COMITE CONSULTATIF INTERNATIONAL TELEPHONIQUE

(C.C.I.F.)

Xth PLENARY MEETING

Budapest, 3rd—10th September, 1934

VOLUME II

PROTECTION

English Edition

Issued by the International Standard Electric Corporation, London, 1936

VOLUME II.

TABLE OF CONTENTS.

PART 1.

PROTECTION OF TELEPHONE LINES AGAINST INTERFERENCE.

PART 2.

PROTECTION OF TELEPHONE CABLES AGAINST ELECTROLYTIC CORROSION.

PART 3.

PROTECTION OF TELEPHONE CABLES AGAINST CHEMICAL CORROSION.

COMITE CONSULTATIF INTERNATIONAL TELEPHONIQUE

Xth Plenary Meeting, Budapest, 3rd.–10th September, 1935.

PART I.

PROTECTION OF TELEPHONE LINES AGAINST THE INTERFERING EFFECT OF HEAVY CURRENT OR HIGH TENSION POWER SYSTEMS.

Recommendations of the C.C.I.F.

Recommendation No. 1.

Guiding Principles concerning the measures to be taken to protect telephone lines against the interfering effects of heavy current or high tension systems.

The International Telephone Consultative Committee—

(1) *Unanimously recommends :—*

That for the protection of international telephone circuits against interference due to neighbouring power lines or electric traction systems, it is desirable to apply the methods contained in the 1930 edition of the " Guiding Principles concerning measures to be taken in order to protect telephone lines against the disturbing influences of heavy current or high tension power lines."

(2) *Considering however :—*

(*a*) That the investigations carried out during the last few years enable certain points in the 1930 text of the " Guiding Principles " to be completed or modified.

(*b*) That many of the documents presented at the meeting of the 1st C.R. at Stockholm do not concern directly the questions submitted for the examination of this C.R. but may, after further study, afford useful information for the proposed new edition of the " Guiding Principles"

(*c*) That it is desirable, in order to speed up this work, to entrust the preparation of this new edition to a very limited committee :

Unanimously recommends :—

That the preparation of a new edition of the " Guiding Principles " should be given to a Committee composed of the principal rapporteur of the 1st C R. and a representative of the 1st C.R. of each of the telephone administrations of Germany, France and Great Britain, account being taken of the progress made during the last edition.

The international organizations connected with the industry and with distribution and electric traction will be invited to participate in the work of this Committee, being represented by an equally limited number of delegates.

Recommendation No. 2.

Use of electrostatic formulae for determining the electric induction from an alternating current line in a telephone circuit.

The International Telephone Consultative Committee—

Considering :—

That it follows from special investigations of this subject that the effect on the determination of the capacity coefficients of the distribution of the current in the earth is entirely negligible at industrial and telephone frequencies,

Unanimously recommends :—

That there is no reason to modify the development contained in the " Guiding Principles " on the subject of the calculation of electric induction of a power line in a telephone circuit, a development which makes use of electrostatic formulae.

Recommendation No. 3.

Psophometric E.M.F.

The International Telephone Consultative Committee—

Considering :—

That the use of the expression " tension de bruit " (noise voltage) has already given rise to misunderstanding from the fact that this idea has been confused with the difference of potential (weighted) at the terminals of an instrument, while, actually, the quantity defined in the " Directives" under the title of noise voltage is an E.M.F.

Unanimously recommends :—

(1) That from now onwards the quantity defined on page 7 (page 11 of English edition) under the title of " tension de bruit " (noise voltage) should be designated by " force électromotrice psophométrique " (Geräusch E.M.K, psophometric electromotive force) which corresponds to the more precise definition given below ;

(2) That it is desirable to reserve the expression " tension psophométrique aux bornes de . . ." (Geräusch-Klemmenspannung, psophometric potential difference) for the potential difference (weighted) between the said terminals.

Definition of psophometric E.M.F.

(1) **In the case of a complete telephone connection,** subject to interference from neighbouring power lines or traction systems, this interference with telephone conversation can be compared with the interference which would be produced by an 800 p : s current, and the magnitude of this current, which makes the interference the same in the two cases can be found.

If the receiver used in this way has a resistance of 600 ohms and a negligible reactance (an inequality ratio transformer being used where necessary) the psophometric E.M.F. at the end of the connection is defined as twice the 800 p : s voltage measured across the receiver under the conditions just defined.

The psophometric E.M.F. thus represents the E.M.F. of a source of 600 ohms internal resistance and of zero reactance which, when connected directly to the standard receiver of 600 ohms resistance and zero reactance, produces the same 800 p : s current as in the adjustment given above.

(2) It has been possible to design an instrument called a psophometer which, in the particular case considered, when it is connected directly to the terminals of the 600 ohm receiver, gives as a reading half the psophometric E.M.F.

By the general title of psophometric potential between any two points is meant the reading of the apparatus connected between these two points.

(3) When instead of a complete connection, only a part of this connection is considered, *the psophometric E.M.F. relative to the end of this section* is defined as twice the psophometric voltage

measured at the terminals of a resistance of 600 ohms connected across the end of the section, an inequality ratio transformer being used, where necessary.

Recommendation No. 4.

Objective measurements of line noise.

The International Telephone Consultative Committee—

(1) *Considering :—*

That it is more and more necessary to have an instrument for the objective measurement of psophometric E.M.F. which shall be adopted for a long period by all the administrations and private operating companies ;

That, in addition, the provisional characteristics fixed for this instrument in the recommendation of the Plenary Meeting of Paris, 1931, has enabled experimental apparatus to be set up, and that more recent tests have led to a greater precision in the requirements which this instrument must satisfy,

Unanimously recommends :—

That from now on the psophometric E.M.F. as defined above, should be measured by means of a psophometer fulfilling the conditions of the Note below.

(2) *Considering :—*

On the other hand, that in all cases where it is a question of determining whether the noise in a line exceeds a permissible limit, it appears preferable, in order to obtain perfectly comparable results which will be more easily interpreted, to make these measurements directly on the line without bringing in the individual characteristics of the other lines and apparatus connecting it to the subscriber's receiver.

Unanimously recommends :—

That in the cases considered above, it is desirable to make the measurements using a psophometer having the characteristic weighting curve defined below (psophometer for commercial telephone circuits) without using any auxiliary circuit model.

The instructions for the use of the apparatus are also given in part II of the Note below.

(3) *Considering :—*

Finally, that the interfering effect in lines is different according to whether it is a question of commercial telephony or of radio programme transmission so that it is impossible to use the same apparatus in the two cases.

Unanimously recommends :—

That it is necessary to distinguish clearly these two questions and to have re-examined by the 3rd, 4th and 5th C.R.'s the weighting curve for use with special circuits for radio programme transmission* in order to adapt the curve to the present technical requirements of these circuits.

NOTE.

SPECIFICATION OF THE PRINCIPLE AND METHOD OF USE OF PSOPHOMETERS EMPLOYED ON COMMERCIAL TELEPHONE CIRCUITS.

I. Specification of Principle.

(*a*) **Weighting curve.**

Table I below and the attached curves give, under the heading of weighting factor, the relative

* See Part 4 of Volume IV of the White Book, 1935.

values of average interfering effect of different frequencies when the value of the real voltage at each frequency at the terminals of a receiver is the same.

TABLE I

Table of weighting factors.

(*See Figs.* 1 *and* 2 *on p.* 117.)

Frequency	Weighting Factor.		
	Relative Values.	Neper.	db.
16.7	0.115	— 9.07	— 78.8
50	2.48	— 6.00	— 52.1
60	4.10	— 5.50	— 47.7
100	15.0	— 4.20	— 36.5
150	46.0	— 3.08	— 26.7
180	80.0	— 2.53	— 21.9
200	105.0	— 2.25	— 19.6
300	300	— 1.20	— 10.5
400	400	— 0.92	— 8.0
500	472	— 0.75	— 6.5
600	560	— 0.58	— 5.0
700	705	— 0.35	— 3.0
800	1000	0.00	0.0
900	1405	+ 0.34	+ 3.0
1000	1840	+ 0.61	+ 5.3
1050	1880	+ 0.63	+ 5.5
1100	1770	+ 0.57	+ 5.0
1200	1260	+ 0.23	+ 2.0
1300	795	— 0.23	— 2.0
1400	527	— 0.64	— 5.6
1500	419	— 0.87	— 7.6
1600	353	— 1.04	— 9.0
1800	289	— 1.24	— 10.8
2000	254	— 1.37	— 11.9
2200	225	— 1.49	— 13.0
2400	200	— 1.61	— 14.0
2600	177	— 1.73	— 15.0
2800	159	— 1.84	— 16.0
3000	141	— 1.96	— 17.0
3500	80.0	— 2.53	— 21.9
4000	45	— 3.10	— 26.9
5000	19	— 3.96	— 34.4

Note.—The relative values above should be taken as the basis, the corresponding values in neper and db. are approximate.

Each weighting factor is given with respect to the corresponding weight at 800 p : s. Opposite each relative value are given corresponding values in nepers and decibels.

The psophometer should contain a filter network associated with a measuring instrument. Its characteristics are such that if to the input terminals of the psophometer is applied an alternating voltage whose amplitude remains constant whatever the frequency, the value given by the instrument shall be proportional to the relative weighting factor of the frequency in question.

The characteristics should depart as little as possible from the values given in Table I so that the deviations do not exceed the permissible limits specified in Table II.

TABLE II—LIMITS.

50 and 60 p : s	.. ..	± 2 decibels or	± 0.23 neper.
60 to 150 ,,	.. ..	± 3 ,,	± 0.35 ,,
150 ,, 400 ,,	.. ..	± 2 ,,	± 0.23 ,,
400 ,, 800 ,,	.. ..	± 1 ,,	± 0.12 ,,
800 ,,	.. ..	0 ,,	0 ,,
800 ,, 1800 ,,	.. ..	± 1 ,,	± 0.12 ,,
1800 ,, 3000 ,,	.. ..	± 3 ,,	± 0.35 ,,
3000 ,, 5000 ,,	.. ..	± 5 ,,	± 0.58 ,,

In addition the maximum ordinate of the curve shall be between 1000 and 1100 p : s.

The characteristics of the psophometer shall be as stable as possible under practical operating conditions, i.e. in spite of transport, changes of temperature, etc.

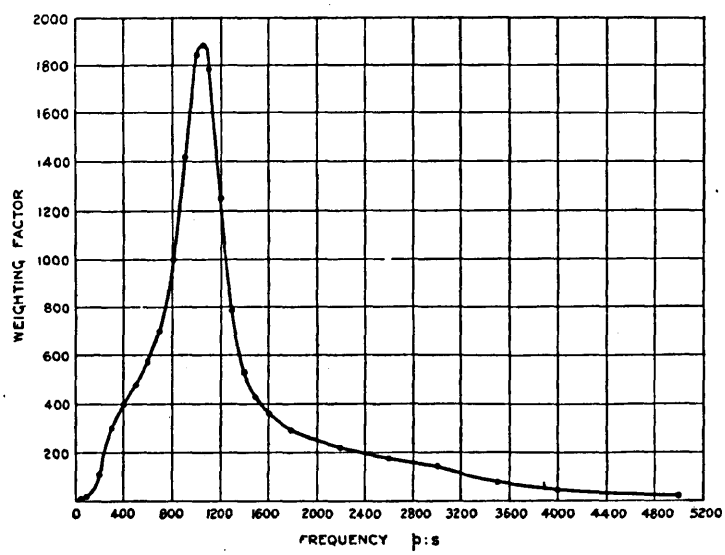


FIG. 1.

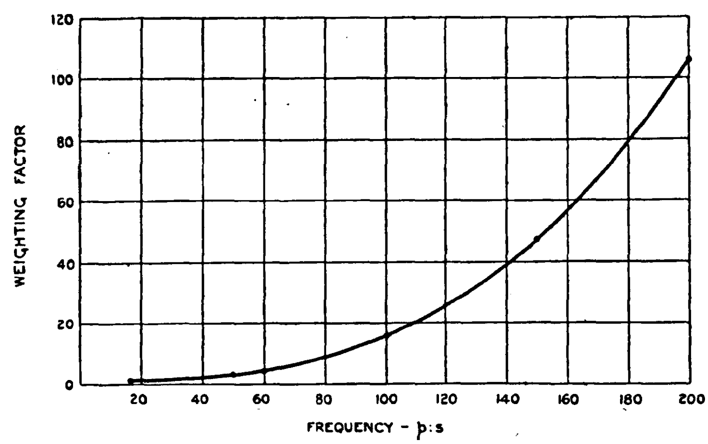


FIG. 2.

Relative values of the average interfering effect at different frequencies when the value of the real voltage at each frequency at the terminal of a receiver is the same.

(*b*) **Measuring instrument.**

The measuring instrument should be graduated* so that when a voltage at 800 p : s is applied to the input terminals of the psophometer the reading of the instrument is equal to the applied voltage.

In the case of a mixture of frequencies, the reading of the instrument should be equal to the square root of the sum of the squares of the readings corresponding to each component if it existed alone.

(*c*) **Input impedance.**

For the whole band of frequencies from 15 to 5000 p : s the input impedance of the psophometer should be as large as possible and in any case at least 10000 ohms.

A non-reactive resistance of 600 ohms is provided so that where necessary it can be connected across the input terminals of the set.

(*d*) **Sensitivity.**

The psophometer should enable a clear reading to be obtained when an 800 p : s voltage of at least 0.05 mV is applied to the input. It should also permit a direct reading of voltages up to at least 100 mV. For the whole range of the scale and for all frequencies the readings of the apparatus should be proportional to the amplitude of the applied voltage.

(*e*) **Calibration.**

The psophometer includes an arrangement which enables the gain of the amplifier to be adjusted to the desired value before each series of tests with an accuracy of at least 5 per cent.

(*f*) **Special conditions of construction.**

Balance. The balance of the psophometer with respect to the frame should be as good as possible. In any case, the application of a voltage of 200 V at 50 p : s, a voltage of 30 V at 300 p : s, or a voltage of 10 V at 800 p : s, between the short circuited input terminals and the frame should not give a reading greater than 0.05 mV.

Freedom from effect of external fields. The freedom from the effect of external fields should theoretically be absolute.† For this reason the psophometer and associated battery boxes should be shielded and all the shields should be provided with terminals so that they can be earthed during use. Shielded conductors should also be used for the various external connections of the psophometer.

Weight. The apparatus should be portable and its weight as small as will permit the above conditions to be fulfilled.

II. Method of Use.

(*a*) When it is desired to determine whether the noise produced in a circuit exceeds a permissible limit, the measurement of psophometric E.M.F. should be made on the line itself without the use of any additional device to take account of the individual characteristics of the circuits and apparatus connecting the subscriber's receiver.

(*b*) For the measurements the circuit should be closed through 600 ohms, an inequality ratio transformer being used where necessary to match the impedance of the line to 600 ohms. Under these conditions, the psophometric E.M.F. has a value twice the reading of the measuring instrument.

(*c*) For the measurement the various shields of the apparatus and associated leads should be earthed.

* See page 122 of vol. I of the White Book, 1935, the table correlating the calibration given in the specification of the C.C.I.F. for the psophometer (on the one hand), and the calibration used in the psophometer of the A. T. & T. Co. (on the other hand). Page 79 in this edition.

† For example a psophometer has been made for which the reading was 0.8 mV per oersted of external field, the psophometer being turned in such a direction that the effect of the field was a maximum. (The psophometer was placed 1 metre from a cable carrying a current of 10A at 300 p : s.)

(*d*) The position and orientation of the psophometer should be chosen so as to reduce as far as possible the effect of external fields.

Recommendation No. 5.

Technical information on the psophometers at present in use.

The International Telephone Consultative Committee—

Considering :—

That the recommendation entitled " Objective measurement of line noise " definitely fixed the characteristics of the psophometer, and that the administrations and private operating companies are actually constructing these instruments ;

That it will be of interest to draw up a list of technical details of the operating and constructional features of these instruments,

Unanimously recommends :—

That it is desirable for the administrations and private operating companies to communicate to the C.C.I.F. the required information in accordance with the following questionnaire, accompanying it with a schematic.

Operating and constructional details of existing psophometers.

Sensitivity :— 800 p : s voltage at input of psophometer giving (*a*) the maximum reading of the measuring instrument. (*b*) the first reading clearly visible.
Nature and number of parts used .. { Inductance coils. Transformers. Condensers. Vacuum tubes.
Overall dimensions (cm).
Weight (kg).
Supply voltage (V).
Current drain (A).
Input impedance (ohms).
Sensitivity to external fields. Reading of the instrument for each oersted of external field strength at 300 p : s when the apparatus is oriented with respect to the field so that the deviation is a maximum.
Balance. Reading of the instrument when the following voltages are applied between the short-circuited input terminals of the set and the frame :— a voltage of 200 V at 50 p : s. ,, ,, 30 V at 300 p : s. ,, ,, 10 V at 800 p : s.
Exact shape of the characteristic curve of the apparatus :—to be given as a separate sheet, a linear frequency scale being used and the weighting factors being given on a logarithmic scale in terms of the 800 p : s value.
Maximum deviation between the ordinates of the curve and those of the standard C.C.I.F. curve. (The negative sign indicating that the psophometer gives a smaller weight than that of the standard curve) :— from $16\frac{2}{3}$ to 60 p : s. ,, 60 ,, 150 ,, 150 ,, 400 ,, 400 ,, 1050 (for 800 p : s the deviation is zero) ,, 1050 ,, 1800 ,, 1800 ,, 5000
Method of calibration.

Recommendation No. 6.

Objective measurement of equivalent interfering voltage.

The International Telephone Consultative Committee—

Considering :—

That in accordance with the definition of equivalent interfering voltage, the weighting factors for each frequency is exactly the same (apart from the coupling factor) as that used in the definition of psophometric E.M.F.

Unanimously recommends :—

(1) That it is desirable, in principle, to measure the equivalent interfering voltage (or equivalent interfering current) by means of a psophometer connected to the line or power system (whatever the nature) by means of a device simulating the characteristics of the coupling between the given power line and the telephone line.

(2) That in practice a single instrument can be used for this measurement giving indications identical with those which would be given by the arrangement just described in the first paragraph.

Recommendation No. 7.

Distributed unbalance of a telephone line with respect to earth ; noise ratio (coefficient de sensibilité).

The International Telephone Consultative Committee—

Considering :—

(1) That the study of the idea of " impedance unbalance with respect to earth " (as defined on page 47 of the " Guiding Principles ") has shown that, in general, it is not possible to establish a direct relation between the psophometric E.M.F. and the values of this unbalance as measured at the end of the circuit ;

(2) That it is nevertheless useful to retain this simple idea which enables the state of the circuits to be appreciated approximately from the point of view of installation and maintenance.

(3) That, furthermore, it is desirable to study :

(*a*) whether for different frequencies there exists a statistical relation between the longitudinal E.M.F. and the difference of potential which is produced at the end of the circuit by the unbalances when the circuit is closed through its characteristic impedance and when no transverse E.M.F. is induced in the circuit.

(*b*) whether it is possible, in addition, to establish a statistical relation between the psophometric E.M.F. and the weighted longitudinal E.M.F.

Unanimously recommends :—

(1) That for the maintenance of circuits it is desirable to retain the definition and methods of measurement of " impedance unbalance with respect to earth " as given in the " Guiding Principles."

(2) That a new idea of noise ratio (coefficient de sensibilité) should be introduced, which relates to the ratio between the psophometric E.M.F. and the weighted longitudinal E.M.F.

Note.—In this connection the work of the 7th Comité d'Etudes of the 1st section of the C.M.I. should be taken into consideration.

Recommendation No. 8.

Localised unbalance with respect to earth.

The International Telephone Consultative Committee—

Considering :—

That in the case of short lines the unbalance to earth of the line itself is generally negligible in comparison to the unbalances in the terminal apparatus and that it is possible to put forward a new definition of localised unbalance which enables a direct calculation of psophometric E.M.F. when the weighted longitudinal E.M.F. is known,

Unanimously recommends :—

That for this particular case the following definition should be adopted. Having given a circuit with telephone apparatus at each end a first test is made by applying to each of the wires an E.M.F., E, at telephone frequency. If the circuit is not perfectly balanced a voltage e appears across the receiver of the telephone set. In a second test a symmetrical E.M.F., E^1, of the same frequency is applied in the metallic circuit, adjusted so that the voltage across the receiver is e as before.

The degree of localised unbalance with respect to earth is, for the frequency in question, the ratio

$$\delta_r = E^1/E$$

The same method can be used in the laboratory to determine the unbalance of terminal apparatus independently of the line.

Note.—In order to carry out this measurement it is convenient to use the following circuit (Fig. 2a), consisting of a three winding transformer of which the two secondary windings have a small impedance and are perfectly balanced with respect to the primary. The reversal of the connections to one of the secondary windings enables the second test to be made (Fig. 2b).

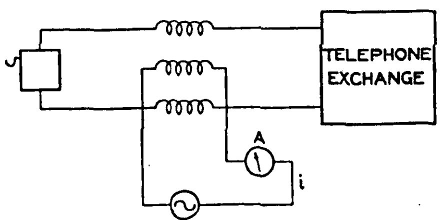


FIG. 2a.

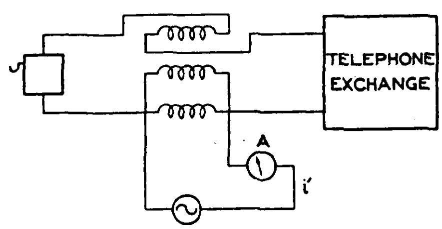


FIG. 2b.

From the value of the current in the primary winding the degree of localised unbalance is deduced from the formula :—

$$\delta_r = E^1/E = 2i^1/i,$$

It is unnecessary to use a voltmeter to measure the equality of the voltages across the receiver in the two tests, this equality can be determined aurally with sufficient precision.

Recommendation No. 9.

Reduction of the Disturbing voltage of rectifiers.

The International Telephone Consultative Committee—

Considering :—

That it is possible to obtain a substantial reduction in the disturbing voltage of traction lines supplied by rectifiers by the use of a choke coil in conjunction with resonant shunts.

That, on the other hand, the Hungarian Administration has suggested the use of a device, comprising, in addition to the resonant shunts, a filter, replacing the choke coil.

That, in any case, this device is more cumbersome and is not perhaps sufficient to suppress all the frequencies,

Unanimously recommends :—

That, so far as the reduction of the disturbing voltage of rectifier installations is concerned, devices comprising a choke coil in conjunction with resonant shunts are recommended for use.

That for six-phase rectifiers it seems desirable to design the characteristics of these shunts so as to reduce the disturbing voltage as far as is technically possible to at least one-tenth of the value it would attain if no resonant shunts were used.

Recommendation No. 10.

Tests in connection with rectifiers.

The International Telephone Consultative Committee—

Considering :—

That the rectifiers with or without grid control can cause serious audible interference not only on telephone circuits which parallel the rectified current lines but also in telephone circuits near three-phase lines supplying the rectifiers ;

That Administrations and Operating Companies are very greatly interested in knowing accurately the special properties of grid-controlled rectifiers from the point of view of their effect on telephone transmission before this new type of apparatus is applied extensively in practice,

Unanimously recommends :—

That Administrations and private operating companies should get into touch with the professional organizations of the industry and electrical distribution of their countries so that they may profit by all opportunities of testing this type of installation to complete the information already received on this subject (refer specially to documents entitled C.C.I.F. 1934, 1st C.R. Document No. 19 and Document No. 22) and to draw from it conclusions therefrom on the normal limiting values of telephone voltage form factor.

Recommendation No. 11.

Effect of transpositions in a power line.

The International Telephone Consultative Committee—

Considering :—

That the diminution of the disturbing effect of the residual components of the various harmonics of alternating voltages and currents, obtained by means of transpositions according to the methods described in the "Guiding Principles," depends on numerous factors, such as the wave form of the generator, the length of the line, the type and arrangement of transformers, etc.;

That, consequently, a theoretical study of this complex problem does not appear to lead to results of practical utility;

That, on the other hand, it appears, from studies made in the United States of America, that omitting the transposition at the point where two complete rotations (barrels) should coincide would tend to reduce the residual voltages and currents,

Unanimously recommends :—

That there appears to be no inconvenience caused by omitting that transposition;

That, concerning the problem as a whole, it does not seem opportune to undertake new investigations of this subject.

Recommendation No. 12.

Devices for protecting operators against acoustic shock.

The International Telephone Consultative Committee—

Considering :—

That, from the point of view of the protection of operators against acoustic shock, three types of apparatus have been discovered which are particularly suitable, these are : coherers, arrangements of rectifying elements, arrestors associated with voltage transformers;

That there is little difference in the sensitivity of these devices but that the method of use is somewhat different;

That the study of coherers can be considered as finished, and furthermore, that a long experience has been obtained of their use in service which shows that they give good results, on the condition, however, that they are vigilantly maintained;

That the preliminary studies and tests in service of arrangements of rectifying elements and arrestors with transformers have given very encouraging results, that these devices appear to require little maintenance and that, in particular, arrangements of rectifying elements are in actual service in certain networks,

Unanimously recommends :—

(1) That it is unnecessary to carry out comparative studies on coherers.

(2) That in connection with arrangements of rectifying elements, it is desirable to collect results of actual practical tests obtained in networks where they are in service with a view to discovering what are their best conditions of use.

(3) That in connection with arrestors with transformers, it is desirable to continue the tests in order to determine the results that can be obtained with them.

Recommendation No. 13.

Earthing a Long-distance Telephone Circuit in a Cable.

The International Telephone Consultative Committee—

Considering :—

That, in the present state of the art, cables are made with extremely low unbalances between the various circuits and earth, particularly so with respect to the circuits in the inside layers of the cable.

That these unbalances are sufficiently low if the circuits are not to be earthed ;

That, on the contrary, each earthing—even with apparent symmetry—involves a risk of bringing into play inductance and resistance unbalances for each circuit which is earthed.

That the dielectric strength between two conductors in a cable is considerably lower than that between the conductors and the lead sheath and, therefore, the earthing of certain circuits is apt to cause a risk of breakdown of the dielectric between the conductors when the cable is exposed to serious induction effects.

That, when the cable is subjected to an induced voltage of considerable magnitude, the presence of an earth allows currents to flow with an amplitude which in some cases exceeds the limit which may be permitted in order to maintain the good magnetic quality of the loading coils.

Unanimously recommends :—

1. That it is recommended not to earth a circuit in a long-distance cable at any point.

2. That, as a general rule, it is recommended not to earth any point of an installation (telephone or telegraph), which is metallically connected to a long-distance cable circuit.

3. That, in all cases, where special reasons demand the earthing of an installation which is directly connected to the conductors of a cable, the following precautions should be taken :—

(*a*) The earthing should be done so as not to interfere with the balance of the circuits with respect to earth or neighbouring circuits.

(*b*) The breakdown voltage of all the remaining conductors of the cable with respect to the earthed circuit should be appreciably greater than the highest voltage which, by reason of the induction of neighbouring power lines, may be present between these conductors and the earthed circuit.

(*c*) When a telegraph installation is connected to a cable the prescriptions of the C.C.I.F. on the subject of co-existence of telegraphy and telephony on the same circuit should also be observed.

Recommendation No. 14.

Connection of a Public Telephone System to Telephone Circuits Associated with Power Installations.

The International Telephone Consultative Committee :—

Considering :—

That distributors of electric energy require connections between circuits suspended on pole lines or in cables of the public telephone system and carrier frequency circuits superimposed on the high tension conductors or ordinary telephone circuits, suspended on the high tension poles.

That, if such arrangements are allowed, every precaution should be taken absolutely to prevent dangers arising from any derangement of the coupling devices between the lines.

That experience in certain countries for over ten years has shown what precautions should be taken.

Unanimously recommends :—

That from a technical standpoint it appears possible to permit these connections being made, provided the installations conform to the prescriptions given below.

These prescriptions are in two parts : one covers the case of telephone lines carried on the same pole as the high tension line ; the other applies to carrier circuits superimposed on high tension lines.

I. Conditions to be Fulfilled in Cases where a Telephone Line, L_1, Carried on the Poles or in the Cables of a Public Telephone Network, is Connected to an Ordinary Telephone Line, L_2, Suspended on the High Tension Line Poles.

(*a*) The coupling devices between the two telephone Lines L_1 and L_2 should conform to the best practices of the art.

(*b*) In the event of contact between the high tension conductors and the wires of line L_2 the possibility of high tension current entering the telephone line L_1 should be satisfactorily eliminated by the coupling device, which should, generally, be equipped with an insulating transformer, lightning protectors and fuses of sufficient capacity.

(*c*) In no case, even when the accidental contact above assumed occurs, should the voltage produced in line L_1 exceed 250 volts.

(*d*) All connections to earth, made on the coupling devices, should be carried out in accordance with the usual rules covering the earthing of high tension installations, imposed by each country.

(*e*) Regarding operating practice, the owner of the private lines should be responsible for the regular conditioning of the whole installation and for its maintenance in conformity with the rules outlined above.

II. Conditions to be Fulfilled in Cases where a Telephone Line, L_1, Carried on the Poles or in the Cables of a Public Telephone Network, is Connected to a Telephone Line, L_3, Operated as a Carrier Circuit, Superimposed on the High Tension Line.

(*a*) The coupling devices between the two telephone lines L_1 and L_3 should conform to the best practices of the art.

(*b*) In all cases, even when a breakdown occurs in the coupling device between the high tension line and the carrier circuit, the possibility of high tension reaching line L_1 should be rigorously guarded against.

(*c*) In no case, even when a breakdown as above assumed takes place, should the voltage produced in line L_1 exceed 250 volts.

Bearing in mind the high voltages used in carrier telephony (for example, the plate voltage) an insulating transformer should be inserted between the carrier installation and line L_1, which transformer should be capable of withstanding without damage a potential of at least three times the maximum voltage which may occur under normal operation conditions in a carrier telephone installation.

(*d*) All connections to earth, made on the coupling devices, should be carried out in accordance with the usual rules covering the earthing of high tension installations imposed by each country.

(*e*) Regarding operating practice, the owner of the private lines should be responsible for the regular conditioning of the whole installation and for its maintenance in conformity with the rules outlined above.

Recommendation No. 15.

Principles of Protection.

The International Telephone Consultative Committee—

Considering :—

That there exist at the present time great differences in the protective systems used and that it would be of interest to unify these systems, making them simple, efficient and economical, *Unanimously advises :—*

1. That the principle of protection should be first of all to choose judiciously the constructional characteristics of lines and installations and their conditions of installation and that, in general, a supplementary role should be assigned to the protective devices.

2. That, in general, any telephone circuit (interurban circuit or subscriber's loop) entirely in underground cable and not having any direct earth connection and not being connected to any earthed installation, should not be provided with any protective device ;

That, under these conditions, if the circuit is exposed to induction from power lines, the total longitudinal induction should not exceed 60 per cent. of the breakdown voltage of any part of the cable circuit ;

That if the induction exceeds this limit for a certain part of the circuit, for example, the transformers, it is desirable to replace those parts of the circuit which do not comply with the above condition or to reduce the value of the induction.

Recommendation No. 16.

Ideal Protective Device.

The International Telephone Consultative Committee—

Considering :—

That the protective devices actually used have been developed, some to protect against atmospheric discharges and others to protect against risk of contact with or induction from high tension lines.

Unanimously advises :—

That an ideal protective device should fulfil both of the two above noted requirements ;

That such a device can apparently be constituted in the following way :—

1. A simple arrestor (saw tooth or knife edge . . .) of which the breakdown voltage is about 2000 volts.

2. A fuse where the wire fuses in less than *n* seconds when it carries a current between 0.5 and 1 A ;—which does not give rise to an arc if a source of supply of 750 V (E.M.F.) and adequate power is connected to its terminals,—and which can withstand ten successive discharges of 8 joules, spaced at intervals of 10 seconds.

3. A rarefied gas arrestor whose breakdown voltage is about 300 volts and which can withstand without damage both the prolonged flow of a current insufficient to cause the fuse to operate and the flow of a current greater than that which will cause the operation of the fuse in the required time ;

Considering also :—

That at the present time a fuse fulfilling these conditions is not available,

Unanimously advises :—

That administrations and private operating companies should submit this specification to the manufacturers of their countries, inviting them to study its production.

Recommendation No. 17.

Exact Determination of the Principal Characteristics of Protective Devices.

The International Telephone Consultative Committee—

Considering :—

That the chief characteristics of the various protective devices used in different countries, as already reported by administrations and operating companies and tabulated hereinafter, do not appear to be based on the same principles of measurement and designation ;

That, on the other hand, precise and well-defined data should be available for a comparison between the various forms of the same protective device.

Unanimously recommends :—

That the chief characteristics of the protective devices used in various countries and tabulated in the following Appendix should be verified with due regard to the recommendations made in Note I, entitled : " Principal characteristics of protective devices."

That Administrations and operating companies are invited to complete the information already supplied to the General Secretariat of the C.C.I. in conformity with these recommendations.

NOTE I.

PRINCIPAL CHARACTERISTICS OF PROTECTIVE DEVICES.

This note enumerates the constructional and functional characteristics of protective devices which should be considered when a comparison is to be made between different types. Where it has appeared useful the principle of a measuring method for determining the characteristics has been indicated. For certain characteristics an exact definition has been added.

In this note merely a study of protective devices has been contemplated. In fact, the determinations indicated should be applied to several specimens of the same type and should be compared among themselves. When it is necessary to ascertain if samples conform with a standard, simplified methods may obviously be used.

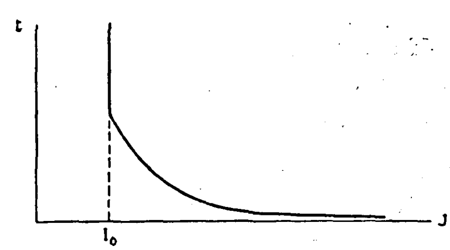
I. FUSES.

(*a*) **Description.**—Material and dimensions of the fuse wire ; form and, when possible, method of replacing the fuse wire ; if possible, operating details, etc.

(*b*) **External form.**—Method of mounting and admission of current, accessibility. . . .

(*c*) **Resistance.**

(*d*) **Operating value.**—It is possible to plot a characteristic curve representing as a function of the current J flowing through the fuse (direct or alternating current), the time t required to blow the fuse. That curve is asymptotic on the one hand to the line $t = 0$ and on the other hand to a line parallel



to the time axis. If I_0 is the abscissa of that line, its value may be adopted as the operating current of the fuse. (*See* curve.)

(*e*) **Calorific capacity.**—The calorific capacity of a fuse is the maximum energy which can be almost instantaneously absorbed by the fuse without blowing it. In practice it is sufficient to determine this value to within $\pm$ 10 per cent. To ascertain the calorific capacity, repeated discharges from a bank of condensers are sent through the fuse. If C is the capacity of this bank of condensers and V the voltage to which they are charged, then the energy absorbed by the fuse is $\frac{1}{2} CV^2$, provided the losses in other parts of the discharging circuit are negligible. The latter should be wired up with heavy conductors and all contacts should be good.

One can ascertain whether or no the losses in the discharging circuit are negligible, either by varying the capacity and the voltage or else by testing several fuses simultaneously. It is immaterial to the calorific capacity of a fuse, whether fuses are wired in series or parallel.

Since, during a thunderstorm, several atmospheric discharges may follow each other in almost immediate succession and that, therefore, heat may be stored up in the fuse, it is desirable to test with at least ten discharges, at intervals of ten seconds.

(*f*) **Voltage under which the current can be interrupted.**—When a fuse is connected to a source of direct current (or to a supply network) of high voltage and great power, it may be feared that the fusing of the wire may be followed by an arc. In order to ensure that an arc is not maintained in the cartridge of the fuse the following method may be used: in series with the fuse either a circuit breaker or else another fuse is connected which is capable of operating until a longer period has elapsed than is required for the fuse under test to blow. Thus the operation of the circuit breaker or the larger fuse indicates the maintenance of an arc in the smaller fuse. In general, this test requires means which are not ordinarily at hand in telephone laboratories.

II. HEAT COILS.

All the characteristics listed under the title of fuses, with the possible exception of calorific capacity, should be considered in connection with heat coils or any other device used for the same purpose.

At any rate it is of great interest accurately to define the characteristic curve under (*d*) and the voltage referred to in (*f*) above.

It should also be noted whether or not the heat coil is of the regenerative type, either automatic or hand-operated. It should therefore be ascertained how many times a heat coil may be used.

III. LIGHTNING ARRESTORS.

(*a*) **Description.**—Nature, shape and arrangement of the electrodes and their external connection. Nature and atmospheric pressure surrounding the electrodes.

(*b*) **External construction.**—Method of mounting and entry of current, accessibility. . . .

(*c*) **Insulation.**

(*d*) **Operating voltage.**—If a continuous voltage is applied to the terminals of a lightning arrestor, and is then gradually raised, a value will be found above which the arrestor will operate; this is indicated by the flow of a current, which can be measured on an instrument.

The voltage thus defined may be called the operating voltage of the arrestor. Certain types of arrestor lend themselves to an interpretation of their function through the plotting of a characteristic curve, showing the relation between the continuous voltage at the terminals of the arrestor and the amount of current passing through it. In general, this curve presents several parts corresponding particularly to the functioning of the discharge and that of the arc. It is useful to determine (within perhaps $\pm$ 20 per cent.) the values of the current density, at which changes occur.

Heating-up of the arrestor should be avoided when obtaining the characteristic. Also, in case of high values, the time allowed for the current to flow should be reduced and the intervals between operations prolonged.

Incidentally, it will be of interest to observe how the voltage varies at the terminals of the arrestor when the testing current is applied for an appreciable length of time. Similarly, it will be of interest to observe how the operating voltage varies at the end of more or less prolonged operations of the protector.

An arrestor may be dissymmetrical, depending on the direction of the voltage applied ; in that case the characteristic just defined will not be the same if the voltage is reversed. This point should be investigated.

Note.—When alternating current is used a rapid determination of the operating voltage may be made and the dissymmetry feature of the arrestor verified by means of an oscillograph, which shows the behaviour of the current and its wave form. For this investigation it is necessary to use a source of voltage free from harmonics.

(*e*) **Ruggedness.**—It is necessary to determine the life of the arrestor, during which it will not deteriorate, nor show important changes in the operating voltage after cooling, when passing currents of various strengths, increasing in value, step by step, from 0.1A up to the point where the fuse associated with the arrestor blows.

Since in practice a current greater than I_0 is interrupted in a given time (as shown by the characteristic curve), it is necessary to ascertain that the arrestor will stand a large number of charges during the time required for the associated fuse to blow.

This test may be made with direct or alternating current, as required.

NOTE A.

Protection of Exchange.

(1) 2–10 m of protection cable (with 0.51 mm diameter wires) placed at the junction points of aerial and underground cable when the sheath of the underground cable entering the exchange has a total length of 10 m or more.

(2) When the cable entering the exchange is aerial or where the sheaths of underground cables entering the exchange have a total length less than 100 m, a section of protection cable with 0.4 mm diameter wire should be used with a length of at least 2 m.

(3) No fuses are used when the cable only contains interurban circuits and when the underground section between the aerial section and the exchange exceeds the lengths specified below for the given conditions :—

2 miles when the biggest conductor of the underground section is No. 19 Ga.
4 miles when the biggest conductor of the underground section is No. 16 Ga.
8 miles when the biggest conductor of the underground section is No. 13 Ga.

(4) When any of the above conditions are not fulfilled, as, for example, in the case of entrance cables of small exchanges, 7A fuses should be used at the exchange.

NOTE B

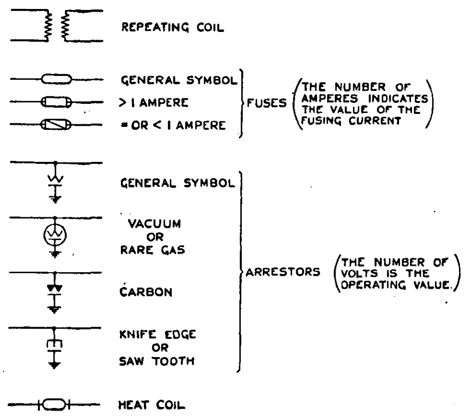
Protection of Exchange.

Protection is ensured by means of a cable of 0.51 mm diameter wires at the junction between aerial and underground cable, when the sheaths of all the underground cables entering the exchange have a total length at least equal to 100 m. If the total length is less than 100 m a section of cable of 0.4 mm diameter wires is used with a length of at least 2 m. If any of these conditions are not fulfilled as, for example, in the case of entrance cable or small exchanges, 7A fuses should be used at the exchange.

APPENDIX.

Tabular representation of protective devices used on telephone installations in various countries to protect personnel and installations against possible damage from power lines or from atmospheric discharges.

CONVENTIONS.



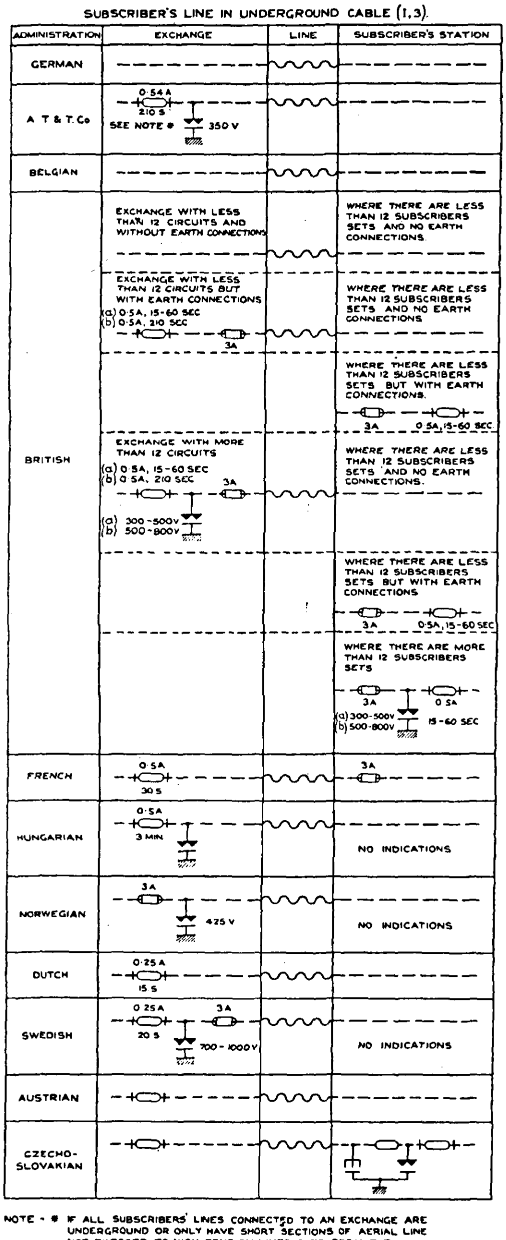
INTERURBAN CIRCUIT IN UNDERGROUND CABLE (I,1).

ADMINISTRATION	EXCHANGE	LINE
GERMAN		CABLE, LOADING COILS, REPEATING COILS, TESTED WITH 2000 V. RMS. TO EARTH AT 50 p.s
A.T.&T. Co.		
AUSTRIAN		
BELGIAN		
BRITISH	ORDINARY: (a) 0·5A, 15-60 SEC. (b) 0·5A, 210 SEC. (a) 300-500 V. (b) 500-800 V. 3A 3A WITH REPEATING COIL: (a) 0·5A, 15-60 SEC (b) 0·5A, 210 SEC. (a) 300-500 V (b) 500-800 V. 3A 3A ASSOCIATED WITH A REPEATER	
FRENCH		
HUNGARIAN	0·5A 3 MIN. GRADUALLY SUPPRESSED	
NORWEGIAN	0·5A 45 S. 425 V.	
DUTCH	0·25A 15 S.	
SWEDISH	3A 700-1000 V	
CZECHO-SLOVAKIAN		

AERIAL INTERURBAN CIRCUIT (I, 2).

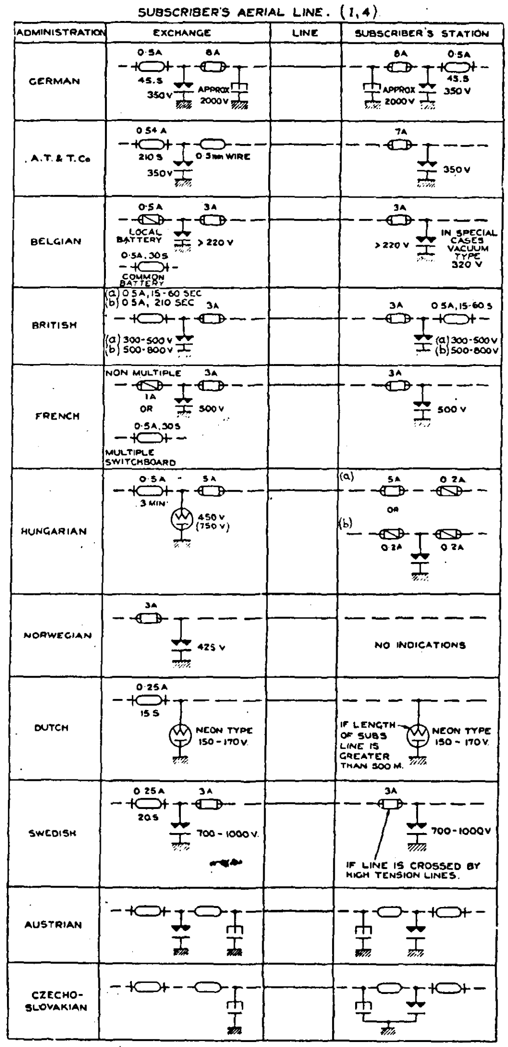
ADMINISTRATION	EXCHANGE. A.	LINE.	EXCHANGE. B.
GERMAN	0·5A 45 S 8A APPROX: 2000 V		SAME AS EXCHANGE A.
A.T.&T Co	0·5 mm WIRE 350 V		SAME AS EXCHANGE A.
BELGIAN	0·5A OR 0·5A 30 S 3A. > 220V. IN SPECIAL CASES VACUUM TYPE (320V)		SAME AS EXCHANGE A.
BRITISH	(a) 0·5A, 15-60 SEC (b) 0·5A, 210 SEC 3A (a) 300-500 V. (b) 500-800 V		SAME AS EXCHANGE A.
FRENCH	1A. 3A. NON MULTIPLE SWITCHBOARD 500 V		3A. 0·5A. 30 S. 500V. MULTIPLE SWITCH-BOARD.
HUNGARIAN	0·5A 3 MIN 5A 450 V. (750 V.)		SAME AS EXCHANGE A.
NORWEGIAN	0·5A 45 S. 3A. 425 V		SAME AS EXCHANGE A.
DUTCH	0·25A 18 S NEON TYPE 150-170 V		SAME AS EXCHANGE A.
SWEDISH	0·25A 20 SEC 3A. 700-1000 V		SAME AS EXCHANGE A.
AUSTRIAN			SAME AS EXCHANGE A.
CZECHO-SLOVAKIAN			SAME AS EXCHANGE A.

SUBSCRIBER'S LINE IN UNDERGROUND CABLE (I, 3).



NOTE - * IF ALL SUBSCRIBERS' LINES CONNECTED TO AN EXCHANGE ARE UNDERGROUND OR ONLY HAVE SHORT SECTIONS OF AERIAL LINE NOT EXPOSED TO HIGH TENSION LINES OVER 250 V, THE CARBON ARRESTORS CAN BE OMITTED.

SUBSCRIBER'S AERIAL LINE. (I, 4)



INTERURBAN CIRCUIT NOT ENTIRELY IN CABLE (I, 5)

ADMINISTRATION	EXCHANGE A	LINE	EXCHANGE B
GERMAN	0 5 A 8 A 45 S APPROX 2000 V EXCEPT IN CASE WHERE THE CABLE IS ENTIRELY UNDERGROUND	350 V APPROX 2000 V	8 A 0·5 A. 45 S APPROX 2000 V 350 V
A. T. & T. Co. (SEE NOTE A)	CARBON ARRESTOR (350 V)	OPEN WIRE LINE SHEATH OF UNDERGROUND CABLE. C SHEATH OF AERIAL CABLE JUNCTION POINT OF UNDERGROUND AND AERIAL CABLE	F CARBON ARRESTOR (350 V)
	F FUSE (7 A CONTINUOUS, 10·5 A FOR 5 MIN) C CARBON ARRESTOR (710 V) PLACED BETWEEN THE OPEN WIRE LINE AND THE SHEATH OF THE AERIAL CABLE (PRESENT PRACTICE CONSISTS IN CONNECTING THE ARRESTOR TO THE CABLE SHEATH RATHER THAN TO EARTH AT THE JUNCTION OF CABLE AND OPEN WIRE LINE).		
BELGIAN	NO SPECIAL INDICATIONS	> 220 V. IN SPECIAL CASES VACUUM TYPE (320 V)	NO SPECIAL INDICATIONS
BRITISH	(a) 0 5 A, 15 - 60 SEC (b) 0 5 A, 210 SEC 3A (a) 300-500 V (b) 500-800 V	IN CASES WHERE THE CABLE IS SUBMARINE OR UNDER RIVER AND IN CASES WHERE THE UNDERGROUND CABLE CONTAINS IMPORTANT CIRCUITS AND WHERE THE COST OF THE PROTECTIVE APPARATUS DOES NOT EXCEED HALF THE COST OF THE UNDERGROUND CABLE 3A	(a) 0 5 A, 15 - 60 SEC (b) 0 5 A, 210 SEC 3A (a) 300-500 V (b) 500-800 V
	AS ABOVE	IN OTHER CASES	AS ABOVE
FRENCH	NO SPECIAL INDICATIONS	SAWTOOTH TYPE OR	NO SPECIAL INDICATIONS.
HUNGARIAN	NO SPECIAL INDICATIONS	450 V (750 V) 5A	NO SPECIAL INDICATIONS
NORWEGIAN	NO SPECIAL INDICATIONS	NO INDICATIONS	
DUTCH	0·25 A 15 S.	150 - 170 V NEON TYPE	NO SPECIAL INDICATIONS
SWEDISH	NO SPECIAL INDICATIONS	350 V 3A	NO SPECIAL INDICATIONS
AUSTRIAN			

SUBSCRIBER'S LINE NOT ENTIRELY IN CABLE. (I, 6).

ADMINISTRATION	EXCHANGE	LINE	SUBSCRIBER'S STATION
GERMAN	350 V EXCEPT IN CASE WHERE THE CABLE IS ENTIRELY UNDERGROUND	8A APPROX 2000 V	8A APPROX 2000 V. 350 V. NORMALLY AS I, 4
A T & T Co. (SEE NOTE B)	B CARBON ARRESTOR (350 V.)	OPEN WIRE LINE. SHEATH OF UNDERGROUND CABLE C SHEATH OF AERIAL CABLE JUNCTION POINT OF UNDERGROUND AND AERIAL CABLE.	F CARBON ARRESTOR (350 V.)
	F FUSE (7A CONTINUOUS, 10 5 A FOR 5 MIN.) B HEAT COIL (0·35 A CONTINUOUS, 0·54 A FOR 210 SEC) C CARBON ARRESTOR (710 V.) PLACED BETWEEN THE OPEN WIRE LINE AND THE SHEATH OF THE AERIAL CABLE. (PRESENT PRACTICE CONSISTS IN CONNECTING THE ARRESTOR TO THE CABLE SHEATH RATHER THAN TO EARTH AT THE JUNCTION OF CABLE AND OPEN WIRE LINE.)		
BELGIAN	NO SPECIAL INDICATIONS	>220 V IN SPECIAL CASES VACUUM TYPE (320 V)	NO SPECIAL INDICATIONS
BRITISH	(a) 0 5 A, 15-60 SEC (b) 0·5 A, 210 SEC 3A (a) 300-500 V (b) 500-800 V		3A. 0·5 A, 15-60 S (a) 300-500 V (b) 500-800 V
FRENCH	1A 3A 500 V OR 0 5A 30 S NORMALLY AS I, 3	OR 10 A IF THE LINE IS MORE THAN 5 KM OR IS PARTICULARLY SUBJECT TO LIGHTNING	3A. 500 V NORMALLY AS I, 4
	1A 3A 500 V OR 0 5A 30 S. NORMALLY AS I, 3.	IF THE LINE IS LESS THAN 5 KM AND IS NOT PARTICULARLY EXPOSED.	500 V NORMALLY AS I, 4
HUNGARIAN	NO SPECIAL INDICATIONS	450 V (750 V) 5A	5A
NORWEGIAN	NO SPECIAL INDICATIONS	NO INDICATIONS	NO SPECIAL INDICATIONS
DUTCH	0 25 A 15 S	150-170 V NEON TYPE	ONLY WHEN THE LENGTH EXCEEDS 500 M
SWEDISH	NO SPECIAL INDICATIONS	700-1000 V.	NO SPECIAL INDICATIONS
AUSTRIAN			
CZECHO-SLOVAKIAN			

PART II.

PROTECTION OF TELEPHONE CABLES AGAINST CORROSION DUE TO ELECTROLYSIS

I.—Advice of the International Telephone Consultative Committee.

Recommendation No. 1.

Information on the Effects of Electrolysis.

The International Telephone Consultative Committee—

Considering :—

That research on faults on underground cables and the repair of these faults may involve considerable cost ; that the interruptions in the service which may result from the presence of these faults should be avoided with great care ; that even if the repair has been carried out as well as possible, the quality of the cable may be decreased and its normal life reduced,

Unanimously recommends :—

That it is desirable in the interests of long distance telephony to publish certain information capable of assisting the different Administrations and operating companies in overcoming the effects of electrolysis due to return currents from electric traction.

Recommendation No. 2.

Collaboration with Interested Organizations.

The International Telephone Consultative Committee—

Considering :—

That certain appropriate measures taken at the time of installation or during the maintenance of telephone cables can reduce the importance of electrolytic effects, and that the most effective means of overcoming the damage is certainly to diminish the magnitude of their cause, that is to say, to prevent the establishment of excessive difference of potentials between the return conductors of the tradition current and the lead sheath of the cables.

That this result can be obtained by observing certain technical rules during the installation of the traction lines, by means of a proper adaptation of the feeding network and of the return current network to the operating conditions of these lines, and by means of particular care taken in the installation of this network.

That, nevertheless, in order to be able to define with sufficient precision these different precautions, it is necessary to take into account the general conditions of operation of the traction system.

That in the case of important railway lines, the present knowledge on the question does not yet permit the establishment of rules which would be applicable to these lines, but that the present development of electric traction on the networks of general interest justifies the continuation of the studies undertaken in this respect.

That, on the other hand, the adoption of proper precautions to be taken for each particular case, in the maintenance of telephone cables, often assumes sufficient knowledge of the operating conditions of the neighbouring railway lines ; also that the interests of the Telephone Administrations and operating companies do not differ, in this case, from the interests of other Administrations.

Unanimously recommends :—

That it is desirable that the study of measures of protection against stray currents should be followed by the C.C.I.F. in collaboration with the international organisations officially representing the different interests in question, such as the International Union of Tramways, Local Railways and Public Motor Transport, the International Union of the Gàs Industry and the International Union of Railways.

That it is to be recommended that each Administration or operating telephone company, while applying to its underground networks measures capable of increasing their security from risk of damage due to electrolysis, will enter into collaboration with the Administrations of electric traction networks, as well as with the other interested Administrations (water, gas, electric distribution) in order to study in common, in each particular case, the best conditions for installation, maintenance and supervision of the networks, and jointly to take all useful precautions.

Recommendation No. 3.

Studies of Electric Drainage and Earth Plates.

The International Telephone Consultative Committee—

Considering :—

That the employment of earth plates (déversoirs) and the practice of electric drainage should be followed with extreme reserve, a definite and unanimous opinion not yet having been given ;

Unanimously recommends :—

That the attention of the interested Administrations and operating companies should again be drawn to the necessity for continuing the study of the questions concerning electric drainage and earth plates (déversoirs).

Recommendation No. 4.

Plan of Recommendations.

The International Telephone Consultative Committee—

Considering :—

The preliminary project of provisional recommendations concerning the measures to be taken for the protection of cables against electrolytic corrosion, published by the C.C.I.F. in 1927 (and reprinted in the Yellow Book of the C.C.I.F. 1930, pp. 653–677) has for three years been examined by Administrations and Telephone Operating Companies and by the International Union of Tramways, the local Railways and Public Motor Transport (U.I.T.).

That this project has been the object of an important study by the International Union of Tramways, a study which has given rise to detailed discussion on the part of very competent authorities on electrolysis matters.

Considering also :—

That, with the exception of a few secondary points, the principal difference between the two regulations drawn up respectively by the C.C.I.F. and by the U.I.T. is that the U.I.T. fixes a maximum of 2.5 volts for the difference of potential between any two points of the network, while the C.C.I.F. limits to 0.8 volt the value of the voltage between the rails and earth in the corrosion zones.

Considering besides :—

That in order to determine whether one or the other of these limits is exceeded, a preliminary calculation is always made of the distribution of current in the system of rails and return feeders, on the assumption that this system is perfectly insulated from earth, and that this calculation is evidently the same whatever conclusions are to be drawn from it.

Considering, on the other hand :—

That the difference between the two regulations results from the fact that after the preliminary calculation the C.C.I.F. consider the effect of the leakage resistance between the rails and earth in order to determine the points of zero potential in the network, on the assumption that the currents which flow through this leakage resistance do not change essentially the calculated distribution of currents and voltages in the system of rails and return feeders.

Considering, in addition :—

That the C.C.I.F. calculation uses for the leakage resistance mean values which agree with those found by the Bureau of Standards (U.S.A.) as the result of a long series of measurements, and which also agree essentially with those indicated in the study of the U.I.T.

Considering :—

That for this reason it should be considered that the regulation of the C.C.I.F. based on a calculation which takes into account the two factors, rail resistance and leakage resistance, is more satisfactory from the technical point of view than that of the U.I.T., which only considers the first.

Considering also :—

That it is possible to make certain modifications in the original project of recommendations drawn up by the C.C.I. in order to take into account the justified remarks drawn up by the U.I.T., and in particular to state that the rule of the maximum potential of 0.8 volt should not be applied to sections of track for which the mean leakage resistance between rails and earth is high.

Unanimously recommends :—

1. That instead of the project of recommendations concerning the measures to be taken to protect cables against electrolytic corrosion, appearing in the Yellow Book (pp. 653-679), should be substituted the following new project of which the Administrations and operating companies should make the greatest possible use.

2. That this project be brought officially to the knowledge of the C.M.I. and that this commission be invited to carry out tests and to exchange views necessary in order to arrive at an agreement between all interests on a text for the recommendations.

Proposed Recommendations concerning the measures to be taken for the protection of cables against electrolytic corrosion.

In elaborating the present Recommendations, the C.C.I.F. proposes to gather together certain information capable of assisting the different Administrations and operating companies to overcome the effects of electrolysis due to return currents from electric traction.

At the present time, while it is relatively easy to detail the principle of most of the technical measures to be taken, it is scarcely possible to fix their precise limits. The measures that can be proposed can only result in a compromise between the technical aim to be attained and the economical possibilities of realising this.

It has seemed useful, nevertheless, in order to fix the ideas, to give some precise numerical values for the limits to apply to the technical measures recommended. It is in this spirit that the numerical values in the text of the Recommendations have been determined.

From another point of view the Recommendations can only be considered as expressing the opinion of the majority of the technical advisors taking part in the work of the C.C.I.F., certain Administrations and operating companies not accepting all the numerical limits proposed. All the questions of an administrative and economic order, and, in particular, all the questions of regulations and legislation relative to the problem of the proximity of electric traction lines and telephone cables, are outside the sphere of the Committee and have been left on one side.

In particular, the Committee has abstained from entering into details of the rules of prodecure which should be followed in the reports between the Administrations and Operating telephone companies and the services of electric traction, production or distribution of electricity. It believes, however, that it can make a very general recommendation.

In order to obtain every advantage from the measures to be taken for the protection of telephone cables, and in order to facilitate their practical application, it is desirable that the telephone or electrical services interested should collaborate with the greatest goodwill. The reciprocal interchange, in a systematic and regular manner, of all useful information relating to the construction of existing or projected lines, to the changes of condition of operating of existing or proposed installations in the neighbourhood, is much to be recommended.

A. General.

1. According to tests made up to the present, the stray currents resulting from alternating-current installations of usual frequency do not exercise any harmful influence on metallic masses in the soil. The danger of electrolytic corrosion results only from direct-current installations.

Experience has shown that a network of pipe lines or of cables can be considered as practically free from corrosion due to stray currents, if it nowhere approaches closer than approximately 200 metres to a direct-current installation, which normally or accidentally has one conductor earthed, or to all works, structures or ducts, which are metallically connected with the said installation.*

In certain cases, however, such as that in which the earth is a very good conductor or in which a water course is present, this distance of 200 m may not be sufficient.

In their present form these recommendations apply only to corrosion caused by electric traction installations. Electric distribution installations will be subject to special recommendations.

Amongst electric traction installations themselves the recommendations do not concern traction lines with independent sub-structure, when the latter is insulated from earth throughout its entire length (wooden sleepers, special insulation at level crossings, etc.). For traction lines with independent substructure, and notably for railway lines of general interest, special recommendations will be formulated when actual data on this question have been obtained.

2. From the point of view of the danger to which underground metallic conduits are exposed, it is necessary to distinguish, in a traction network established along a road, between the region in which the pipes and the cables are at a potential less than that of the rails, where, as a result, the current enters the conduits, and that in which the conduits have a voltage greater than that of the rails and where, in consequence, the current leaves the latter.

In the following text are used the expressions " entrance zone " to designate the zone where the stray currents enter the sheath of the cables, and " exit zone " (or zone of anode corrosion), the zone where the currents leave the sheath.

* New tests will be made to determine, exactly, the distance at which the danger of corrosion may be considered negligible.

3. When conditions exist so that an attack on pipes or cables by stray currents from the traction installation may be produced, it is necessary to apply special measures to avoid dangerous corrosion as much as possible.

4. Measures of protection should be applied in the first instance to the construction and operation of the electric traction system, the latter being the first cause of the stray currents.

Besides, these measures are generally easier to apply technically than equally effective measures applied to the cable. The latter can, in general, only be usefully applied in new installations or at the time of an important reconstruction. When installing new metallic conduits in the neighbourhood of existing or projected traction systems, these conduits should themselves be protected against corrosion by appropriate measures.

In addition, it should be remarked that, apart from the electrolytic or chemical action which they can produce, the stray currents can be harmful by themselves—for example, where at the crossing of tracts of general interest of which the rails carry signalling currents, they are capable of using these tracks. This consideration is added to the preceding ones in order to justify the necessity of limiting as much as possible the currents which pass to the earth in a power installation.

5. The measures proposed here result from a compromise between the technical aim to be attained and the economic possibilities of realising it : although they are not sufficient to overcome all danger from corrosion, they will probably ensure that the normal life of a cable will not be much reduced by electrolysis.

6. From the technical point of view it is desirable that the application of these measures be made the object of a systematic collaboration between all the interested services (electric railways, electric distribution, gas, water, etc.).

B. Protective measures applicable to electric traction networks.

Generalities.

1. Experience has shown that from the point of view of the extent of danger from corrosion it is necessary to take into account the following factors :—

(*a*) Situation and extent of underground metallic networks ;
(*b*) Nature of the track and its foundations ;
(*c*) Position of the points of connection of the return feeders to the rails.

In practice, two distinct types of traction network occur ; urban and suburban tramway systems. The first are usually characterised in the following way :—

(*a*) In practically the whole of their extent they are superimposed on underground metallic networks relatively close together (water, gas, power cables and telephone cables) ;
(*b*) The track is formed of grooved rails buried flush with the surface of the ground ;
(*c*) They are supplied by a generating station or substation placed at the centre of the points of connection to the rails of the return feeders arriving at the station.

The suburban tramways, in their turn, generally present the following characteristics :—

(*a*) They are situated in regions where underground metallic networks are few or non-existent ;
(*b*) The track is formed of flanged rails on an independent road bed ;
(*c*) They are supplied by a generating station or substation situated outside towns or their immediate outskirts.

In the case of both urban and suburban tramways the danger of corrosion will be less, the smaller the difference of potential between the rails and the earth at any point ; the efforts of the traction companies should therefore be directed towards that object. However, since the cause of electrolytic corrosion is not the voltage between the rails and earth but the current produced by this voltage, and since this current depends not only on the magnitude of the voltage but also on the leakage resistance between the rails and earth, it is clear that, other things being equal, it is not necessary to be so severe with a suburban tramway as with an urban tramway, since the track of the former is usually much better insulated from the earth than that of the latter. This is why the present Recommendations only consider the limitation of the voltage between rails and earth in the case of urban tramways.

The above having been pointed out, it should be mentioned that the conditions set out above under (*a*), (*b*) and (*c*) can be combined in various ways and that in practice networks occur which are neither urban nor suburban tramways, according to the strict meaning of the above definition, or which can be considered as either one or the other. Each particular case should be considered on its own, and the present Recommendations should be broadly interpreted.

For example, an urban tramway network, supplied by a generating or substation situated outside the town or its immediate suburbs, would be classed as an urban tramway in the district covered by the town and its immediate suburbs and as a suburban tramway outside that district, and in particular at the points of connection of the return feeders to the rails in the extra-urban zone. Inversely, a suburban tramway supplied by a generating or substation situated in a town or its immediate suburbs would be considered as an urban tramway in the zone where underground metallic networks are frequent, assuming that the tracks extend over this zone.

2. In order to reduce the amount of stray currents, an attempt should be made to :—

(*a*) Prevent current flowing into the earth by ensuring as good an insulation as possible of the traction return current system and by reducing the voltage difference between the rails and the earth ;
(*b*) Facilitate the return of current by the rails by ensuring their good conductivity.

Measures in connection with the track :—

3. It is necessary as far as possible to place the rails on a well-drained foundation of low conductivity.

All metallic contact between the rails and conducting structures (bridges, lightning rods, lamp standards, etc.) in contact with underground metallic pipe lines should be avoided.

4. As the conductivity of the rails themselves is determined by their profile it is desirable to maintain carefully the good conductivity of all joints.

5. The resistance of a joint should not exceed that of 3 m of rail, except joints at crossings and points. Further, the increase in the resistance of a section of track due to the joints should on an average not exceed 10 per cent. of the resistance of this section without joints.*

At points and crossings, joints in grooved rails are difficult of access because they are buried in the road ; furthermore, they are subjected to greater mechanical forces, in particular, the central pieces or the tongues. It is therefore not possible to apply to these joints the same regulations as those in other parts of the track. For these reasons, at points and crossings, grooved rails should satisfy the following conditions :—

(*a*) Joints, immediately after installation or after any important repair should not have a resistance greater than that of 3 m of rail ;
(*b*) Joints, which a subsequent check shows to have a resistance higher than that of 20 m of rail should be put into repair as soon as possible.

At points in the case of flanged rails the inside rails cannot be considered as participating in the conductivity, because, in general, the tongues of movable points are not shunted by electrical bonds. In the same way the central pieces of branches and crossings, in the case of flanged rails, can only be bridged by bonds of great length and consequently of high resistance. This is why it is necessary to insist that the resistance of joints in the outside lines of rails should be maintained as low as possible.

* A section of track is defined as a continuous section which contains no cross-over, no points and no connection to return feeders.

This condition is easy to fulfil as flanged rails are easily accessible. Consequently, at branch lines and crossings, the flanged rail joints satisfy the following conditions :—

(*c*) The resistance of each joint of the two outside lines of rails should never exceed the resistance of 3 metres of rail ;

(*d*) If the transverse connections satisfy the conditions of paragraph (9) the tongues of the points need not be shunted by means of special bonds.

6. In order to maintain the track in the best possible condition from the point of view of its conductivity, it is recommended that once a year all points and crossovers should be verified, as well as joints in sections of the track for which calculations have shown a value of mean voltage drop exceeding 0.0005 volt per metre. (The definition of mean voltage is given in paragraph 12 below.)

It is also recommended that the resistance of all other joints should be measured every five years. They should be repaired as soon as possible if the measured resistances exceed the values of paragraph 7 of this chapter.

An exception is made for welded joints which should nevertheless be examined for cracks each year. Those which are defective should be repaired.

7. To equalise the current density as far as possible in all the lines of rails of a track or of parallel tracks, transverse connections should be made.

At points and cross-overs a transverse connection should be placed between all the lines of rails, before and after the point or cross-over.

The dimensions of the transverse connections should be arranged so that the resistance measured between any two points on two parallel lines of rails does not exceed, per metre of distance between the two lines of rails in question, 1 milli-ohm in the case of grooved rails and 1.5 milli-ohms in the case of flanged rails.

Immediately before and after points or cross-overs in the case of flanged rails, this resistance should not exceed 0.25 milli-ohm.

Return feeders.

8. The distribution of potential at points on the rails can be controlled by using return feeders whose action is regulated, if necessary, either by means of additional resistances or by means of automatic boosters. The load can also be divided between several generating stations.

9. The return feeders as well as the busbars should be insulated from earth throughout their whole length. This insulation should be checked periodically. If the rails are connected to the negative terminal of the generators, it is necessary to choose as far as possible for the connections of return feeders situations where the earth is dry and distant from large pipes and cables, since it is in the neighbourhood of these points of connection that the danger of electrolytic corrosion is most pronounced.

10. The connections between return conductors and rails should be maintained in good condition.

Polarity of contact wires.

11. It is possible to reduce the danger of corrosion by means of the voltage of the contact wires.

When the positive pole is connected to the contact line, the zones of anodic corrosion are found in the neighbourhood of the points of connection to the return feeders. When the negative pole is connected to the contact line the zones of anodic corrosion are distant from these points and, in addition, these zones tend to follow the movements of the tramcars.

In order to reduce the harmful effect of stray currents, use may be made either of a periodic reversal of the polarity of the contact wires (which, in the case of a daily reversal, can produce a reduction of three-quarters) or of a three-wire system of supply.

The best condition in each case can be chosen from a study of the local conditions.

It should be noted that the reversal of the polarity of the contact wires raises certain operating difficulties in the case of networks supplied from several sub-stations. In addition, in large towns in which separate networks occur having crossing points, the adoption of this measure for one of the networks necessitates the use of special arrangements to ensure the installation of this network with respect to the others at points of crossing.

Justifying Calculations.

12. In order to verify whether the arrangements taken to ensure the return of current are satisfactory (in particular the choice of locations for the connections of return feeders and the distribution of potentials), calculations can be made to see whether the mean voltage drops along the rails and the differences of mean potential between the rails and earth* remain within the limits given below. The principle of the method of calculation is indicated in Appendix I.

13. On any section of the track of an urban tramway, the mean drop of voltage per metre, calculated on the assumption of an increase of rail resistance of 10 per cent. at the joints (see paragraph 6), should not be greater than 0.001 volt.

14. The mean voltage drop per metre of a section of the track of a suburban railway calculated as indicated in paragraph 12 should not exceed 0.0012 volt in sections on roads and should not exceed 0.0014 volt in sections with independent road bed.

15. The mean voltage drop between two points of a tramway (urban or suburban) should not exceed a number of volts equal to twice the distance in a straight line between these two points expressed in kilometres.†

16. In zones of territories supplied by an urban tramway where stray currents leave pipe lines or metallic cable sheaths, the mean differences of potential calculated between rails and earth should not exceed 0.8 volt along sections of rail having a small resistance to earth (e.g., buried rails).

For sections with a high average resistance to earth (e.g. flanged rails on a separate road bed) it is not necessary to limit the mean difference of potential between rails and earth.

Methods of electrical measurement.

17. Measurements carried out in accordance with the methods given in Appendix 2 permit the state of the network to be verified in practice. They constitute an approximate check on the results of the calculation of voltages or mean differences of potential.

For very extensive networks, for which the calculation in accordance with paragraph 12 would be too complicated, measurements are indispensable to verify whether their condition conforms with the regulations of paragraphs 13, 14 and 15.

C. Protective Measures applied to Underground Cable Networks.

1. In order to avoid electrolytic corrosion it is necessary to attempt to reduce as much as possible the flow of stray currents in the cable sheaths in an electrolytic medium. To do this it is necessary

* The differences of mean potential or mean voltage drop are defined as the values obtained by calculations for the different sections of track, taking as the power in a given section, the mean power, i.e., the number of kilowatts obtained by dividing by 24 the number of kilowatt-hours supplied on the average to the contact wire during a working day.

† Although the conditions of paragraphs 13 and 14 seem to be sufficient from the point of view of electrolytic corrosion, other considerations such as telegraphy or signalling on telephone lines with earth return make it desirable to fix a maximum limit for the difference of instantaneous voltage between any two points on the tramway line.

principally, to reduce the intensity of the stray currents flowing in cable sheaths by increasing the insulation of the sheaths with respect to earth and with respect to the traction network. In certain cases, on the contrary, it may be advantageous to provide a metallic path in order to prevent the flow of current direct from the sheath to the electrolytic medium.

2. The cables should be placed as far as possible from tramway installations ; the crossings of the tramway lines being the dangerous points, it is necessary to reduce their number as much as possible.

3. When studying cable routes, it should not be forgotten that certain soils favour electrolytic corrosion (especially dampness, organic substances, soluble alkalis, bases and acids, etc.).

4. All metallic contact between the cable sheaths and conducting objects or structures in connection with the tracks of traction systems should be avoided.

5. It is necessary to avoid as far as possible infiltrations and stagnant water in the conduits as well as in the connection boxes or in the manholes.

6. In manholes and in terminal boxes, as well as at junction points, bare cables should be connected together by means of metallic connections soldered to the sheaths.

In cases where the underground conduits containing telephone cables are constructed of metallic pipes, these should also be connected electrically at these points.

7. A simple layer of insulating paint or a thin insulating covering provides very little guarantee against penetration by water, and cannot provide a permanent protection against corrosion. Such insulating layers are often found to be dangerous, since, after a certain time, at points which have become uncovered, a more intense corrosion takes place.

8. When the insulating sheath which covers the cable sheath is sufficiently thick and is itself protected, both from the mechanical and from the chemical point of view, by armouring or by some similar arrangement (cable sheath, conduits of Zores iron, etc.), the protection against electrolytic corrosion can be considered sufficient. Such means of protection are recommended, particularly in the following cases : crossings by cables of tramway lines, crossing over metallic bridges, proximity to metallic structures connected more or less to the track.

9. It has been proposed to increase the electrical resistance of cable sheath by installing insulating joints with a view to preventing electrolytic trouble. These insulating joints should only be installed at points where the ground is sufficiently dry. They should be made so as to give mechanical resistance, durability and imperviousness.

In the case of several cables placed in the same conduit and arriving at the same point, the final use of insulating joints should be made for all of them. Their use should be avoided for cables subject to serious induction from direct or alternating current lines.

10. Earth plates buried in the earth and connected to the cable sheath (déversoirs) present several of the disadvantages of drainage connections* ; it is advisable to restrict their use to points where the current leaves the cable sheath, and never to use them in regions where it is not possible to ensure that the earth plate will never be positive with respect to the cable sheath.

It does not seem that this procedure should be recommended for the protection of cables against electrolysis due to return currents from traction networks, a change in the distribution of these currents

---

* See Section D in connection with this subject dealing specially with electric drainage.

(produced, for example, by a modification in the traction network) being capable of modifying the polarity of some of these earth plates with respect to the cable sheath.

D. Protective Measures by means of Electric Drainage.

1. Under the heading of electric drainage is included a system comprising the use of metallic conductors for connecting to the return current network of the traction system certain points of the cable sheath which without drainage would tend to become positive with respect to the earth. The object is to conduct by a metallic path to the generating station the current which flows in the cable sheaths in such a manner as to decrease the amount of current which leaves these sheaths and enters the earth.

2. The use of drainage raises a certain number of different kinds of objections :—

This practice is very costly (cost of installation, of maintenance and of inspection high).

It can become ineffective as a result of accidental alteration in the distribution of the currents circulating in the cables ; in particular the magnitude of these currents can become too great ; on the other hand, cable may be exposed to cathode corrosion at places where the earth is of an alkaline nature.

It can become a cause of danger to telephone installations when a short circuit is produced on the traction network, and a cause of danger to the personnel dealing with the maintenance or operation of the telephone cables when the continuity of the rails has become broken by accident.

Finally, drainage, having as its effect the increase in the extent of the return current network of the traction system in all directions, can increase considerably the probability of corrosion at some point in the cable network or in neighbouring metallic conduits.

3. However, these disadvantages can be considerably decreased in certain cases—for example, when only a single traction line exists and where the route of the telephone cables is parallel to this track and has no branches. In such a case drainage connections can be permitted on the condition that a relatively small quantity of current is drained ; this quantity should not exceed that which is necessary to prevent the harmful effect of electrolysis.

4. In all cases where a drainage system is adopted it is necessary that this system should be established in accordance with the following principles :—

(*a*) The most convenient point for making the connection to the cable sheath is the point where measurements show that the current leaving the cable to enter the earth has the greatest possible value. It is necessary, in order that the drainage shall be satisfactory, that the potential of points where the connections are arranged, which were positive with respect to the earth before the adoption of this measure, should become, on the contrary, lower than the voltage of the earth in the neighbourhood.

(*b*) Drainage connections should only be installed at the negative busbar of the traction current generator or at points where the return feeders are connected to the rails.

(*c*) The drainage should be arranged in such a way that the cable sheath being drained has throughout its length a negative potential with respect to the earth.

(*d*) It is essential to reduce all drainage to the minimum necessary for the protection of telephone cables. This can be done either by the choice of a suitable section of the conductors used for the drainage or by the use of additional resistances.

(*e*) An effective watch should be kept in order to check the conditions of operation of the drainage system : periodical measurements of drainage current are necessary. To this end all useful arrangements should be taken during the installation of the system to enable these measurements to be carried out easily.

(*f*) It is equally necessary to take care of the possibility of being able to interrupt the drainage connections at all times, when, apart from this precaution, currents could circulate of reverse polarity and of magnitude or of duration capable of leading to damage.

(*g*) It is necessary, finally, to install fuses in drainage connections or to use circuit breakers adapted to local conditions in order to interrupt the connection in case of short circuits on the traction network.

APPENDIX I.

TO THE RECOMMENDATIONS CONCERNING THE MEASURES TO BE TAKEN FOR THE PROTECTION OF CABLES AGAINST ELECTROLYTIC CORROSION.

PRINCIPLE OF THE METHOD TO BE FOLLOWED FOR CALCULATING THE DISTRIBUTION OF RETURN CURRENTS IN A TRAMWAY NETWORK.

In order to avoid electrolytic corrosion it is necessary to reduce, as far as possible, differences of potential between different points of the rail and the earth.

This is obtained particularly when the sections of track carrying too great a value of current are discharged conveniently by means of return feeders of sufficient cross-section connected to the rails at properly chosen points. The method of calculation indicated here serves as a guide in the choice of these arrangements.

It would be possible to determine exactly the distribution of return currents in the rails and in the earth as well as the distribution of potentials, if the following information was known :—

The geometric configuration as well as the electrical characteristics of the track network.
The position of the return feeders as well as their electrical characteristics.
The insulation resistance of the rails with respect to earth at each point of the track network.
The conductivity of the earth at each point.

Finally, the values at each instance of the current entering the rails at each point of the network where there is a locomotive. It is evident, also, that these values of current entering the rails depend on the configuration of the feeder network and the electrical characteristics of this network, as well as on those of the machines, and, finally, on all the data given above.

Nevertheless, as the effects of electrolysis depend, not on the instantaneous values of the current, but on their integral with respect to time, it is sufficient to take into account in the calculations the mean values of the current.

It should be remarked that certain of the data necessary for the exact solution of the problem cannot be known. Nevertheless, in practice the approximate solution is relatively easy of calculation, and permits a sufficiently exact idea to be obtained of the distribution of the potential which determines the extent of the electrolytic action.

It is possible in effect to assume, in order to simplify the calculations as far as concerns the electrolytic effect, that everything takes place as if the mean values of the current supplied to the rails by the generators had the same value per unit length at all points in the same section of track.

The values of these currents that must be introduced into the calculation can be deduced, either from the readings of instruments installed in the locomotives, if it is a question of a system already established, or, in general, from empirical relations giving the consumption of the machines as a function of the weight transported, of the speed, of the gradient of the track, etc.

In addition, for a first approximation, as long as the distribution of currents in the rail network and the distribution of potential along this network are studied, it seems permissible to neglect the losses of current along the rails.

These losses are small in general, and, in addition, the better the network is established the smaller are these losses.

The only effect of neglecting these losses will be that the differences of potential determined between the points and the rail will be larger than those present in reality.

Experience has shown that when the differences of potential calculated under these conditions do not exceed the value of 0.8 volt specified in paragraph 16 of Section B of the Guiding Principles, the damage caused by the corrosion is reduced to permissible limits.

In any case, if it is assumed that the losses of current in the earth are negligible, the presence of the earth can be neglected in the calculation of the distribution of currents in the rail network and of the distribution of potentials along this network.

This calculation can be made in the following manner :—

1. The mean linear density of the feeder current is known at each point of the rail network. The value I of the total current entering the whole network can thus be determined.

2. Currents entering the rail network can only leave by the feeders ; the sum of the currents leaving by the feeders is thus equal to I.

3. Suppose, to start with, that there exists a single feeder F_1 of known position. Knowing the value of the current entering at each point, and also the value I_{F1} of the current leaving by the feeder, which in this case is equal to I, we can determine absolutely (and independently of all electrical characteristics of the feeder) the value of the current which passes each point in the rail network. This determination is made by means of Kirchhoff's laws. By applying Ohm's law the value of the potential at each point is obtained, the potential of reference being that of a point chosen arbitrarily.

Let M be any point in the rail network.

Assume the following symbols :—

I_{M1}, the mean value of the current passing the point M,

V_{M1}, the mean potential at this point (the second index 1 indicates that I_{M1} and V_{M1} have been calculated on the assumption that all the current I leaves by the feeder F_1).

4. This being so, consider the case where p feeders are used, F_1, F_2, F_i, F_p, of which the position is known.

The preceding calculations can be repeated for each feeder, assuming that it exists alone.

Denote by :

I_{M1}, I_{M2}, I_{Mi}, I_{Mp}, the different values of current which passes the same point M of the rail network.

V_{M1}, V_{M2}, V_{Mi}, V_{Mp}, the different values of potential of the same point M (the potential of reference being that of an arbitrary point, but the same in all cases) calculated on the assumption of the existence of a single feeder.

It is important to note that these quantities can be calculated once and for all from the values of current entering the network and the position of the feeders, independently of all electrical characteristics of the feeders.

This having been done, denote by I_{F1}, I_{F2}, I_{Fi}, I_{Fp}, the values of currents leaving feeder F_1, F_2, F_i, F_p.

We have, therefore :—

$$\sum_{i=1}^{i=p} I_{Fi} = I \qquad \text{(1)}$$

Also the value of current at a point M will be equal to :

$$I_M = \frac{\displaystyle\sum_{i=1}^{i=p} I_{F1} \; I_{M1}}{\displaystyle\sum_{i=1}^{i=p} I_{Fi}} \qquad \text{(2)}$$

The value of potential at point M will be :

$$V_M = \frac{\displaystyle\sum_{i=1}^{i=p} I_{Fi} \, V_{Mi}}{\displaystyle\sum_{i=1}^{i=p} I_{Fi}} \qquad \text{(3)}$$

5. Thus, on the assumptions made up to the present, the knowledge of the value of the currents leaving each feeder permits the complete determination of the distribution of current in the rail network as well as the distribution of potentials.

In the application we can start from different data, according to the object of the study. We can thus start with the value of the current which leaves the rails at each feeder. In order to obtain this result effectively, it is necessary to determine the electrical characteristics of the feeders in such a way that they satisfy certain conditions.

Let R_1, R_2, R_i, R_p, be the resistance to be given to each of the feeders.

Denote by V_1, V_2, V_i, V_k, V_p, the values of potential at points 1, 2, i, k, p, where these feeders are connected to the rails.

According to the general equation (3), the expression for this is :—

$$\left.\begin{aligned} V_1 &= \frac{\displaystyle\sum_{i=1}^{i=p} I_{Fi} \, V_1}{\displaystyle\sum_{i=1}^{i=p} I_{Fi}} \\ V_k &= \frac{\displaystyle\sum_{i=1}^{i=p} I_{Fi} \, I_{Mi} \, V_k}{\displaystyle\sum_{i=1}^{i=p} I_{Fi}} \end{aligned}\right\} \qquad \text{(4)}$$

As all the feeders are connected to the same busbar at the generating station, we must have :—

$$V_1 - R_1 I_{F1} = V_k - R_k I_{Fk} = V_p - R_p I_{Fp} \qquad \text{(5)}$$

These p equations (4) and these (p–1) equations (5) are not sufficient to determine the $2p$ unknowns (values of V_k and values of R_k). We can, therefore, for example, fix the arbitrary value of one of these unknowns.

It should be noted that it is nevertheless necessary, in order that the integral solution should have a physical meaning, that the values found for the different resistances should be positive.

We can also determine the distribution of return currents in the different feeders in such a way that the points where all the feeders are connected to the rails are at the same potential.

The system of equations to be solved is thus :—

Relation (1).

The p equations (4).

To which must be added the (p–1) equation (6).

$$V_1 = V_2 \ldots = V_k \ldots = V_p \qquad \ldots\ldots (6)$$

There are thus the total of ($2p$) equations to calculate $2p$ unknowns (the values of I_{Fk} and of V_k). The solution of the problems is thus completely determined.

We can finally determine what is the distribution of currents in the rail network when the return feeders have a resistance determined in advance.

Let V_k be the value of potential at a point where feeder F_k is attached ; R_k the resistance of this feeder.

The system of equations to be solved is therefore :

Relation (1).

The p equations (4).

The (p–1) equation (5).

There are thus $2p$ equations to calculate $2p$ unknowns (the values of I_{Fk} and of V_k). The solution to the problem is again determined.

6. In any case, when the values of the current leaving by each feeder are determined we can, by means of equation (3), calculate the distribution of potentials along the rails, the potential of reference being that of an arbitrary joint chosen at the start. This permits us to ensure that the mean drop in potential per metre, and the mean drop of potential between any two points of the networks, shall not exceed the limiting values indicated in paragraphs 13, 14 and 15 of Section B of the Recommendations.

It is interesting to know, in order to determine the importance of circulating currents in the earth capable of producing electrolysis, the difference of potential existing between the rails and the earth. In fact, the value of the current density leaving the rails to enter the earth, or leaving the earth to re-enter the rails, is at each point proportional :

To the difference between the potential of the rail and the potential of the earth.

To a certain co-efficient representing the losses of the track with respect to the earth.

Denote by i_M the density at any point M of the current leaving the rails to enter the earth. If at this point the current leaves the earth to re-enter the rails, i_M will be negative.

Let V_M be the potential of the rail at point M and V_{Mt} be the potential of the earth in the neighbourhood of point M, measured with respect to the potential of reference which has already been mentioned.

Let C_M also be the coefficient of leakance of the track at point M per unit length of track.

We have therefore :—

$$i_M = C_M \; (V_M - V_{Ms}) \qquad \text{.......................................} (6a)$$

Nevertheless, the variations of potential of the earth along the rails of an electric traction network are always considerably smaller than the variations in potential of the rail itself.

We can thus see that only a small error in the expression for the current density flowing between the rails and the earth is produced when we give the same value V_o to the potential of the earth at all points.

When it is a question of a network of which one of the points is connected to a good earth point we should evidently assume that the potential of this point is exactly equal to the potential V_o.

When, on the contrary, it is a question of a network not having at any point a direct connection to earth, and having well insulated feeders, we can determine the mean value V_p of the potential of the earth from the following considerations :—

We know that in such a case the sum of the currents leaving the rails towards the earth is equal to the sum of the currents returning to the rails—in other words, the algebraic sum of all the currents leaving the rails (or returning to the rails) is zero.

This condition is as follows :—

$$\int C_M \; (V_M - V_o) \; dl = 0 \qquad \text{.......................................} (7)$$

The integral being taken over the whole length of the network of rails.
From this we obtain :—

$$V_o = \frac{\int C_M \; V_M \; dl}{\int \; C_M \; dl} \qquad \text{.......................................} (8)$$

In connection with the values to be given to the coefficients of losses C_M, experience has shown that we can assume that these coefficients keep the same value throughout the whole length of a network if the same type of rail is used throughout, and if the rails are installed throughout in the same way. In such a case the coefficients are eliminated from formula (8). When this is not the case, it is convenient to divide up the total network into regions within which we can give these coefficients a uniform value. It is sufficient, however, for the calculation that these coefficients be determined by an approximately constant factor.

We can, for example, adopt the following values for C :—

$C = 1$ for a double track with grooved rails.
$C = 0.7$ for a single track with grooved rails.
$C = 0.1$ for a single track with flanged rails.

Thanks to these circumstances, we can determine for formula (8) a more complete expression.

Consider the section of track (in the sense defined in the Recommendations) or, more precisely, the part of a section of track for which we can give C a uniform value.

Let A and B be the extremities of this part of the section.

L the length of the section.

J the mean value of the total feeder current entering the section.

V_A and V_B, the potential of the points A and B measured with respect to the potential of reference which has already been mentioned.

For this part of the section we obtain integral :—

$$\int_A^B V_M dl$$

But if l is the distance separating the point M from the point A, we have from Ohm's law :—

$$V_M = V_A + r \int_A^M \left(I_A + J\frac{l}{L} \right) dl$$

r representing the resistance of the track, I_A the current flowing in the track at the point A (positive in the direction of B towards A).

We have :—

$$V_M = V_A + rl\, I_A + r\frac{J\, l^2}{L\, 2}$$

In particular :—

$$V_B = V_A + rL\, I_A + r\frac{J\, L^2}{L\, 2}$$

From which :—

$$\int_A^B V_M dl = L\left(V_A + r\, I_A \frac{L}{2} + r\frac{JL^2}{L\,6}\right)$$

$$= \frac{L}{2}(V_A + V_B) - \frac{L^2}{12} rJ.$$

In general, even for a rather long section, the term of the second degree in L is negligible. There remains, therefore :—

$$\int_A^B V_M\, dl = \frac{L}{2}(V_A + V_B)$$

and the expression for Vo can be written

$$V_0 = \frac{\sum CL\,(V_A + V_B)}{2 \sum CL}$$

the summation being extended over all the sections of the traction network.

When the preceding calculations have been made we can form for each point of the network the difference $V_M - V_0$, and make certain that at no point do these differences exceed the value of 0.8 volt indicated in paragraph 16 of Section B of the Recommendations.

If this is not so, it signifies that the number of return feeders is too small or that the resistances of these feeders are not efficiently arranged ; or, further, that the location of the connection points of the feeders to the rails has not been properly chosen.

It is necessary, then, to study as above the configuration of the feeders or of the rails satisfying the given conditions.

APPENDIX II.

TO THE RECOMMENDATIONS CONCERNING THE MEASURES TO BE TAKEN FOR THE PROTECTION OF CABLES AGAINST ELECTROLYTIC CORROSION.

Electrical Measurements in Connection with Electrolytic Corrosion.

Electrolytic corrosion being due to stray currents which leave the metallic sheaths of cables, it is desirable to measure directly the intensity of the stray currents in the sheaths themselves or in the earth at the points where these currents enter or leave. There are different methods, of which a number are mentioned below, for carrying out these measurements.

On the other hand, stray currents are caused by differences of potential which exist between the rails and the sheath, and whose importance, other things being equal, is greater, the greater the resistance of the track. Consequently, it is desirable, in order to determine the conditions of a tramway network, to proceed to measure the differences of potential and the drop in voltage, and to measure the resistance of the rail joints.

I.—Measurements of the Stray Current Intensity.

A.—In the metallic cable sheath,

B.—In the earth at the point of entering and leaving the metallic cable-sheath.

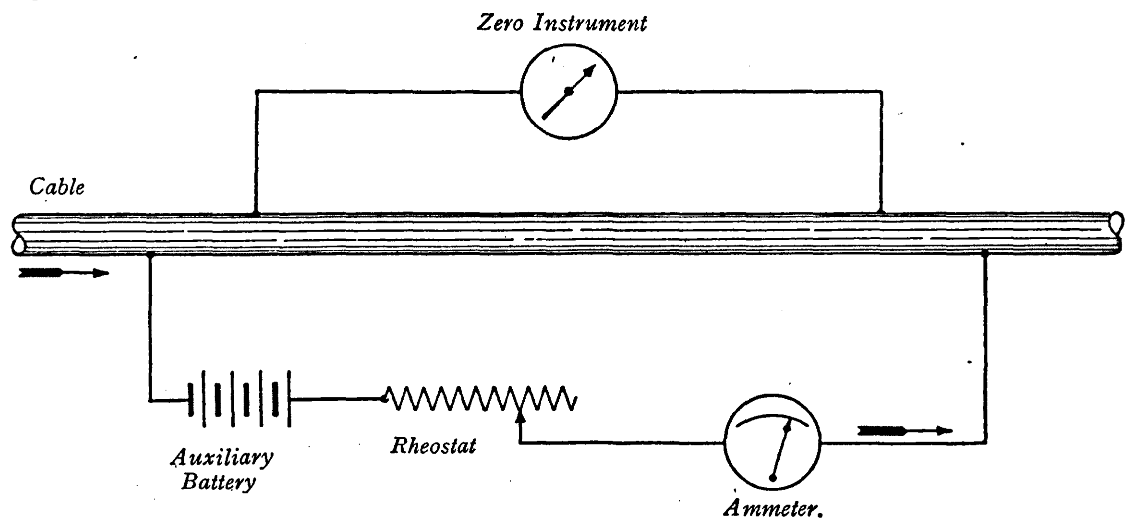
A.—Measurements of the intensity of the stray currents in the cable sheath.

The intensity of the currents which flow in the metallic sheath of a cable can be measured by one of five methods :

1. The intensity of the stray current flowing in a given length of the sheath can be deduced from the measurement of the difference of potential drop between the two extremities, after having calculated the electric resistance of the given length of sheath from the geometric dimensions and the resistivity of the metal. This method, however, gives rise to error because of the irregularity of the sheath, and because of the damping of the oscillation of the voltmeter shunted by the small resistance of the sheath.

2. In order to measure the stray currents flowing in the metallic sheaths of the cable, this sheath can be interrupted and an ammeter of as small a resistance as possible connected (in practice from $\frac{1}{100}$ to $\frac{1}{10}$ of an ohm).

3. In order to avoid breaking the continuity of the metallic sheath of the cable, the current which circulates in this sheath can be compensated by means of an auxiliary battery associated with the rheostat and an ammeter. A sensitive measuring instrument with a short period of oscillation, preferably pivoted (zero instrument)* ; enables it to be determined when this compensation has been properly obtained. The connections are shown below :—



* See note on p. 150

Note : For this zero instrument a galvanometer which is sensitive to differences of potential at the terminals should be used having a short transitory period, owing to the rapid variations in the magnitudes of the stray currents which flow in cable sheaths liable to corrosion. On the other hand, the sensitivity of the galvanometer to current need not be particularly great. Consequently, a low resistance galvanometer is better for these tests than a high resistance galvanometer.

The German telephone administration generally uses a direct reading pivoted galvanometer having a resistance of about 5 ohms and a sensitivity (with respect to the applied voltage) such that one scale division corresponds to a potential of 30 microvolts, which is sufficient for the majority of cases encountered in practice. A galvanometer is available which has a sensitivity twice as great, also the Zeiss moving coil galvanometer whose sensitivity is 10 to 100 times greater ; the resistance of this last galvanometer reaches 5 to 10 ohms ; with the Zeiss galvanometer it is possible to measure currents in pipes where the intensity is only a few milliamperes.

Mirror galvanometers, which are used in communication work only for the measurement of insulation, have a sufficient sensitivity but their transitory period is too long. Direct reading suspension galvanometers which are also sometimes used for insulation measurements usually have insufficient sensitivity from the point of view of applied voltage.

The British administration use an instrument called the " No. 36 Tester " for measuring currents in cable sheaths.

(1.) A voltmeter with three centre zero scales.

1.25— 0 —1.25 millivolts.
25 — 0 — 25 ,,
250 — 0 — 250 ,,

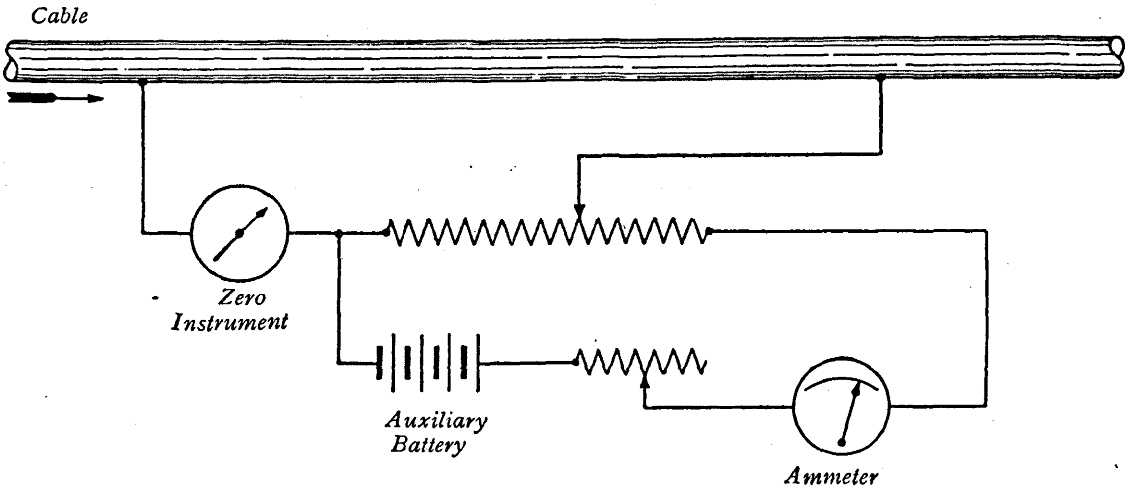
When the 250 millivolt scale is used the resistance is 2000 ohms.

(2.) An ammeter with three scales :—

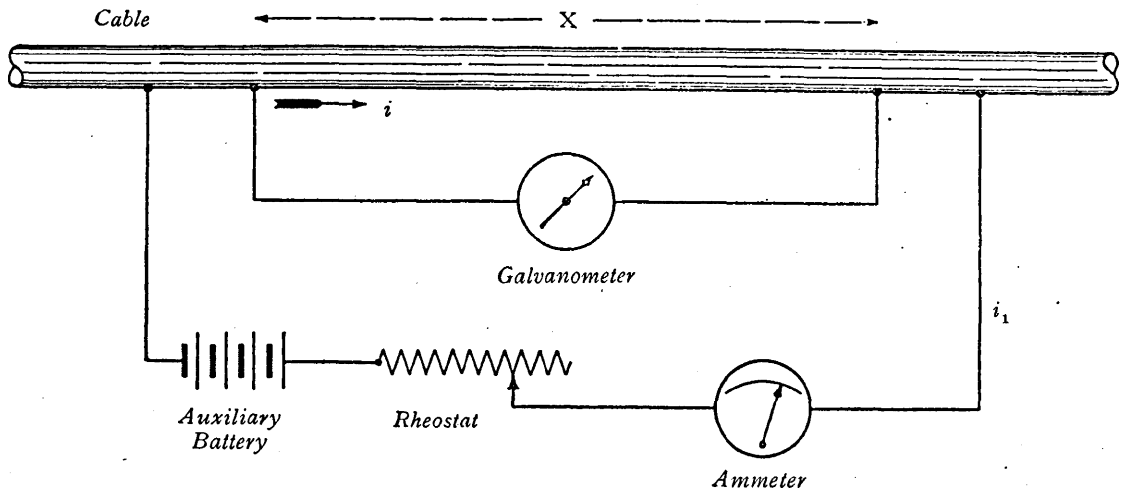
0 — 50 milliamperes.
0 — 500 ,,
0 —5000 ,,

When the 50 milliampere scale is used the resistance is 0.216 ohms, with corresponding values for the other scales.

4. Instead of compensating the currents, the voltage along the metallic sheath of the cable can be compensated for according to the following, but it is then necessary to calculate the currents which flow in the sheath, knowing the resistance of the sheath.



5. Finally, the value i of the current flowing in the cable sheath and the resistance X of the sheath can be deduced from two successive readings on a galvanometer connected to the two extremities of the sheath. Arrangements of the connections are shown below, and the theory is as follows. Let i be the intensity of the stray current in the cable sheath at the instant of measurement.



On this current another current i_1 is superposed provided by a battery and measured by an ammeter. The current i_1 is as big as possible and the resistance of the rheostat is so big that the stray current is not shunted appreciably by it. The deflection d is read on the galvanometer. The terminals of the battery are quickly reversed and a new deflection d' is read.

If k denotes a numerical coefficient depending on the galvanometer, then :—

$$(i+i_1)X = kd$$
$$(i-i_1)X = kd'$$

from which is obtained :—

$$i = i_2 \frac{d+d'}{d-d'}$$

$$X = k \frac{d-d'}{2i_1}$$

B.—Measurements of the intensity of stray currents in the earth at the point where they enter or leave the cable sheath.

Experience has shown that a current of 0.75 mA per dm^2 of an iron pipe is dangerous from the point of view of corrosion of this pipe. The corresponding value for lead sheaths is in inverse proportion to the electrolytic equivalent of iron and lead. There are three methods of measuring this current.

1. The Haber method, which uses two non-polarisable electrodes of known area buried in the earth at a known distance one from the other and connected to a milliammeter. This method only gives the mean value of the density of the stray currents in the earth, and, further, the use of these plates alters the distribution of the stray currents in the earth.

2. A method at present being studied in Switzerland uses non-polarisable electrodes of small dimensions placed in a small trough which has been constructed in the earth near the cable.

This method allows measurements to be obtained for each position of the electrodes in the trough : (1) the current which circulates between them through the earth, and (2) the specific resistance of the part of the earth between these electrodes. From this a complete investigation can be made of the stray current paths.

3. Another method used in Germany makes use of a metallic electrode connected to the metallic sheath of the cable by a milliammeter. A cylinder is employed for the electrode having a known surface taken from the sheath identical to that of the cable and filled with tar. After waiting for a short time a reading of the milliammeter is taken in order to allow the accumulator, consisting of the electrode and the sheath, to discharge.

II.—Measurements of the Differences of Potential and Drop in Voltage.

In order to measure the difference of potential between a point of the rail and a point in the metallic sheath of the cable a high resistance milli-voltmeter is used and is connected to two contacts. In order to avoid error due to humidity, these contacts are preferably of the same metal as the objects with which they are in contact. The contacts should be as good as possible and have as small a resistance as possible. It is an advantage for the measuring instrument to have a zero at the centre of the scale ; the moving part should have a very small oscillation period.*

It is desirable in this measurement to take into account the E.M.F. of the local electrolytic couple consisting of the two contacts of different metals.

In order to measure the drop in voltage between two points on the rail similar arrangements are used ; no correction is required because the contacts are of similar metal. When the two points and the track between which the drop in voltage is to be measured are sufficientiy far apart, use is made of pilot wires, which make it necessary to introduce a correction factor to take into account the resistance of these wires.

---

*For measuring the difference of potential between cable and earth and between cable and rail the British Administration use the No. 26 voltmeter, which has three centre zero scales :—

0.25— 0 — 0.25 volt	—resistance	1000
2.50— 0 — 2.50 ,,	— ,,	10000
12.5 — 0 —12.5 ,,	— ,,	50000

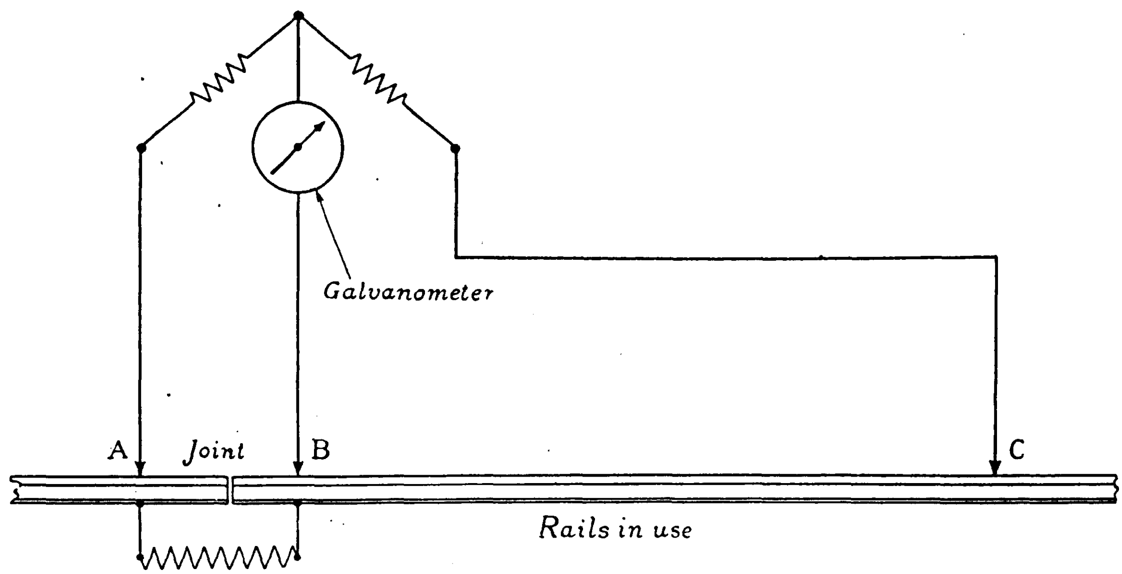
In addition, the British Administration uses for electrolysis tests a Zeiss galvanometer with the following characteristics :—

The resistance is from 5 to 7 ohms, a current of 3×10^{-7} A gives a deflection of a division read with a microscope having a magnification of 80. These galvanometers are usually employed to give a continuous record on a photographic film.

III.—Measurements of the Resistance of Rail Joints.

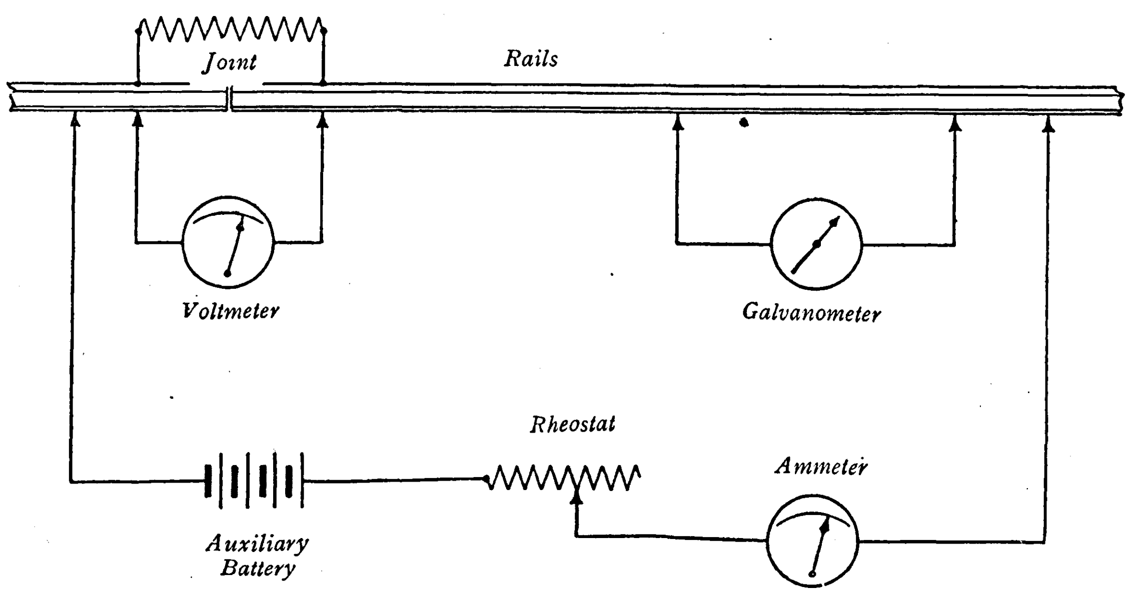
Two methods exist, using respectively, a Wheatstone Bridge, and a comparison method.

1. *Wheatstone Bridge method.*—The resistance *A—B* of the joint is compared by means of the Wheatstone Bridge with the resistance *B—C* of a certain length of rail. The difference of potential produced between the joints *A* and *C* by the traction current which flows in the rail serves as a battery; a galvanometer is used as a zero instrument.



2. *Comparison method.*—The arrangement of the method is as follows :—

The measurement is made when there is no traction current circulating in the rails. An auxiliary battery, a rheostat, a voltmeter and a galvanometer are used. The rheostat is regulated in such a way that the deflection of the galvanometer is constant and well determined. In this case the reading of the voltmeter, in which the scale is calibrated in metres of rails, indicates directly the resistance of the joint as an equivalent length of rail.



PART 3.

PROTECTION OF TELEPHONE CABLES AGAINST CHEMICAL CORROSION.

PROPOSED RECOMMENDATIONS CONCERNING THE MEASURES TO BE TAKEN FOR THE PROTECTION OF CABLES AGAINST CORROSION DUE TO CHEMICAL ACTION.

Definition.—A metal suffers from self-corrosion when its surface corrodes and is covered with a non-adherent product. When the latter has been removed we usually find that the metallic object has lost a part of its weight.

Principal Causes of Chemical Corrosion.

Lead can be attacked by bases as well as by acids. Nevertheless, it is one of the most resistant metals from a chemical point of view.

The lead should enter into direct contact, neither with pure cement, nor with water containing lime, nor with alkaline bodies. Cinders are equally dangerous. Chemical corrosion can also be produced in certain soils when there exist organic acids resulting from the decomposition of wood or other vegetable matters. Certain kinds of wood appear to attack the lead ; it has been noticed that oak in particular produces corrosion. Sewer water is harmful. Lead does not dissolve in hard water ; but soft water, in particular, marsh water containing organic acids, attacks it.

Lead and Alloys.

Telephone cables are contained in lead sheaths of three different types :—

(*a*) Commercially pure lead.
(*b*) An alloy containing 1 to 3 per cent. of tin.
(*c*) An alloy containing 1 per cent. of antimony.

It is not possible at the present time to state which of these three types of cable sheath is the most resistant to chemical corrosion, the data received on this subject being contradictory. However, it is certain that alloys present a superiority as regards mechanical resistance.

Rules Relating to the Installation of Cable Circuits.

(*a*) *Cables in the Earth.*—Unless they are covered with a protective coating or with chemically inert material, lead cables should not be placed directly in the soil.

(*b*) *Cables in Conduits.*—The choice between different kinds of conduits (iron tubes, concrete, sand, stone, wood, etc.) is made chiefly from technical and economic considerations ; cables in conduits are usually sufficiently well protected against chemical action from constituents of the soil.

A thick covering of vaseline applied to the surface of the cable sheath at the time of installation will assist in preventing chemical corrosion.

The conduits should be made as water-tight as possible without incurring unjustifiable expense.

If it is impossible to protect the conduit against infiltration of harmful liquids, it is necessary to place the cables in a sheath which has been covered with a protective layer impregnated with a preservative compound.

All necessary arrangements should be made to guarantee and maintain this layer perfectly water-tight.

A lengthy test has shown that with a well-constructed conduit of concrete, of which parts have been sufficiently dried to start with, and provided in the interior with a chemically inert coating, the damage is practically negligible from the point of view of operation and maintenance.

If wood conduits are used, these should be previously impregnated with a preservative substance which does not attack lead.

APPENDIX

TO THE RECOMMENDATIONS CONCERNING THE MEASURES TO BE TAKEN FOR THE PROTECTION OF CABLES AGAINST CORROSION DUE TO CHEMICAL ACTION.

Method for Determining whether Corrosion is Chemical or Electrolytic.

When placing cables in conduits or in pipes, any direct contact between the sheath and the soil should be avoided, but it is impossible to prevent infiltration of water : this water may come from the surface of the earth and penetrate into the conduits by the inspection holes or at the points where the conduits are connected together ; it can evidently contain, in variable quantities, the bodies existing in the neighbouring soil ; in any case of corrosion it is necessary to see whether the damage is due to chemical corrosion or to electrolytic action produced by stray currents.

It is certain that considerable assistance would be obtained if each time it were possible to say what was the cause of the damage from the exterior appearance of the corroded sheath. The result of the corrosion, either chemical or electrolytic, varies according to the nature of the material with which the sheath is in contact. When the lead remains exposed for some time to the action of the air or the soil, the products of the corrosion are usually a mixture of lead hydroxide and of lead carbonate similar to commercial white lead. When chemical salts such as chlorides, sulphates and nitrates are found in the neighbourhood of the sheath, the corresponding lead compound will result. These products may result from ordinary corrosion or electrolytic corrosion. The study of the constitution of the products of corrosion does not give by itself a sufficiently precise indication to decide on the cause of the corrosion. There is, however, a lead compound of which the presence in the products of corrosion enables it to be stated that the origin is electrolysis due to stray currents. This is lead di-oxide (PbO_2). The reddish-brown colour of this compound and its chemical actions are characteristic ; it is thus easy to determine its presence, even when it only exists in very small quantities. Nevertheless if it be true that the presence of lead di-oxide can be considered as sufficient index of the electrolysis by stray currents, its absence in certain cases does not show that corrosion is not of electrolytic origin.

Electrolysis by stray currents does not necessarily give rise to the formation of di-oxide ; and, once formed, this compound is easily decomposed by the contact of organic reducing compound ; the electric current which has formed this oxide can, when reversed, destroy it completely.

It is useful to analyse the residue taken from the corroded lead sheaths with a view to determining whether or not they contain peroxide. One of the reagents used for this purpose is formed of a diluted solution of 5 per cent. or more of tetramethyldiaminodiphenylmethane in a 50 per cent. solution of acetic acid.

The salts deposited in the attacked sheath are allowed to fall on a white plate containing a little of the reagents ; if clear blue layers are formed in the mass of the liquid, it is an indication that the salts contain lead di-oxide. In the case where only very small traces of lead di-oxide exist it is necessary to wait 10 to 20 seconds before the precipitate is formed.

It is to be noted that certain other oxidisable materials, including the copper compounds, produce the same reaction ; but in the case of corrosion to cable sheaths these compounds are not likely to be present.

In Germany, another method is used for finding the cause of corrosion. It consists of a comparison between the quantities of lead chloride existing in the products of corrosion and the proportion of the salt existing in the earth in the neighbourhood of the points attacked. If the products of corrosion contain a greater proportion of lead chlorides than the proportion contained in the earth, it is assumed that this corrosion should be attributed to the passage of an electric current.