth with respect to the microphone and at a conventional volume measured with a specified volume meter.

The C.C.I.F. considers only the second case and for this reason it is not absolutely essential that the conventional position adopted for the mouth should correspond exactly with the mean position of subscriber's mouths nor that the normal volume for telephonometric tests should coincide exactly with the mean value of volumes found in service.

On the other hand, it is a great advantage if this conventional mouth position and this normal volume for telephonometric tests is used universally when it is simply a matter of communicating from one country to another general information on reference equivalents.

It follows from this that the values of sending and receiving reference equivalents corresponding to this conventional mouth position and normal volume for telephonometric tests are not necesarrily the same as those particulars for the same items in actual use.

From these considerations the above conventions can be admitted so far as the mouth position and the " normal volume for telephonometric tests " are concerned, although the results of measurements of the head dimensions in Europe have given appreciably different mean values from those which appear above, particularly for the angles α and β. These values do, howver, fall within the range of variation in service of the measured values. (Actually, the statistical mean values found in Europe as a result of several determinations conducted in various countries and which have been adopted for A.E.N. determinations in the C.C.I.F. Laboratory are :

$$\alpha = 22° \qquad \beta = 12°54' \qquad \delta = 13.6 \text{ cm},$$

while the values retained for reference equivalent measurements are :

$$\alpha = 15°30' \qquad \beta = 18° \qquad \delta = 14 \text{ cm}.$$

3.4.3 Measurement of the sidetone reference equivalent

It is necessary to consider two kinds of sidetone ; speech sidetone and room noise sidetone.

The determination of speech sidetone reference equivalent must be made with speech or equivalent arrangements : the vocal power to be used for these tests is the " normal vocal power for telephonometric measurements "

The determination of room noise reference equivalents must be made with reference subjective acoustic intensity for room noise.

Whenever a result of a sidetone reference equivalent measurement is quoted for a telephone set it is necessary also to state the value of the impedance to which it was connected during the measurement, the value of the feeding current and the sending and receiving reference equivalents of the telephone set.

(a) If it is a question of speech sidetone, a telephonometric measurement is made of the side-tone reference equivalent (voice and ear measurements), while speaking in a silence cabinet into the microphone of the set concerned, with the mouth at the " normal speaking distance " (see above) from the diaphragm of the microphone, while the receiver of the set is placed some distance away in a silence cabinet where the sound level heard in this receiver is compared with that in the receiver of the Master Reference System (or with that in the receiver of a working standard whose reference equivalent is known).

Equality of sounds heard is obtained by adjusting the " balancing attenuator ". A hidden loss attenuator situated close to the talking position enables the apparent sensitivity value of the complete S.F.E.R.T. to be varied at will before the measurement and by an amount unknown to the listener. The value of sidetone reference equivalent of the telephone system is equal to the sum $S + Q$ of the attenuation values of the " hidden loss " and " balancing " attenuators.

(b) For measurement of the room noise sidetone reference equivalent of a telephone set by aural comparison between a Master Reference System (or a calibrated working standard) and the sidetone path from microphone to receiver of the telephone set considered, one should, strictly, employ a " normal room noise " produced by a loudspeaker situated at a specified distance from the microphone.

The noise source could consist, for example, of a gramophone pick-up reproducing from a disk on which typical room noises had been recorded. The C.C.I.F., having adopted a reference room noise for A.E.N. determinations (see Section **3**.1.4 above) advises the use of such a noise.

The measurement technique used in the C.C.I.F. Laboratory is given in Figure 38 below, where the real voice is replaced by a noise source giving the reference room noise at the positions of the two microphones (1 and 2).

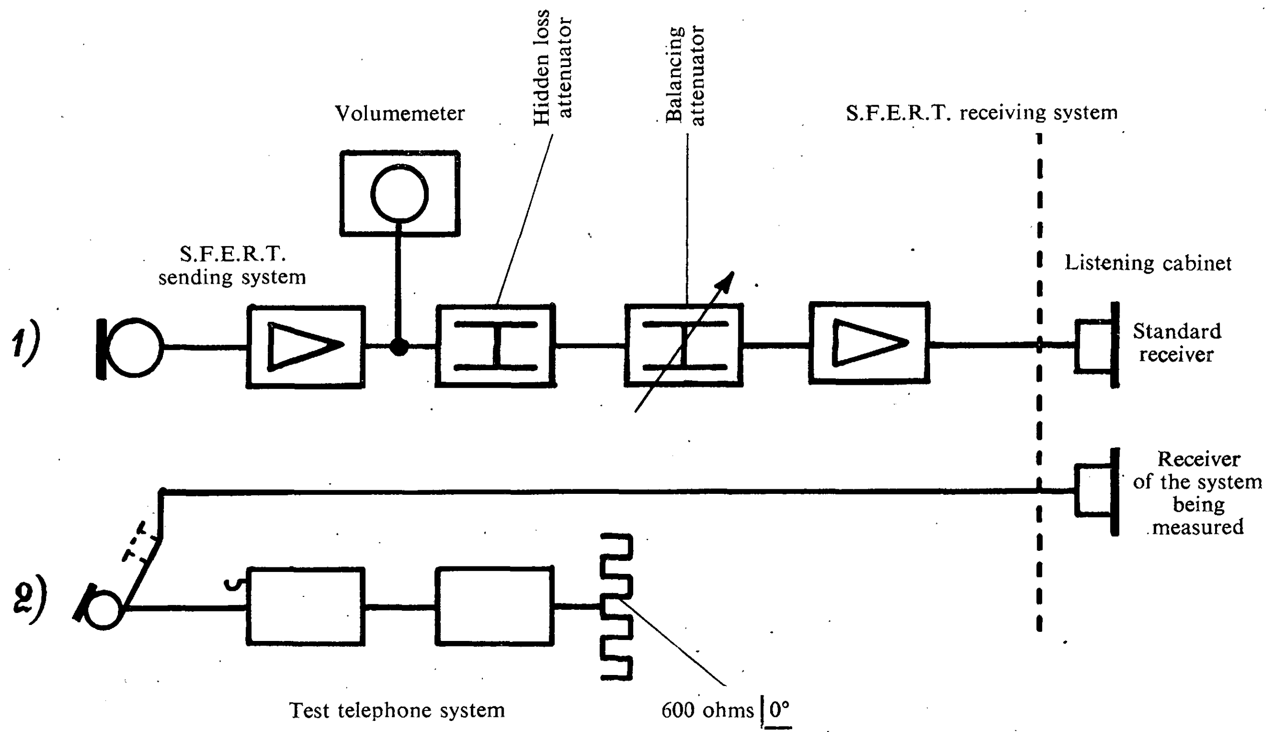


FIGURE 38. — *Measurement of the sidetone reference equivalent of a commercial telephone system*

Note. — The C.C.I.F. is at present studying the test conditions together with a measuring technique for determining the speech and room noise sidetone reference equivalents.

3.4.4 Methods of subjective determination of transmission quality

1. — *Repetition observation tests*

On of the criteria used for assessing the quality of transmission in service is based on the observation of repetitions in the course of telephone conversations conducted under commercial service conditions.

No direct measurement of effective transmission losses exists having international agreement.

So far as trunk telephone circuits are concerned, attention is confined to the individual measurement of various " transmission impairments " due respectively to circuit noises, distortions, etc., without even being certain that close agreement to the effective transmission can always be obtained by calculation, for example by adding the reference equivalent of the circuit (which is approximately equal to the loss at 800 or 100 c/s) to the transmission impairments due to the circuit distortions (attenuation distortion, phase distortion, non-linear distortion) and the transmission impairments due to various noises (induced noise, repeater noise, crosstalk noise, etc.), these transmission impairments being defined as has been shown in the first part of this book and measured as indicated below.

To measure the transmission impairment due, for example, to a certain circuit noise present on a trunk telephone circuit by means of repetition rate, the following method is employed :

During a sufficiently long period, for example 50,000 to 100,000 seconds) the repetitions are noted of one or other of the correspondents conversing on the test circuit of constant reference equivalent q on which are introduced successively various levels of an artificial noise of the same characteristics as the circuit noise considered, but of adjustable level ; the curve is drawn of repetition rate (number of repetitions per 100 seconds) as a function of the level of the artificial circuit noise.

On the other hand, the reference equivalent of the test circuit (which remains noise-free) is increased from the value q and the curve is drawn of the repetition rate as a function of the increase Δq in reference equivalent of the test circuit.

By comparing these curves, it is possible to determine the increase in reference equivalent of the test circuit which produces the same increase in repetition rate as the circuit noise of the specified level and characteristics which are considered : this increase in reference equivalent Δq is equal to the transmission impairment due to this circuit noise, expressed in transmission units (nepers or decibels).

The test circuit used for measurements by this method should reproduce the average conditions of a typical commercial trunk telephone call. Each Administration or Private Operating Company should set it up using the sending and receiving systems of its own working standard (with typical room noise) and connecting these sending and receiving systems together by means of a circuit (or better still an artificial line) of adjustable attenuation and similar in all respects to the trunk circuit considered (particularly from the point of view of the various distortions), except that this circuit (or artificial line) used for the measurements is noise-free (no circuit noise).

The method of repetition observations indicated above can be adapted for measurement of the transmission impairment due to a certain distortion (for example : limitation of the band of frequencies effectively transmitted, or attenuation distortion), of the trunk circuit considered, on condition that, instead of the circuit noise, the quantity is taken which characterises the magnitude of the distortion considered (in the above example, the bandwidth of frequencies effectively transmitted by the trunk circuit).

In the case of such a measurement, the test circuit used comprises (in addition to the sending and receiving systems of the working standard together with the typical room noise) an artificial line with an artificial circuit noise similar to that of the trunk circuit, and of which all the other characteristics are equally similar to those of the trunk circuit, except that this artificial line does not present the distortion of the type considered.

2. — *Immediate appreciation tests*

The method of immediate appreciation tests is described in Annex 23 of the *Book of Annexes* to Vol. IV of the *Green Book.*

3. — *Other methods*

For example, Annex 24 of the *Book of Annexes* to Volume IV of the *Green Book* describes a method used by the British Administration for subjectively determining telephone transmission quality.

3.5 METHODS FOR EVALUATING TRANSMISSION QUALITY ON THE BASIS OF OBJECTIVE MEASUREMENTS

These measuring methods are being studied by the C.C.I.F.

A method which has been used by the Swiss Administration is described in Annex 25 of the *Book of Annexes* to Vol. IV of the *Green Book.*

A descriptive summary of a new method for evaluating " relative transmission performance ratings " of complete connexions by means of objective measurements, which is now being studied by the American Telephone and Telegraph Company, forms the subject of the document " C.C.I.F. — 1952/54 — 4th C.E. — Document No. 58 " (see also in Volume I of the *Green Book*, Annex 5 to Question 7 of the List of Questions to be studied by the 4th Study Group during 1956/57).

A more detailed and more complete description of this method is given in the " Bell System Technical Journal " (May 1955).

3.6 MEASUREMENTS FOR MAINTENANCE OF SUBSCRIBERS' TELEPHONE EQUIPMENT FOR FACTORY ACCEPTANCE TESTING

3.6.1 Maintenance of subscribers' equipment

To assure good transmission on international connections, the C.C.I.F. recommends periodical testing of each subscriber's equipment.

Different procedures exist for making check tests from the exchange of the correct functioning of subscribers' stations by means of subjective or objective measurements.

The most important of these are the following :

1. *Subjective measurements.* — *(a)* Quick conversation test ; *(b)* Complete telephonometric test.

2. *Objective measurements.* — It is possible to envisage maintenance also based on the procedures used for factory acceptance testing. (This form of maintenance does not involve the exchange.)

1. Subjective measurements

(a) *Quick conversation test.* — This method is used mainly in the United States (by the American Telephone and Telegraph Company) and in Switzerland. Furthermore, in Great Britain, the transmission quality of telephone equipment in public kiosks and subscribers' stations having extension sets is assessed by means of a conversation with the exchange test desk clerk *.

Nevertheless, the American Telephone and Telegraph Company foresees that, with the system it intends to adopt for assessing transmission quality **, it will become feasible to measure the transmission quality of subscribers' equipment and lines in service by expressing it in the same form as for planning. It is therefore expected that in the future tests made in service will assume more importance for statistical studies of transmission quality if not for maintenance.

(b) *Complete telephonometric test.* — This method seems to be no longer used.

2. Objective measurements

(a) *Measurements made from the test desk.* — In Switzerland the checking of transmission quality is made in a subjective manner by an exchange of conversation with the test desk which deals with fault control for each terminal trunk exchange. From this test desk measurements and checks of subscribers' lines can also be made from the point of view of insulation, loop resistance, transmission of dialling impulses, etc.

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* The British Administration considers that the cost of applying preventive maintenance to other types of telephone sets would not be justified.

** See § 3.5 above.

(b) *Electrical measurements of a general nature.* — To check the transmission quality of subscriber's telephone equipment in service, the Dutch Administration uses the same measuring equipment and methods as for factory testing ; nevertheless it must be understood that the permissible limits are somewhat larger. These measuring methods are described in Section 3.6.2 below.

(c) *Use of special measuring equipment for checking telephone equipment.* — The Federal German Administration uses the following methods.

The testing of telephone equipment to check the transmission quality of subscriber's telephone equipment in service is applied mainly to the measurement of microphone and receiver capsules, because their transmission quality depends very much on the material used and the quality of manufacture. Specifications have been fixed for microphone and receiver capsules against which they are checked by means of the equipment for Objective measurement of reference equivalents described in Annex 21 of the *Book of Annexes* to Volume IV of the *Green Book.*

The equipment for objective measurement of reference equivalents enables the reference equivalents of microphone and receiver capsules to be measured. For microphone capsules, non-linear distortion and microphone noise are measured at the same time as reference equivalent by means of the modulation products. Furthermore it is possible to check the " sensitivity-frequency " characteristic by means of a visual display. A detailed description of this equipment for measuring reference equivalents objectively is attached as an annex.

The microphone capsules are divided according to their sensitivity into groups in steps of 3½ db and the receiver capsules in steps of 2½ db. These groups correspond for microphone capsules to values of sending reference equivalent 8 to 4½ db, 4½ to 1 db and 1 to −2½ db and, for receiver capsules, to values of receiving reference equivalent 0 to −2½ db, −2½ to −5 db and −5 to −7½ db. This allocation into groups is then used to associate the capsules with corresponding groups of subscribers' lines (loop resistance 0 to 250 ohms, 250 to 500 ohms and 500 to 750 ohms).

For this allocation the capsules are stamped with the figures I, II or III. Thus it is possible not only to compensate for too high values of reference equivalent of subscribers' lines but also, on replacement of capsules when the telephone set is repaired, to make sure that the capsules have not been changed after being put into service. For this reason the lineman who is dealing with the location of faults must always have with him some capsules of the various groups ; capsules which are removed from subscribers' sets are checked at the headquarters stores depot for objectively measuring reference equivalents so as to determine whether they are still serviceable.

The measurement and grouping of microphone and receiver capsules with the aid of the equipment for objectively measuring reference equivalents was introduced several years ago in the Federal German Posts and Telecommunications Administration. Each headquarter has at its telecommunications stores depot one such measuring equipment operated by non-specialist female staff.

The measuring precision is such that when the same capsule is measured with a different measuring equipment the differences are less than 1 db. The grouping of capsules and their correct allocation to the telephone sets can, so far as present experience has shown, be done without difficulty. They are considered by the telephone service staff, particularly the officers on fault location duties, as a great step forward because they been able to ensure that, by means of this grouping, the variations of receiving loudness can be compensated for different lengths of subscriber's line. A large percentage of capsules in service (about 1/3 of the microphone capsules and 1/6 of the receiver capsules) are due for replacement which will result in a great improvement in transmission quality. It has been possible to prove that most of the microphone capsules in service did not correspond to the present conditions. This also applies to the receiver capsules but to a lesser extent.

3.6.2 **Factory acceptance testing of subscribers' equipment**

The methods used in various countries are described below for information.

Denmark

In addition to inspection and mechanical examination, the equipment is given the following transmission test :

The handset is placed in a support containing a sound source (artificial mouth) and a microphone (artificial ear).

With an 800 ohms generator connected to the terminals of the equipment, the acoustic pressure produced by the telephone receiver is measured and this appears on a cathode ray oscillograph as a function of frequency over the frequency band 300-3400 c/s. In this way a simultaneous check is provided of the receiver capsule and the electrical receiving circuit.

A feeding bridge and a line impedance of 800 ohms are connected to the terminals of the equipment and the voltage at these terminals is measured while a constant acoustic pressure of 20 dynes per square centimeter, provided by the sound source, is applied to the microphone. The voltage obtained appears on a cathode ray oscillograph as a function of frequency over the frequency band 300-3400 c/s. In this way a simultaneous check is provided of the microphone capsule and the electrical sending circuit.

The oscillograph is provided with a transparent scale on which are drawn the limit curves for sending and receiving, i.e. the mean curves ± 2 db.

United States

In addition to measurements on the various component parts of the telephone equipment, the principal measurements made upon subscribers' telephone equipment in the factory by the American Telephone and Telegraph Company are the following :

1. Once the assembly of the handset is complete :

   (a) both the shape and the level of the " sensitivity-frequency " characteristics of the microphone and receiver are determined by means of a cathode ray oscillograph on a screen on which curves corresponding to the tolerance limits are drawn ;

   (b) the d. c. resistance of the carbon microphone is measured and upper and lower limits have been fixed for this.

2. When the telephone set is completely assembled :

   (a) the ringing is tested, a given input voltage being applied ;

   (a) to check the circuit continuity rather than to detect faulty components, a howl is applied to the microphone by an acoustical path in order to excite it and the following measurements are made :

      1) the output voltage across an artificial line representing the subscriber's line,

      2) the acoustic pressure produced by the receiver and transmitted by the sidetone path.

The measurements described above are made on all sets and not on a sampling basis.

NETHERLANDS

The Dutch Administration has put measuring equipment at the suppliers' disposal by means of which they are required to examine the sensitivity of each microphone and receiver capsule delivered to the Administration.

In addition it is necessary to measure the resistance of each microphone capsule while white noise of spectrum restricted to the band 300-3400 c/s is applied to the microphone in an acoustic chamber. The microphone is connected to an electrical circuit which, for both a.c. and d.c., is equivalent to the average conditions obtaining when the microphone is connected in the telephone network. The d.c. resistance is also measured in this condition at the current which would apply in practice. The noise voltage produced by the microphone is measured by means of a d.c. voltmeter connected in a Graztz circuit. The voltmeter indicates approximately the r.m.s. value.

For measuring the telephone receiver the reciprocity principle is used by applying the white noise to the receiver by an acoustical path and measuring the voltage across the receiver.

In this case too, the receiver is connected in a circuit which has the same nominal impedance as that of normal telephone equipment.

The levels measured in this way yield a statistical distribution and the Administration requires that no microphone or receiver capsule may be accepted which departs more than ± 3 decibels from the mean. The absolute level of the mean is also fixed by the Administration.

So far as the " sensitivity-frequency " characteristic is concerned the manufacturers are required to guarantee, for each capsule, that this complies with the tolerances specified in the Administration's standard. Experience has shown that the Dutch Administration can confine itself to checking from time to time by sampling whether the relevant clauses concerning the " sensitivity-frequency " characteristic are being observed. In general, the Administration uses the same measuring equipment for checking as is used in the factory. The measuring equipment used by the manufacturer for final checking in the factory must have been approved by the Administration. Furthermore the Administration has reserved itself the right to make measurements on the microphones and receivers in the factory.

The transmission characteristics of each induction coil must be guaranteed by the manufacturer. He can conduct his checking during manufacture in a manner approved by the Dutch Administration.

Federal German Republic

For tests made from the transmission point of view, the Federal German Posts and Telecommunications Administration uses, for the acceptance of subscribers' telephone equipment by its telecommunications stores depots, the equipment for objectively measuring reference equivalent described in Annex 21 of the *Book of Annexes* to Volume IV of the *Green Book*. It has been possible to prove that, in the case of good manufacture, there are scarcely any faults in assembling telephone equipment. It is therefore sufficient to make random tests at the time of acceptance. Nevertheless on delivery all microphone and receiver capsules are again measured and grouped as described above. Furthermore all reconditioned telephone equipment must be tested but this is an easy matter because only a small number of items is generally involved.

When testing telephone equipment the mean sending and receiving loss is measured between the frequency limits of 200 and 4000 c/s. The resistances of line, receiver and microphone are each replaced by a 600 ohms resistor.

United Kingdom of Great Britain and Northern Ireland

General. — The processes of manufacture and the measurements made by the manufacturer are liable for inspection at any time by the Inspection Branch. Acceptance measurements are made on every piece of equipment manufactured or on samples chosen at random at the discretion of the Inspection Branch. The nature of the acceptance measurements is determined by agreement between the purchasing authority and the manufacturer before the contract is placed.

Electro-acoustical measurements on telephone microphones and receivers. — Working standards of the same type as the equipment being purchased are maintained by the Inspection Branch, ultimately referred to objective measurements and subjective comparisons (on the loudness basis) with a high quality transmission system which is itself calibrated. For factory acceptance measurements it is therefore necessary merely to compare the sensitivity of the equipment tested with that of a working standard which serves to calibrate the measuring equipment.

Consequently these measurements are not very sensitive to the characteristics of the measuring equipment. Variations are permitted in the form of the equipment used for acceptance measurements in factories of different manufacturers. These may take the form of a simple type of measuring instrument using a single wide band of frequencies, or a multi-band measuring instrument using a number of relatively narrow frequency bands, or a curve tracer which displays the " sensitivity-frequency " characteristic of the equipment tested on a cathode ray oscilloscope screen.

For microphones, the simple type of measuring instrument comprises a source (corresponding to a warble tone or a continuous spectrum noise) which feeds a loudspeaker or an artificial mouth. The microphone is given a conditioning treatment, placed in a standardized position and the output voltage across a standard circuit is observed by means of a voltmeter. Measuring equipments of this simple type are in general use but a few curve tracers are also used ; these two types of equipment indicate the overall sensitivity ; the supplementary information given by the curve tracer provides a useful aid to the manufacturer by giving immediate warning of any departure of the manufacturing processes from normal.

For measurement of telephone receivers the source feeds the receiver being measured which is placed on an artificial ear ; the output voltage of the artificial ear is measured across a standard circuit by means of a voltmeter. The design of an artificial ear for factory testing is described in an article on probe microphones by R. B. Archbold in the *Post Office Electrical Engineers' Journal*, **45**, 145, January 1953. For the type of subscriber's telephone receiver normally manufactured, acceptance measurements are specified with a three frequency band measuring equipment.

Complete telephone sets are measured in a similar manner to that which has been described for telephone microphones and receivers but with a single band of frequencies. The standard circuits with which they are measured may, however, be different. The sidetone characteristics of telephone sets are also measured with a single band of frequencies.

SWITZERLAND

All subscribers' equipment including spares purchased by the Swiss Telephone Administration is acceptance tested. This work is entrusted to the stores testing section of the research and testing laboratory of the P.T.T. Headquarters.

Certain items of subscribers' equipment are purchased by the Administration and after being checked are returned to the suppliers concerned for assembly. Thus carbon microphones and receivers are measured by means of an equipment for checking capsules. Dial contacts are checked together with their speed of return and impulse ratio by means of a stroboscopic procedure. The capacitance and insulation resistance of condensers are measured. The handle of the handset and various cords are also checked.

The assembled equipment (without handset) is given a service test which guarantees the correct operation of the dial, bell and sending and receiving parts. The mechanical assembly, wiring and various resistors are also checked.

This stores testing section has the further task of checking stores returned by exchanges as faulty. The check is done by means of the same equipment as that used for acceptance testing. Microphone and receiver capsules are measured in this way, in particular by means of the capsule checking equipment, when, for any reason, they do not give complete satisfaction in service.

Except for checking carbon microphones and receivers, relatively simple and well known methods are involved.

Receivers and particularly carbon microphones are components which can change in use and whose transmission properties, unlike the remainder of the telephone set, have a fairly large dispersion.

For the routine checking of receivers and carbon microphones, a capsule checking equipment is available specially designed for this purpose. The suppliers of capsules to the Swiss Administration possess similar, if not the same, equipment.

This equipment is described in Annex 22 of the *Book of Annexes* to Volume IV of the *Green Book*.

A testing source supplies two sinusoidal voltages : one at 500 c/s and a second which sweeps the frequency band of 4000 to 300 c/s five times per second. The frequency scale from 300 to 4000 c/s is approximately logarithmic.

Check of a receiver capsule. — The receiver is fixed in a capsule holder and fed by means of a Model 29 set with a sinusoidal voltage at 500 c/s. In addition to this voltage it is possible to pass a direct current through the receiver of which the polarity can be changed. A subjective check shows whether the distortion factor of the receiver is small and whether the diaphragm driving mechanism is properly centred.

The capsule holder with the receiver is then placed on an artificial ear and fed with a warble tone of 4000 to 300 c/s. The artificial ear consists of a condenser microphone, a coupler and amplifiers.

To obtain an exact measurement of the sound intensity which corresponds to the subjective impression, the instrument for measuring reference equivalent takes account of the different frequency components according to a root mean square law, determines a value averaged over time and immediately indicates the reference equivalent. The " sensitivity-frequency " characteristic of the capsule can be seen on the screen of a cathode ray oscilloscope.

The receiver capsule is considered acceptable provided the distortion test (500 c/s) is satisfied when the reference equivalent falls within the limits $+2\frac{1}{2}$ to $-1\frac{3}{4}$ db. Furthermore the " relative sensitivity-frequency " characteristic should lie within the mask placed in front of the screen of the cathode ray tube.

Check of a carbon microphone. — The carbon microphone is placed in a mounting jig with a cover which provides a certain degree of attenuation to room noise. The microphone is fed with about 50 mA direct current but no sound is yet applied. The mounting jig is then rotated by hand. The displacement of the carbon granules which results from this gives rise to a disturbing voltage in the microphone which can light up a glowing lamp (illuminating voltage 6 mV peak value). When the capsule is rotated the lamp generally lights up but with a good microphone it should go out as soon as it is at rest. This relatively simple check enables the microphones (and particularly used ones) which tend to give rise to disturbing effects to be rejected.

After removing the cover of the capsule holder the microphone is placed in an acoustical chamber where a warble tone of 4000 to 300 c/s is applied to it. The acoustic pressure is controlled by means of a condenser microphone associated with an adjustable amplifier.

The following values are indicated simultaneously : reference equivalent, d.c. resistance, modulation products and " sensitivity-frequency " characteristic. Reference equivalent is measured in the same way as for receiver capsules according to a root mean square law of addition. The modulation products of microphones are measured as another quality criterion, whilst they are being energised by the 4000 to 300 c/s acoustic field. This modulation voltage which is measured at the output of a high-pass filter (cut-off frequency 5000 c/s) gives a measure of the disturbing noises caused in normal use.

A microphone capsule is considered acceptable when it has satisfied the noise test, when the reference equivalent is within the limits $+3\frac{1}{2}$ to $-1\frac{3}{4}$ db, when the d.c. resistance falls between 40 and 90 ohms, when the modulation noise does not exceed 15 mV and when the relative " sensitivity-frequency " characteristic falls within the limits of the mask placed in front of the screen of the cathode ray tube.

The amplifiers of the capsule checking equipment can be calibrated by means of arrangements included in the equipment. The inaccuracy in the measurement of reference equivalent is about ± 0.5 db.

These equipments are intended for routine check of the normal microphone and receiver capsules used by the Swiss Administration. To measure any other type of telephone set a telephone transmission reference system is available

3.7 BIBLIOGRAPHY ON SUBJECTS DEALT WITH IN VOL. IV OF THE " GREEN BOOK "

ABBREVIATIONS

a) Publications in German

Arch. Techn. Mess.	*Archiv für Technisches Messen*
Fernmeld. Zeitschr.	*Fernmeldetechnische Zeitschrift*
N.W.D.R. — Techn. Hausmitt. Siem. Z.	*Siemens Zeitschrift*
Telegr. u. Fernspr. Techn.	*Telegraphen- und Fernsprech-Technik*

b) PUBLICATIONS IN ENGLISH

Great Britain

J.I.E.E.	*Journal of the Institution of Electrical Engineers*
J.P.O.E.E.	*The Post Office Electrical Engineers' Journal.*
Proc. Roy. Soc.	*Proceedings of the Royal Society*

Japan

Elect. Comm. Lab. Tech. Jour.	*Electrical Communication Laboratory Technical Journal*
Jour. Inst. Elect. Comm. Engrs. of Japan	*Journal of the Institute of Electrical Communication Engineers of Japan*
Monthly Jour. Elect. Comm. Lab.	*Monthly Journal of the Electrical Communication Laboratory*

United States

J.A.S.A.	*Journal of the Acoustical Society of America*

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