INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE

(C. C. I. F.)

XVIIth PLENARY ASSEMBLY

GENEVA, 4-12 OCTOBER 1954

VOLUME II

PROTECTION

Part I — Recommendations of the C. C. I. F. concerning the protection of telephone lines and the constitution of telephone cable sheaths.

Part II — Various documents.

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PART ONE

RECOMMENDATIONS OF THE C.C.I.F. CONCERNING THE PROTECTION OF TELEPHONE LINES AND THE CONSTITUTION OF TELEPHONE CABLE SHEATHS

PART 1

RECOMMENDATIONS OF THE C.C.I.F. CONCERNING THE PROTECTION OF TELEPHONE LINES AND THE CONSTITUTION OF TELEPHONE CABLE SHEATHS

CHAPTER I

PROTECTION OF TELEPHONE LINES AGAINST INTERFERENCE

Recommendation No. 1 (Former Recommendation No. 1.—Yellow Book, Volume VI, Florence 1951, pages 148 and 149).

Connexion to earth of a long distance telephone line in cable

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that at the present state of the technique, cables are now made in such a manner that the capacitances of the various circuits with respect to the sheath are very exactly balanced, particularly as regards the interior layers;

that this balance of the capacitances is sufficient as regards circuits devoid of all earth connexions;

that on the other hand every connexion to earth, even with apparent balance, risks bringing into play the unbalances of inductance and resistance of each of the circuits on which such connexion to earth is effected;

that the dielectric strength between the conductors of a cable is appreciably smaller than that which exists between the conductors and the sheath, and that, consequently, the connexion to earth of some of the conductors would create a danger of breakdown of the dielectric separating the conductors when the cable is subjected to severe induction;

that when a loaded cable is subjected to a high induced e.m.f., the presence of connexions to earth would permit the passage of currents the value of which could, in some cases, exceed the limit for preserving the magnetic properties of the loading coils;

Unanimously recommends:

1. that it is desirable not to make any connexion to earth, at any point whatever, on a long distance line in cable;

2. that, as a general rule, it is desirable not to make any connexion to earth at any point whatever on an installation (telephonic or telegraphic) connected metallically to a long distance line in cable;

3. that, however, if for special reasons, an earth connexion must be made to an installation directly connected to the conductors of a cable, the following precautions should be taken:

a) The earth connexion must be made in such a manner as not to affect the balance of the circuits with respect to earth or with respect to the neighbouring circuits;

b) The breakdown voltage of all the other conductors of the cable with respect to the conductors of the circuit connected to earth, must be appreciably greater than the highest voltage which, owing to induction from neighbouring power lines, could exist between these conductors and those of the circuit connected to earth;

c) When the installation connected to the cable is a telegraphic installation, it is also necessary to conform to the recommendations of the International Telephone Consultative Committee on the subject of the conditions of coexistence of telephony and telegraphy. (C.C.I.F. Green Book, Volume III.)

* * *

Recommendation No. 2 (Former Recommendation No. 2 of the Yellow Book, Volume VI, Florence 1951, pages 148 to 150).

The linking-up of telephone circuits associated with high voltage installations to lines carried on the supports or in the cables of the public telephone network

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that distributors of electric power need to connect circuits of power line carrier systems, or ordinary telephone lines carried on the supports of high voltage lines or formed by telephone conductors contained in the same sheath as the power conductors of a high tension cable, to lines on the supports or in the cables of the public telephone network;

that if such connexions are to be permitted, it is necessary to take every precaution for the absolute avoidance of the dangerous consequences which would result from a fault on the coupling arrangements, and especially the development of an excessive voltage between the wires of the telephone line carried on the supports or in the cables of the public telephone network;

that experience is sufficient to indicate what precautions should be taken

Unanimously recommends

that, from the technical point of view, it would appear possible to allow these connexions provided that the installations fulfil the conditions given below. (These conditions are in two sections: one concerning the case of telephone lines erected on common supports with high voltage lines or formed by telephone conductors contained in the same sheath as the power conductors of a high tension cable; the other being the case of power line carrier current systems routed on high voltage lines.)

I.—*Conditions to be satisfied in the case of the linking-up of a telephone line* L^1 *placed on the supports or in the cables of the public telephone network with an ordinary telephone line* L^2 *erected on the supports of a high voltage line or formed by telephone conductors contained in the same sheath as the power conductors of a high tension cable.*

a) The coupling arrangements between the two lines L^1 and L^2 should conform to the best technical rules;

b) In the case of a contact between the conductors of the high voltage line and the wires of the Line L^2, the possibility of the propagation of a high voltage on the wires of the telephone line L^1 should be absolutely precluded by the coupling equipment as a whole (in general, this equipment will include an isolating transformer as well as arrestors and fuses of adequate capacity);

c) In no case, even when an accidental contact as indicated above occurs, should the peak voltage which could appear between the wires of the line L^1 exceed 250 volts;

d) All the earth connexions to be made on the coupling equipment should be in conformity with the usual regulations in force in each country, relating to earth connexions for the protection of electric installations;

e) The owners of private lines should be responsible for the correct functioning of the whole of the installation, and for its permanent maintenance in accordance with the conditions mentioned above.

II.—*Conditions to be satisfied in the case of the linking-up of a telephone line* L^1 *placed on the supports or in the cables of the public telephone network with a telephone circuit* L^2 *formed by a high frequency carrier current system propagated on a high voltage line.*

a) The coupling arrangement between L^1 and L^2 should conform to the best technical rules;

b) In all cases, even if a breakdown occurs in the coupling arrangement between the high voltage line and the carrier current telephone apparatus, the possibility of the propagation of a high voltage on the line L^1 must be absolutely precluded;

c) In no case, even in the hypothetical case of a breakdown foreseen above, should the peak voltage which can appear between the wires of the line L^1 exceed 250 volts.

Because of the high anode voltages generally used in the carrier current apparatus itself, the transformers inserted between this apparatus and the Line L^1 should be such that they can withstand, without breakdown, a voltage at least equal to three times the maximum anode voltage.

d) All the earth connexions made on the coupling equipment should conform with the usual regulations in force in each country, relating to earth connections for the protection of electric installations;

e) The owners of private lines should be responsible for the correct functioning of the whole of the installation, and for its permanent maintenance in accordance with the conditions mentioned above.

* * *

Recommendation No. 3 (Former Recommendation No. 3 — Yellow Book, Volume VI, Florence 1951, page 150).

Principle of Protection

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that the protective devices that can be used on circuits constitute weak points and can be the source of interruptions, and that it is important to reduce their number,

Unanimously recommends

that the principle of protection must first be a wise choice in the design of the lines and installations and of their conditions of construction so that the protective devices only perform a complementary role;

that any telephone line (trunk circuit or subscriber's line) entirely in cable and not having any direct connection to earth or not being connected to earthed installations, should not, as a general rule, be provided with protective devices.

* * *

Recommendation No. 4 (Modification of former Recommendation No. 4 of the Yellow Book, Volume VI, Florence 1951, pages 151 to 154).

Principal characteristics of protective devices

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that there is need to be able to set down precise and well defined data to facilitate comparison between various makes of the same protective device, Unanimously recommends

that to determine the principal characteristics of the protective devices, the recommendations contained in the Note which follows entitled "Principal characteristics of protective devices" should be followed.

Remark.—Based on the recommendations of this Note, Administrations and Private Telephone Companies associated with the C.C.I.F. have sent the information contained in the Documentary part of this work on pages 35 to 60, under the title "Table of protective arrangements used on telephone installations in various countries, to protect personnel and installations from possible danger due to power lines or atmospheric discharges."

NOTE 1

Principal characteristics of protective devices

This note enumerates the constructional and operating characteristics of protective devices which it appears necessary to consider when comparing different types of devices. Where it would be useful, the principle of a method of measurement which enables these characteristics to be determined has been indicated. Furthermore, for certain of these characteristics a precise definition has been proposed.

In this note, only the study of general types of protective devices is dealt with. In fact, the tests indicated must be effected on several samples of the same type and comparison made between the results. When it is a question of ensuring that the samples conform to a standard, simplified methods can be employed.

I. *Fuses*

a) *Description.*—Material and dimensions of fuse wire; shape and if necessary the type of housing for the wire, and when necessary, operating characteristics.

N.B.—Telephone fuses should, when operated, completely break the circuit in which they are inserted.

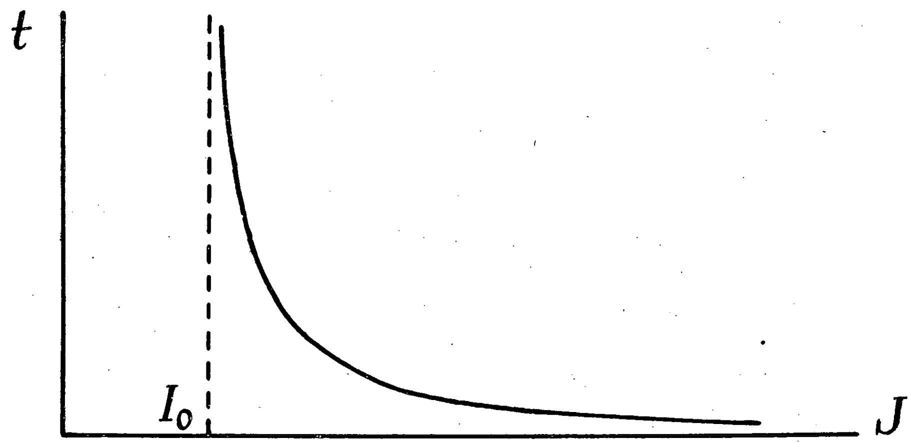
b) *External arrangements.*—Method of fixing and of connexion in circuit; stability of fixing arrangements in case of vibrations, size, appearance or marking.

N.B.—Whereas telephone fuses are designated by the value of their fusing current, as defined in *d)*, fuses for power installations are defined by the value of the current which may normally flow through them without causing a rupture. It is therefore important to take every precaution in the external appearance and marking of fuses to distinguish them from one another.

c) *Electrical Resistance.*

d) *Operating characteristics.*—It is possible to plot a characteristic curve showing the relation between the current J flowing in the fuse (d.c. or a.c.) and the time t necessary for the current to cause the fuse to blow. This curve is asymptotic both to the horizontal axis $t = 0$ and to an ordinate parallel to the time axis. Let I_0

be the abcissa at which this ordinate cuts the current axis; it is convenient to adopt I_0 as the value of the fusing current of the fuse (see figure below).



e) *Heat capacity.*—It is convenient to define the "heat capacity of a fuse" as the maximum value of the energy which can be absorbed almost instantaneously by the fuse without causing it to operate. In practice it is sufficient to determine this value to an approximation of $\pm 10\%$. For the determination, capacitors are discharged repeatedly through the fuse; if C represents the capacitance, V the voltage to which the capacitors are charged, then the energy absorbed by the fuse is equal to $\frac{1}{2} CV^2$, provided the losses in other parts of the discharge circuit are negligible. It is therefore advisable to use fairly heavy gauge wire and to avoid bad contacts.

It can be ensured that losses in the discharge circuit are negligible either by varying the capacitance and the voltage, or by making simultaneous tests on several fuses: it should have no effect on the result of the heat capacity per fuse whether these fuses are grouped in series or in parallel.

As, during a storm, several atmospheric discharges can follow each other almost immediately and that, consequently, heat can accumulate in the interior of the fuse, it is advisable to make a series of at least ten discharges at ten second intervals.

f) *Voltage below which the current may be broken.*—When the terminals of a fuse are connected to a large power direct current source (or network), of fairly high voltage, the fusing of the wire may be followed by the formation of an arc. To ensure that there is no sustained arc in the fuse-case under a given voltage, one may proceed in the following way: place, in series with the fuse, either a cut-out or another fuse which will operate only after a time which is greater than for the fuse under study. Thus the operation of this cut-out, or the blowing of the heavier fuse, will indicate the maintenance of an arc in the smaller fuse. Generally the performance of this test requires equipment which is not generally available in telephone laboratories.

II. *Heat Coils*

All the characteristics indicated in respect of fuses, except perhaps the heat capacity, are to be taken equally into consideration in the case of heat coils, or any other equipment performing the same function.

However, it is of great importance to determine fairly accurately the characteristic curve defined in *d)* and the voltage defined in *f)* above.

It is also desirable to note if the coil is made in such a manner as to be suitable for re-use either automatically, or after some attention. An attempt should be made to determine the number of times a coil can be used.

III. *Lightning Arrestors*

a) *Description.*—Nature, shape and arrangement of the electrodes and the method of connecting them to the exterior of the arrestor; nature and pressure of atmosphere surrounding the electrodes.

b) *External arrangements.*—Method of fixing and of connexion in circuit; size.

c) *Insulation.*

d) *Operating voltage.*—If a d.c. voltage is connected to the terminals of the lightning arrestor, and gradually increased, the value at which breakdown takes place can be determined; the indication of this breakdown is the passage of a current which may be observed by means of a measuring instrument.

The voltage thus defined is called "the breakdown voltage of the lightning arrestor." For certain types of lightning arrestors it is possible to determine a characteristic curve relating the value of the d.c. voltage at the terminals of the lightning arrestor to the value of the current which flows through it. This curve consists, in general, of several parts corresponding in particular to operation in glow conditions, and operation in arc conditions. It is useful to determine (perhaps to an accuracy of $\pm$ 20%) the values of current at which a change of operating conditions will take place.

The overheating of lightning arrestors must be avoided in determining the characteristics; thus, in the case of high values, the duration of the current should be reduced and successive tests well spaced.

Furthermore, it is of interest to observe how the voltage at the terminals of the lightning arrestor varies during a prolonged duration of current. It is also of interest to observe how the breakdown voltage varies after a more or less prolonged discharge.

A lightning arrestor can present unbalance in operation with respect to the direction of the voltage; in such a case, the characteristic which has just been defined is not the same if the direction of the applied voltage is reversed. It is desirable to examine this point.

In the case of rarefied gas type arrestors, it is important to compare the breakdown voltage when the arrestor is placed in light or in darkness.

It is likewise desirable to compare the breakdown voltage which has just been defined with that obtained when the arrestor is subjected to a sudden application of voltage.

Remark.—Using alternating current, a rapid determination of the breakdown voltage can be made and the balance of operation of the arrestor verified by employing an oscilloscope to observe the passage and waveform of the current in the lightning arrestor.

For the tests previously described it is necessary to use a source of voltage free from harmonics.

e) *Characteristics of robustness.*—It is necessary to determine the maximum time for which the arrestors will support, without deterioration (fusing of the electrodes, cracking of the container...), currents of constant value from 0.1 amps to several amperes.

If the test is made on several samples of a given type of arrestor with different currents, a curve can be established to show the time required for destruction as a function of the current. This curve, which characterizes the robustness, may be compared with the operating characteristic of the fuse, previously defined. This comparison allows a proper choice to be made of a suitable fuse for placing on the line side of a given type of arrestor.

In the case of an arrestor to be used with a fuse, it is well to insure that the arrestor will withstand a great number of operations at a current intensity and for a period sufficient to ensure that the fuse with which it is associated will blow.

These tests may be made as required with either direct current or alternating current.

f) *Regularity and stability of operation.*—The regularity of operation is defined as the constancy of the breakdown voltage of the arrestor in the course of successive operations. The stability of operation means that once a condition is established in an arrestor either as a glow discharge or an arc, there will not be a spontaneous change from one condition to the other.

g) *Uniformity of performance.*—Arrestors of the same type of construction and with the same nominal characteristics, used under the same conditions, must behave as far as possible in the same way. This uniformity should be found not only within a batch of arrestors but should also apply to arrestors made at different times.

* * *

Recommendation No. 5 (Former Recommendation No. 5 (modified) of the Yellow Book, Volume VI, Florence 1951, pages 181 to 184).

Psophometer for commercial telephone circuits

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that since the psophometer for commercial telephone circuits was specified (Directives concerning the protection of telecommunication lines against the adverse effects of electric power lines, Rome Edition 1937, revised at Oslo 1938), considerable progress has been made in the design of subscribers' telephone apparatus, particularly in the uniformity of performance with frequency;

that the "Joint Sub-committee on Development and Research of the Edison Electric Institute and the Bell Telephone System" (Engineering Report No. 45*) has carried out numerous tests to determine the curve to prescribe for the filter network of the psophometer in order to allow for the improved qualities of the subscribers' telephone apparatus;

that numerous tests and measurements made in the last few years have shown that the electro-acoustic qualities of subscribers' telephone apparatus used in Europe are very similar to those of the American apparatus and that consequently, there is no need to carry out in Europe tests similar to those carried out by the Joint Sub-committee,

Unanimously recommends

that the weighting attributed to the various frequencies in the filter network of the psophometer used for measurements at the terminals of a trunk circuit of the commercial telephone service must be those of the table which follows (see also the curve on page 16). Only the values corresponding to the underlined frequencies need be regarded as specifying the filter network of the psophometer and only these need be taken into consideration for verification tests of the apparatus. The other values, obtained by interpolation, are given to facilitate possible calculations.

By convention the numerical values are determined by attributing the value of 1000 to the weighting relative to 800 c/s. The logarithmic ratios of weightings are determined by attributing to this same frequency the value of 0 nepers or 0 decibels.

Permissible tolerances

The permissible tolerances are:—

50 to 300 c/s	± 2 decibels or ± 0.23 neper
300 to 800 c/s	± 1 decidels or ± 0.12 neper
at 800 c/s	± 0 decibels or ± 0 neper
800 to 3000 c/s	± 1 decibels or ± 0.12 neper
3000 to 3500 c/s	± 2 decibels or ± 0.23 neper
3500 to 5000 c/s	± 3 decibels or ± 0.35 neper

Note.—During the XVIth Plenary Assembly, Florence 1951, the C.C.I.F. considered that it was extremely desirable not to modify the table of weights and the specification of the psophometer, for as long a period as possible, for example ten years.

Measurements at the terminals of the subscriber's telephone receiver.—The psophometer which was standardized by the XVIth Plenary Assembly of the C.C.I.F. for the measurement of relatively stable circuit noises includes, for the use of this

* The French translation of this report was given in document "C.C.I.F. 1947/1948—1 C.R. — Document No. 2."

Table of weights of the psophometer for commercial telephone circuits

Frequencies c/s	Weights			
	Numerical Values	Square of the numerical values	Value in decibels	Value in nepers
16.66..	0.056	0.003136	− 85.0	− 9.79
50	0.71	0.5041	− 63.0	− 7.25
100	8.91	79.3881	− 41.0	− 4.72
150	35.5	1,260.25	− 29.0	− 3.34
200	89.1	7,938.81	− 21.0	− 2.42
250	178	31,684	− 15.0	− 1.73
300	295	87,025	− 10.6	− 1.22
350	376	141,376	− 8.5	− 0.98
400	484	234,256	− 6.3	− 0.73
450	582	338,724	− 4.7	− 0.54
500	661	436,921	− 3.6	− 0.41
550	733	537,289	− 2.7	− 0.31
600	794	630,436	− 2.0	− 0.23
650	851	724,201	− 1.4	− 0.16
700	902	813,604	− 0.9	− 0.10
750	955	912,025	− 0.4	− 0.046
800	1,000	1,000,000	0.0	0.000
850	1,035	1,071,225	+ 0.3	+ 0.034
900	1,072	1,149,184	+ 0.6	+ 0.069
950	1,109	1,229,881	+ 0.9	+ 0.103
1,000	1,122	1,258,884	+ 1.0	+ 0.115
1,050	1,109	1,229,881	+ 0.9	+ 0.103
1,100	1,072	1,149,184	+ 0.6	+ 0.069
1,150	1,035	1,071,225	+ 0.3	+ 0.034
1,200	1,000	1,000,000	0.0	0.000
1,250	977	954,529	− 0.20	− 0.023
1,300	955	912,025	− 0.40	− 0.046
1,350	928	861,184	− 0.65	− 0.075
1,400	905	819,025	− 0.87	− 0.100
1,450	881	776,161	− 1.10	− 0.126
1,500	861	741,321	− 1.30	− 0.150
1,550	842	708,964	− 1.49	− 0.172
1,600	824	678,976	− 1.68	− 0.193
1,650	807	651,249	− 1.86	− 0.214
1,700	791	625,681	− 2.04	− 0.234
1,750	775	600,625	− 2.22	− 0.255
1,800	760	577,600	− 2.39	− 0.275
1,850	745	555,025	− 2.56	− 0.295
1,900	732	535,824	− 2.71	− 0.311
1,950	720	518,400	− 2.86	− 0.329
2,000	708	501,264	− 3.00	− 0.345
2,050	698	487,204	− 3.12	− 0.359
2,100	689	474,721	− 3.24	− 0.373
2,150	679	461,041	− 3.36	− 0.386
2,200	670	448,900	− 3.48	− 0.400
2,250	661	436,921	− 3.60	− 0.414
2,300	652	425,104	− 3.72	− 0.428
2,350	643	413,449	− 3.84	− 0.442
2,400	634	401,956	− 3.96	− 0.456

Table of weights of the psophometer for commercial telephone circuits (continued)

Frequencies c/s	Weights			
	Numerical Values	Square of the numerical values	Value in decibels	Value in nepers
2,450	625	390,625	− 4.08	− 0.470
2,500	617	380,689	− 4.20	− 0.484
2,550	607	368,449	− 4.33	− 0.499
2,600	598	357,604	− 4.46	− 0.513
2,650	590	348,100	− 4.59	− 0.528
2,700	580	336,400	− 4.73	− 0.544
2,750	571	326,041	− 4.87	− 0.560
2,800	562	315,844	− 5.01	− 0.576
2,850	553	305,809	− 5.15	− 0.593
2,900	543	294,849	− 5.30	− 0.610
2,950	534	285,156	− 5.45	− 0.627
3,000	525	275,625	− 5.60	− 0.645
3,100	501	251,001	− 6.00	− 0.691
3,200	473	223,729	− 6.50	− 0.748
3,300	444	197,136	− 7.05	− 0.812
3,400	412	169,744	− 7.70	− 0.886
3,500	376	141,376	− 8.5	− 0.979
3,600	335	112,225	− 9.5	− 1.09
3,700	292	85,264	− 10.7	− 1.23
3,800	251	63,001	− 12.0	− 1.38
3,900	214	45,796	− 13.4	− 1.54
4,000	178	31,684	− 15.0	− 1.73
4,100	144.5	20,880.25	− 16.8	− 1.93
4,200	116.0	13,456	− 18.7	− 2.15
4,300	92.3	8,519.29	− 20.7	− 2.38
4,400	72.4	5,241.76	− 22.8	− 2.62
4,500	56.2	3,158.44	− 25.0	− 2.88
4,600	43.7	1,909.69	− 27.2	− 3.13
4,700	33.9	1,149.21	− 29.4	− 3.38
4,800	26.3	691.69	− 31.6	− 3.64
4,900	20.4	416.16	− 33.8	− 3.89
5,000	15.9	252.81	− 36.0	− 4.14
> 5,000	< 15.9	< 252.81	< − 36.0	< − 4.14

Note.—If for certain telephone transmission systems calculations are to be made from the psophometric weights, and if it appears necessary to have for frequencies greater than 5,000 c/s, values more precise than those of the preceding table, the following values can be adopted.

Frequencies c/s	Weights			
	Numerical Values	Square of the numerical values	Value in decibels	Value in nepers
5000 à 6000	< 15.9	< 252.81	< − 36.0	< − 4.14
> 6000	< 7.1	< 50.41	< − 43.0	< − 4.95

Frequency characteristic curve of the filter network of the psophometer used for measurements made at the terminals of a trunk circuit of the commercial telephone service psophometer at the end of an international telephone circuit (see above), a filter network which takes into account the characteristics of a fairly modern type of telephone set used in the U.S.A. and also the mean characteristics of the National Telephone network of the U.S.A. In American practice, when using this psophometer at the terminals of the telephone receiver, it is adapted for use by suppressing the part of the filter network which takes account of the characteristics of commercial telephone circuits. It does not appear essential to have recourse to such a modification in Europe, since the characteristics of telephone sets used in Europe are very varied. The choice of a single characteristic for the filter network, which would result from a modification of this kind, would probably also be as arbitrary as that which would be obtained by using, without modification, for measurements at the terminals of the telephone receiver, the psophometer with the filter network specified by the XVIth Plenary Assembly of the C.C.I.F. for the measurements at the terminals of a trunk circuit of the commercial telephone service (see above).

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

For fundamental investigations, Administrations may wish to employ special filter networks as appropriate to the investigation to be undertaken.

* * *

Recommendation No. 6 (New Recommendation).

Arrangements for protection against acoustic shocks

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that there already exist protective devices against acoustic shocks, based on the use of rectifier elements, which are effective and which take up little room and are not costly;

that the installation of these devices eases the fulfilment of the requirements in which exposures between telephone lines and electric lines are admissible and on the other hand they suppress the disagreeable effects of certain circuit noises (clicks).

Unanimously recommends

that it is desirable to provide acoustic shock absorbers for all operators' positions;

that it is also desirable to provide such devices for subscribers' instruments and for linesmen's portable sets when the conditions are such that acoustic shocks are to be feared (thundery regions, stations liable to be connected to lines exposed to induction, stations provided with certain types of lightning arrestors or other protective devices whose normal functioning may produce voltage peaks at the terminals of the telephone receiver), in particular when telephone head-sets are employed.

* * *

Recommendation No. 7 (This Recommendation completes, modifies and replaces former Recommendation No. 9 of the Yellow Book, Volume VI, page 190).

Modification to the Directives, relating to the determination of the conditions in which parallelisms are permissible between telecommunication lines and power lines

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that the international groups representing the producers and distributors of electrical energy have asked for an investigation into the possibility of increasing to a value greater than 430 volts, the limit of the longitudinal electromotive force induced along telecommunication lines when a short circuit to earth affects neighbouring power lines;

that the reasons advanced in favour of this proposition may be summarized as follows:—

a) the calculation of the longitudinal e.m.f. in the case of a short circuit, is taken on the hypothesis that this fault takes place under the most unfavourable conditions, especially in respect of the resistance of the fault to earth, the position of the fault, the configuration and the loading of the power network at the moment of the short circuit;

b) the limit of 430 volts sometimes makes it extremely difficult to place power lines and telecommunication lines in proximity or leads to the adoption of solutions which are not satisfactory from the economic point of view: the constant development of both systems tends to multiply such situations;

c) the probability of this incident is often rather small and its duration may be very brief;

that however this last argument only applies rigorously to certain high voltage lines which are very well constructed and which have modern equipment;

that, on the other hand, the higher permissible limit asked for would only be accepted when it is recognized as being possible to guarantee sufficient security to telecommunications personnel and installations, if necessary by the adoption of appropriate additional precautions;

that already in this spirit the XVIth Plenary Assembly has made Recommendation No. 9 (Yellow Book, Volume VI, Protection, page 190) approving the insertion in the Directives of the following paragraph which has been inserted in the last publication of that document (Rome Edition, Revised at Oslo and brought up to date at Geneva in 1952) (paragraph 237):

In certain cases it is impossible to ensure that the longitudinal induced e.m.f. will not exceed the limits defined in the forgoing paragraphs. Each special case should be investigated to determine a solution which, on the whole, is the most rational and economic. In making the investigation, details such as the mechanical construction of the power line, the probability of incidents on that line, the efficacy of the protective gear of that line against earth faults, any alterations that may possibly be made to the equipment and to the working of the telephone line, the efficacy of the telephone line protective apparatus which may possibly be improved, the importance of breakdowns on that line...;

that with a view to simplifying the practical application of these principles it has been proposed to define under the name of *high security electric lines* those lines which fulfil certain stated conditions and for which special rules less severe that the general rules may be applied systematically,

Unanimously recommends

1. that there is at present no case for increasing *in a general way* to a value greater than 430 volts, the limit for the longitudinal electromotive force induced along telecommunication lines when a short circuit to earth affects neighbouring power lines;

2. that there is need to confirm the principle previously admitted and recalled above concerning the possibility of allowing, when this appears appropriate, greater values for this induced e.m.f. under certain conditions;

3. that in particular those conditions relative to the quality of the construction of the electric line, the small probability of incidents on that line, the reduction of their duration due to the efficacy of the protective arrangements on that line against earth faults, may be considered as satisfied in the case of lines defined in the appended note as *high security electric lines*, and that in consequence, after a possible modification to the telecommunication line, exposures between a telecommunication line and a high security electric line may be considered as permissible if the telecommunication line is an open-wire line, when the induced electromotive force in the case of a short circuit does not exceed 650 volts (provisional value) and that even when this limit is exceeded, the possibility of allowing an exposure is not excluded, but it is then necessary to make the special study recommended in paragraph 237 of the Directivies;

4. that in regard to telecommunication cables where all circuits are terminated on transformers it is necessary to retain in all cases the existing recommendations set out in paragraph 236 of the Directives, that is to limit the value of the permissible longitudinal electromotive force to 60 per cent of the lowest of the values of the dielectric strength test voltage of the conductors of the cable with respect to the sheath and that of the equipment (loading coils, balancing condensers, terminating boxes and transformers, etc.) with respect to the sheath or the earth.

Note.—The International Union of Railways (U.I.C.) has observed that the recommendation raising the limit of the induced longitudinal e.m.f. in cases of electric lines of high security to 650 volts which is now applicable to telecommunication lines shall not, in general, apply to signalling circuits of railway systems.

NOTE

High security power lines

High security power lines are those which meet the following conditions:

A. *Overhead lines.*

1. *Mechanical and electrical characteristics.*

1.1. The dimensions and other characteristics of conductors, supports (poles, pylons), insulators, attachments of conductors to the insulators and other structural elements of the line must be chosen so that the whole assembly offers a breakdown resistance and a stability which are sufficient in the most unfavourable circumstances to which the line may be exposed, in particular on account of overloads due to wind, icing and temperature effects.

1.2. The distances between the conductors and the earthed metal work must be such that, in the most unfavourable circumstances, no flash over between conductors and the earthed metal work can occur either in normal conditions of use or when internal over-voltages occur on the network.

1.3 The insulators must be suitable for the highest mechanical loading and for the highest electrical voltages which they have to withstand in use under all the climatic conditions most likely to occur *.

2. *Geographical situation.*

The lines should not cross regions which are particularly unfavourable from the stand-point of fault (for example stormy regions, regions where the lines are exposed to pollution or condensation...), unless special arrangements are adopted to reduce this probability.

Thus in the case of lines crossing thunder-storm regions and carried on metallic supports these arrangements can consist in providing the line with earth wires and in making the earth connexions of the pylons such that their resistance is sufficiently small.

In the case of lines crossing regions where there is a possibility of pollution, these arrangements can consist in the use of a construction, or of an appropriate equipment of insulators of proved effectiveness.

3. *Elimination of earth faults.*

3.1. The lines must be equipped with protective arrangements and switch-gear such that the total duration of the passage of an earth fault current should be as short as possible, never exceeding 0.5 second and being in the majority of cases less than 0.2 second.

3.2. Guarantees must be provided that when the line is in operation these protective arrangements are always maintained in good operating condition.

* The application of existing national rules is often sufficient to ensure that the conditions for the mechanical and electrical characteristics of the lines are satisfied.

B. *Underground cables.*

Underground high-voltage transmission cables (for example greater than 60,000 volts), constructed according to the best technical rules and corresponding to the conditions given in 3.1 and 3.2 regarding the elimination of earth faults are considered as being high security lines.

* * *

Recommendation No. 8 (New Recommendation).

Modification to the Directives relative to the definitions of the equivalent disturbing voltage and the equivalent disturbing current of a power line or installation

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that the Directives concerning the protection of telecommunication lines against the adverse effects of electric power lines (Rome Edition, 1937, revised in Oslo 1938 and brought up to date in Geneva in 1952) define the equivalent disturbing voltage and the equivalent disturbing current of a power line or installation by means of expressions containing a factor k_f and a factor h_f which are functions of frequency and which take into account the method of coupling between the lines concerned as well as, possibly, the service conditions of the power line;

that it has been suggested that the possibility of simplifying these definitions be examined by making these factors k_f and h_f equal to unity, whereby it would be possible to assign to the power line or installation the same value either for the equivalent disturbing voltage or the equivalent disturbing current independent of the nature of the exposed telephone line thus facilitating the conditions for determining these values;

that the study of the question has made it apparent that in certain circumstances such a simplification would lead to wrong conclusions as to the amount of trouble on the telephone line while in other cases, probably the more frequent, it would not lead to any difficulty,

Unanimously recommends

that there is no need provisionally to simplify the expressions which serve to define the equivalent disturbing voltage nor the equivalent disturbing current of a power line or installation (Directives Chapter IV, paragraph 14, sub-paragraphs 86 and 89) by omitting from these expressions factors k_f and h_f, which are functions of frequency and which take into account the method of coupling of the lines concerned and sometimes the service conditions of the power line;

that it is advisable, however, to mention at the end of these definitions the following point:

> Calculations concerning interference due to induction, based upon the measured values of equivalent disturbing voltage or current are never

rigorous, in particular because they do not take account of the fact that the mutual induction between two lines is for the same separation a function of frequency and because, in the case of telephone lines in cables, the values attributed to the coefficients k_f and h_f are based on rather rough approximations. Thus, for practical applications the following convention can be admitted:

Whenever it is established, either through a comparison of several measurements made with and without multiplying arrangements, or through the similarity of the test conditions to those of previous tests, that the orders of magnitude of the results are little affected by the factors k_f and h_f, then the whole of the measurements can be made by attributing a value of unity to these factors, the values thus determined being employed for the calculations of interference.

* * *

Recommendation No. 9 (New Recommendation).

Modifications to the Directives, concerning the calculation of the mutual inductance between two lines with earth return

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that up to the present, in the absence of a practical method of taking into account the finite length of the lines when calculating the mutual inductance between lines with earth return, the Directives have recommended the use of a method neglecting this feature;

that in the course of the last few years, different studies have been made towards a solution of this problem and establishing formulae and numerical tables required for such calculations;

that it is clear, however, on the one hand, that the application of these methods would introduce a certain amount of complication and would prolong greatly the time taken for the calculation of mutual inductances; on the other hand, the increase in precision of the calculated results so obtained as compared with the results given by the previous method, would very frequently be of no great importance for practical purposes, the field of application being therefore more in the nature of research;

Unanimously recommends

that there is no need to recommend generally the use of a method more precise than that which is at present described in the Directives for the practical calculation of mutual inductance between two lines with earth return;

that, however, in a forthcoming edition of the Directives it would be desirable to publish in the Documentary Part, some indications which will permit, if desired, the determinations of the corrections to be applied to these calculations in order to take account of the finite length of the lines;

considering, on the other hand,

that in the case of oblique exposure and crossings the calculation of the mutual inductance may be effected more easily than by the method indicated in the Directives due to the use of formulae and tables of numerical values;

Unanimously recommends

that there is need to recommend for such calculation the method described in the following note:

NOTE

Calculation of the mutual inductance for a section of oblique exposure or for a crossing

1. The developments which follow are made on the assumption that in the exposure considered the magnetic field of the inducing line is cylindrical.

Even when this is not the case the correction which would allow the fact to be taken into account that the inducing line is of finite length is in practice negligible except in special cases where great precision is necessary.

2. At the distance d from the inducing line the mutual inductance per unit length between this line and a line parallel to it is given by a certain function $m\ (\alpha d)$,

α representing $\sqrt{4 \pi \mu_o \sigma \omega}$

σ conductivity of the earth

ω the angular frequency of the inducing current ($\omega = 2\pi f$)

μ_o the permeability (non rationalised) of the earth, which is moreover, assumed to be equal to that of air.

If all these quantities are expressed in GGS units, then d must be expressed in centimetres and μ_o should be taken as unity.

If the quantities are expressed in M.K.S.A. units, then d must be expressed in metres, δ in mhos per metre, ω in radians per second, and

$$4 \pi \mu_o = 4 \pi \cdot 10^{-7} \text{ henrys per metre}$$

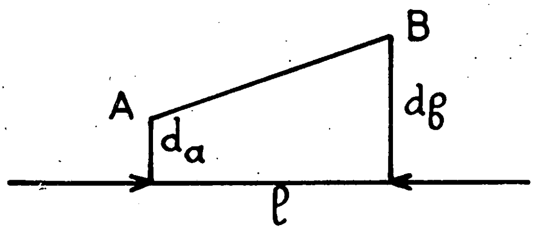
This function $m\ (\alpha d)$, (which is represented by the function designated M in the table on page 92 of the Directives brought up to date at Geneva in 1952), is a complex function and may be written separating the real and imaginary parts as:

$$m\ (\alpha d) = m_q - j m_p$$

3. If an oblique exposure is considered formed by a portion AB, the projection of which on the inducing line is of length l and if d_a and d_b are respectively the distances of A and B from the inducing line, it is possible to express the total mutual inductance between the portion AB and the inducing line by the expression:

$$M_{AB} = l \frac{\int_{\alpha d_a}^{\alpha d_b} m\ (\alpha d) \cdot d\alpha d}{\alpha d_b - \alpha d_a}$$

The factor l in this formula represents then the average value of the mutual inductance per unit length m in the interval of variation of αd.



4. The rigorous calculation of the real and the imaginary components of M may be easily made with the aid of a table of the functions:

$$S_q(\alpha d) = \int_0^{\alpha d} m_q(\alpha y) \cdot d\alpha y$$

$$S_p(\alpha d) = \int_0^{\alpha d} m_p(\alpha y) \cdot d\alpha y$$

We then have:

$$M_{q\,AB} = \frac{l\left[S_q(\alpha d_b) - S_q(\alpha d_a)\right]}{\alpha d_b - \alpha d_a}$$

$$M_{p\,AB} = \frac{l\left[S_p(\alpha d_b) - S_p(\alpha d_a)\right]}{\alpha d_b - \alpha d_a}$$

$$M_{AB} = M_{q\,AB} - j\,M_{p\,AB}$$

5. It is frequently possible, without serious error, to calculate the modulus of the total mutual inductance between two lines, consisting of a number of sections, which are placed at different distances from the inducing line by simply adding the moduli of the mutual inductance of the individual sections. To this degree of approximation, it is justifiable to assume the following expression for the modulus of M for the portion AB:

$$|M|_{AB} = \frac{l\int_{\alpha d_a}^{\alpha d_b} m_n(\alpha y) \cdot d\alpha y}{\alpha d_b - \alpha d_a}$$

where

$$m_n(\alpha y) = |m(\alpha y)|$$

6. In cases where the ratio d_b to d_a does not exceed 2, it is admissible to replace the factor l in the preceding formula (mean value of m_n in the interval $\alpha\, d_a$, $\alpha\, d_b$) by the value of m_n corresponding to the arithmetic mean value of the distance viz.:

$$\frac{d_a + d_b}{2}$$

Apart from this case, it is very much easier to obtain the value of $|M|_{AB}$ by one of the following methods:

7. If a table is available of the function

$$S(\alpha d) = \int_0^{\alpha d} m_n \ (\alpha y) \ d\alpha y$$

it suffices to apply the formula

$$|M|_{AB} = l \frac{S(\alpha d_b) - S(\alpha d_a)}{\alpha d_b - \alpha d_a}$$

The following table gives the values of S (αd) expressed in microhenries per kilometre.

TABLE OF S (αd) IN MICROHENRIES PER KM.

α d	S (α d)	α d	S (α d)	α d	S (α d)	α d	S (α d)
0.001	1.7	0.01	13	0.1	80	1	363
0.0012	2.0	0.012	15	0.12	92	1.2	397
0.0015	2.4	0.015	18	0.15	108	1.5	440
0.002	3.1	0.02	22	0.2	133	2	494
0.0025	3.8	0.025	27	0.25	155	2.5	538
0.003	4.5	0.03	31	0.3	176	3	561
0.0035	5.1	0.035	35	0.35	195	3.5	582
0.004	5.7	0.04	39	0.4	213	4	598
0.0045	6.3	0.045	43	0.45	230	4.5	611
0.005	6.9	0.05	47	0.5	245	5	620
0.006	8.1	0.06	54	0.6	274	6	634
0.007	9.2	0.07	61	0.7	299	7	644
0.008	10.4	0.08	67	0.8	322	8	651
0.009	11.5	0.09	74	0.9	343	9	656
0.010	12.6	0.10	80	1.0	363	10	660

Moreover, without serious error, $\alpha\, d_b$ and $\alpha\, d_a$ may be replaced both in the denominator and in the numerator by neighbouring values whereby $|M|_{AB}$ may in general be calculated without any interpolation in the table.

8. In the absence of this table $|M|_{AB}$ may still be calculated by the following formula, which also gives a result that is very nearly the same as would be obtained by applying the rigorous formula:

$$|M|_{AB} = l \frac{100}{d_b - d_a} \left[G(d_b) - G(d_a) \right]$$

where

$$G(d) = d \, l \, n \left(1 + \frac{K^2}{d^2} \right) + 2 \, K \; arc \; tg \, \frac{d}{K}$$

This formula gives the value of $|M|_{AB}$, expressed in microhenries, if :—

l is the length of the approachment in kilometres, d_a and d_b are the values in metres of the distances of the points A and B from the inducing line,

$$K = \sqrt{\frac{6 \times 10^5}{\sigma f}},$$

σ = conductivity of the earth in MKSA units (mhos per metre),

f = frequency in cycles per second.

9. In the case of a crossing one can calculate by the methods described the mutual inductances for sections on both sides of the line being crossed by assigning to the value of d relative to the common end of these sections either the value of the vertical distance between the lines at the point of crossing or more simply and with little error, a value of zero.

* * *

Recommendation No. 10 (New Recommendation).

Modifications to the Directives, relative to the evaluation of the risks of danger due to electric induction

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that to determine the conditions in which exposures of open-wire telephone lines to A.C. power lines or A.C. traction lines are admissible, the Directives evaluate the risks of danger due to electric induction from consideration of the importance of acoustic shock which may arise as a result of transients on the power line;

that the importance of acoustic shock does not seem to depend directly on the amount of energy brought into play in the telephone circuit during the discharge of the line through the telephone receiver and lightning arrestors, as has been assumed in the Directives; that, moreover, the risk of acoustic shock is much reduced when as in most countries, protective devices against acoustic shock are used and which have been shown to be generally sufficiently effective;

that at present the situation to be considered as most dangerous is that of a person (for example, a linesman or a worker within a telephone exchange taking measurements on or splicing conductors) who, being more or less in direct contact with earth, is also in contact with a wire of a line subject to sufficiently great effects of electric induction;

Unanimously recommends:

1. that there is need to remove from the text of the Directives the advice concerning risk of acoustic shock as well as the rules to follow to ensure that this risk is eliminated (in particular, sub-paragraphs 60 and 61 of Chapter IV, Section A sub-paragraphs 169 to 180 of Chapter VII, Section 1, paragraph 23, also sub-paragraphs 277 to 280 of Chapter IX, Section 1, paragraph 35a, also sub-paragraphs 385 to 411 of Chapter XI, Section B, paragraph 46 should be deleted).

2. that the following text should be included in Chapter IV, Section A:

"There is a risk of danger when, under normal operating conditions of an A.C. traction line with rail return, or as a result of an accidental earth fault on one phase of an overhead single-phase or three-phase line with the neutral point normally insulated, the discharge current to earth of the two wires in parallel of a telephone circuit through an impedance of negligible value exceeds 15 milliamperes (R.M.S.)"

3. that the present text of paragraph 23 should be replaced by the following:

"*Paragraph 23—Danger.*

a) As indicated in sub-paragraph 22 *a)*, the following recommendations apply only in cases of lines with the neutral point insulated.

b) The discharge current to earth of the two wires of a telephone circuit, uniformly exposed to induction, is given in milliamperes by the following formula:

$$i = 2\,\pi f \cdot \frac{36}{Z' + 4}\; l\; \frac{E}{4}\; \frac{bc}{a^2 + b^2 + c^2}\; p\,q\,r \cdot 10^{-6}$$

where

f = frequency in cycles per second,

E = supply voltage of the power system in volts,

a = separation of the two lines in metres,

b = average height of the conductors of the electric line above ground in metres,

c = average height of the conductors of the telephone line above ground in metres,

l = length of section of approachment in kilometres,

Z' = number of permanently earthed wires in the group of wires to which the telephone circuit in question belongs,

p, q, r = screening factors due the nearness of earthed bodies.

One puts... (present text of sub-paragraphs 174 to 177).

In the case of a telephone circuit having several exposures, the values of the currents arising from each section are calculated by means of the preceding formula and their sum is taken.

c) A telephone circuit should be considered as being exposed to danger if the total current thus calculated exceeds 15 milliamperes (R.M.S. value). "

4. that the text of the above mentioned sub-paragraphs 277 and 278 should be replaced by the following:

"The discharge current to earth of the two wires of a telephone circuit is calculated as in the cases of a balanced A.C. overhead power line. Accordingly, the measures of paragraph 23 are applicable."

5. that in the forthcoming edition of the Directives, Section B of Chapter XI shall be modified in accordance with the preceding texts.

CHAPTER II

PROTECTION OF TELEPHONE CABLES AGAINST CORROSION

Recommendation No. 11 (Former Recommendation No. 13, Yellow Book, Volume VI, Florence 1951, page 187).

Recommendations for the protection of underground cables against the action of stray currents arising from electric traction systems

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that the location of faults on underground cables and the repair of these faults can entail great expense;

that the interruptions to service likely to be caused by the occurrence of these faults must be avoided with the greatest care;

that even after a repair has been made as expertly as possible, the quality of the cable may be lessened and its normal life reduced;

that since the approval of the "Recommendations concerning the protection of cables against electrolytic corrosion" (Rome Edition 1937, revised at Oslo 1938), studies have made it possible to carry certain important modifications and additions into the text:

Unanimously recommends

that, at the time of laying the cables, Administrations and Private Telephone Companies comply with the "Recommendations for the protection of underground cables against the action of stray currents arising from electric traction installations Florence 1951".

Considering on the other hand

that the adoption of precautions suitable for each particular case in the maintenance of telephone cables, often presupposes a sufficient knowledge of the working conditions of neighbouring traction lines;

Unanimously recommends

that it is desirable that each Administration or private telephone company when applying to its underground network measures likely to improve their security with respect to risks of damage due to electrolysis, should collaborate both with the Administrations of electric traction networks and with other interested Administrations (water, gas, electricity distributors) for the common determination in each particular case, of the best conditions for construction, maintenance and supervision of the networks and to take in concert all useful action.

* * *

Recommendation No. 12 (New Recommendation).

Modifications to the "Recommendations for the protection of underground cables against the action of stray currents arising from electric traction systems" (Florence, 1951)

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that since the establishment of the "Recommendations for the protection of underground cables against the action of stray currents arising from electric traction systems" (Florence, 1951) as a result of newly acquired information various corrections must be made to the present text,

Unanimously recommends

that the following modifications should be made to the present text of the "Recommendations for the protection of underground cables against the action of stray currents arising from electric traction systems" (Florence, 1951):

1. Paragraph 1.6.2, sub-paragraph 15, page 5: replace the present text of this sub-paragraph by the following text:

"This method of protection does not impose so severe a limitation of the stray currents (coming from traction networks) as the preceding one; however, the use of this method does not exonerate Organisations operating the traction networks from taking account of the recommendations of Chapter II, relating to the construction and maintenance of those networks; the application of this method of protection is on the other hand facilitated by the putting into practice, on a more or less large scale, of the provisions relative to underground pipes and cables which involve the application of the first method."

2. Paragraph 2.1., sub-paragraph 24, page 7: replace the sentence under *b)* by the following:

"*b)* to facilitate the return of the current through the rails by ensuring low electrical resistance of the track and by judiciously arranging the return system, so as to regularize in particular the potential distribution along the network of rails as far as possible."

3. Paragraph 2.2.3., sub-paragraph 28, page 7: replace the beginning of this sub-paragraph by the following text:

"In particular when these rails are laid on wooden sleepers, the sleepers must be in sound condition and, if they are impregnated, they should not be treated with a product which gives them an appreciable electric conductivity. The ballast must be clean..."

4. Paragraph 2.2.3., sub-paragraph 29, page 7: replace the present text of this sub-paragraph by the following text:

"If the rails are laid on reinforced concrete sleepers, it is necessary to insert an insulating plate between the rail and the sleeper; attention must be paid to ensure that the ballast is sufficiently thick and well maintained, in order to ensure the best possible insulation of the track with respect to earth.

"In addition the bolts fixing the rails to the reinforced concrete sleepers must be very carefully insulated.

"The provisions of sub-paragraph 28 above concerning the ballast must also be applied to tracks laid on reinforced concrete sleepers.

"It is preferable not to use metallic sleepers on D.C. electrified lines. In the case where the use of these sleepers cannot be avoided, attention must be given to ensure that the ballast is sufficiently thick and well maintained because this affords the best possible insulation of the track from earth, this condition being all the more important since a track on metallic sleepers does not normally lend itself to the use of insulating plates between rail and sleeper."

5. Paragraph 2.2.4., sub-paragraph 35, page 8: delete this sub-paragraph.

6. Paragraph 2.5., sub-paragraph 63, page 11:

To take account of certain forms of application of electrical protection, replace in the last phrase "this arrangement is incompatible..." by "this arrangement may be incompatible..."

7. Paragraph 5.3.2.1., sub-paragraph 158, page 22: add the following note at the end of the present sub-paragraph:

"*Note.*—Attention is drawn to the fact that certain metal rectifiers which are subjected to a current which is nearly always in the same direction, can age and thus become conducting to currents in the opposite direction; when an accidental reversal of the current takes place, they do not function and no longer play the part expected of them. This fact must be taken into account when it is proposed to study a system of electrical protection using rectifiers."

* * *

Recommendation No. 13 (Former Recommendation No. 14, Yellow Book, Volume VI, Florence 1951, page 198).

Recommendations concerning the protection of underground cables against corrosion

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that draft recommendations concerning measures to be taken to protect cables against corrosion due to chemical action, were made in 1927, but studies since that date have made it possible to introduce certain modifications and some important additions;

that moreover it has been found that the majority of the measures against chemical corrosion are of more general application and concern practically all types of corrosion;

Unanimously recommends

that at the time of laying cables, Administrations and Private Telephone Companies should comply with the "Recommendations concerning the protection of underground cables against corrosion, Paris 1949".

* * *

Recommendation No 14 (Former Recommendation No. 14 completed. — Yellow Book, Volume VI, Florence 1951, pages 198 and 199).

Modifications to the "Recommendations concerning the protection of underground cables against corrosion" (Paris 1949)

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that since compiling the "Recommendations concerning the protection of underground cables against corrosion (Paris 1949)" information newly received has shown that the calcium-lead alloy mentioned in Chapter IV of the said Recommendations has not given the results hoped for;

that on the other hand, some corrections must be made to the present text,

Unanimously recommends

that the following amendments should be made to the "Recommendations concerning the protection of underground cables against corrosion (Paris 1949)".

1. *Sub-paragraph 1*, 2nd line: omit the words "*Chemical or*".

Note.—When preparing a new edition of the Recommendations the terminology and definitions of paragraph 1.1.2. should be carefully revised. The terminology finally adopted must be subsequently employed throughout.

2. *Sub-paragraph 7*, pages 5 and 6 omit the words "and chlorides".

3. *Sub-paragraph 36*: add the following to this para:—

"This reagent is prepared by dissolving 3 grams of tetramethyl-diamine-diphenylmethane in a solution of 50 grams of glacial acetic acid and 50 grams of water.

"It is used in the following way: the reagent is put in contact with the lead corrosion products, the operator placing himself in such a position as to be able to observe any possible colouration of the reagent against a white background; when that is not possible the reagent is placed directly upon the cable sheath. In the presence of lead peroxide an intense blue colour is obtained. If the lead peroxide only exists in the form of traces, a certain time is required for the colouration to take place; in this case before forming a conclusion as to the presence or absence of lead peroxide a period of waiting should be allowed of about 5 minutes. The reaction is very sensitive.

"However, attention should be drawn to the fact that this method is not absolutely certain and that, when no colouration is produced, it cannot be concluded that there is no electrolytic corrosion."

4. *Sub-paragraph 38*: modify as follows the two sub-paras. at the left of the table:

1st Sub-paragraph, 2nd phrase: instead of "In severe cases..." to read "In certain cases..."

2nd Sub-paragraph read "The product of corrosion is often in the form of..."

5. *Sub-paragraph 128*: delete—Lead alloy H containing 0.04% calcium.

6. *Sub-paragraph 130*, lines 7 and 8, delete the phrase:

"The position of the alloy H in this classification has not been determined in a series of comparative tests."

7. *Sub- paragraph 134*, line 6, delete the words "and H".

8. *Sub-paragraph 142*, line 1, after the paragraph title insert the following text:

"Due to the development of suitable methods of manufacture, it is possible to obtain a product having the following properties: polythene..."

9. *Sub-paragraph 143*: replace the present text by the following:

"4.3.3. Jointing of polythene.—The technique of jointing polythene sheathed cables to one another or to lead sheathed cables has not yet reached finality."

10. *Sub-paragraph 256*: delete paragraph 2 concerning the application of a lubricant consisting of an emulsion of sodium silicate and petroleum jelly.

11. *Sub-paragraph 273*, line 5 to read:

"either to the rails (soutirage, forced drainage), or to a sacrificial electrode earth."

12. *Sub-paragraph 274*, last line, in brackets in place of "elastic" to read "classic".

CHAPTER III

CONSTITUTION OF TELEPHONE CABLE SHEATHS

Recommendation No. 15 (Former Recommendation No. 16, Yellow Book, Volume VI, Florence 1951, page 200).

Elasticity of cable sheaths

THE INTERNATIONAL TELEPHONE CONSULTATIVE COMMITTEE,

Considering

that the ductility of cable sheaths depends, as does in general their various mechanical and chemical properties, primarily on their chemical composition and structure;

that at present a large range of alloys having various ductile qualities is employed;

that, depending on the method and conditions of installing cables it may be advantageous to look for the predominance of certain properties;

that some measure of supervisions during manufacture and acceptance tests after manufacture would appear to ensure some guarantee that the sheath would have the qualities proper to the alloy as given in the Specifications,

Unanimously recommends

that it would be desirable to indicate in cable specifications the constitution of the alloy or alloys which must be used, the choice being determined in such a manner that the cable would possess the properties most suitable for the use to which it is to be put;

that it be ensured that the method of manufacture guarantees an appropriate and regular treatment of the metal and avoids the formation of longitudinal sections insufficiently strong from the mechanical point of view:

that upon acceptance, it be confirmed on the one hand that for the whole length of the sheath, its constitution is made up to the clauses of the specification and that all the parts of the sheath are of a homogeneous structure and composition.

PART 2

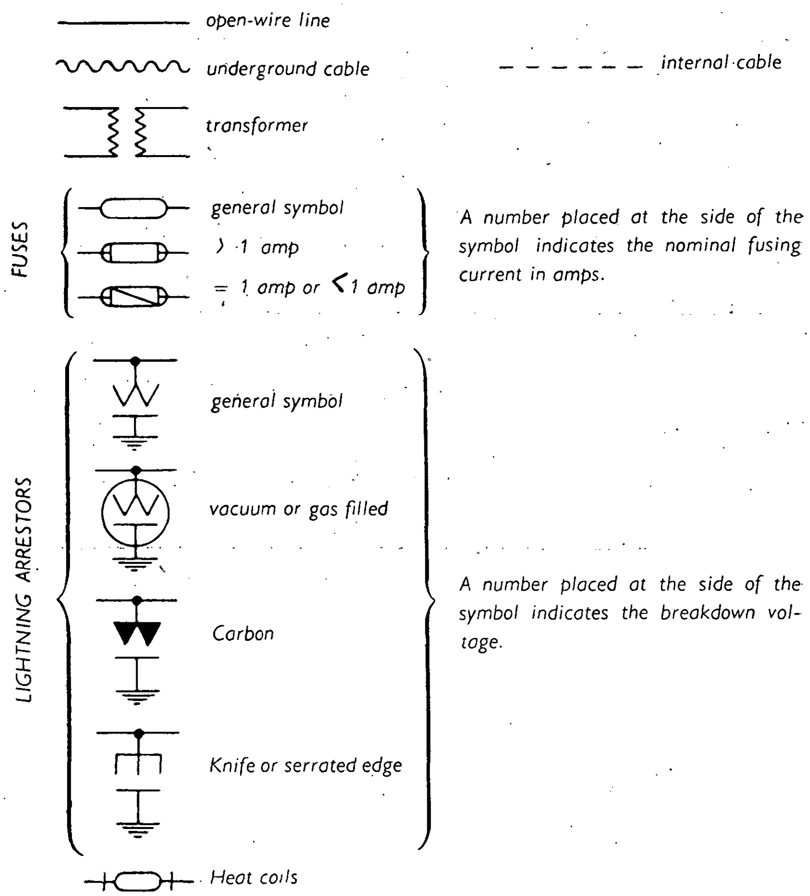
VARIOUS DOCUMENTS

CHAPTER I

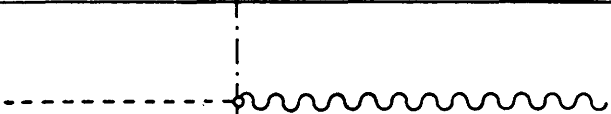
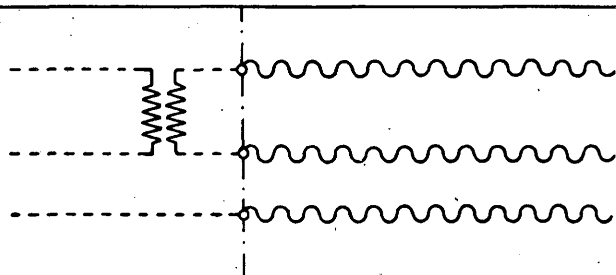
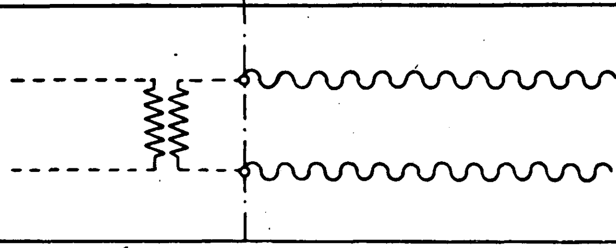
PROTECTIVE ARRANGEMENTS

A. Table of protective arrangements used on telephone installations in various countries to protect personnel and installations against possible danger due to power lines or atmospheric discharges.

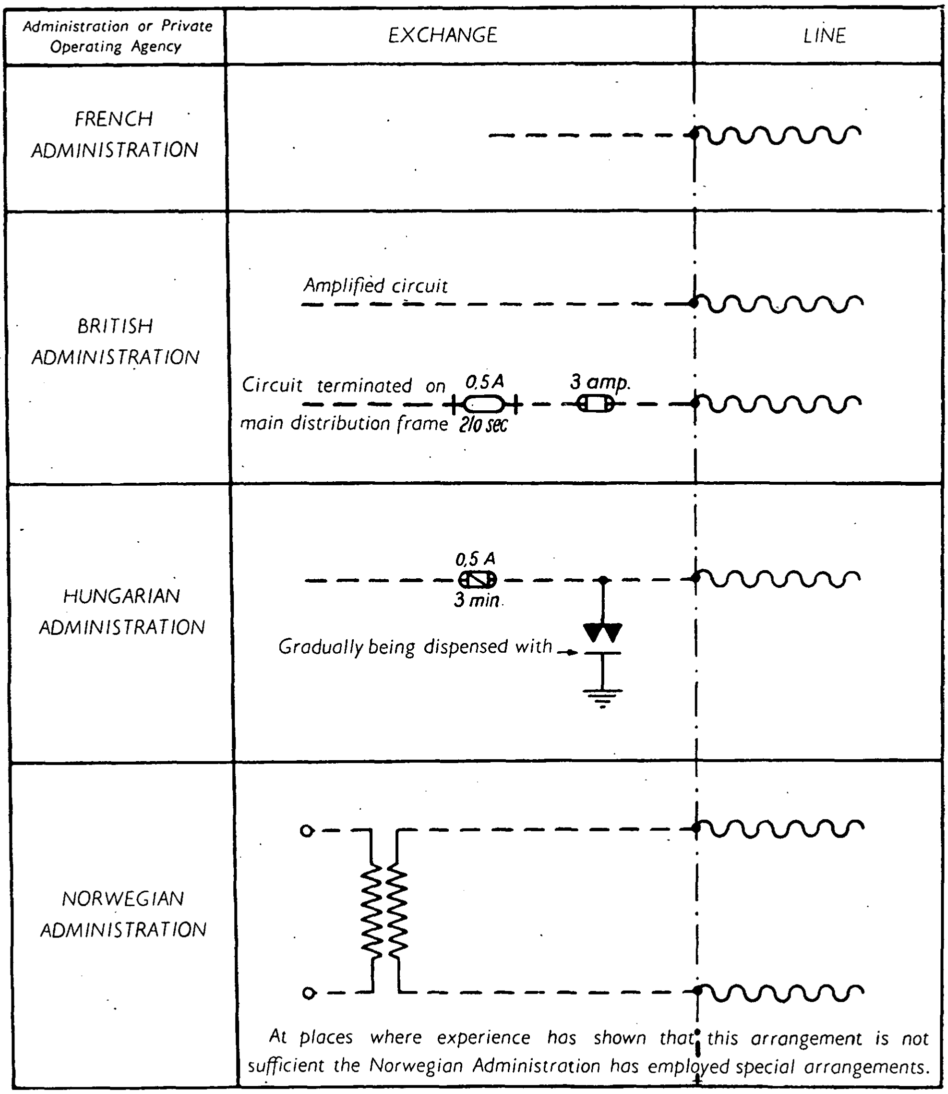
LEGEND



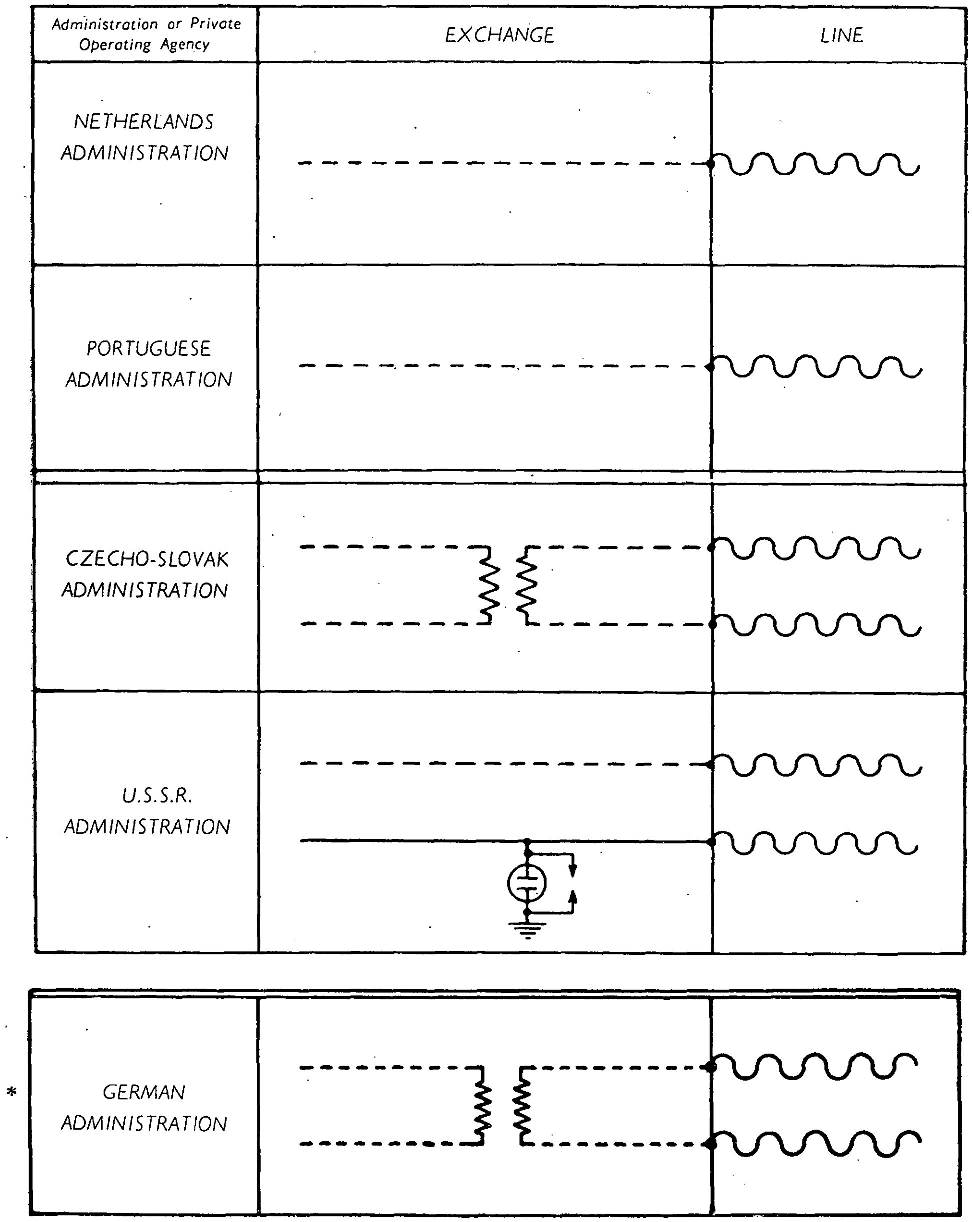
1. TRUNK CIRCUIT IN UNDERGROUND CABLE

Administration or Private Operating Agency	EXCHANGE	LINE
AMERICAN TELEPHONE AND TELEGRAPH COMPANY	 *NOTE. Protection by carbon lightning arrestors is applied at the exchange in the case where the cable in consequence of its location is likely to be subjected to induced e.m.fs. from power lines, magnetic storms or lightning. This practice is very general, particularly with long underground cables crossing open country, with the exception that carbon lightning arrestors are not connected to coaxial pairs.*	*Cables, loading, coils, transformers tested at 1800 V R. M. S. 50 c/s with respect to earth.*
AUSTRIAN ADMINISTRATION		
BELGIAN ADMINISTRATION		

1. (contd.) TRUNK CIRCUIT IN UNDERGROUND CABLE

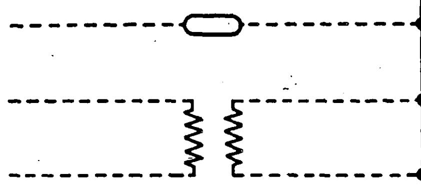
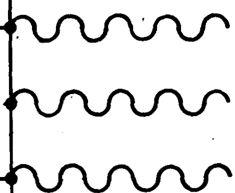


1. (contd.) TRUNK CIRCUIT IN UNDERGROUND CABLE

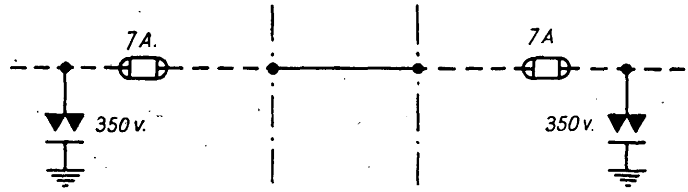
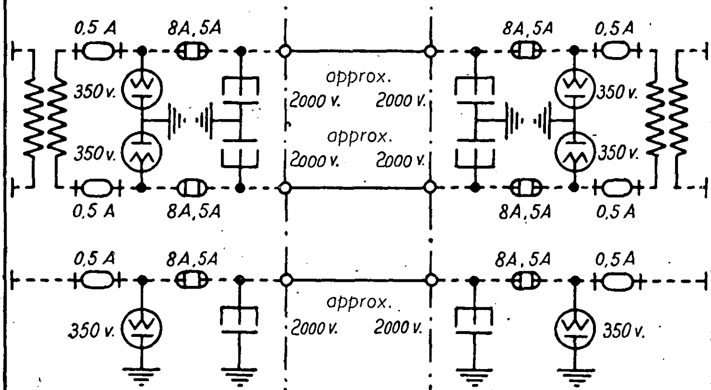
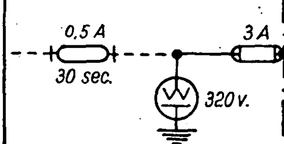


* Federal German Republic.

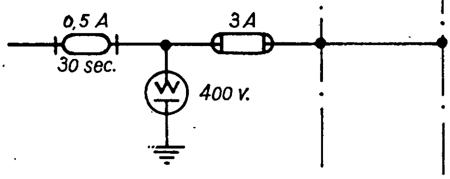
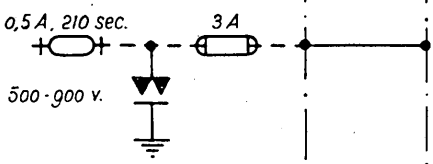
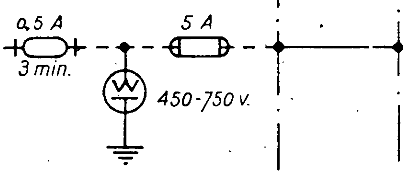
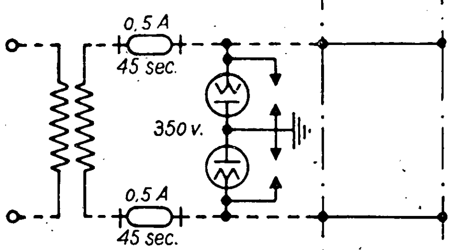
1. *(contd. and concluded) TRUNK CIRCUIT IN UNDERGROUND CABLE*

Administration or Private Operating Agency	EXCHANGE	LINE
ADMINISTRATION AND PRIVATE COMPANIES OF DENMARK		

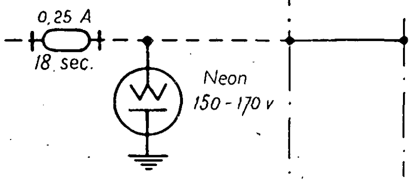
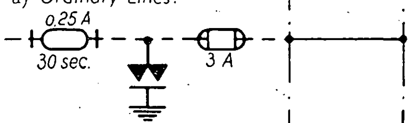
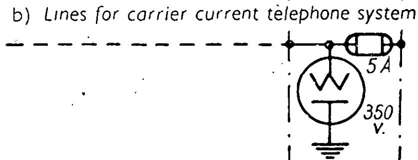
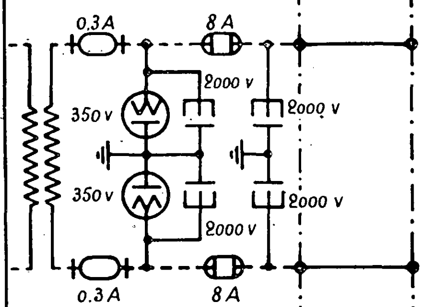
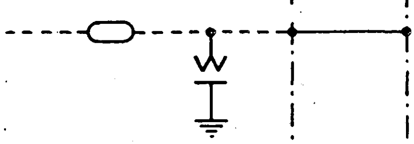
2. *TRUNK CIRCUIT ON OPEN-WIRE LINE*

<table>
<tr><th>Administration or Private Operating Agency</th><th>EXCHANGE A</th><th>LINE</th><th>EXCHANGE B</th></tr>
<tr><td rowspan="2">AMERICAN TELEPHONE AND TELEGRAPH Co.</td><td colspan="3">
</td></tr>
<tr><td colspan="3">NOTE. The use of this protective arrangement assumes that the open-wire circuit enters directly into the Exchange without the insertion of a lead-in cable, a situation which rarely arises in the Bell System. The situation generally met in the Bell System is shown in "3, Trunk Circuit not entirely in cable".</td></tr>
<tr><td rowspan="2">AUSTRIAN ADMINISTRATION</td><td>EXCHANGE A</td><td>LINE</td><td>EXCHANGE B</td></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>BELGIAN ADMINISTRATION</td><td colspan="2">
</td><td>As exchange A</td></tr>
</table>

2. *(contd.)* TRUNK CIRCUIT ON OPEN-WIRE LINE

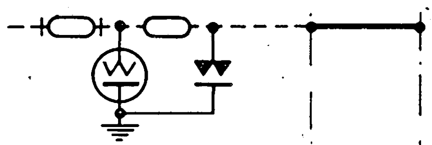
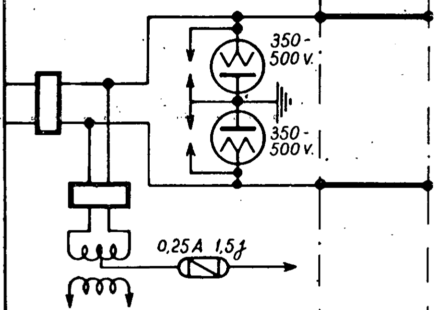
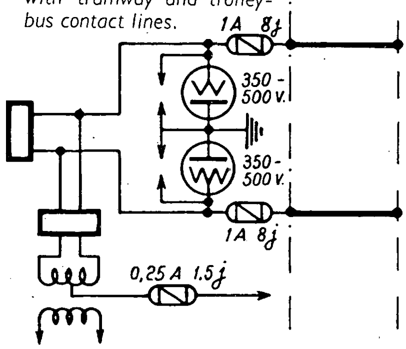
Administration or Private Operating Agency	EXCHANGE A	LINE	EXCHANGE B
FRENCH ADMINISTRATION			As Exchange A
BRITISH ADMINISTRATION			As Exchange A
HUNGARIAN ADMINISTRATION			As Exchange A
NORWEGIAN ADMINISTRATION	 At places where experience has shown that this arrangement is not sufficient, the Norwegian Administration has employed special arrangements.		As Exchange A

2. (contd.) TRUNK CIRCUIT ON OPEN-WIRE LINE

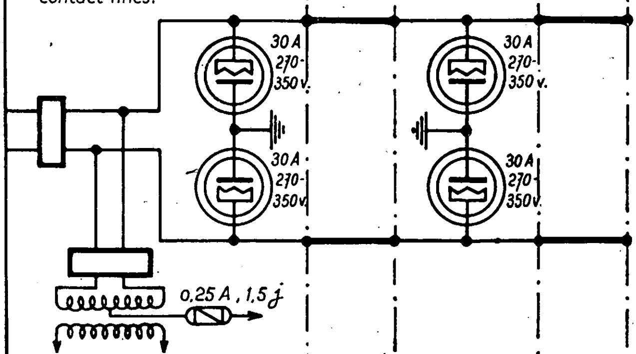
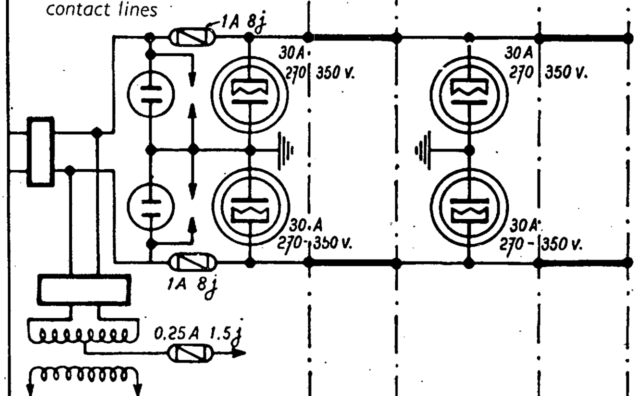
Administration or Private Operating Agency	EXCHANGE A	LINE	EXCHANGE B
NETHERLANDS ADMINISTRATION	 NOTE. The Netherlands Administration is gradually replacing open-wire overhead lines by underground cables.		As Exchange A
PORTUGUESE ADMINISTRATION	a) Ordinary Lines. 		As Exchange A.
	b) Lines for carrier current telephone system. 		As Exchange A
* GERMAN ADMINISTRATION			As Exchange A
DANISH ADMINISTRATION AND PRIVATE COMPANIES			As Exchange A

* Federal German Republic.

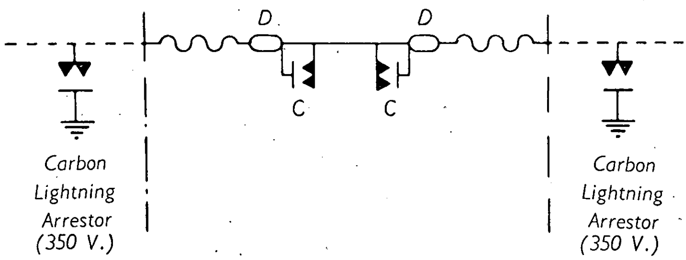
2. (contd.) TRUNK CIRCUIT ON OPEN-WIRE LINE

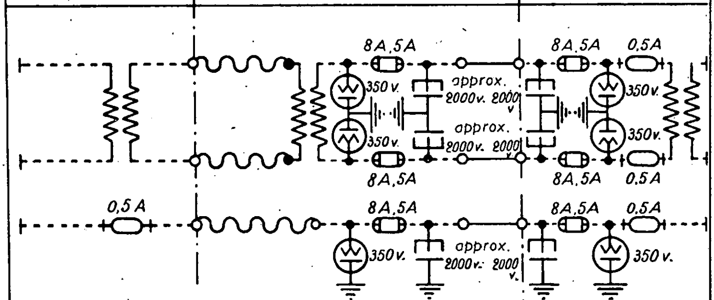
Administration or Private Operating Agency	EXCHANGE A	LINE	EXCHANGE B
CZECHO-SLOVAK ADMINISTRATION			As Exchange A
U.S.S.R. ADMINISTRATION	A. Ordinary cases a) In the absence of crossings with tramways or trolley-bus contact lines.  		As Exchange A
	b) When there are crossings with tramway and trolley-bus contact lines.  		As Exchange A

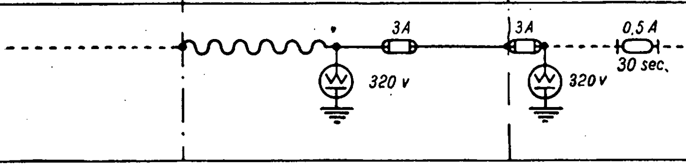
2. (contd.) TRUNK CIRCUIT ON OPEN-WIRE LINE

Administration or Private Operating Agency	EXCHANGE A	LINE	CONTROL POINT OF LINE	LINE	EXCHANGE B
U.S.S.R. ADMINISTRATION	*B. Overhead Trunk circuit near to a high voltage power line (when the e.m.f. induced by the short circuit current of the power line is greater than 750 V).* a) *In the absence of crossings with tramway or trolley-bus contact lines.*  b) *When there are crossings with tramway or trolley-bus contact lines*  				

3. *TRUNK CIRCUIT NOT ENTIRELY IN CABLE*

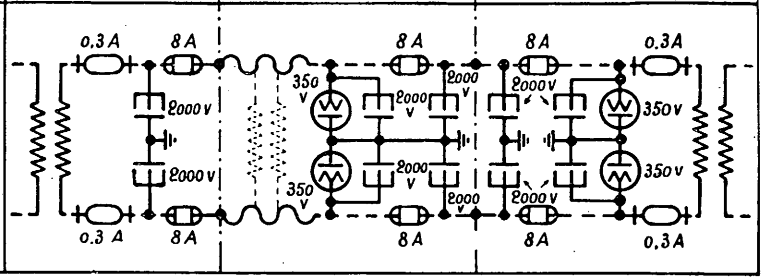
<table>
<tr><th>Administration or Private Operating Agency</th><th>EXCHANGE A</th><th>LINE</th><th>EXCHANGE B</th></tr>
<tr><td>AMERICAN TELEPHONE AND TELEGRAPH Co.</td><td colspan="3">


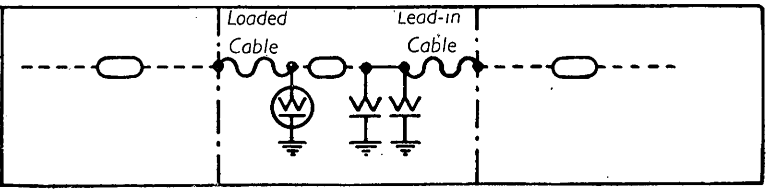
C. Carbon lightning arrestors (750 V) connected between the overhead wires and the cable sheath.
D. A length 2 to 10 ft long (1 ft = 30.5 cm) of cable with small diameter conductors (not greater than 0.51 mm (24 A.B. and S.), to serve as fuses. This cable with small diameter conductors can be omitted
1. if the diameter of the main cable conductors is not greater than 0.51 mm,
2. if the cable only contains trunk circuits and if the resistance of each of the conductors exceeds 100 ohms between the exchange and the first point where the telephone circuit can come into contact with power lines of a voltage greater than 250 V with respect to earth.
</td></tr>
<tr><td rowspan="2">AUSTRIAN ADMINISTRATION</td><td>EXCHANGE A</td><td>LINE</td><td>EXCHANGE B</td></tr>
<tr><td colspan="3">


</td></tr>
<tr><td>BELGIAN ADMINISTRATION</td><td colspan="3">


</td></tr>
</table>

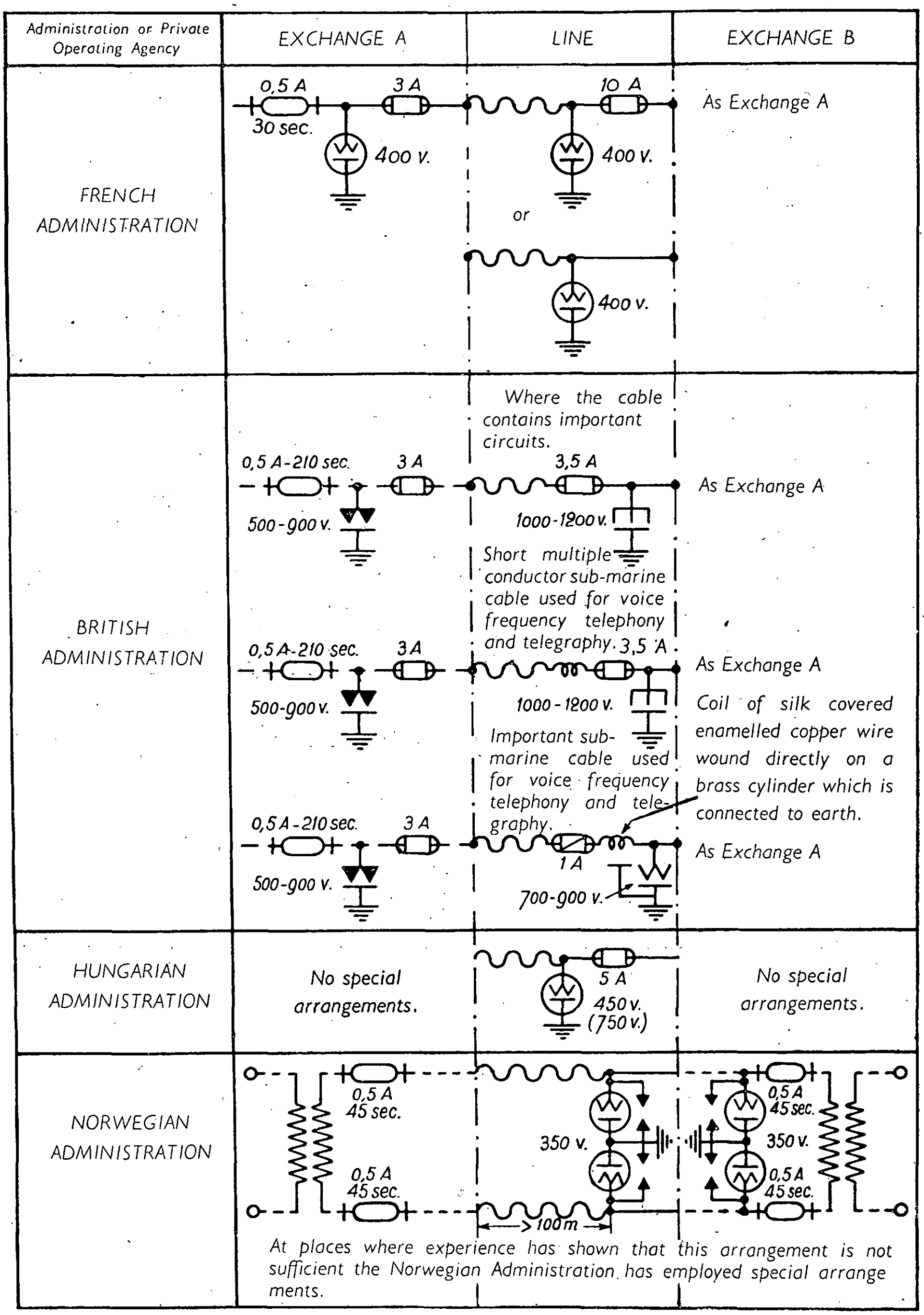
3. *(contd.)* TRUNK CIRCUIT NOT ENTIRELY IN CABLE

	EXCHANGE A	LINE	EXCHANGE B
* GERMAN ADMINISTRATION			

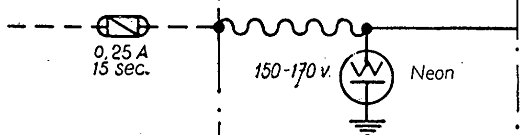
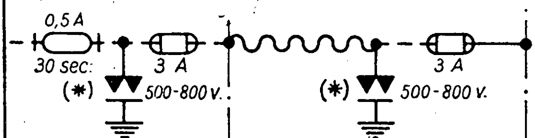
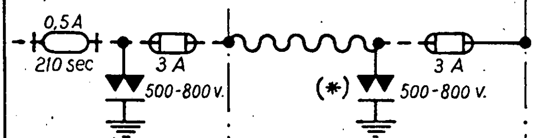
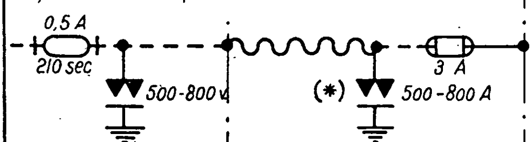
DANISH ADMINISTRATION AND PRIVATE COMPANIES			

* Federal German Republic.

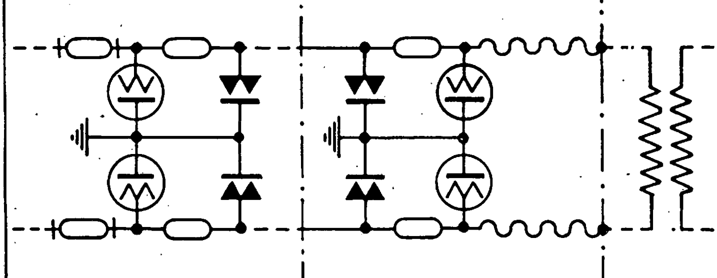
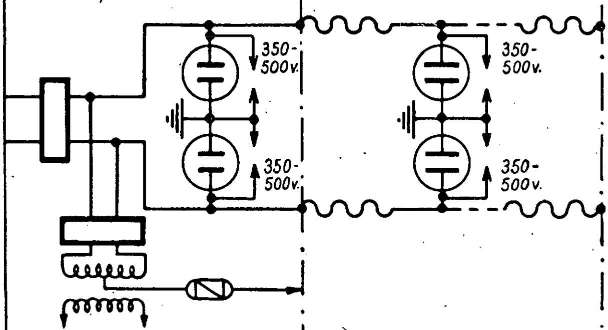
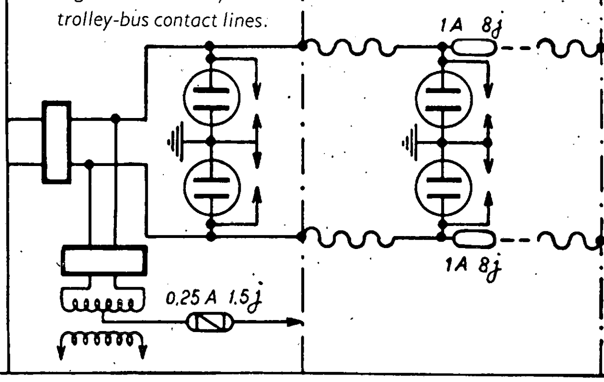
3. (contd.) TRUNK CIRCUIT NOT ENTIRELY IN CABLE



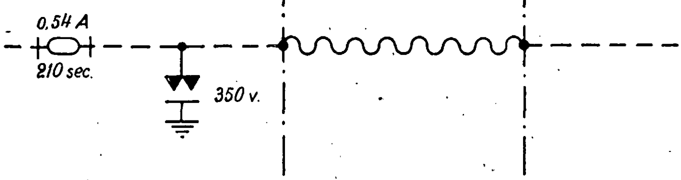
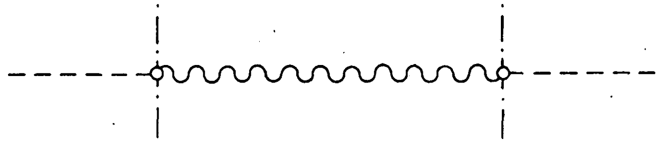
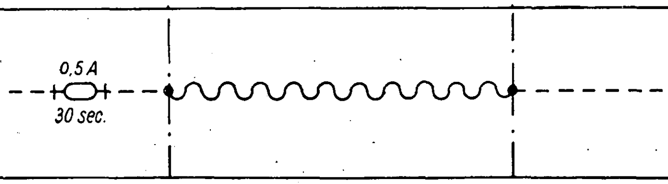
3. (contd.) TRUNK CIRCUIT NOT ENTIRELY IN CABLE

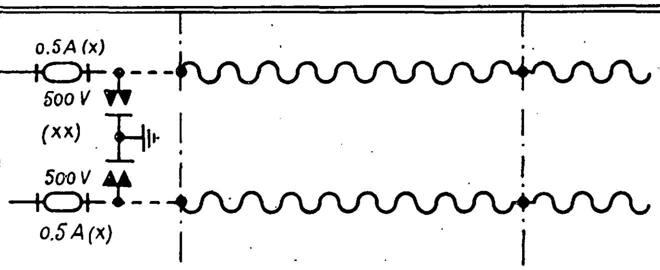
Administration or Private Operating Agency	EXCHANGE A	LINE	EXCHANGE B
NETHERLANDS ADMINISTRATION	 *NOTE.—The Netherlands Administration is gradually replacing open-wire overhead lines by underground cables.*		*No special arrangements*
PORTUGUESE ADMINISTRATION	a) *Local battery telephone installations.* 		*As Exchange A (under a) or under c)).*
	b) *Semi-automatic telephone installations.* 		*As Exchange A (under a) or under c)).*
	c) *Automatic telephone installations.*  (✱) *NOTE.—In the case of telephone lines exposed to dangerous high voltages, the Portuguese Administration replaces the carbon lightning arrestors by 350 V vacuum arrestors.*		*As Exchange A (under a) or under c)).*

3. *(contd.)* TRUNK CIRCUIT NOT ENTIRELY IN CABLE

<table>
<tr><th>Administration or Private Operating Agency</th><th>EXCHANGE A</th><th>LINE</th><th>EXCHANGE B</th></tr>
<tr><td>CZECHO-SLOVAK ADMINISTRATION</td><td colspan="3"></td></tr>
<tr><td rowspan="2">U.S.S.R. ADMINISTRATION</td><td colspan="2">a) In the absence of crossings with tramways and trolley-bus contact lines.

</td><td>As Exchange A</td></tr>
<tr><td colspan="2">b) When there are crossings with tramway and trolley-bus contact lines.

</td><td>As Exchange A</td></tr>
</table>

4. *SUBSCRIBER'S LINES IN UNDERGROUND CABLE*

Administration or Private Operating Agency	EXCHANGE	LINE	SUBSCRIBER'S PREMISES
AMERICAN TELEPHONE AND TELEGRAPH Co	 NOTE. If all the subscribers' lines to an exchange are in underground cable or only contain short overhead sections unlikely to come into contact with power lines of a voltage higher than 250 V, the carbon block lightning arrestors can be omitted.		
	EXCHANGE	LINE	SUBSCRIBER'S PREMISES
AUSTRIAN ADMINISTRATION			
BELGIAN ADMINISTRATION			

GERMAN ADMINISTRATION *	 (x) 0.3 A in the case of central battery. (xx) No protective arrangements if all the subscriber's lines are entirely in cable.

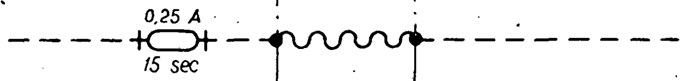
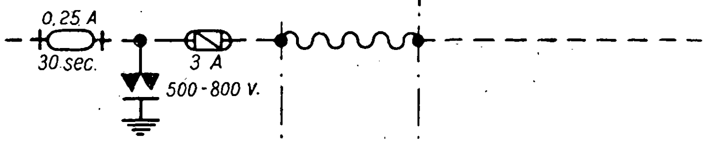
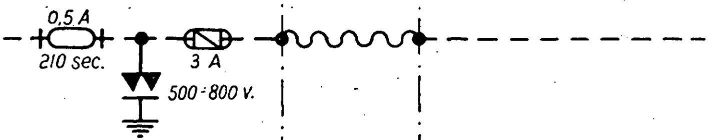
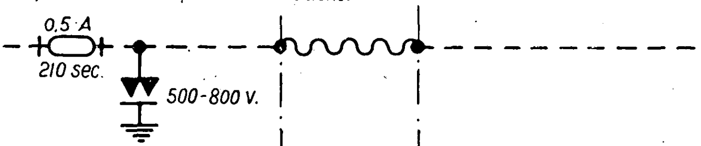
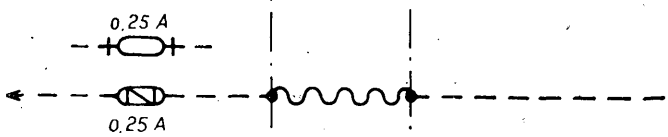
* Federal German Republic.

4. (contd.) SUBSCRIBER'S LINES IN UNDERGROUND CABLE

Administration or Private Operating Agency	EXCHANGE	LINE	SUBSCRIBER'S PREMISES
FRENCH ADMINISTRATION	0,5 A 30 sec		3A or
BRITISH ADMINISTRATION	Exchange with less than 12 circuits and without connexion to earth. Exchange with connexion to earth and (or) with more than 12 circuits. 0,5 A 210 sec 3 A		Without connexion to earth. With connexion to earth 5 A.
HUNGARIAN ADMINISTRATION	0,5 A 3 min.		No information.
NORWEGIAN ADMINISTRATION	0,5 A 45 sec.		No information.
	At places where experience has shown that this arrangement is not sufficient, the Norwegian Administration has employed special arrangements.		

DANISH ADMINISTRATION AND PRIVATE Cos.			

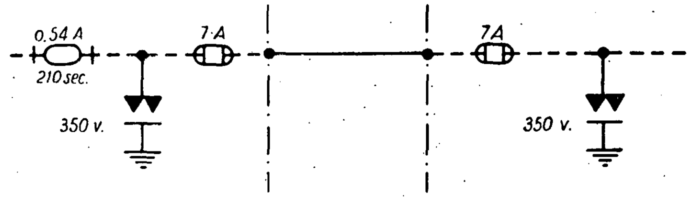
4. *(contd.) SUBSCRIBER'S LINES IN UNDERGROUND CABLE*

Administration or Private Operating Agency	EXCHANGE	LINE	SUBSCRIBER'S PREMISES
NETHERLANDS ADMINISTRATION	 NOTE. The Netherlands Administration doubts the necessity for placing protective equipment on a subscriber's line entirely in underground cable.		
PORTUGUESE ADMINISTRATION	a) Local battery telephone installations. 		
	b) Semi-automatic telephone installations. 		
	c) Automatic telephone installations. 		
CZECHO-SLOVAK ADMINISTRATION			
U.S.S.R. ADMINISTRATION			

5. SUBSCRIBER'S CIRCUIT ON OPEN-WIRE LINES

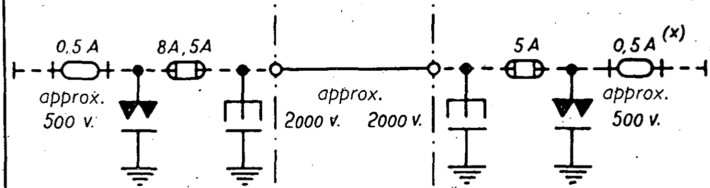
Administration or Private Operating Agency	EXCHANGE	LINE	SUBSCRIBER'S PREMISES

AMERICAN TELEPHONE AND TELEGRAPH Co.



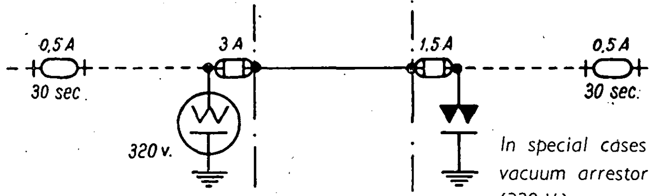
NOTE. The use of this protective arrangement assumes that the open-wire circuit enters the exchange without the insertion of a lead-in cable, a situation which rarely arises in the Bell System.
The situation most generally met is shown in "6. Subscriber's circuit not entirely in cable".

AUSTRIAN ADMINISTRATION



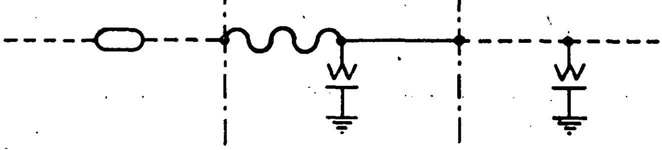
(x) No heat coils if the subscriber has no connexion to earth.

BELGIAN ADMINISTRATION

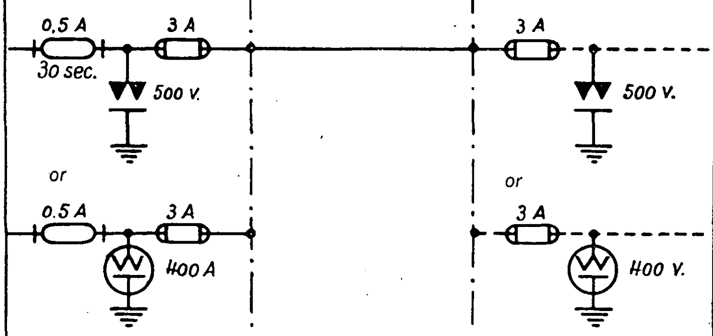
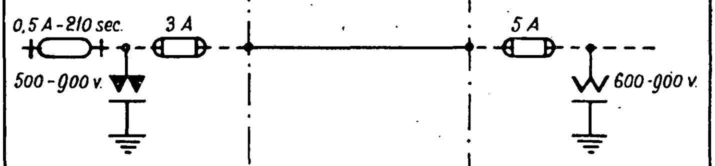
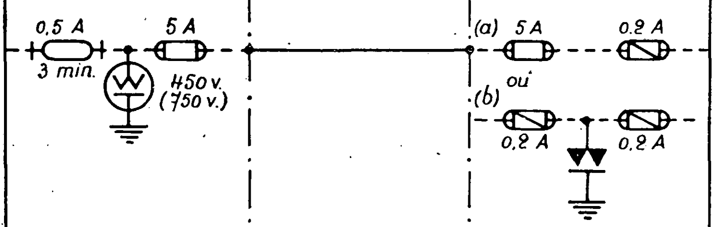
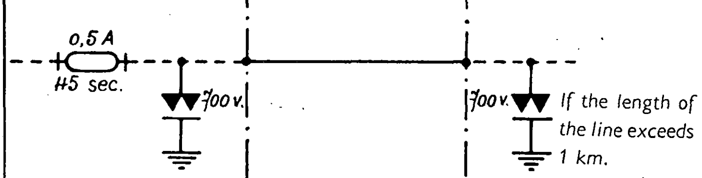


In special cases a vacuum arrestor (320 V.).

DANISH ADMINISTRATION AND PRIVATE COMPANIES



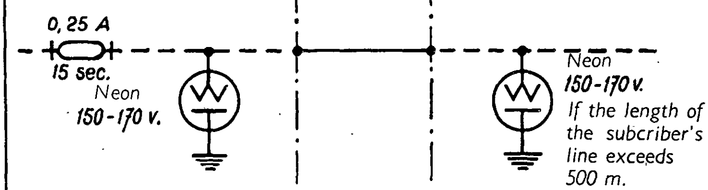
5. (contd.) SUBSCRIBER'S CIRCUIT ON OPEN-WIRE LINES

Administration or Private Operating Agency	EXCHANGE — LINE — SUBSCRIBER'S PREMISES
FRENCH ADMINISTRATION	
BRITISH ADMINISTRATION	
HUNGARIAN ADMINISTRATION	
NORWEGIAN ADMINISTRATION	 At places where experience has shown that this arrangement is not sufficient the Norwegian Administration has employed special arrangements.

5. (contd.) SUBSCRIBER'S CIRCUIT ON OPEN-WIRE LINES

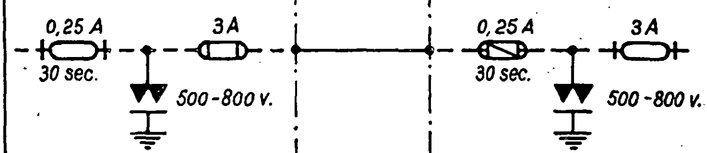
Administration or Private Operating Agency	EXCHANGE	LINE	SUBSCRIBER'S PREMISES

NETHERLANDS ADMINISTRATION

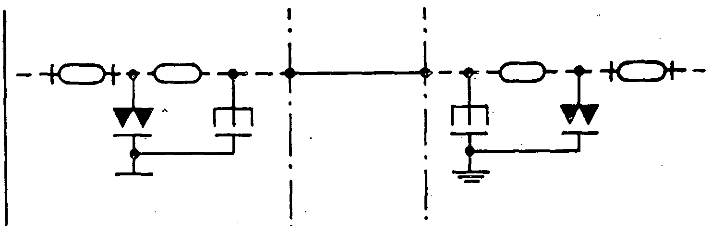


NOTE. The Netherlands Administration is gradually replacing open-wire lines by underground cables.

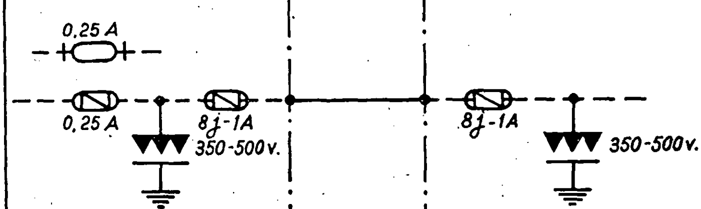
PORTUGUESE ADMINISTRATION



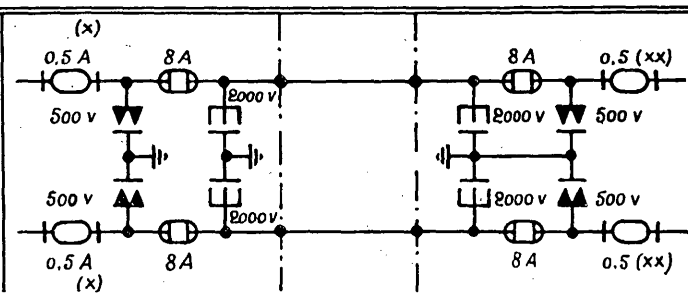
CZECHO-SLOVAK ADMINISTRATION



U.S.S.R. ADMINISTRATION



GERMAN ADMINISTRATION *



(xx) No heat coils if the subscriber's installation has no connexion to earth.
(x) 0.3 A in the case of central battery.

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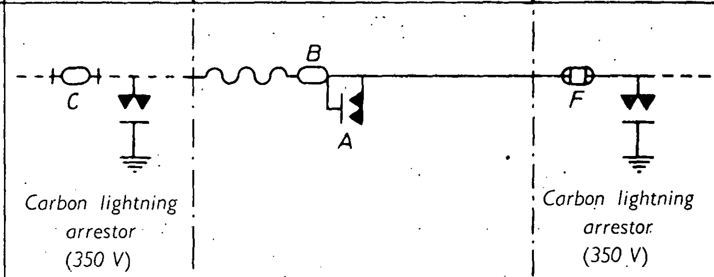
* Federal German Republic.

6. SUBSCRIBER'S CIRCUIT NOT ENTIRELY IN CABLE

<table>
<tr><th>Administration or Private Operating Agency</th><th>EXCHANGE</th><th>LINE</th><th>SUBSCRIBER'S PREMISES</th></tr>
<tr><td>AMERICAN TELEPHONE AND TELEGRAPH Co.</td><td colspan="3">



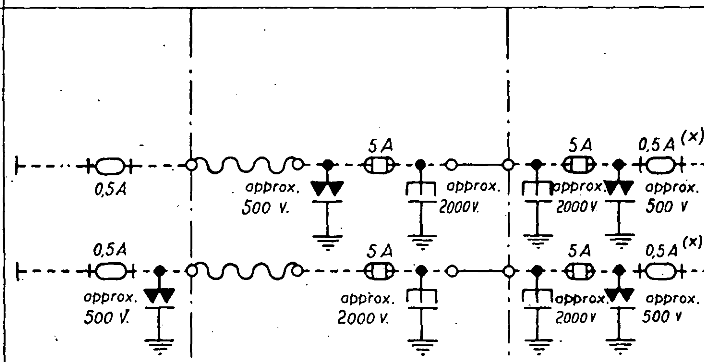
A. *Carbon arrestors (750 V) placed between the conductors and the cable sheath. These arrestors are used on all conductors if any open-wire section of a circuit is more than ½ mile (1 mile = 1609 metres approx.) in length from the cable terminal. Otherwise they are not generally employed.*

B. *A length 2 to 10 ft long (1 ft = 30.5 cm) of cable with small diameter conductors (not greater than 0.51 mm [24 A.B. and S.]) to serve as fuses. This cable is inserted between the exchange and the first point where the circuits are susceptible to contact with power lines of a voltage greater than 250 V.*

C. *Heat coil (0.35 A continuously—0.54 A for 210 seconds).*

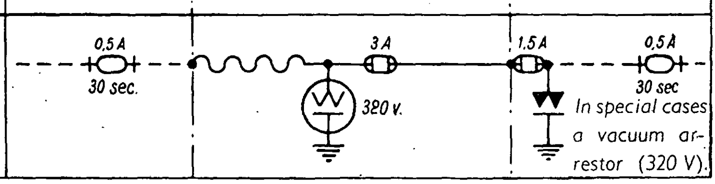
F. *Fuse (7 A continuously—10.5 A for 5 mins.).*

</td></tr>
<tr><td>AUSTRIAN ADMINISTRATION</td><td colspan="3">



(x) No heat coils if the subscriber's installation has no connexion to earth.

</td></tr>
<tr><td>BELGIAN ADMINISTRATION</td><td colspan="3">



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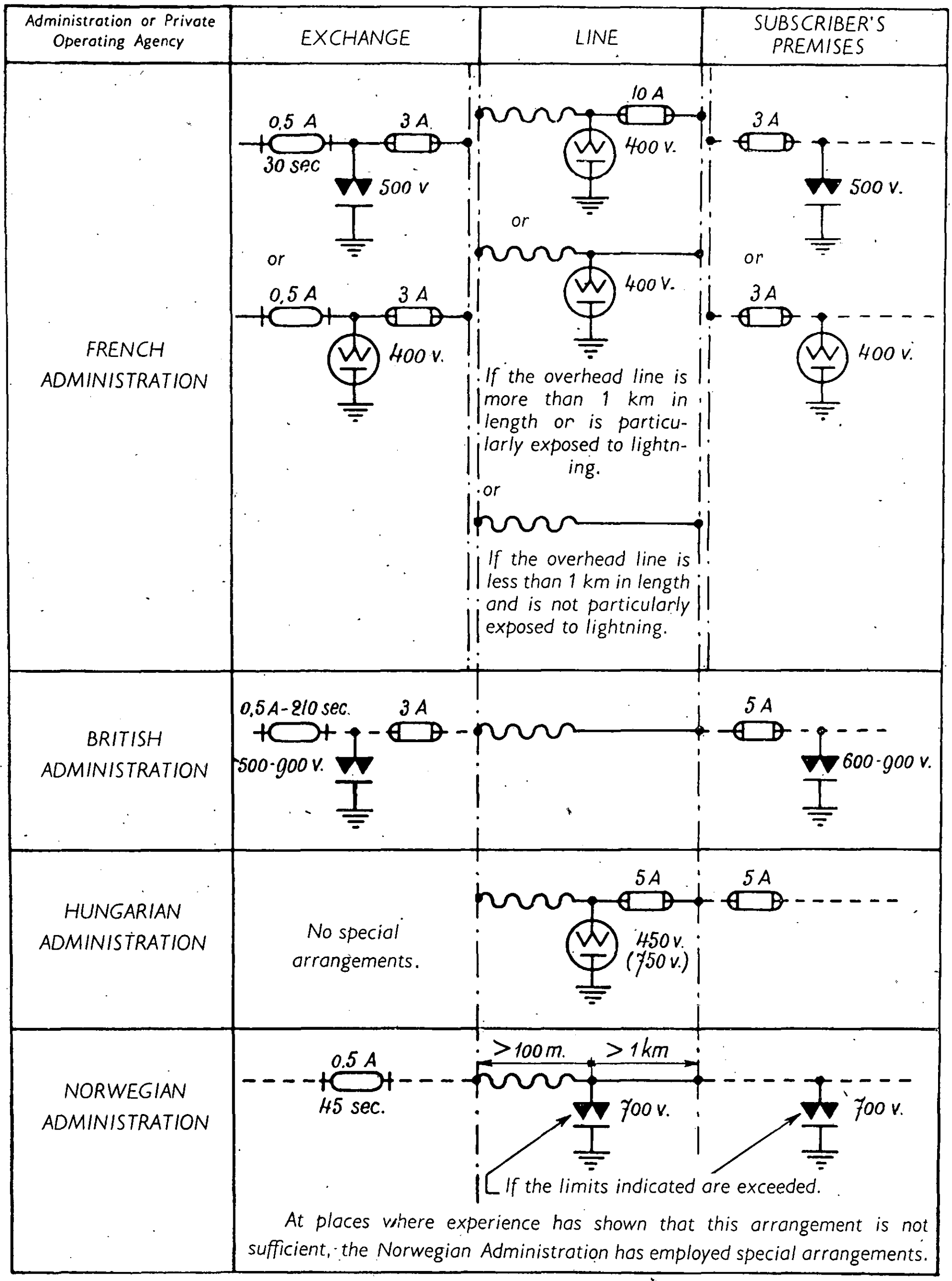
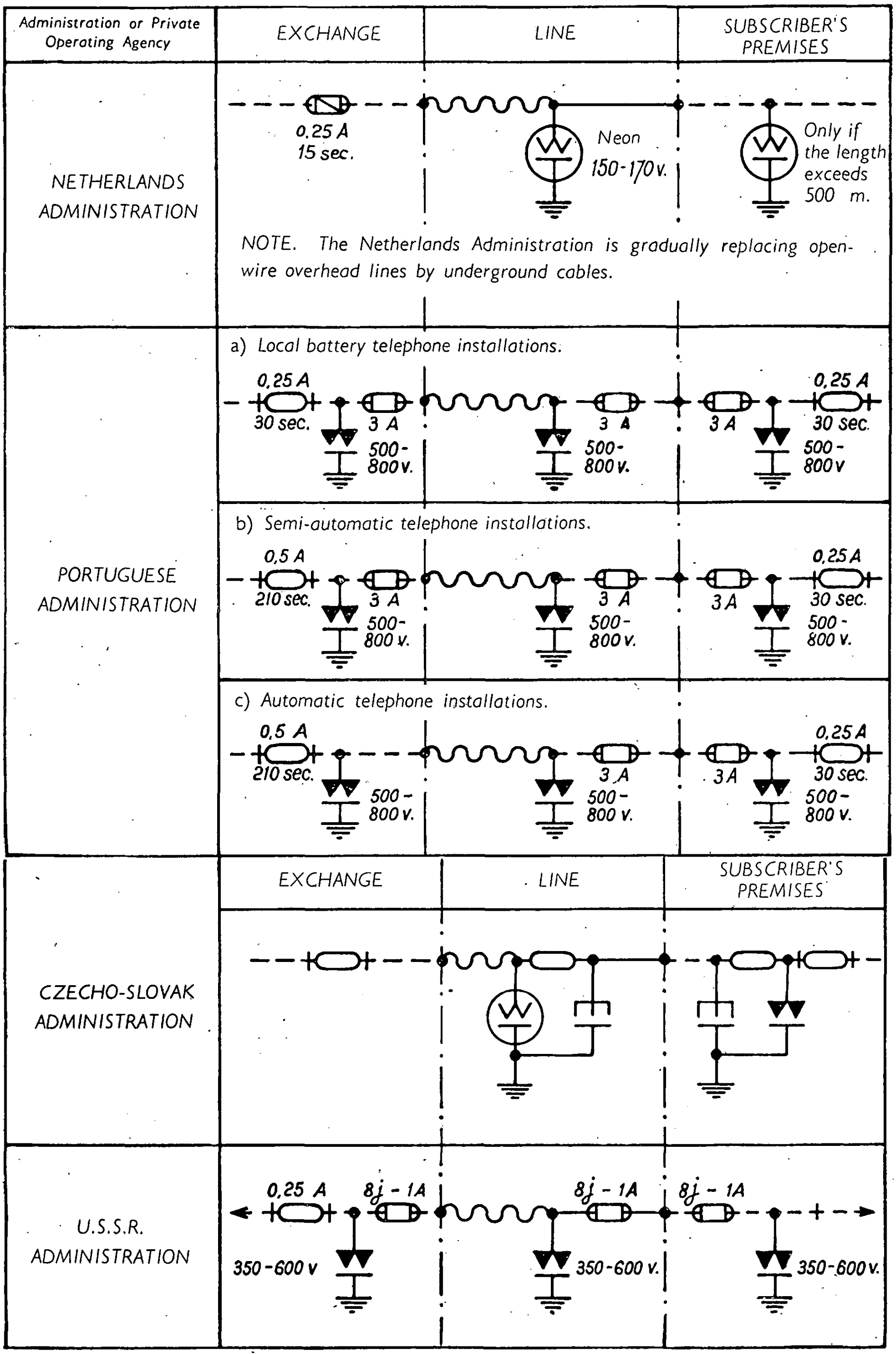
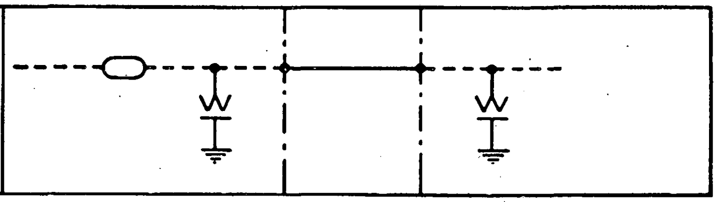
6. (contd.) SUBSCRIBER'S CIRCUIT NOT ENTIRELY IN CABLE

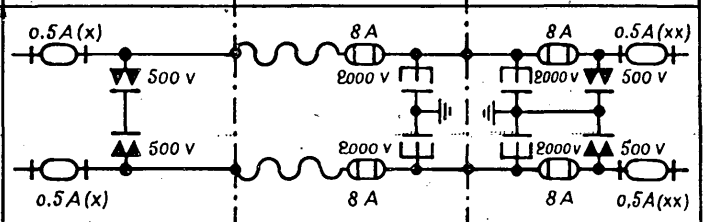


6. (contd.) SUBSCRIBER'S CIRCUIT NOT ENTIRELY IN CABLE



6. (contd.) SUBSCRIBER'S CIRCUIT NOT ENTIRELY IN CABLE

DANISH ADMINISTRATION AND PRIVATE SUPPLY COMPANIES	

Administration or Private Operating Agency	EXCHANGE	LINE	SUBSCRIBER'S PREMISES
GERMAN ADMINISTRATION*			

(x) 0.3 A in case of central battery.

(xx) No protective arrangements if all subscriber's lines are entirely in cable.

* Federal German Republic.

B. Protective arrangements that may be adopted for telephone lines exposed to severe induction, in order to reduce the voltages between wires and earth.

Amongst the devices that have thus far been used with satisfactory results may be mentioned:—

a) discharge tubes installed along lines,

b) short-circuiting earthing relays associated with lightning arrestors,

c) isolating transformers,

d) neutralizing transformers,

e) coupling coils between lightning arrestors, designed to facilitate simultaneous discharge of the arrestors.

The principle of operation of these devices and the principal characteristics that should be considered to determine under which circumstances each of these devices may be used to advantage, are indicated below.

a) Discharge Tubes

To limit the voltage to a permissible value, there may be installed at appropriate distances along telecommunication lines exposed to severe induction from neighbouring power lines, gas-filled tubes (for instance, tubes containing a mixture of argon and neon with a trace of a radioactive substance for the purpose of accelerating ionization) which are capable of supporting for a certain period the passage of an electric current of several amperes.

The characteristic features of such tubes have been described in detail in the *Journal of the Post Office Electrical Engineers*, Volume 45, pp. 104 to 110 and in the *C.C.I.F. Document—1925/1954—1st S.G.—Document No. 38.* Methods for the determination of the spacing of these tubes for the protection of any given line as well as for the calculation of the resistance of the earthing points required, are described in *C.C.I.F.—1952/1954— 1st S.G.—Documents Nos. 12 and 38.*

In the experience of administrations which have employed such tubes, a total of up to 15 can probably be used in a repeater section of an audio frequency* open-wire circuit. The employment of these tubes is mainly advantageous in the case of open-wire lines. With cables containing many pairs, serious difficulties arise from the accommodation of the tubes and the complicated earthing systems that would be required.

The other points arising in connection with the employment of such tubes are the following:

1) The earthing systems must be good and in consequence they are sometimes expensive.

2) It is necessary to provide acoustic shock absorbers for all telephone sets that may be connected to the ends of such lines or to the telephone exchanges concerned.

* The C.C.I.F. is studying the question as to how many of such tubes may be employed without impairment of transmission both on audio and on carrier circuits.

3) It is necessary to maintain the quality of such tubes and to check them after every thunder-storm or incident occurring on the line.

* * *

b) Earthing relays associated with lightning arrestors or discharge tubes

*b*1) FIRST SYSTEM.

The principle of this system is shown in Figure 1. On the operation of one of the lightning arrestors the relay R closes the contacts γ_1 and γ_2, whereby the two wires of the line are connected to earth.

As soon as the fault is cleared the armatures are released, the contacts γ_1 and γ_2 are broken and the circuit is restored to its normal condition.

The speed of operation of the relay is a function of the discharge current that passes through it from the line. Experience has shown, for instance, that certain relays are operated by a current of 1.5 amperes within 13 milliseconds and by a current of 15 amperes within 2 milliseconds.

The relay contacts will withstand a current of several tens of amperes for several seconds.

In cases where an open-wire line comprises a fairly large number of wires (for instance, 10 to 50), the scheme shown in Figure 2 may be applied.

The earthing of each pair is here effected by a separate relay. All the relays are controlled by a pilot relay, which is very sensitive and is connected to the secondary of a saturated transformer, the primary of which is at one end earthed and at the other joined to the earth terminals of all the arrestors protecting the circuits.

As soon as one of the lightning arrestors operates, the pilot relay operates and in turn operates all the others relays whereby all the wires of the line are connected to earth.

The saturated transformer is designed to limit the current in the pilot relay, whatever the current may be in the primary. Whatever the value of the discharge current the total time required for the device to operate may be made less than 25 milliseconds.

Special features of these devices.

The efficiency and reliability of operation of these devices depends upon the resistance of the earthing systems that are used. These must be low enough to ensure that, during the duration of a fault, the potential of the wires is not raised to a high value by the currents passing through them.

When this condition is fulfilled these devices have the following advantages:

As the lightning arrestor functions only for a very short time there is less risk of deterioration and its life is thus considerably lengthened.

With this device there is no need for the fuses on the line side, whereby avoiding inconveniences to the telephone service.

During the whole time of the fault the two ends of the line are connected to earth; the residual voltage on the wires is therefore reduced to a very low figure

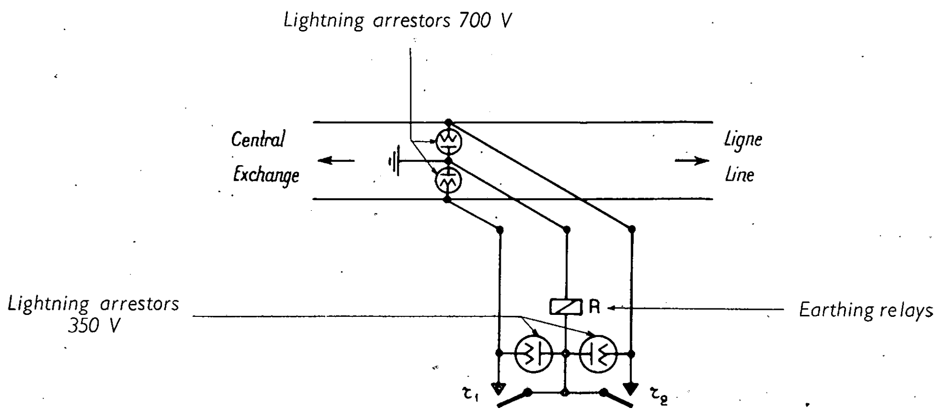


Figure 1

Earthing relays; case of a single circuit

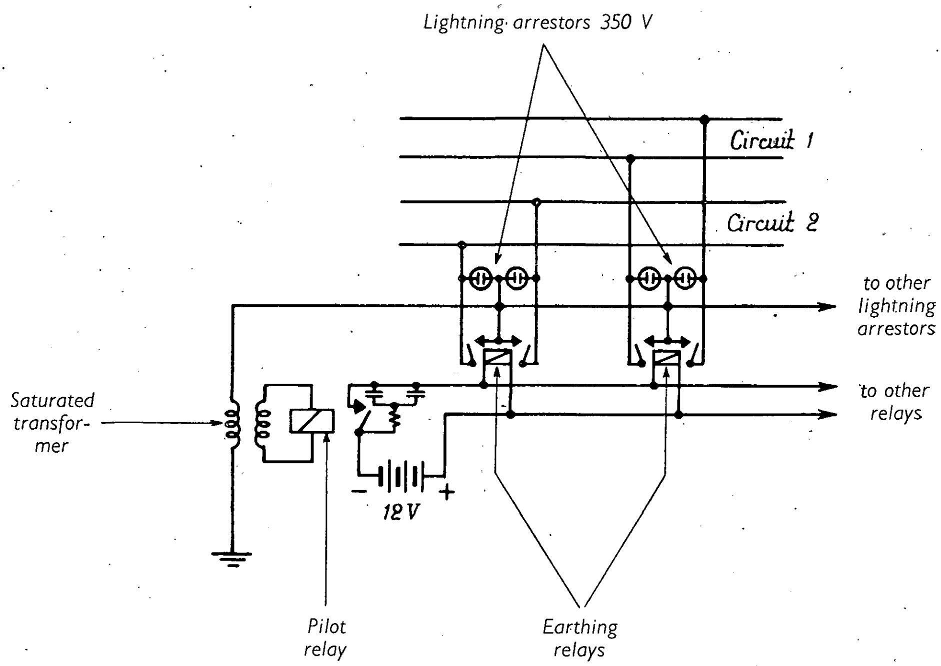


Figure 2

Earthing relays; case of several circuits (whereas with classical protection, the total voltage appears across the isolated line as soon as the fuses have blown). Hence there is a appreciable reduction in the risk to men working on the line.

As a result of the short period of functioning of the lightning arrestors the risk of recurrent acoustic shocks is eliminated. Moreover (at the subscriber's set or other installation connected to the circuit), the duration of intense currents due to the non-simultaneous operation of the arrestors is reduced to a minimum.

As they do not form part of the transmission circuit, these devices do not affect the transmission characteristics as may other types of protective devices such as isolating transformers or neutralizing transformers.

Maintenance of these devices is easy: it is sufficient to check periodically the short-circuiting contacts and in the case of multiple earthing relays, the state of the battery and the setting of the pilot relay.

It might be mentioned, however, that the simultaneous earthing of the two conductors during the whole duration of the fault may cause some inconvenience, particularly in cases where a group of circuits is connected to an automatic exchange.

Difficulties might also be expected where central battery subscribers' lines are involved.

b2) SECOND SYSTEM *(Note submitted by the Italian Telephone Administration).*

The principle of this system—which was developed by the SET Telephone Company—is shown in Figure 3. It consists of two separate relays in series with the two wires of the circuit (one relay in each line wire) and joined mechanically with each other.

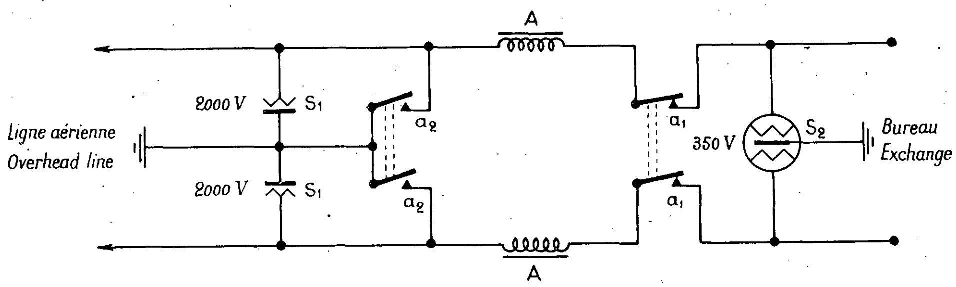


Figure 3

Protective arrangements at exchange

As soon as one of the relays (or both) operates, the contacts a_2 are closed and after a short delay, the contacts a_1 are opened. By this means it is possible to earth the two wires of the line and at the same time to disconnect the exchange from the line. The re-establishment of normal service conditions is effected manually on receipt of an alarm signal; good contact at the contacts a_1 in series with the wires of the line may thus be ensured by the action of a spring.

The complete device contains a pilot 3-electrode gas-filled discharge tube with a striking voltage of 350 volts S_2 and two lightning arrestors S_1, which may be set to any desired value between 1000 and 2000 volts.

Advantages of the device.

1. Apart from the advantages arising from the direct earthing of the line, the device ensures that at the same time the line is disconnected from the exchange.

2. The device functions even in cases where, due to any cause, an abnormally large current flows in the circuit and where the arrestors fail to operate.

3. The impedances of the two relays facilitate the operation of the arrestors S_1 in the case of atmospheric discharges. Moreover, their impedance is sufficiently low as not to cause any objectionable attenuation in the telephone circuit even when the circuit is operated with carrier frequencies.

Furthermore, in the case of atmospheric discharges involving voltages high enough to operate the dischargers S_2, but insufficient to operate the lightning arrestors S_1 and of too short a duration to operate the relays, the device protects the exchange equipment which is then subjected only to the residual voltage of the dischargers S_2.

Electrical characteristics of the device.

1. Minimum operating current: 3 amperes (R.M.S. value) at 50 c/s.
2. Operating time: about 15 milliseconds.
3. Resistance of each relay at 50 c/s: 0.45 ohm.
4. Insertion loss between 600 ohms of the two relays:
   at 800 c/s : 0.02 neper,
   at 150 kc/s: 0.15 neper.

Note.—Efforts are being made towards the development of automatic resetting of the device. With the incorporation of this feature the devices among other things would have the advantage of being capable of installation at places away from the exchange. The employment of earthing systems independent of the telephone exchange earth system would, in this case, eliminate the danger of a possible excess voltage accross the exchange earth system.

c) Isolating transformers

On manual or on automatic circuits with a.c. dialling and signalling, by inserting isolating transformers, the portion of the line exposed to high induction can be divided into sections in which the maximum permissible voltage will not be exceeded. However certain operating difficulties are caused which cannot be ignored. These are:

a) greater attenuation especially for the low frequency signalling current, and greater attenuation distortion;

b) in the case of carrier circuits, the apparatus must have sufficiently small harmonic distortion;

c) complications in insulation testing and localization of faults on the intermediate sections.

The use of these isolating transformers makes it impossible to use direct current for dialling and signalling.

In consequence, the administrations who have had experience of this method of protection have recommended that the number of transformers inserted in a line must not be greater than four or five (including the transformers at the terminations).

As an example, transformers of this type used in Switzerland have the following characteristics:

Ratio of transformation: 600/600 Ω, 600/1000 Ω, 600/1600 Ω.

Characteristic as a function of frequency:

attenuation at	50 c/s	0.1 neper
	150 to 4000 c/s	0.05 neper

Impedance unbalance: $<$ 0.002 per cent

Test voltage: the windings must be able to withstand for 2 minutes, a test voltage of 4000 V at 50 c/s. between them or between each of them and the case.

Impulse breakdown voltage: 25,000 volts approx.

d) Neutralizing transformers

Neutralizing transformers enable the total e.m.f. applied to the wires of the telecommunications line to be reduced appreciably but modify only very slightly the transmission characteristics of the line.

Principle.—A neutralizing transformer consists of three windings of which two are identical; they are coupled in such a way that all three always embrace sensibly the same flux.

Each of the two identical windings (termed in this note secondaries) is connected in series with one of the wires of the circuit to be protected. The third (the primary) is connected in series with a pilot wire which runs parallel to the telephone pair and is on the same supports, in such a way that it is subject to the same inductive effects as the telephone wires. The pilot wire is connected to earth at its two ends (Figure 4).

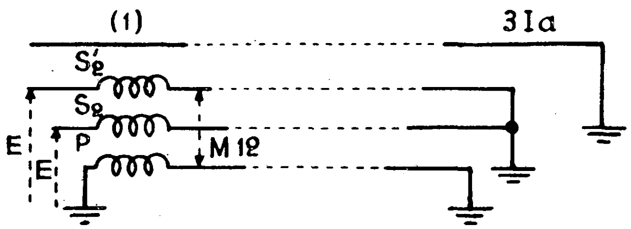


Figure 4

If the telephone wires are either completely isolated from earth or are connected to earth at one end only, the impedance offered by the transformer to the induced currents flowing through the pilot wire, must be considerably greater than that which arises from the rest of the circuit consisting of this wire and the earth. Thus, the voltage drop due to the induced current occurs almost entirely between the terminals of the primary winding; it differs very little from the e.m.f. induced along the line. The same value of e.m.f. is induced by the transformer between the terminals of each of the secondary windings. The connection of these windings to the telephone wires must be made in such a way that the e.m.f. induced by the transformer is in opposition to the longitudinal e.m.f. and thus neutralizes it almost completely.

If therefore the wires are connected to earth at one end the other end will be at a very small potential. The application of Thevenin's theorem then shows that if the other ends of the wires are now connected to earth, the current which will flow through them will be very small.

The distribution of the voltages along the wires depends on their connection to the earth, the distribution of the longitudinally induced e.m.f. and the location of the neutralizing transformer or transformers. Naturally, it is the same for the capacitance currents between the different points of the conductors and earth; if the conductors are completely isolated the distribution of the voltages will be in such a way that the algebraic sum of all the capacitance currents will be zero.

Particulars of use.

By means of the choice of a suitable specification (windings of low resistance, high values of their inductance, low values of various losses, of capacitances between windings...), neutralizing transformers can be made which modify very little the transmission characteristics of telephone circuits either at audio frequencies or with the much wider band used for carrier working.

Neutralizing transformers can be inserted in circuits which operate on a D.C. basis without distortion of calling, dialling or supervisory signals, such as are used for automatic working. Some transformers have a larger number of windings for the treatment of a greater number of circuits. However, three-winding transformers, made on the principle indicated facilitate the conditions in respect of crosstalk, even when several primaries are grouped in parallel on the same pilot wire.

Another application of neutralizing transformers is their use for protecting telephone circuits which enter a generating station or a high-voltage sub-station from the effects of high earth potentials.

To neutralize the potential difference between the earth and the wires, the primary of the transformer is inserted in a short pilot wire (some hundreds of metres) one end of which is connected to the earth which varies in potential at the generating station or sub-station, and the other end to a point where the earth potential is practically constant. This arrangement is shown in Figures 5 and 6.

As a typical example attached herewith are details of the characteristics of two types of neutralizing transformers made in France and intended to pass bands of frequency with upper limits of 3000 and 10,000 c/s respectively.

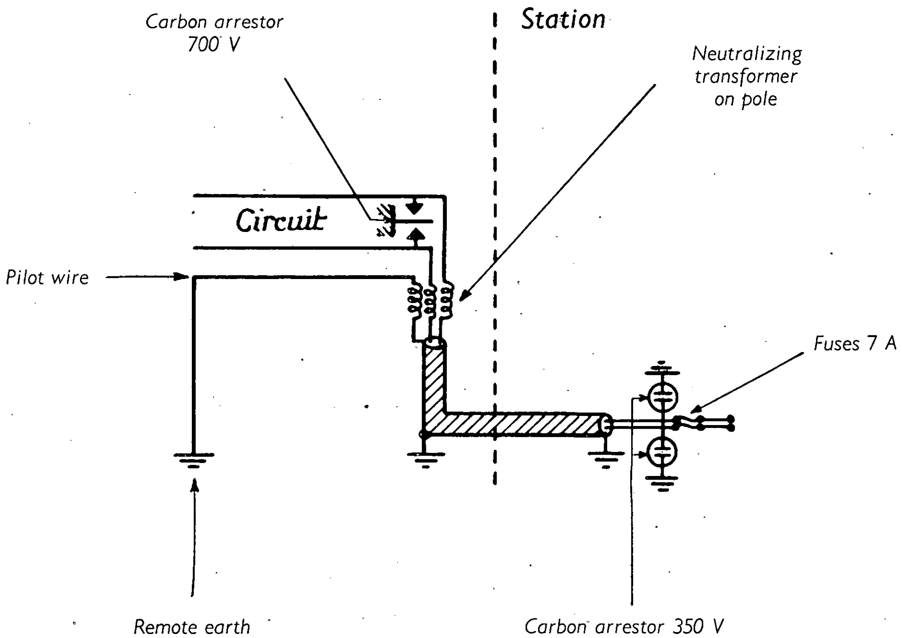


Figure 5

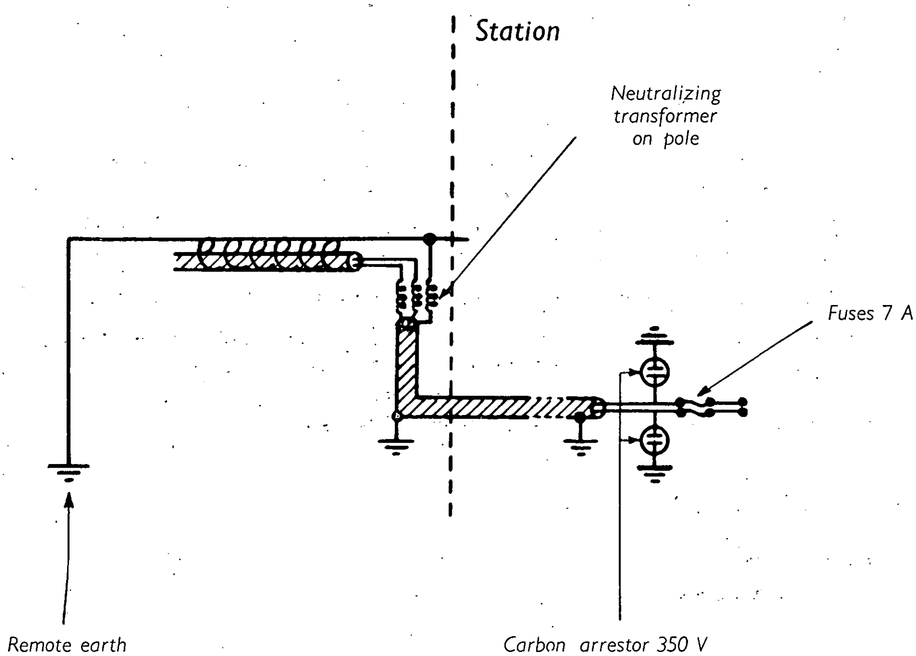


Figure 6

ANNEX 1

Neutralizing transformer type 315-B (pass band 3000 c/s)

Characteristics :

Number of windings: 3

primary (compensating circuit)
secondary 1 } for placing in the telephone circuit
secondary 2 }

Number of turns: the same in each of the three windings.

Primary voltage: maximum 3000 volts r.m.s. applied intermittently.

Maximum secondary current: 0.35 amperes r.m.s. in each winding continuously.

Resistance to D.C.:

primary: 64 ohms approx.
secondary 1: 64 ohms approx.
secondary 2: 64 ohms approx.

Resistance balance of the secondary windings: not worse than 0.2 per cent approx.

Inductance of primary winding and each secondary winding:

frequency = 200 c/s, voltage $<$ 1 V r.m.s. } 12 henrys approx.
frequency = 50 c/s, voltage $>$ 300 V r.m.s. } $>$ 50 henrys approx.

Coupling between windings: (measured at 1000 c/s)

1. Inductance of primary winding at 1000 c/s, one secondary being short circuited: 13 mH approx.
2. Inductance of secondary winding 1, winding 2 being short circuited: 20 mH approx.
3. Inductance of both secondary windings connected in opposition: 20 mH approx.

Capacitance between windings: capacitance of secondary 1 short circuited, to secondary 2 short circuited and joined to the metal case and frame: 4.5 millimicrofarads.

Test of dielectric strength: 9000 V r.m.s. applied between the two windings.

Response curve of the whole of the two secondary windings placed between a generator of 800 ohms and a load impedance of 800 ohms:

loss of 1 db approx. between 30 and 3000 c/s,
loss of 3.7 db approx. between 30 and 10,000 c/s.

Form of magnetic circuit :

Circuit having three limbs.

Weight approximately :

35 kilograms.

Annex 2

Neutralizing transformer type 315 (pass band 10,000 c/s)

Characteristics :

Number of windings: 3

primary (compensating circuit)
secondary 1 } for placing in the telephone circuit.
secondary 2 }

Number of turns: the same in each of the three windings.

Primary voltage: maximum 3000 volts r.m.s. applied intermittently.

Maximum secondary current: 0.35 amperes r.m.s. in each winding continuously.

Resistance to D.C.:

primary: 40 ohms approx.
secondary 1: 80 ohms approx.
secondary 2: 80 ohms approx.

Resistance balance of the secondary windings: not worse than 0.2 per cent approx.

Inductance of primary winding, and each secondary winding:

frequency = 22 c/s, voltage < 1 V r.m.s. } 10 henrys approx.
frequency = 50 c/s, voltage > 1 V r.m.s. } 40 henrys approx.

Coupling between windings: (measured at 1000 c/s)

1. Inductance of primary winding at 1000 c/s, one secondary being short-circuited: 10 mH approx.
2. Inductance of secondary winding 1, winding 2 being short-circuited: 7 mH approx.
3. Inductance of both secondary windings connected in opposition: 9 mH approx.

Capacitance between windings:

Capacitance of secondary 1 short circuited, to secondary 2 short circuited and joined to the metal case and frame: 3.5 millimicrofarads.

Test of dielectric strength:

9000 V r.m.s. applied between the two windings.

Response curve of the whole of the two secondary windings placed between a generator of 800 ohms and a load impedance of 800 ohms: loss of 1 db approx. between 30 and 10.000 c/s.

Form of magnetic circuit :

A circuit with two limbs with each of the primary and secondary windings split equally between them.

Approximate weight :

80 kilograms.

e) Coupling coils between lightning arrestors (also called equalizing coils)

These coils have been known for a long time and have been proved effective for the reduction of transverse voltages likely to result from the non-simultaneous operation of the two lightning arrestors connected to a pair of conductors.

Figures 7 and 8 show two arrangements using these coils.

The method of operation is exactly the same in both cases. Owing to the inevitable slight difference in the mechanical construction and in the electrical characteristics of two lightning arrestors (even when these are situated in the same envelope) one of the lightning arrestors discharges before the other; the resulting current which passes through half of the coil produces in the other half an e.m.f. which, added to that which is applied by the line, is sufficient to cause the second lightning arrestor to discharge.

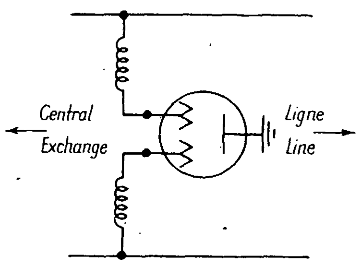


Figure 7

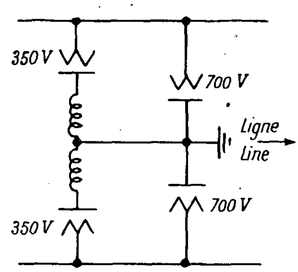


Figure 8

The arrangement in Figure 7 is used, for example, on the supervisory and control circuits in cables which run alongside electrified railways. It is particularly desirable that on such circuits the risk of acoustic shock and distortion of signals should be reduced as much as possible. Other types of arrestors can be used instead of the three-electrode tube shown in Figure 7.

The arrangement in Figure 8 is used on overhead carrier current telephone lines, on which are installed voice frequency telegraph systems, in the case where such lines cross regions known for the frequency and violence of their storms.

There again, the function of the coupling coils is to suppress the transverse voltages due to lightning or to low-frequency induction, which would otherwise produce acoustic shocks or a distortion of the signals.

The breakdown voltage of the lightning arrestors connected in series with the coils is relatively low (e.g. 350 volts). That of the lightning arrestors connected in shunt between the line conductors and the earth is greater (e.g. 700 volts); the function of the latter is to combat voltage surges having a high peak value.

One of the advantages of equalizing coils is that they function in the case where the induced longitudinal e.m.f. is in the neighbourhood of the breakdown voltage of the lightning arrestors. In the absence of such a coil the condition might arise in which one only of the lightning arrestors breaks down and this would result in the whole of the applied e.m.f. being impressed upon the terminals of the telephone receiver.

Unlike isolating transformers, equalizing coils have no degrading effect at all on the transmission characteristics or the maintenance of the protected circuit. Their principal drawback is their high price and this probably explains why they are applied on a somewhat restricted basis.

CHAPTER II

ARRANGEMENTS FACILITATING THE MAINTENANCE OF TELECOMMUNICATION LINES

1. USE OF GAS UNDER PRESSURE IN CABLES

A. Information supplied by the American Telegraph and Telephone Co. in 1953

The introduction (in the Bell System of the United States of America) of trunk cables filled with compressed gas actively commenced some twenty years ago and has now attained the point where practically 100 % of the long trunk cables, including both aerial and underground cables, are now under gas pressure. Two systems are used:

—the one, the older, which consists of a periodic or static filling of the cables,

—the other, more recent, known under the name of the continuous flow system.

Some of the more important characteristics of the systems and some of the results which it has been possible to obtain in the maintenance of cables are as follows:

I. SYSTEM OF PERIODIC OR STATIC FILLING.

1. *Type of gas utilised.*—Dry nitrogen is used exclusively principally because it can be obtained without delay at low cost in any part of the U.S.A. as it is produced commercially in great quantities for various uses. Tests are made with dry air for certain special applications.

2. *Gas pressure.*—Underground and submarine cables are maintained under a pressure of 9 lbs per square inch (1 lb per sq. in. = 70.3 grammes per sq. cm.): and aerial cables at a pressure of 6 lbs per sq. in. The higher pressure used for underground and submarine cables is to overcome hydrostatic pressure to which such cables may be subjected due to flooding of cable chambers or for similar reasons. A higher pressure is permissible in this case because, due to the smaller variations of temperature, there is less risk than with aerial cables of the pressure causing damage to the cable sheath.

3. *Sectioning of cable for gas pressure.*—The length of the sections in which a cable is divided for the application of compressed gas is, on the average, approx.

10 miles (1 mile = 1609 metres) but there is a trend towards increasing the length to 25 miles or more. Each of the sections is sealed at each end to prevent the flow of gas from one section to another. In the case of ordinary cables, the seals are made in situ by impregnating the core of the cable with wax and a compound of asphalt. In the case of coaxial cables, factory made seals are necessary. Apart from this question of seals, the introduction of coaxial cables has not appreciably modified the construction of the gas pressure system. There are two reasons for sectioning the cables:

a) the refilling of a long length of cable after gas has escaped is avoided,

b) for the localisation of faults, because one fault is prevented from masking another fault which might occur at almost the same time.

4. *Contactors and valves.*—Contactors which are designed to operate when the pressure falls to 3 lbs per sq. in. below the normal value and which send an alarm signal on a pair of wires to an adjacent telephone exchange, are placed at intervals of approx. 2 miles. The valves for measuring the pressure are placed at approx. 3000 ft. intervals (1 ft. = 30.48 cm.). Resistance measurements on the alarm conductor pairs show the location of the contactors which have operated; measurements of the pressure at valves near this contactor enable the pressure gradient along the cable sheath to be determined, and consequently the fault in the sheath to be located precisely. Ordinarily such faults have not been repaired immediately. In the majority of cases, the gas pressure effectively prevents the entrance of moisture for a fair time which permits the existing practice of repairing faults only during normal working hours, and can even enable work to be delayed over a weekend.

5. *Special applications.*—Generally, bottles of gas are used to bring the sections of cable to the necessary pressure and are then removed. There have been cases of submarine faults where a bottle was left, attached to each end until the fault had been repaired, which enabled the cable to remain dry in the relatively high hydrostatic pressure conditions met with in such a case, and for the relatively long periods required for the repair of such faults. This method has sometimes been applied to cables which were not normally pressurized.

Note.—More detailed information is given in the article "Gas pressure for telephone cables" by R.G. Giese, American Institute of Electrical Engineers' Technical Paper 47-77, December 1946.

II. Continuous flow system.

This system consists in the maintenance of pressure in the cables by continuous injection of gas from a central injection point.

The injection apparatus consists of a compressor-dehydrator containing drying elements using silica gel for the supply of compressed air, or an equipment of one or more containers of compressed nitrogen situated in an exchange. In an urban area, a total of about 300 miles of trunk cable sheaths and toll cables radiating from the same exchange are thus supplied by a compressor-dehydrator. Similar arrangements form the subject of tests undertaken with the object of maintaining long distance cables which were previously maintained under pressure by the first system. It is hoped that this method will reduce maintenance costs as a result of the reduction of the number of journeys along these cables for maintenance.

III. Results obtained.

The results obtained by maintaining cables under pressure in the Bell System can be assessed in various ways and expressed as follows:

1. The number of single-pair faults in 100 miles of cable per year has diminished regularly as the number of cables under pressure has increased. Experience gained on a large part of the trunk cable network shows that the fact of passing from the situation where no cables were under pressure to where all cables were under pressure resulted in a reduction of 87.5% in the number of faults.

2. As mentioned in par. 1 above, gas pressure contributes considerably to the security and continuity of service. It can be said that without the use of gas pressure it would not have been possible with any success to cope with the load of traffic during the war years and even at the present day.

3. The costs of maintaining cables under gas pressure seem very little different from those of cables maintained without gas pressure. Considerations which tend to reduce expenses due to compressed gas are as follows:

a) Faults on cables without gas pressure entail frequent night work and overtime for their repair, while those in pressurized cables have generally a sufficient reserve of gas to protect the cable until the fault can be repaired during normal working hours.

b) With compressed gas, faults due to a puncture in the cable sheath are discovered as soon as they occur. Without the warning and protection given by gas pressure, some of these punctures would be dangerous to the telephone service and could cause extensive faults on the cable pairs, the repair of which would require more time and expense and which in many cases, would need the replacement of lengths of cables which could otherwise be repaired.

B. Information Supplied by the British Telephone Administration in 1953

1. *Cables under continuous gas pressure.*

The earliest experiment by the B.P.O. of maintaining cables under continuous gas pressure was made in 1929. The cable chosen was an existing trunk cable routed through rather severe corrosion areas. Due to the existence of a number of incipient sheath defects further faults were caused by the introduction of the internal pressure in the cable, the sheath of which was already weakened in places by corrosion attack. Because it was so difficult to make the cable gas tight it was decided eventually to abandon the attempt, and it was not until 1949 that further trials on a small scale were put in hand.

From the outset it had been considered that the addition of any apparatus, e.g. pressure gauges, external to the cable was undesirable, so pressure operated contactor devices, small enough to be contained within the cable joints, were developed. These at first took the form of small U tube mercury manometers, but they have now given place to small aneroid type mechanisms, so designed that a metallic bellows open to the cable pressure on the inside, and held in its unoperated position by a spring, when the cable pressure is 10 lbs per sq. in. (see Figure 1).

If the pressure falls to 6 lbs per sq. in. the bellows are compressed by the spring sufficiently to close two electrical contacts associated with the control circuit.

An interurban cable, approximately 12 miles long, was selected for the trial, the whole length being treated as one gas section. By-pass pipes with valves were provided at loading points. It has been the aim that a locator should give a precise location of any break in the sheath without the need for resorting to pressure measurements along the route to determine the pressure gradient. To achieve this, close spacing of the contactors in necessary and their operating characteristics have to be uniform within ± 0.1 lbs per sq. inch. In the actual trial, the contactors were placed at approximately 0.2 mile intervals depending on the positions of accessible joints. The trial installation was completed in 1950.

2. *Fault locator.*

The purpose of the locator is three-fold:

a) To give an alarm at the controlling station immediately a contactor operates.

b) To indicate the exact position of the operated contactor.

c) To indicate the sequence in which any other contactors may subsequently operate so that the pressure gradient on either side of the first operated contactor is roughly indicated.

Conditions *a)* and *b)* are easily met. All the contactors along the route are wired in parallel across a control pair which at the remote end is connected to an auxiliary pair of wires. The control pair and the auxiliary pair are connected at the controlling end through a relay set to a Murray Bridge as shown in Figure 2. Operation of any contactor along the route operates the relay set which (i) gives the alarm,

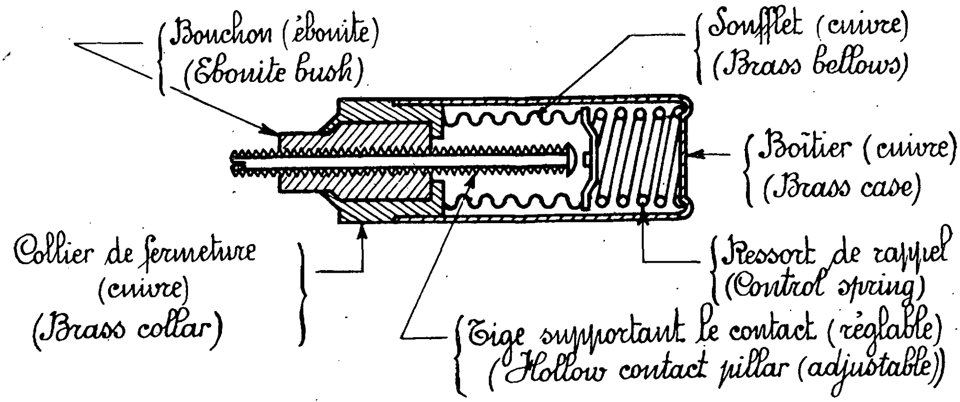


FIGURE 1

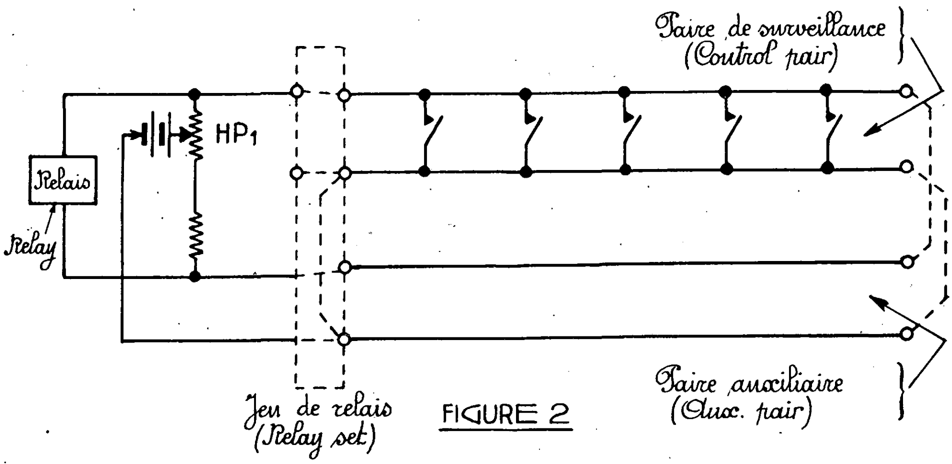


FIGURE 2

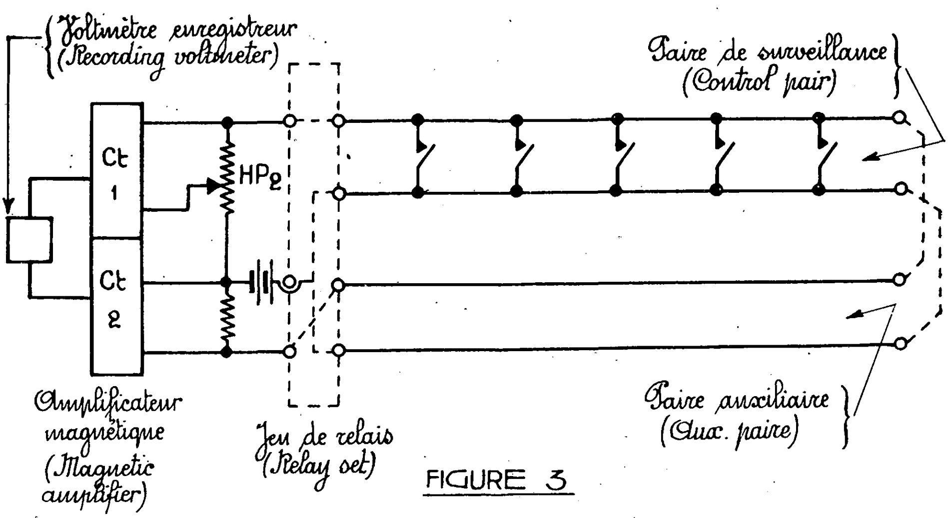


FIGURE 3

and (ii) starts an electric motor which is connected to a helical potentiometer (HP1). The motor drives the potentiometer until the bridge balances when the drive ceases. The potentiometer reading indicates the position of the operated contactor.

With regard to condition *c)* it will be appreciated that as the pressure along the cable continues to fall, as a result of the sheath defect, successive contactors operate at intervals depending on their distance from the fault point. As viewed from the controlling end, they may be on the near side or far side of the contactor initially operated. Each subsequent operation of a contactor throws the bridge into an unbalanced condition.

When dealing with a 20 lb/mile (0.9144 mm) conductor cable, and contactor spacing of 0.2 miles, the percentage change in resistance due to the operation of a second contactor is small, and as the maximum line current must be limited to avoid damage to the loading coils, the out of balance voltage across the peaks of the bridge is also small and considerable difficulty has been experienced in finding a relay which would operate reliably in this position. This has been solved by the use of a magnetic amplifier. After the Murray Bridge has been balanced it is disconnected by the relay set and the control pair and auxiliary pair are connected to the magnetic amplifier as shown in Figure 3. The input voltage to circuit 1 depends on the resistance to the operated contactor along the control pairs and the input voltage to circuit 2 on the resistance along the auxiliary pair and back along the control pair from the remote end. By means of the motor driven potentiometer HP2 controlled by the relay set, the input voltages are automatically balanced so that there is no output from the amplifier, the output terminals of which are connected to a moving chart recording voltmeter which was started up when the first contactor operated. The operation in due course of a second contactor alters the input voltage to circuit 1 or circuit 2 depending on its position and an output voltage is obtained from the amplifier, which is recorded on the chart. Operation of a third contactor, which, if the contactor operating pressures are equal, will be on the other side of the initial contactor, approximately restores the balanced condition of the amplifier. The process is repeated as subsequent contactors operate. The chart therefore indicates the time and sequence of contactor operation, and from these and a knowledge of the precise spacing of the contactors, the position of the actual break in the sheath can be calculated. Experience is as yet limited, but on the faults which have been located to date an accuracy of $\pm$ 20 yards in 12 miles has been consistently obtained. While the original installation was made on one cable only, the scheme is now being extended to seven cables radiating from the controlling office. One locator serves all the cables which are connected to it by a line finder circuit.

The complete apparatus is entirely quiescent, no current being drawn from the supply until a contactor operates under a fault condition.

C. Information Supplied by the Danish Telephone Administration in 1953

1. *Introduction.*

The coaxial pair cable of the Danish P.T.T. København-Kolding-Römö is constructed with a pneumatic maintenance equipment, all sections of underground cables being under a constant effective pressure of 0.5 atmosphere. In consequence, perforation of the lead sheath of the cable will not allow penetration of water into the cable before the pressure decreases nearly to zero; this will require several hours even in the case of a complete breakage of the cable owing to the reserve of gas contained in the cable itself.

For the supervision of the state of pressure in the cable, manometers are incorporated in the cable at each normal joint, that is to say at intervals of about 300 metres; these manometers short circuit a special pair in the cable if the pressure falls below 0.3 atmosphere. The pair in question is connected at København and at Kolding, to a supervising apparatus which will give an alarm immediately on the closing of the contact of the manometer, and which will permit in addition the determination of the time when the short circuits of the manometers occurred with respect to the first manometer whose contact was the first to close. This information will permit a localisation of any important leak with an error of less than 50 metres.

2. *Conditions to which the supervisory apparatus and the methods of measurement must conform.*

The following conditions must be fulfilled:

a) The first closing of a contact must give audible and visible alarm in the supervisory station.

b) Once the alarm is given it should be possible to determine with an error less than 100 metres by measurements made from *one* end of the cable, the position of the manometer which has operated.

c) The next manometers to operate must also give an alarm and with the aid of measurements, it should be possible to fix the position of the manometers in question with similar error to that mentioned under *b)*.

As an alternative, the supervisory apparatus may be adapted for the automatic recording of measurement data which can be deduced from the information mentioned under *c)*.

It is assumed that the contact resistance of the manometer is negligible, that the resistance of the conductors measured is uniform (about 27 ohms per km—single wire), and that the temperature of the cable is the same throughout the route to be supervised, for which the maximum length is assumed to be 110 km. The minimum distance between two manometers is considered to be equal to 300 metres.

3. *Theoretical considerations.*

3.1. *First alarm.*

The first alarm (condition a) is given most simply by the arrangement shown in figure 1.

A relay A in series with a battery U is connected to the pair *a-b* (resistance "r" ohms/km), connected to the manometers. When the manometer causes a short circuit, the relay A operates and gives the alarm. The voltage *V* and the resistance of the relay RA are determined from maximum data of the manometers and the length of the section to be supervised.

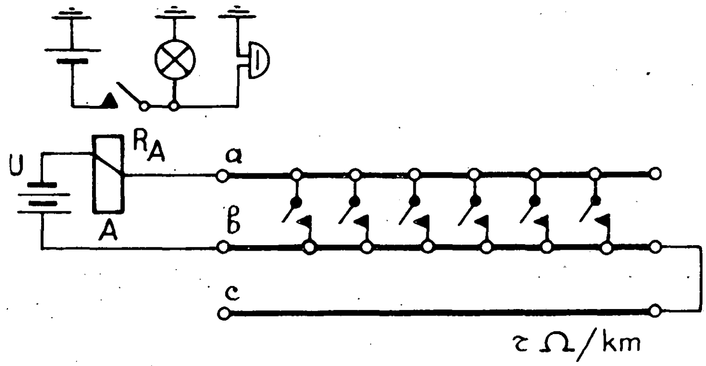


Figure 1

Supervision of the pair connected to the manostats

3.2. *Localisation of a manometer whose contact has closed.*

It is supposed that two manometers can close their contacts almost simultaneously, i.e. in the time which elapses between the first alarm and the completion of the localising measurement. This could happen for example, if a leak occurred at a point situated midway between two manometers. Hence, the problem consists as much in the determination of the distance *x* to the nearest manometer which short circuits pair *ab* (Figure 2), as in the determination of the distance y from this point up to the next manometer whose contact has closed. The condition that the measurement is made from only one end of the cable implies that this measurement may not be made only with the aid of the pair *ab* connected to the manometers, but that use must still be made of an auxiliary conductor *c*.

Figure 2 represents the schematic arrangement of the apparatus serving to localise the first manometer as well as the indication of the functioning of the following manometers. The apparatus is composed of a Wheatstone Bridge with equal arms of which three arms are composed of two resistances R_2 and R_1. The fourth arm is chosen by the switch O.

When O is in the position 1-2 and when R_1 is adjusted to balance the bridge we have:

$$R_1 = r \cdot l + r(l - x - y) + \frac{1}{2} ry + r \cdot x = r(2l - \frac{1}{2} y)$$

or

$$y = 4\left(l - \frac{R_1}{2 . r}\right) = 4\, l\left(1 - \frac{R_1}{R_{10}}\right) km$$

where R_{10} is the loop resistance *a-c* measured *before* the short circuiting of the manometer.

When O is in position 2, R_3 is adjusted so as to rebalance the bridge without touching R_1. At the balance position, we have then the relation:

$$R_1 = R_3 + 2 \cdot r \cdot x$$

which gives immediately:

$$x = \frac{R_1 - R_3}{2 \cdot r} = l \cdot \frac{R_1 - R_3}{R_{10}} km$$

After the adjustments of R_1 and R_3 as above, a recording is made of the current in the diagonal of the bridge with the aid of a recording moving coil galvanometer. Any variation of the distance y will be recorded with O in the position 1-2, while variations of the distance x are recorded in position 3.

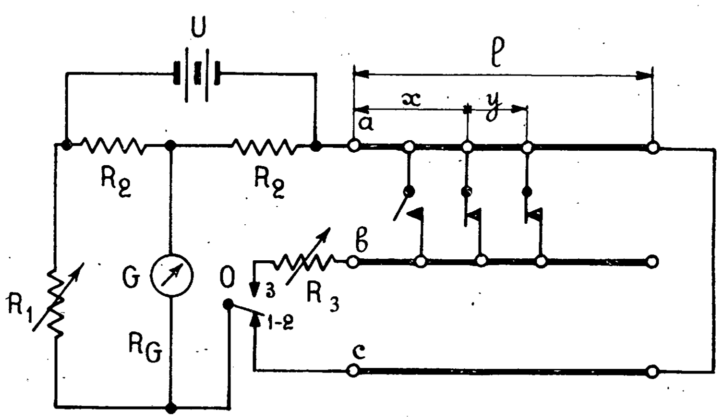


Figure 2

Diagram showing the principle of observation by a recording galvanometer

In this way, the curves traced giving the current in the diagonal of the bridge as a function of time allow the determination of the position of the following manometer whose contacts close; the instants in which the short circuits occur can serve as a basis for an evaluation of the importance of the fault. It can be seen from Figure 2 that equal variations of x and y (in km) will involve resistance variations four times greater in position 3 than in position 1-2. To obtain the same current in the diagonal of the bridge for equal variations of x and y the galvanometer sensitivity can be reduced to a quarter, when the switch is in position 3.

In practice the values used are: R_1 approximately equal to 6000 ohms and R_2 equal to 2000 ohms. The galvanometer has a sensitivity of $\pm$ 25 μA and an internal resistance R_G = 300 ohms. With a battery voltage U of 45 volts, a "sensitivity" of 1.8 μA per 300 metres or about 6 μA per km is obtained.

4. *Conclusion.*

A precise localisation of the position of the fault, in the preceding conditions, is possible especially where serious faults are concerned. In such a case the simple indication of the manometers will often permit the finding of the fault. In other cases use is made of a radioactive tracer gas for an exact localisation of the fault, the tracer gas being injected at the joint suspected as being the nearest to the location of the fault.

The same procedure is used where faults are so small that their determination with the aid of manometers would be uncertain. In this case, the manometers only indicate a faulty region in a pressure section which is sufficient, however, to serve as a starting point for the localisation of faults by radioactive tracer gas.

D. Information supplied by the French Telephone Administration in 1954

1. *General.*

The French Telephone Administration has developed during the construction of its 400 km network of coaxial cables, a system of maintenance under pneumatic pressure which is at present largely completed and functions effectively.

The aims sought were the following:

a) Protection of the cable against entry of water and more particularly dampness.

b) Operation of an alarm in the case of gas leakage.

c) Automatic localisation of a fault between points regularly distributed along the line.

Moreover studies permitted the determination of the characteristics that the installation should possess to ensure protection of the cable pending the arrival of a repair team within a period considered normal after the operation of the alarm.

The method chosen is that of the permanent maintenance of gas pressure in the cable. This can only be applied under the correct conditions on a cable that is perfectly gas tight in every respect. The duration of the protection, which a given installation will provide, is however, a function of the dimensions of the sheath fault, of its position with respect to the supply apparatus for the compressed gas and of the maintenance pressure.

The faults against which the characteristics of the installation allow provision in a satisfactory manner correspond to faults equivalent to a circular hole of 5 mm in diameter. Arrangements have been made for a surpressure of 100 gF/cm² for the possible case where, for example, the presence of a 1 metre head of water would require it.

2. *Pneumatic pressure and separation of the groups of compressed gas units.*

With these considerations and the pneumatic transmission characteristics of the French four pair coaxial cable, the pneumatic maintenance pressure was first fixed at 800 gF/cm² and was lowered to 650 gF/cm². To this pressure, corresponds a maximum separation of supply units of about 36 km.

3. *Composition of the supply units.*

The volume of the French four pair coaxial cable is from 500 to 550 litres per kilometre.

The permanent supply units for the compressed gas are of two kinds:

a) Groups of cylinders of compressed gas (nitrogen) at 150 kgF/cm² with reducing valves and safety appliances. These groups are installed in intermediate unattended stations.

b) Electric air compressor units. These are installed in attended repeater stations. They are fitted with drying apparatus and consequently force dry air into the cable.

The groups of cylinders consist of four cylinders each containing 4 m³ which are put into service in succession.

The compressor units are capable of delivering 1000 litres of air per hour.

The two systems include a pressure regulator permitting the adjustment of the nominal supply pressure to the nominal value of between approximately 500 gF/cm² and 1000 gF/cm². The variation with respect to the nominal pressure is 40 gF/cm².

4. *Alarm arrangements.*

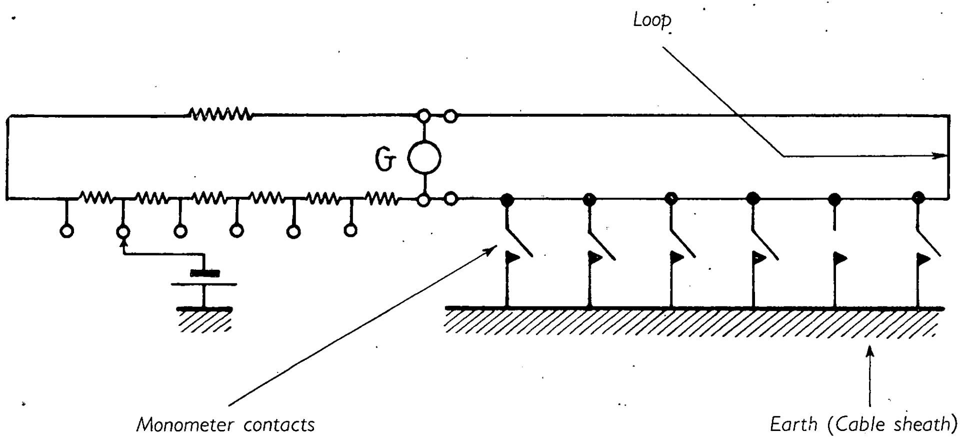
The supervision of the state of pressure in the cable is insured by means of manometers placed in small columns, buried under the protection of a small concrete shelter and fixed on the jointing sleeves.

The manometers are placed at 1830 metre intervals. They are composed of a barometric chamber whose movements operate a microswitch and devices for adjustment and control. For a working pressure of 650 gF/cm² in the cable the operational pressure is adjusted to 500 gF/cm²; the pressure of restoration is 580 gF/cm². In the field, the regulation of the apparatus is adjusted in such a way as to have the same working margin for all the apparatus of a section of localisation of approximately 30 km. The limits of operation after adjustment are $\pm$ 10 gF/cm².

The microswitch connects one wire of the pair used for supervision and localisation to earth.

5. *Operation of the alarm and localisation between stations.*

The manometers are in groups of 20 or 30 on a supervisory pair known as the localisation loop of which the origin is at an attended repeater station. This loop is inserted in a Wheatstone's bridge, of which the circuit is given below and which finds automatically its balance point in the case of the first earthing of one of the manometers.



The alarm is given at this instant and is recorded by the apparatus. The propagation of the reduction in pressure causes the operation of the second manometer beyond or nearer the first. The modification of the balance of the bridge which results from this causes a new recording with a lamp indication. Assuming a regular propagation and a high stability in the setting of the manometers, the fault can be considered as being included within a half interval (915 metres) by these indications.

6. *Localisation in the field.*

With a view to the future and to facilitate localisation in the field by some procedure (diagrams, pressure distance, injection of radioactive gas or of tracer gas) or even to facilitate the checking of the pneumatic state of the cable, pressure outlets under covers have been situated every 460 metres; these outlets comprise a valve beneath a soldered cap.

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Note.—The characteristics defined in the documents referred to above are the characteristics of prototype installations. They differ on certain points from the characteristics described in this note, in particular the maintenance pressure has been lowered on two occasions.

2. USE OF TRACER GAS FOR THE LOCALISATION OF FAULTS

A. Information supplied by the Danish Telephone Administration in 1953

Use is made of a radioactive tracer gas to localise precisely a fault on a telecommunication cable under gas pressure. The method consists in using the leakage of the gas itself (air or nitrogen) to indicate the position of the fault. For that it is necessary that this gas be marked in a way which renders it easy to distinguish from any other sort of gas found in the neighbourhood of the cable.

The localisation of faults is carried out according to the following plan: the approximate situation of the fault is determined by measurements to the first manometer(s) to close (see above paragraph 1 *c.* "Use of gas under pressure in cables". Information communicated by the Danish Telephone Administration), assuming that the cable section had been under normal working pressure before the fault occurred. At the two ends of the cable section, the pressure is then established and this pressure is maintained constant for a sufficient time as to form a steady flow of gas in the cable. At the end assumed to be the nearest to the point of the fault, a radioactive gas is introduced which is carried through the cable by the flow of gas. The radioactive gas is searched for with an appropriate apparatus (Geiger-Muller counter), until the point of the fault is found where the gas escapes from the cable with the air. Below are given some remarks of the different aspects of the method.

With the object of rapid and certain fault localisation it is desirable that the radioactive gas reaches the point of the fault as quickly as possible; but it must also be assured that it does not go past the fault point. These two conditions are best fulfilled when a steady flow of gas is formed in the cable. (By a steady flow of gas is meant a state where currents of air of constant speed are coming from the two ends of the cable section, and are directed towards the point of the fault). The steady state is obtained by maintaining a constant pressure and having the same value at both ends of the cable section over a reasonable time. The speed of gas flow will then be determined by the pressure maintained at the ends, by the position of the fault point, by the magnitude of the fault and the pneumatic constants of the cable. The time necessary to obtain the steady state of flow will depend in the same way on the constants which have just been mentioned. The flow of gas in the cable is determined by the rate of admission of air at both ends, and once this admission has become constant, a state of equilibrium is established. As has already been mentioned, the time of establishment of this state depends on the cable and the nature of the fault. In a certain number of cases, the time for the establishment of equilibrium has been of the order of 48 hours in the coaxial cable in question.

The injection of a radioactive gas in the cable can be made in various ways. For the measurements, a method has been successfully employed which comprises the introduction into the cable of a small quantity of radium emanation at the same time as the air serving to maintain the steady gas flow within the cable.

Radio emanation (also called niton) is the first disintegration product given by radium and exists as a gas. Niton is radioactive with a half-life period T = 96 hours approximately which is to say that by the end of this time, half of the substance is transformed. The disintegration products of niton, called the descendants, have a very short half-life period and give a rather strong radiation. As can be seen it is exactly these descendants which are used when localising faults.

The quantity of niton, necessary for fault location, depends on the test conditions and is chosen in taking these into account. For the measurements carried out up till now, quantities of niton have been used of between 5 and 20 millicurie (1 curie = 0.62 mm^3 of niton). With appropriate handling, such minute quantities of niton are harmless and, in most cases, they could be obtained as surplus products from existing sources of niton.

Niton is often obtained in small glass ampoules, and the injection into the cable can be made by breaking the ampoule in an air current. The ampoule is broken immediately at the entry of the cable so that the whole of the niton is carried into the cable by the gas flow. The speed of displacement of the radioactive gas will be equal to the speed of the air flow within the cable, and at the beginning the whole of the niton will proceed as a sort of "air plug".

With the object of finding the faults, it is necessary to know the speed of displacement within the cable, of the niton "plug". This speed is, as has been mentioned, equal to the rate of flow and can be determined by direct measurements, by establishing the time of arrival of the "plug" of niton at two points of the cable. When the distance between these two points is known, the speed can be calculated. This determination of the speed can be made for example at 50 or 100 metres from the injection end. It should be pointed out that for the measurement, use is not made of the niton "plug" itself, but that of the descendants deposited in the cable. As the quantity of niton and that of the descendants resulting from it, is very small, the radiation will not be noticeable through the covering of earth, about 80 cm thick, which is above the cable. In consequence a part of the earth must be removed above the cable in order to allow the Geiger counter to be lowered close to the cable.

From the measurement of the speed of displacement, and supposing that the state of steady gas flow be maintained in the cable, it is possible to calculate beforehand the times of the presence of the descendants at predetermined points in the cable section. In particular it can be determined at what moment the "plug" of emanation will arrive in the region of the fault. It is advisable, to this end, to repeat the measurement of the speed of displacement as the "plug" travels down the cable. It is easy to arrange this measurement by digging test holes at adequate intervals at which the time of arrival will be determined.

If the speed of the gas flow in the cable is constant, the absence of the "plug" at a fixed control point will indicate that the point of the fault is to be found between the check point and the last of those where the time of arrival has been checked. This is because the niton plug escapes at the same time as the air in the cable at the fault position. During its journey through the earth, the quantity of niton will leave descendants as was the case in the cable, and there will be descendants up to the surface of the soil near the position of the fault. The radiation will be perceptible without it being necessary to dig right down to the cable: all the measurements carried out have confirmed this fact. Search for the fault will be made by carrying the measuring apparatus along the cable, between the last checking point where the passage of the "plug" has been definitely noted, and the checking point where the plug has not arrived at the time calculated; one must continue until the point is discovered where the radiation is strongest. The cable fault must be situated near this spot, and in practice, it has been possible to indicate the position of the fault within a limit of 1 metre. By examining the soil, a more precise location of the position of the fault may be determined, considering that radiation in the soil will be greatest in proximity to the fault.

The time required for the actual location of the fault will depend, as has been mentioned, on the speed of passage of the gas within the cable. An upper limit for the pressure in the cable is fixed by the manometers used: the speed of passage and in consequence the time required for the location of the fault will depend in practice on the situation and the size of the fault and at the same time on the pneumatic constants of the cable considered. The measurements and the locations of faults carried out have all been made on the same type of cable (4 pair coaxial cables 2.6/9.5 mm and 5 service quads paper insulated 0.9 mm) but have been carried out under very different conditions. It has been possible to locate some faults in a few hours, while several days and nights have been required for the location of other faults. As the operation of the cable is not interrupted during the location of these faults, and as the apparatus used can be left unattended (with however a certain amount of supervision) the time of location does not play so important a part as in the case of other methods of fault location. However, it is necessary, as already mentioned, to check at suitable intervals the speed of displacement of the niton "plug", the intervals being chosen in taking account of the rate of flow of gas in the cable.

Atmospheric and soil conditions have no appreciable influence on the location of faults; this fact has been proved by measurements carried out in conditions of weather and soil which differed greatly, for which the exactness of the method was in every case found to be of the order of accuracy mentioned above.

As has been seen, it is necessary for the location of faults, to have equipment for the introduction of gas and for the measurement of the resulting pressures, a gas flow indicator, and of course, an apparatus to ascertain the radioactivity. Regarding the first mentioned equipment great precision and high stability are required, since it is necessary to maintain a steady gas flow for a long time. For the measurement of the radioactive radiation, a very sensitive Geiger counter is used, because of the small quantity of radioactivity present. The apparatus is designed so as to permit a reading of the radiation intensity on an instrument connected to the Geiger counter by a wire approximately 25 metres long. This arrangement considerably facilitates the location of faults, for the apparatus is used during the search by two men, one carrying the Geiger counter along the cable route and the other watching the instrument.

Cable faults which have been located with the aid of this method have been of a very different nature. By way of example, can be mentioned flaws in the lead sheath, scores, imperfect plumbing and holes due to the iron armouring. In most cases, it has been possible to determine the exact position of the fault before exposing the cable; for example, it has been possible to predict in which end of a sleeve, 80 cm long, the fault is to be found. Despite the possibly prolonged time taken for fault location, this method must be considered particularly economic for locating faults because of the relative small amount of digging and reinstatement and the small number of staff required.

B. Information supplied by the American Telephone and Telegraph Company in 1953

The American Telephone and Telegraph Company has developed a method for the detection of faults in the sheaths of *aerial cables* by means of a gas derived from one of the halogen compounds. An apparatus devised to collect the gas and fitted with a detector sensitive to halogen gas is drawn along the cable and detects any gas leakage through fissures in the sheath.

The sensitive element in this gas detecting apparatus is a halogen gas detector developed by the General Electric Company for the location of faults in domestic refrigerators. The element operates on the following principle: an incandescent electrode normally emits positive ions: if a compound including a halogen element (chlorine, fluorine, bromine or iodine) strikes the incandescent electrode, the emission of positive ions increases to a marked degree. The element consists essentially of two coaxial platinum cylinders, the interior cylinder being heated to incandescence by indirect heating. Platinum is used for the electrodes to allow operation in air at the temperature required, without appreciable oxidation. By maintaining the exterior cylinder at a potential 300 V below that of the interior cylinder the emitted ions are collected which gives an ionic current: any compound containing halogen touching the inner cylinder cause an increase in the ionic current. This element is particularly sensitive to the gas freon 12 (CCl_2F_2), a normal refrigerator gas which is inert and non-toxic at normal temperatures. It was therefore logically concluded that, if a telephone cable could be filled with this non-toxic gas under pressure, the sensitive detector could be used to locate the leakages of gas.

More detailed information on this procedure appears in No. 9 of the "Bell Laboratories Record" (September 1952).

3. ARRANGEMENTS FOR CONTINUOUS VERIFICATION OF INSULATION

A. Arrangements used by the Danish Telephone Administration

At the top of Figure 1 is shown an arrangement for supplying up to four actual insulation indicators.

Each of the four indicators, one of which is shown in Figure 1, consists of an electronic valve with the screen grid supplied directly at 130 volts a.c. and of which the anode is also supplied at 130 volts a.c. through a relay A. The cathode is negatively polarised (at a potential of—50 volts approx. with respect to earth). If the insulation resistance between the two conductors *a* and *b* under test and earth is high with respect to the resistor R, the grid of the valve will be at a potential of —100 volts approx. with respect to the earth and therefore —50 volts approx. with respect to the cathode. With this high negative bias voltage, the anode current of the valve is cut off, and for good normal insulation of the conductors, the armature of relay A will not therefore be attracted.

If the insulation of the conductors deteriorates, the grid bias of the valve becomes less negative and when the insulation resistance approaches that of the resistor R, the anode current of the valve will cause relay A to operate. If the relay operates a little "too soon", that is to say, for a conductor insulation resistance a little greater than R, the value of the 0.5 megohm resistor, which forms part of the potentiometer to which is applied the continuous voltage of 100 volts, can be reduced to a certain extent (for example a resistor of 2 megohms can be connected in parallel with the resistor of 0.5 megohms). Thus the indicator can be adjusted once and for all, with reasonable accuracy to give a warning when the insulation resistance falls to a predetermined value. A limiting resistance of 0.1 megohm in the grid circuit ensures that the anode and screen grid currents do not exceed a certain value (in the valve EL3 the anode current does not exceed 18 milliamps approx.; the relay operates with 5 milliamps approx.), even if the conductors *a* and *b* are connected directly to earth. A grid filter formed by a 0.5 megohm resistor and a 0.1 microfarad capacitor ensures that alternating voltage present possibly on the conductors do not cause false alarms. The 16 microfarads electrolytic condenser connected across relay A smooths the current in the relay in the case of alarms due to defective insulation.

A particular point of this arrangement is that non-rectified alternating voltages are applied to the screen grid and anode. Thus by taking advantage of the self-rectifying property of the valve the cost of providing a special anodic rectifier is avoided. The load on the grid voltage rectifier is extremely small, and consequently a rectifier for a very small current can be used. In the case of failure of the grid voltage rectifier, the relay A gives a warning. The heater current is controlled by relay B which supervises the valves of four insulation indicators, the heaters of these being connected in series. As anode current flows in the indicator valves only when there are insulation faults, they can maintain their electronic emission for a prolonged period. The anode current can be controlled by suitable by-pass resistors, as can the voltage produced by the grid voltage rectifier, with the aid of a milliammeter and additional resistance boxes designed for this purpose.

The indicator can be adjusted to operate for different insulation resistances by replacing the resistor R. Suitable values for R are 100 megohms and below. Two or more indicators can be connected to different pairs of conductors in the same cable, these indicators watching the insulation resistance in such a way that warning is given in good time at the first appearance of a fault and of the speed of growth of the fault.

As shown in Figure 1, conductors *a* and *b* can be used in the normal manner for telephone working. The phantom circuit could also be utilized, provided that it is connected to the station by a normal line transformer. However, the conductors of telephone circuits which are more or less connected to earth cannot be used as control conductors.

B. Arrangements used in the U.S.A. by the American Telephone and Telegraph Co.

The alarm system relying upon the use of gas pressure described in 1 above gives a permanent test of conditions likely to worsen the insulation of cables, so that it is not deemed necessary in the U.S.A. to use, in trunk cables, equipment to give an alarm when the insulation resistance of a cable pair has become too low. However on local cable (exchange plant) such equipment is used and a brief description follows.

a) This equipment consists essentially of a relay, the winding of which is connected to one end of one or several spare cable conductors (pilot wires) and at the other end through an adjustable network formed of resistors to a battery connected to earth. The relay operates when the current through it reaches a certain value (predetermined according to the particular value of insulation for which an alarm is required): this relay in turn operates a system of relays to give an alarm signal at the place where it is required. In the case of small cables, this arrangement is permanently connected to the pilot wires, which vary in number from one to eight. In the case of more important installations, the device is automatically connected in turn to a certain number of groups, each consisting of from one to eight pilot wires each of these groups being tested at approximately ten minute intervals.

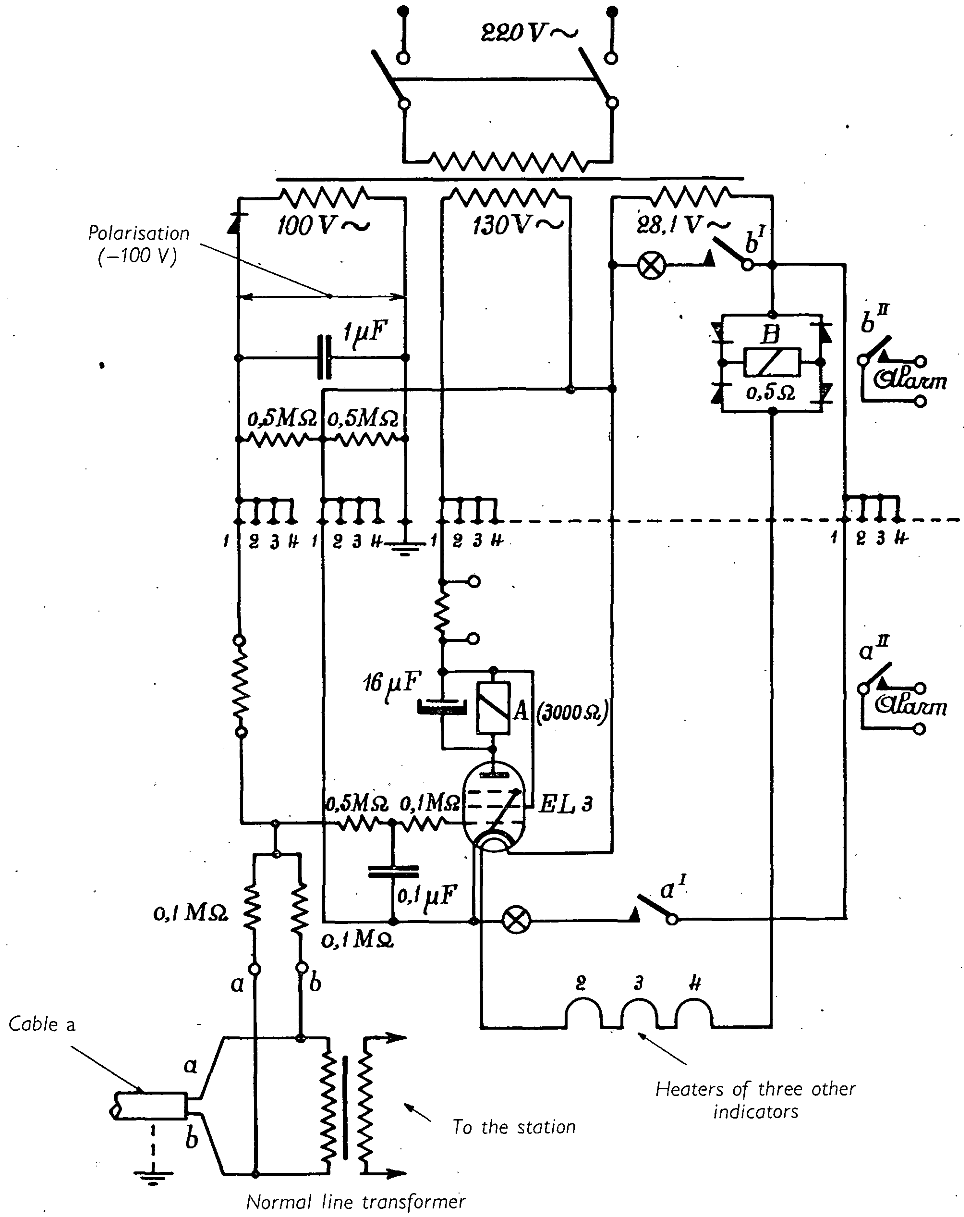

Figure 1

Arrangements for continuous verification of insulation used in Denmark *b)* An arrangement employing a gas filled valve, operated as a detector by the cathode (which functions when the insulation resistance falls to a certain value) which serves to test the subscriber's lines, particularly from the point of view of low insulation in damp weather. This is not an arrangement for the continuous verification of insulation, but rather an arrangement which facilitates the rapid testing of the subscribers' lines connected to a given exchange. Unlike the equipment for the continuous verification of insulation described in *a)* above, this test apparatus is applied to working lines, in damp weather, but the apparatus is arranged to make an engaged test and pass over all the lines found to be engaged.

C. Arrangements used by the French Telephone Administration in the trunk cable network

This equipment is arranged to give an audible and visual alarm when the insulation falls below a fixed value.

It consists essentially (see Fig. 2) of a potentiometer 1 supplied by the high tension battery of the station, the adjustable contact of which enables a voltage to be connected to the cable 2 via the centre points of the line side of the transformers, as with phantom circuits or other similar arrangements.

The voltage is applied to the cable through an adjustable resistor 3 of 1 to 10 megohms. The leakage currents of the cable cause a voltage drop in resistor 3

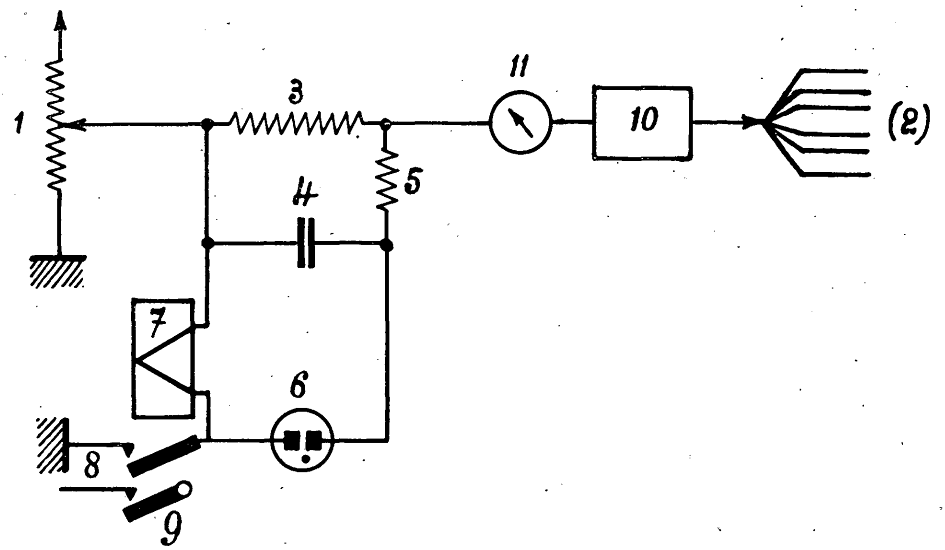

Figure 2

Arrangement for continuous verification of insulation used in France which is applied to the capacitor 4 in series with resistor 5, the object of which is to make variable the time constant of the arrangement.

Finally relay 7 and a discharge tube are placed in series across the capacitor. The relay is provided with a holding contact, the other contacts operate various signals.

The operation is as follows: When the insulation of the cable is in good condition, the voltage which appears at the terminals of the condenser 4 is less than the operating voltage of the discharge tube.

If the insulation of the cable deteriorates the current through 3 increases and also the voltage at the terminals 4. If this voltage becomes greater than the breakdown voltage of the discharge tube, this operates, and condenser 4 discharges through relay 7, which operates, and holds giving an alarm signal.

A filter 10 reduces the interference due to induced voltages, while an indicator 11 shows the permanent current in the cable and therefore gives a measure of its insulation.

D. Arrangements used by the British Telephone Administration

At the present time in Great Britain the insulation resistance of cables is kept under review mainly by manual routine testing of selected pairs, the frequency of such testing depending in each particular case upon the class of cable concerned and whether or not it is terminated at attended or unattended stations. In only a few instances is cable insulation kept under review by automatic means.

Cable fault statistics prepared for the inland trunk cable network show that of the total cable sheath faults the percentage which escape detection by engineering means and which cause dislocation to traffic is, in general, rather high, especially where manual routine testing is not more frequent than once per week. Consideration is therefore being given to the more extended use of automatic "cable watchers". Brief details of cable watchers which have been used on a limited experimental basis are given below.

For cable watchers to be really beneficial it is considered that they should test as much of the cross-sectional area of a cable as possible, and at any rate at least 10% of this area. Although every effort would be made to test on phantom and double phantom circuits, the use of watchers would probably mean that direct-current signalling would not be possible on circuits associated with 10% of the pairs in a cable.

Cable Insulation Watcher Used on Coaxial Cables.

a) An insulation watcher is used to monitor the insulation of composite coaxial cables and is connected to one of the paper insulated control pairs at the controlling terminal station.

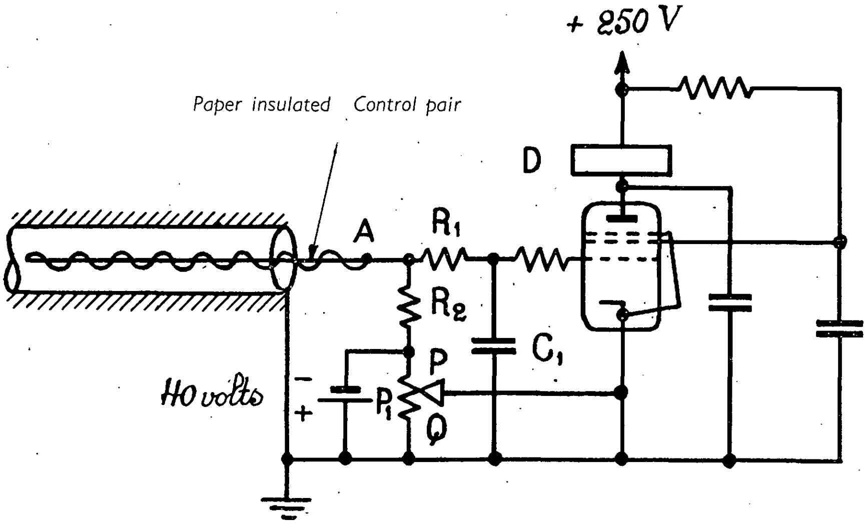

Figure 3

Arrangement for continuous verification of insulation used in the United Kingdom on coaxial Cables

The operation of this arrangement can be seen from Figure 3. With the cable pair connected at point A, the potentiometer P_1 is adjusted so that the negative bias voltage due to the current in the section P of the potentiometer reduces the anode current of the valve to a very low value. When the insulation resistance of the cable decreases, the leakage current which flows in the resistor R_2 which is of high value, produces a positive bias which opposes the previously mentioned negative bias, and if the insulation resistance falls to approx. 50 megohms the resultant bias applied to the grid of the valve will permit sufficient anode current to flow to operate relay D and give the alarm.

The apparatus is adjusted to operate with an insulation resistance of 50 megohms, and give the alarm; an insulation resistance of 100 megohms will not cause the alarm to operate.

The resistor R_1 and the capacitor C_1 constitute a delay circuit having a time constant of approx. 2 minutes, which reduces the effect of induction.

This equipment in itself is satisfactory for the continuous verification of insulation but if it is applied to a pair in a very long cable, the normal insulation resistance of the pair is unfortunately so low that it masks the initial phases of the appearance of a fault.

b) More recent apparatus was developed in 1953 and is being installed in repeater stations. This apparatus is described in detail in the *Post Office Electrical Engineer's Journal*, Volume 46, Part 1, Pages 13 to 15 (April 1953).

This fault indicator which is connected to the interstice pairs of a coaxial pair cable consists of a Wheatstone Bridge connected as shown in Figure 4.

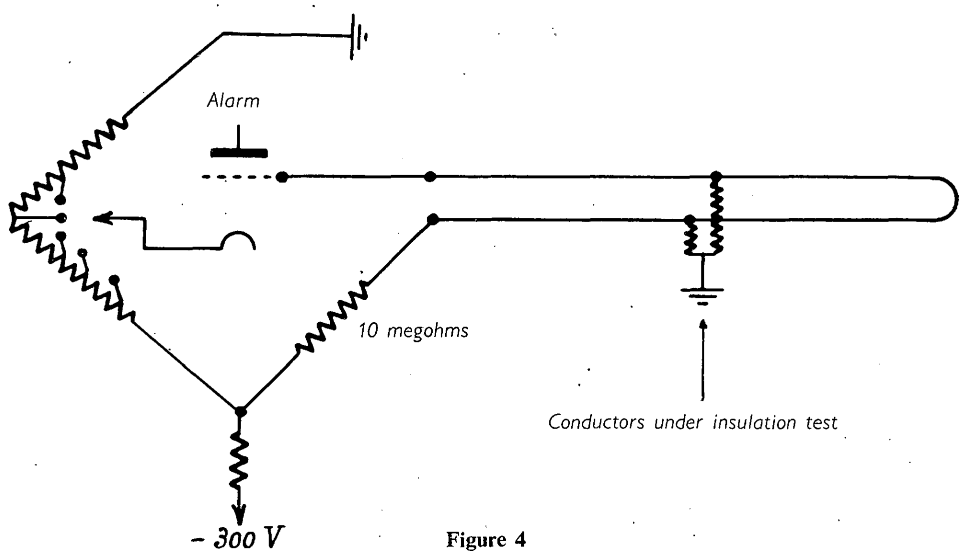

Figure 4

The essential characteristics of the tester, which is mains operated, are as follows:

1. The bridge is normally unbalanced and a negative potential is applied to the grid of the detector valve, thus preventing the operation of the alarm. When on the other hand the insulation resistance of the conductors connected to the tester falls to a low value, the bridge tends to become balanced and, when a sufficient balance has been maintained for 10 minutes, an alarm is operated.

2. By the use of this testing method, the insulation resistance of a length of wire (single conductor) up to 150 miles (approximately 270 km) can be verified. The alarm can be adjusted to operate:

a) when the insulation resistance of the whole falls to 250 megohms.

b) when the insulation resistance falls to half of its normal value.

3. If the conductors joined to the tester are accidentally cut, the voltage on the grid tends to rise to earth potential and the alarm is operated.

4. By adjusting the values of the arms of the bridge, the effective insulation resistance of the conductors joined to the tester can be measured when required.

5. The period of 10 minutes before the alarm is operated prevents the untimely operation which would result, for example, from momentary disconnections due to personnel working on the pairs of the cable etc.

6. Accidental contacts with the conductor joined to the tester are not dangerous as the current is limited by the 10 megohm resistor and the energy of the charge on the cable-pair is not very great.

7. The tester includes a two-stage direct current amplifier with feed-back and the operation of the tester is only slightly affected by fluctuations in the mains voltage.

E. Arrangements for permanent verification of insulation used by the Swedish Telephone Administration

To verify the insulation of cable conductors, both manual and automatic methods are used in Sweden. A description of these methods follows.

Manual supervision of insulation.—Initially only simple arrangements were used as shown in Figure 5 below. Because of the presence of interference in the cables, it is however, often difficult to obtain by this method reliable readings in a reasonable time. Even when using relatively insensitive needle-pointer type galvanometers for maintenance measurements on long distance cables, the interference was inconvenient. It even came to the position where it was necessary to effect measurements during the night in a repeater station in proximity to which strong stray currents arising from tramway systems were flowing towards the cable sheath.

In the case where insulation measurements necessitated the use of reflecting instruments using a beam of light as a pointer, it was necessary to reduce the influence of the disturbances on the measurements. An arrangement meeting this require-

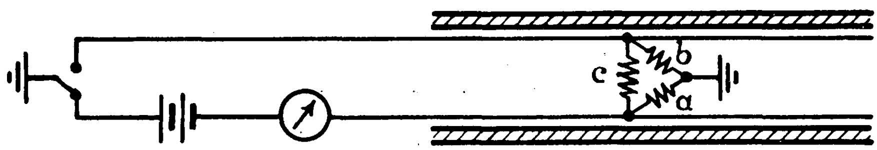

Figure 5

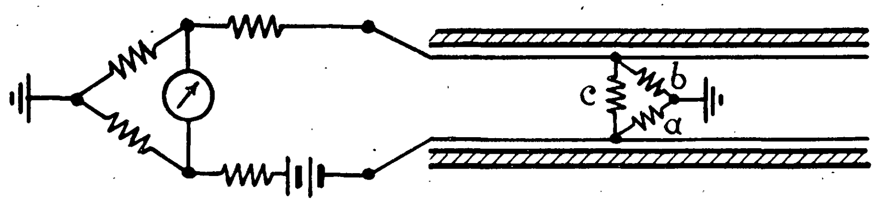

Figure 6

ment has been described by S. Janson; and is shown in Figure 6. In the case which arises in practice where insulation resistances are high with respect to the inserted resistances, the ratio between the testing voltage and the current in the galvanometer is: $2\,ac/\,(2\,a + c)$, if the testing battery is assumed to be inserted in the branch a (as shown in Figure 6).

The expression obtained does not contain the insulation resistance b of the wire b. As, in practice, c is generally much greater than a and b, the above expression simplifies and becomes equal to $2\,a$. If therefore the testing voltage is divided by twice the deflection of the galvanometer, the same value is obtained for the insulation of the wire a as would be given by the method shown in Figure 5. This is sufficiently exact in practical cases, where only the order of the insulation resistances are of interest.

Actually the general trend is to replace by electronic valve arrangements, the highly sensitive galvanometers always used previously for important measurements of insulation on telephone cables. Figure 7 shows one of the electronic valve arrangements used in Sweden, in which, as can be seen, the effect of interference is eliminated. This arrangement, together with the measuring instruments, are the result of collaboration between The Swedish Telephone Administration and Svenska Elektriska A. B. Philips.

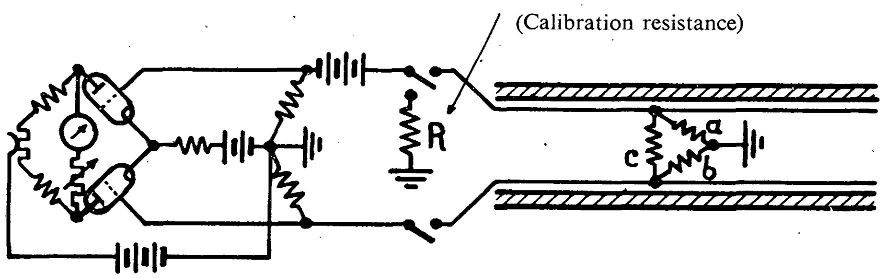

Figure 7

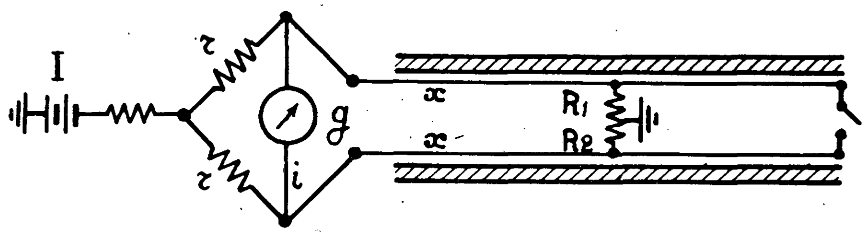

Figure 8

Finally, it is desirable to mention that an arrangement described by W. Hector (Figure 8) can be used with certainty for the subjective verification of insulation after experience has been gained with the method. This method of measurement is based on the hypothesis that the ratio between the fault resistances of the two wires of a telephone cable pair damaged by moisture diverges more from the value of 1 as the insulation of the pair decreases, provided that the insulation resistance is still of the order of one megohm or more.

The principle of this measurement is as follows:

Let R_1 be the insulation resistance, at the point of fault, between wire 1 of a pair and earth,

R_2 the insulation resistance at the same point between wire 2 of the same pair and earth,

x the resistance of each of the wires, between the connection point to the bridge and the point of fault,

r the resistance of the arms of the bridge,

g the resistance of the galvanometer,

I the total current entering the bridge,

i the current in the galvanometer.

Then we have rigorously:

$$i = I \frac{(R_2 + x)\, r - (R_1 + x)\, r}{2r\,(R_1 + R_2 + 2x) + g\,(R_1 + R_2 + 2r + 2x)}$$

As $2\,r$ and $2\,x$ are very small with respect to R_1 and R_2 this simplifies to

$$i \approx I \frac{r}{2r + g} \cdot \frac{R_2 - R_1}{R_2 + R_1}$$

On the other hand, it can be noted that, when the same source is used, the value of the total current I is determined by the resistance

$$\frac{R_1\, R_2}{R_1 + R_2}$$

made up of R_1 and R_2 in parallel, for the resistances of the other elements are very small with respect to those of the insulation faults.

If the deflection of the galvanometer g shows a value of i different from zero, then the insulation of the pair of conductors concerned has decreased.

The arrangement for eliminating disturbances is not only applicable for testing, by Hector's method, the insulation of cables, but it even enables deterioration caused by moisture to be discovered, even if the fault resistance is appreciably greater than the insulation of the cable when in good working condition.

Automatic supervision of insulation.—Supervision is effected with the help of insulation indicators containing glow discharge lamps or electronic tubes. In both cases the indicator is connected to one end of the spare wires in the cable or to superphantom circuits, when there are no spares in the cable. With large installations each indicator is tested daily at a certain time unknown to the station personnel where the indicator is installed. A neighbouring station simultaneously inserts a resistance between the earth and the conductors of the cable connected to the indicator. During the last few years, the construction of the indicators has been improved so as to render them less sensitive to interference.

4. PROTECTIVE MEASURES AGAINST LIGHTNING

The measures to be taken for the protection of telecommunication cables against lightning are summarised below.

In certain countries the damage caused by lightning is a very important source of faults in underground trunk cables. Lightning also causes damage to overhead trunk cables but in this case it is much easier to locate and repair the faults than in the case of underground cables.

The damage resulting from lightning striking the cables or their vicinity comprises:

1. Perforations of the sheath, a single lightning discharge being liable to cause several faults spread over a considerable distance along the cable (several kilometres);

2. Denting of the sheath which, in the case of coaxial pair cables, causes deformation of these pairs and consequently local changes in the characteristic impedance, resulting in transmission defects whose influence is particularly noticeable when these pairs are used to form television circuits. Such faults may render the affected pair unsuitable for television transmission;

3. Breaks or short circuits in the conductors and deterioration of the insulation, due to the production of electric arcs in the interior of the sheath.

The gravity of this damage justifies an extensive study of the precautions to be taken for the laying of cables in regions exposed to lightning, particularly in the case of underground cables when the soil is of high resistivity. In the present state of the research the following indications may be helpful.

I. Choice of the cable route

It would be desirable:

a) to request from the meteorological services all the information that they can supply on the number of stormy days per year (isokeraunic curves) and on the average number of lightning discharges for each stormy day, in the region concerned;

b) to consult studies which have been made on regions specially liable to lightning, the conditions of this liability seeming to depend on discontinuities of the geological composition of the ground as well as on the ionisation of the air;

c) to record, during the usual field studies before the laying of trunk cables, the geological composition of the ground and its resistivity, studying particularly this resistivity at various depths;

d) to avoid as much as possible, in the choice of the route and during the laying of the cable, the immediate proximity of trees, stays, pylons and other metallic bodies.

II. Construction of the cable

a) The breakdown voltage of the insulation between the core and the sheath should be increased. As an indication, it seems that in certain cases, for land cables, satisfactory results have been obtained when the breakdown voltages of the insulation correspond to a test voltage equal to or greater than 2500 volts. For cable sections laid in situations where the execution of repairs would be difficult (river crossings, swamps, bridges, places difficult of access, etc...) it is advisable to use an insulation of greater dielectric strength so that faults are not produced in these sections, but rather in other parts of the cable. It should be pointed out, however, that this arrangement does not always constitute complete protection.

Attention should be paid to special points such as joints, connexions, etc... so that the dielectric strength (breakdown resistance) is just as good as that of the rest of the line.

b) In the case of armoured cables, whether or not aerial or underground cables are concerned, there is an advantage in obtaining by a suitable construction of the sheath and its armouring, as low a value as possible for the high frequency reduction factor. In this respect, favourable results have been obtained in certain countries by using, in addition to tape armouring, an armouring of close wound heavy wires.

c) With the object of avoiding the effects of denting of the sheaths of cables armoured with tape, it is recommended that there be a continuous connexion between the armour and the sheath, or at least a number of connexions closer together than is usual for cables that are not exposed to lightning.

III. Special protective measures applying to underground cables

a) the protection factor of the cable can be increased, for example, by the following methods which have already been applied in certain countries:

—increasing the longitudinal conductivity of the sheath by the use of bare wires placed under the sheath and in contact with it and by the exclusion of insulating gaps;

—division of the current, due to a discharge of lightning, between the sheath and screening wires buried parallel to the cable and at a suitable level above it.

These screening wires must not be connected to the sheath of the cable or its armouring. Furthermore the sheath of the cable thus protected must not be connected to the earthing points.

If several screening wires are used, they should so be laid that, under the electrodynamic action of the lightning currents passing through them, they cannot approach one another.

It should also be pointed out that the screening wires may be cut or interrupted over considerable lengths when they have been subjected to a lightning discharge: it is therefore useful to make provision for a periodical check of their good working order.

It should also be observed that, with regard to the composition of the screening wires, copper is expensive and aluminium is liable to corrode in the soil.

b) the use, in various countries, of metallic sheathed cables covered with a thick layer of insulating material of great dielectric strength, notably rubber, has sometimes given satisfactory results. However, it is not certain that this protection is sufficient in all cases.

c) There is advantage in laying the cable at a sufficient depth.

IV. Special protective measures applying to aerial cables

It is recommended that on each pole a vertical earth wire be placed connecting the aerial cable to earth, and interrupted by an electric discharge tube or arrestor, in order to protect the pole and to reduce the circulation of electric currents along the cable.

In the case of lead-sheathed self-supporting cables, there can be advantage in making in addition, along the whole length of the cable, low resistance connections between the sheath and armouring.

V. Conclusions

Within permissible economic limits, none of the methods listed above affords complete immunity from damage caused by lightning in the case of particularly exposed cables.

Nevertheless, although the use of the above mentioned special protective measures in these cases involves considerable complications, these can be largely justified in the case of important cables, particularly coaxial pair cables.

Note.—Useful information is given in an article "Lightning protection of buried telephone toll cables" by E.D. Sunde (Monograph E 1396 of the *Bell Telephone System Technical Publications* published in Volume 24, April 1945 of the *Bell System Technical Journal*).

5. PROTECTIVE MEASURES AGAINST EXPLOSIVE GASES AND TOXIC GASES WHICH MAY BE ENCOUNTERED IN CABLE CHAMBERS FOR TELECOMMUNICATION CABLES

A. Tests for recognizing the presence of explosive or toxic gases in cable chambers

1. *Explosive and toxic gases*

The gases most frequently encountered in cable chambers fall into two categories, gas or gaseous mixtures which are explosive and toxic gases.

1.1. Gas or gaseous mixtures which are explosive. Amongst these gases, can be quoted the following categories:

a) Natural gas consists of relatively large proportions of methane or ethane or both together, with, in general, small percentages of nitrogen and carbon dioxide. Natural gas is harmless, although if it exists in high proportion in the atmosphere of a chamber, it may produce asphyxia as a result of a lower than normal oxygen concentration.

b) Domestic gas (artificial gas) of which two principal categories can be indicated:

—the older type of domestic gas which came from the distillation of coal or heavy petroleum oils. It contains an important proportion of carbon monoxide which is harmful, with, in general, large percentages of hydrogen and methane. Carbon dioxide, nitrogen and oxygen are only present in relatively small proportions.

—various mixtures the use of which is spreading, for example mixtures of butane and air or mixtures of water vapour, hydrogen and carbon monoxide.

Considering the age of numerous gas mains, the difficulty of rapidly detecting the existence (and rapidly locating the precise position) of a gas leakage, the use at the surface of roads and streets of surfaces of impermeable materials which prevent the diffusion of the gas into the atmosphere through the surface of the road, and finally vibrations produced by the increasing road traffic which causes underneath the road displacements of soil and the formation of pockets where gases can accumulate, it is very important to detect the presence in cable chambers, of gas likely to cause explosions or of toxic gases.

c) Hydrocarbon gases coming from sources other than those mentioned above and certain vapours (slow emissions of methane arising from the decomposition of organic substances in certain soils, leakages of propane or of butane as a result of imperfect sealing of soldering and drying apparatus used in the chambers, petrol vapours arising from leakages in filling stations, etc.).

It should be pointed out that the hydrocarbon gases from various sources are heavy and accumulate at the bottom of cable chambers, while domestic gas of the old type accumulates mainly at the top of the chambers.

1.2. Toxic gases. The one met with the most often in the gaseous mixtures above, and above all in domestic gas, is carbon monoxide (CO).

Finally, mention must be made of the action of carbon dioxide (CO_2) which is found in certain of the above mixtures, in confined atmospheres and which may also result from drying operations: the presence of this gas can render the air unfit to be breathed as a result of the reduction of the concentration of oxygen and consequently may cause asphyxia.

2. *Detection apparatus*

2.1. Workmen are often in the habit of detecting the presence of domestic gas by smell. It should be pointed out in this connection that smell does not always provide information on the presence of gas in the chambers; in addition, this perception varies according to individuals; it must be remembered that certain gases particularly rich in carbon monoxide have no smell. Consequently, it is not enough to be satisfied with the results of such a method.

In this connexion, it is recommended to keep in touch with the gas companies concerned in order to know the characteristics of the gas distributed and possible modifications of its composition.

It is therefore necessary, for the detection of the presence in the chambers of the various gases which may be encountered therein to have detection apparatus. At the present time apparatus does not exist capable of detecting both explosive gases and a small percentage of toxic gases and two types of apparatus must be used.

2.2 The conditions which the apparatus must fulfil are the following:

a) they must detect the gases concerned in an efficient manner;

b) they must be of a robust construction;

c) their price must be moderate;

d) their operation must be easy in order that they may be used by all workmen who, in the cable chambers have to carry out the operations of jointing, soldering, drying, etc...

2.3. Apparatus for the detection of explosive gases.

Two principal types of apparatus are at present used.

a) The explosimeter. Annex 1 gives a description of the apparatus used by the British Telephone Administration *.

b) The osmometer. Annex 2 describes the apparatus used by the French Telephone Administration **.

2.4. Apparatus for the detection of toxic gases (carbon monoxide).

Annex 3 describes the indicator for carbon monoxide using sodium chloropalladite used by the British Telephone Administration ***.

3. *Inspection of cable chambers*

It is desirable that inspection of the state of underground works be systematically organised in large towns, in order that, periodically (for example each quarter), each underground chamber shall be inspected, even if no work is to be done in it at that time.

Besides these quarterly preventative visits, supplementary visits should, of course, be made, when notice is given by the staff of the presence of domestic gas.

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* Similar apparatus is used in the United States and in Italy (Italian Telephone Administration and Società Nazionale Metanodotti SNAM, apparatus constructed by Johnson Williams Ltd., Pale Alto, California U.S.A.).

** The telephone Administration of the German Federal Republic uses the Aladin apparatus based on similar principles.

*** Other apparatus based on the use of phials of palladium chloride (apparatus used in the United States) or other chemical reagents (apparatus LKB Produkter Stockholm and Drägerwerk-Lübeck used by the Austrian Telephone Administration.) Mention can also be made of other devices used notably in Sweden; the Strache gasoscope, the Nellissen gas detecting apparatus, and the Degea carbon monoxide detection apparatus.

The reports made after these visits should be the subject of a careful discussion with the Public Authorities and the Gas Companies concerned. As soon as the presence of domestic gas is noticed, work should be strictly forbidden and entry must not be authorised afresh until after a finding to the contrary by the representatives of the telecommunication services and the gas company. The restriction on access must be the subject of notices to the services concerned immediately upon discovery of the gas.

Finally, it is desirable that instructions given to workmen working in the cable chambers lay down formally the cessation of all work as soon as the team has recognised by smell or by the use of an appropriate detector, the presence of domestic gas, and that the work cannot be recommenced until after the intervention of the competent service and the raising of the official restriction of access.

4. *Precautions to be taken on opening the chambers*

Before commencing any work whatever in a cable chamber, or a joint box, it is absolutely necessary to inspect it carefully to be sure that it does not contain gas.

The cable chambers are provided with covers; in raising the covers, the greatest precautions must be taken to ensure that no sparks are caused as a result of hammer blows, or blows from picks, etc... If, during the cold season, it is necessary to thaw around a cable chamber, a solution of salt must be used for this purpose, or in difficult cases, quick lime; steam thawing apparatus can also be used. Naturally, before raising the cover, it must be ensured that there is no nearby flame (it is strictly forbidden to smoke in the cable chambers or in the neighbourhood of an open cable chamber or joint box).

If such an inspection reveals the presence of gas, no work should be carried out in the cable chamber or joint box, before the leakage of gas is stopped by the gas services and the chamber or box has been emptied of gas. The leakages of domestic gas noticed near a cable chamber must be immediately reported to the gas company. As a general rule, it is desirable to ask the gas companies to inform telecommunication services of the faults which occur on the gas distribution networks. The work to be carried out on the cables and the duct routes near a defective gas main must, if possible, be postponed to a later date, notably until this fault is repaired. In addition, all necessary precautions should be taken; in particular on no account should naked flames be used.

B. Precautions to be taken during work carried out in jointing chambers Lighting of jointing chambers during work

When a jointing chamber is not continuously ventilated by static ventilation arrangements, properly installed and well maintained (see Annex 4), it is desirable to ventilate it before beginning work and also from time to time during the work by means of a powerful portable ventilator (hand or motor driven).

Before entering a jointing chamber, it should be left open for at least 10 minutes even after having ascertained that it contains no harmful or explosive gases. If the jointing chamber has a cover with ventilating grids it is sufficient to open it 3 minutes before entering the chamber, provided that the cover is not blocked by ice or dirt, etc... If it is necessary to work in the chamber, adjacent chambers connected to it by ducts should also be opened, examined for the presence of gas and left open until the work is completed.

If it is necessary to carry out, in a jointing chamber, work over a long period, or work requiring the use of a naked flame, it is necessary (while the workmen are in the jointing chamber) to make, from time to time, a test for the presence of gas or to be sufficiently assured that quantities of gas which are either dangerous or harmful to health are not overlooked. When a tent is used above the chamber this tent should be ventilated in such a way that a current of air (not too vigorous, but constant) be led from the open ducts, through the cable chamber and the tent to the outside thus evacuating the gas which may have penetrated into the chamber. The workmen working in the chamber must be watched at short intervals by a workman remaining outside the chamber, in order that any unusual happening which occurs in the chamber shall be noticed in time. If these measures do not offer sufficient security, in exceptional cases, because the danger presented by the gas is particularly great, all the openings of the ducts should be sealed in order that no toxic gas can penetrate into the chamber. The ducts unoccupied by cables should be filled by means of plugs and the ducts in use should be plugged by means of plugs having an appropriate opening for the passage of the cable, the remaining spaces being filled with a plastic material or, in the case of cables of large diameter, by a textile wrapping.

During work precautions must be taken against the risks of a new accumulation of gas between two tests for the detection of the presence of gas. For this purpose an apparatus is used giving a visual or audible alarm signal when the gas accumulates to such a degree that it becomes dangerous for the workmen to continue working.

Various forms of safety lamps of general application in mines have been tried to this end, but all of them have the objection that the rise of the flame which occurs when conditions become dangerous cannot clearly be seen in a jointing chamber where there is another more powerful source of light for the actual lighting of the chamber during the work.

It is advisable therefore to use a type of lamp similar to that used by miners, but of an appropriate construction and including an alarm arrangement.

It should be pointed out that in fact these lamps serve mainly to indicate the moment when the air in the chamber no longer contains enough oxygen and becomes vitiated so that it is dangerous for workmen to remain in the chamber. Such lamps are used in France and in Great Britain.

However, in Germany a safety lamp is used (Fleissner lamp) which includes a prismatic mirror. It reveals the presence of explosive mixtures of gases by the halos which are formed by the flame and also by the emission of a characteristic noise, which constitutes an audible alarm signal. On the other hand, if it is noticed in the prismatic mirror that the flame falls or goes out, it signifies that the quantity of oxygen in the chamber is insufficient and that there is a risk of asphyxia. The variations of the flame are clearly visible due to the prismatic mirror, and the noise made by the flame in the event of the presence of explosive gas is easily noticed.

In the same way, in the United States, general use is made of a lamp similar to a miner's safety lamp; but this is now giving way to the use of an explosimeter.

Regarding the lighting of jointing chambers, the best method without doubt for avoiding explosion is lighting by means of electric lamps fed at low voltage and avoiding the presence in the chamber of any switch or other device capable of giving rise to spark or arcs. It is necessary to use portable electric lamps with a metallic reflector and case for protection, connected by a cable (e.g. rubber) to a battery of accumulators situated outside the jointing chamber; it is desirable that the connector for the portable lamp be in the battery container so that it is impossible, without unscrewing the lamp bulb, to interrupt the current inside the chamber.

Evidently, this method of lighting requires a charging service for the accumulators (in general, alkaline accumulators which are light and easily maintained are used, although they are more expensive than lead accumulators); but this method of lighting is the only one which offers high security particularly when it is not absolutely certain that explosive or deleterious gases cannot accumulate, even after having made a test which however had not revealed the presence of such gases in the chamber.

C. Jointing, drying and plumbing of cables in jointing chambers where there may be gas

If it is not absolutely certain that no deleterious or explosive gas can accumulate at some moment during the work, in the chamber, it is absolutely necessary to avoid the introduction of a naked flame into the chamber with the exception of safety lamps with alarm arrangements previously mentioned.

In this case, to joint and plumb a cable, recourse may be made to the following method, which does not involve the use in the jointing chambers of lamps with naked flames.

In this method, the plumbing metal and the soldering irons must be heated at the surface and brought down into the cable chamber. For example, in the following manner:

The joints between the conductors of cables will be carried out by twisting together the ends of the conductors; if soldered joints are required, as in the case of trunk cables, a heated copper soldering iron is used and solder with a resin core (the soldering iron being heated outside the chamber and only brought into it at the required moment).

The plumbed joints between the lead sleeve and the cable sheath, containing the joints between conductors, are made by pouring liquid metal (ladle plumbing) at the point of the joint until the temperature of the sleeve and the cable sheath is sufficiently high. During this operation, a cloth or a wad is placed below and near the sleeve and the sheath, in order to collect the liquid metal and to hold it around the sleeve and the sheath until it solidifies in cooling. When the place at which the joint is to be plumbed has thus been sufficiently heated, most of the metal is removed, then new metal is poured and worked around the joint in a plastic mass which is finally given the form of a smooth surfaced collar. By virtue of this procedure no blow lamp flame is used, the necessary heat being secured by the liquid metal which has been poured. But care must be taken in this case to have a well determined proportion of tin in the metal. If the proportion of tin is greater than 40%, it is difficult to complete the plumbed joint as sufficient time does not elapse between, on one hand, the moment where the lead begins to solidify and to form a plastic mass which can be manipulated satisfactorily, and on the other hand the moment when the alloy solidifies. On the contrary, if the proportion of tin is lower than 38%, the plumbed joint may not be perfectly sound.

The drying in situ of cable ends in the cable chambers where there is risk of an accumulation of explosive gases presents some difficulty.

Certain countries use molten paraffin wax for this drying of the joint; with this object the paraffin wax is first heated (of course outside the jointing chamber) to 190° C. approximately. But the use of paraffin wax may present difficulties due to the tendency of the paper to crack when later manipulations are necessary. In addition, the use of paraffin wax makes recognition of the identification marks of the paper insulation of the cable conductors more difficult. The use of heavily coloured paper able to resist the discolouring effect of the paraffin wax, has been shown to be harmful from the point of view of the electrical characteristics of the cable. Another method of drying in situ is used in various countries. It is based on the use of silica-gel, a very hard glassy substance which resembles fine sand and of which the chemical composition is 100% pure silica (SiO_2); it is prepared in such a manner as to have a well defined physical structure; it is chemically inert; it absorbs water vapour contained in the air to a proportion of 40% of its own weight without increase in volume and without ceasing to have a dry appearance. It can then be heated to evaporate the water vapour, and used again, and this cycle of operation can be repeated indefinitely without its efficiency being altered. This substance is used inside a bandage which encloses the joint inside the lead sleeve. This method gives excellent results.

ANNEX 1

Description of an explosimeter used by the British Telephone Administration

The explosimeter consists of a Wheatstone bridge with an activated platinum element in one arm. The bridge is initially adjusted to be balanced. Then, by means of a rubber tube and bulb, the gaseous mixture to be tested is passed over the activated element: any combustible gas existing in the mixture burns at the surface of the element. The electrical resistance of the wire forming this element increases and the bridge becomes unbalanced. The out of balance current is measured by means of a moving coil galvanometer.

The apparatus detects in a reliable manner gas concentrations at least equal to about a third of the minimum explosive limit of the gaseous mixture considered.

* * *

ANNEX 2

Note on the description and use of apparatus called "Osmometers" used by the French Telephone Administration

1. *Description and Operation.*—The indicator for detecting leakages called the "osmometer" (see following figure) is composed of a dial apparatus on which is a needle controlled by a diaphragm working after the manner of the aneroid manometer. This diaphragm closes a cylinder, the other end of which is plugged with a special porous composition through which the gas can pass by endosmosis. By slightly unscrewing the lower part of the apparatus the interior is opened to the atmosphere, which makes the apparatus ready for service.

Assuming that the needle is at zero on the dial and that the valve is open, the apparatus being placed in pure air, and if, on closing the valve, the apparatus is now carried into an atmosphere charged with domestic gas, the needle can immediately be seen to deflect to the left and to take, after a few seconds, a fixed position. The division on which the needle has stopped shows the percentage of the mixture of air and gas. For example, if the needle is on division 5, it would mean that the atmosphere surrounding the apparatus consists of 5% coal gas and 95% air.

The explanation of the operation is as follows: the cylinder, closed by the porous substance, first contains pure air, then, the apparatus being moved into the suspected atmosphere, by endosmosis, the gas penetrates into the cylinder through the porous substance more quickly than the air can escape. A pressure is then set up in the cylinder which acts on the diaphragm which deforms slightly. This diaphragm is connected, as explained above, to a needle, and causes it to take a position which varies according to the deformation.

2. *Use of the apparatus.*—The figure following gives the description and dimensions of the apparatus.

The osmometer has the advantage over chemical detectors, such as a palladium chloride indicating paper, of giving instantaneous readings and furnishing figures of the gas and air contents of the mixture.

It permits a check to be made of the indications furnished by sense of smell, of the presence of domestic gas, particularly in jointing chambers on multiple-way underground routes.

It is employed in three ways:

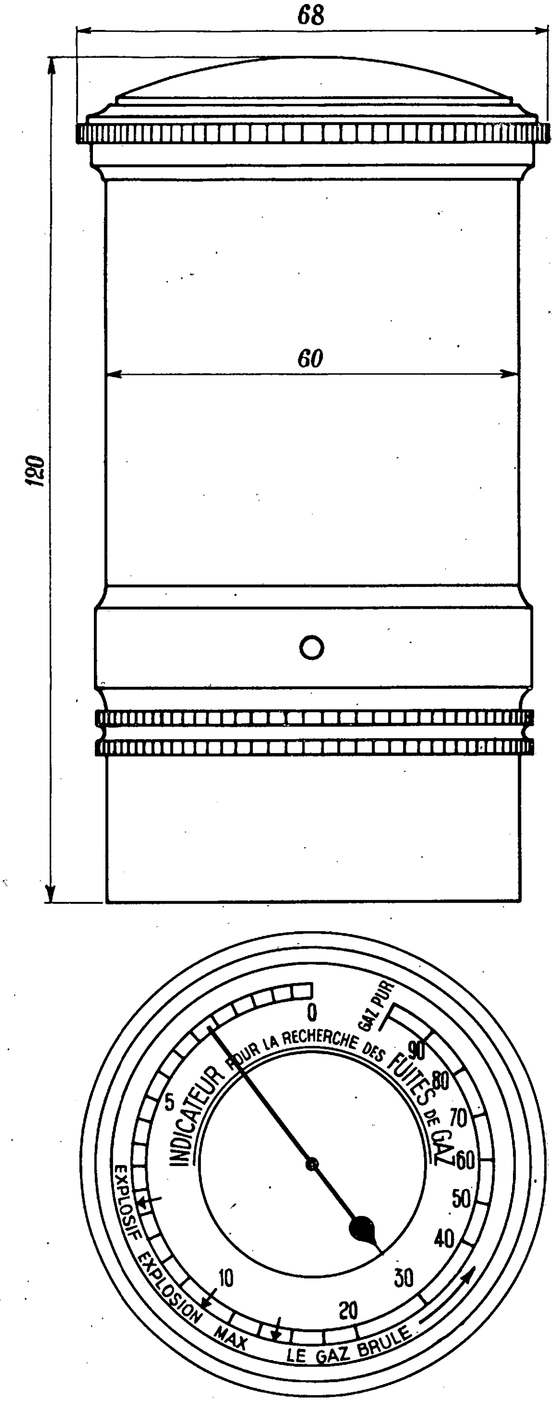
a) Before opening the cover (or lid) of the chamber the osmometer apparatus is placed on the keyhole of the cover the face being packed around with a piece of rag.

b) By lowering the apparatus into the chamber after opening the cover.

c) By placing the apparatus in the ways of the multiple conduit.

Use *b)* is the most general.

Use *c)* permits the actual conduit-way through which gas enters the chamber, to be determined.



Osmometer

(Measurements in millimetres)

It should be noted, in particular, the advantage of using "osmometer" apparatus to determine the absence of domestic gas in chambers after the repair of leakages. Actually, in some cases, even after repair of leakages, the smell of gas can persist; in these conditions the indication by sense of smell only, would not permit entrance to a chamber which has been forbidden owing to the presence of coal gas.

Osmometers of this type are becoming more reasonable in cost and are particularly robust.

ANNEX 3

Description and method of use of the carbon monoxide detector using sodium chloro-palladite employed by the British Telephone Administration

Description.

The sodium chloro-palladite detector of carbon monoxide shown in Figures 1 and 2, which follow, has been evolved with the view to detecting very small quantities of domestic gas or all other gases containing carbon monoxide. The detector itself consists of the following parts:—

1. The case.
2. A rubber disc.
3. A plate which rests on the rubber disc.
4. A cover having coloured buttons.
5. A threaded fixing ring which holds the complete detector together.
6. Test papers used for the tests.

The active substance is a solution of sodium chloro-palladite in acetone and water; it is contained in a small glass phial and must not be used for any purpose other than for which it is intended. This solution does not change if kept in the usual manner. But if its efficacy is doubtful, the phial should be thrown away and a new one used.

In the assembly of these various parts the spare test papers are placed on the base and under the plate (3); a single sheet of test paper is placed between this plate (3) and the cover (4). The fixing ring (5) holds it semi-rigidly in such a way that it is possible to turn the cover (4) without displacing the test paper which is underneath. Between the two coloured buttons of the cover a small circle of white paper appears which is exposed to the atmosphere to be tested.

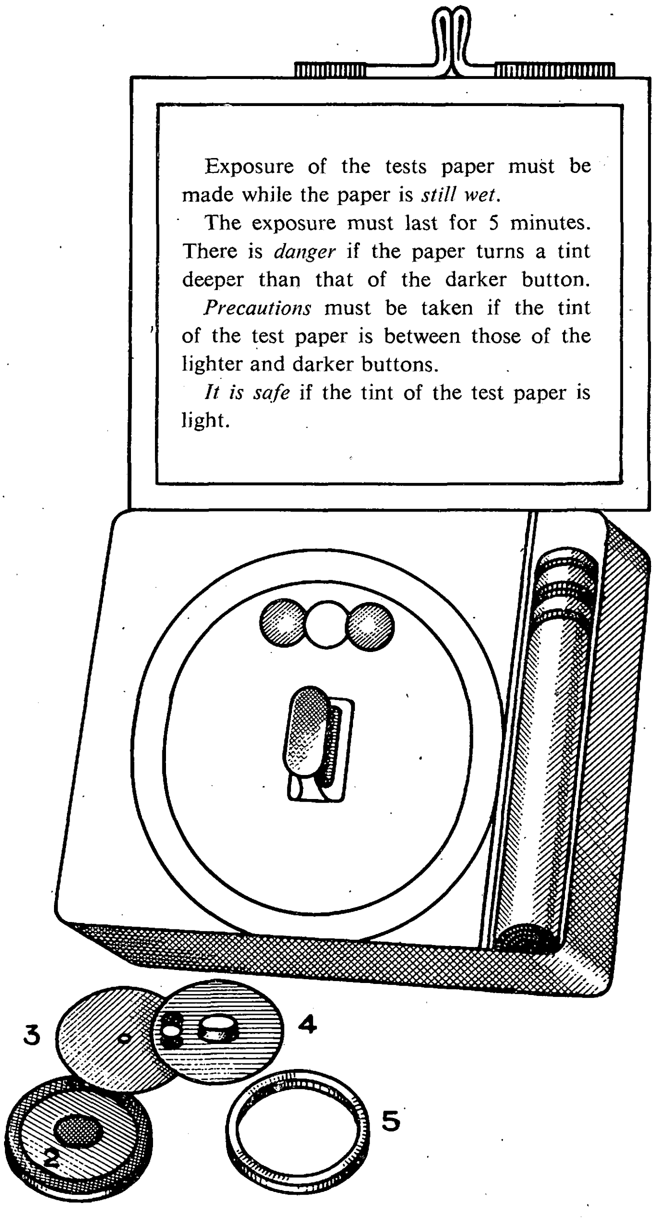
The presence of domestic gas (or all other gases containing carbon monoxide) is detected by the darkening of the part of the test paper exposed.

If the proportion of carbon monoxide in the atmosphere tested attains 0.05%, the test paper becomes of the same tint as the lighter button. If this proportion attains 0.1% the paper becomes of the tint of the darker button.

By turning the cover, 10 successive tests can be made with the same sheet of test paper, a new portion of the sheet being exposed to the atmosphere each time it is turned.

Method of use.—A test must be made with the sodium chloro-palladite indicator in all cases before entering a jointing chamber and before a light of any kind (even a safety lamp) can be taken near to a jointing chamber or joint box.

When a test is made to verify whether there is any gas in the jointing chamber, the cover of the chamber must be raised sufficiently to permit the insertion of the indicator into the chamber to a point situated half way between the roof and the floor, the indicator being held by a string or wire held in the hand.



Figures 1 and 2

The Sodium Chloropalladite indicator of carbon monoxide
1-5 component parts

When a test is taken in a joint box placed under the highway, the indicator must be placed at the entrance of the conduit connecting the joint box to the principal network of underground conduits.

There is no need to delay the execution of all other work which does not require the use of a flame, to effect this test. Buried junction and jointing boxes must be treated in the same manner.

The test must be carried out in the following manner: a small quantity of the reactive solution is placed on the test paper, by pressing lightly the opening of the phial containing this solution on the centre of the uncovered part of the test paper in the hole between the coloured buttons in the cover. It is necessary to use a quantity of liquid just sufficient to completely soak all the visible portion of the test paper, but no more. The apparatus is then ready for use, and it must be exposed for 5 minutes in the atmosphere to be tested. The test must be made immediately after the test paper has been impregnated with the reactive solution. If the paper becomes dry before being exposed, it will no longer indicate the presence of gas.

After exposing it for five minutes, the indicator must be withdrawn and the colour of the test paper compared with the two coloured buttons on the cover.

The cover itself is the colour which the test paper should retain if there is no gas containing cardon monoxide; on the other hand, there is no danger in working in a chamber or joint box so long as the test paper does not become darker than the lighter of the two buttons on the indicator cover. If the test paper takes a tint intermediate between those of the lighter and darker buttons, work can be continued for periods of two consecutive hours without danger, on condition that tests are repeated from time to time for example every half hour. If the test paper shows a deeper tint than that of the darker button on the cover, the atmosphere is dangerous and there is risk of explosion. In such a case the supervising engineer and also the police must be advised. In such conditions no work must be undertaken; and if a jointing chamber is concerned, no one may enter the chamber before well ventilating this chamber and also the adjacent chambers and joint boxes and without having verified by further tests that the chambers and boxes no longer contain gas.

When work is recommenced, it is necessary to remake at intervals not exceeding 30 minutes, the preceding tests by means of the indicator until six consecutive tests have indicated each time that it is safe.

Annex 4

Static ventilation of jointing chambers for underground telephone cables

(Note transmitted by the French Telephone Administration)

The ventilation devices used initially consisted of two orifices fitted with grids mounted at ground level and communicating by pipes ending, for one of the orifices in the upper part of the chamber, and for the other orifice, in the lower part of the chamber. The outlets of the ventilation pipes in the chamber were at each of the two ends of one of the longest diagonals of the parallelopiped formed by the interior walls of the chamber, whence the name "diagonal ventilation" sometimes given to this arrangement.

The following theory was assumed initially and it was thought at first sight to be satisfactory for the operation of this device. In the case of a leakage of gas, the gaseous mixture, lighter than air ("density effect") was evacuated by the upper orifice, whilst fresh air, being heavier, entered by the lower orifice. The atmosphere in the chamber was purified by air flowing across its longest diagonal. The ventilation resulting from this density effect could, when the outside temperature was lower than that of the chamber be accelerated by a "temperature effect". It was evidently implicitly assumed, in this reasoning, that "zero wind" existed at ground level, or an equal effect of the outside wind on each of the grids.

Experience showed that underground chambers fitted with these devices were drier and less subject to condensation than ordinary chambers.

In 1930, the French Telephone Administration undertook systematic studies of the ventilation of underground galleries, and these studies apply equally to the underground chambers for telephone cables, the experimental conditions being as nearly as possible those found in practice (an underground experimental chamber of normal dimensions was specially constructed for these studies and experiments were conducted therein with real leakages of gas).

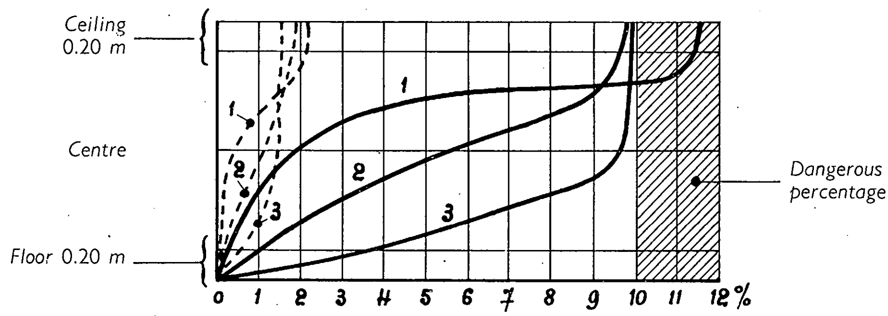


Figure 1

Curves showing the proportions of gas in the chamber, in the case of a zero wind (the effect of density alone ensuring ventilation)

Ventilation section : 640 cm².
Dotted curves : leakages of 1000 to 1200 litres/hour.
Full curves : leakages of 4000 to 4500 litres/hour
Curves 1 : leakages at 20 cm from the ceiling
Curves 2 : leakages at mid-height.
Curves 3 : leakages at 20 cm from the floor.

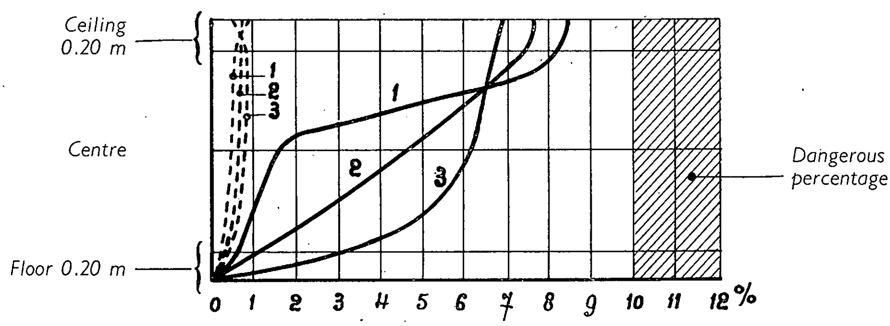


Figure 2

Curves showing the proportions of gas in the chamber, in the case of zero wind (the effect of density alone ensuring the ventilation)

Ventilation section : 240 cm².
Dotted curves : leakages of 1000 to 1200 litres/hour.
Full curves : leakages of 4000 to 4500 litres/hour.
Curves 1 : leakages at 20 cm from the ceiling.
Curves 2 : leakages at mid-height.
Curves 3 : leakages at 20 cm from the floor.

During the research undertaken, statistics studied showed that:

1. during 123 days of the year, the outside temperature is lower than 12° C, the practically constant temperature of these underground chambers; there is continuous ventilation;

2. during 110 days of the year, the temperature does not fall below 12° C; there is no ventilation to be expected;

3. finally there remain 132 days of the year, during which a slight ventilation will be produced during the few hours when the surrounding temperature falls below 12° C.

The ventilation due to this temperature effect is normally very slight and only becomes appreciable in the case of large temperature differences. Thus in the case of hard frost in still weather, it is possible to distinguish clearly, on chambers fitted with the diagonal ventilation arrangement, the air outlet orifice of the chamber: this orifice appears damp, while the other orifice and the pavement are covered by ice or frost.

Calculations have revealed the low pressures brought into play in the case of leakages of gas by the "density effect" to cause ventilation in the cases of average concentrations inferior or equal to the lower limit of inflammability. The ventilation, in calm weather, resulting from the "density effect" in the chambers fitted with the diagonal ventilation arrangement is however quite efficient, as is shown by the curves reproduced in Figures 1 and 2, since a chamber fitted with the arrangement having an opening of 6.4 dm^2 evacuates, continuously, leakages of the order of 4000 to 4500 litres per hour without the atmosphere attaining at any point the concentration of the lower limit of inflammability.

The ventilation resulting from the "density effect" is greatly modified by the effect of wind on the grids. Experiments carried out have particularly drawn attention to this point. The "pressure effect" of the wind appears in a general way as being much more important than the "density effect". This effect would theoretically be zero if the grids were symmetrically placed in the path of the wind. This is rarely so in practice; irregularities are always present (different positions of the grids, buildings, trees, different lengths of pipes, etc.). The pressure effect due to wind can, according to the direction of the wind, either aid or oppose the effect of the density. In this latter case, in the chambers fitted with the diagonal ventilation device the fresh air enters by the upper orifice and the lighter gases leave by the lower orifice. This direction of gas circulation is less favourable than the normal direction, as it appears preferable to evacuate first the more concentrated mixture distributed under the ceiling instead of diluting it first throughout the whole volume of the chamber before evacuating it, which may present a certain risk.

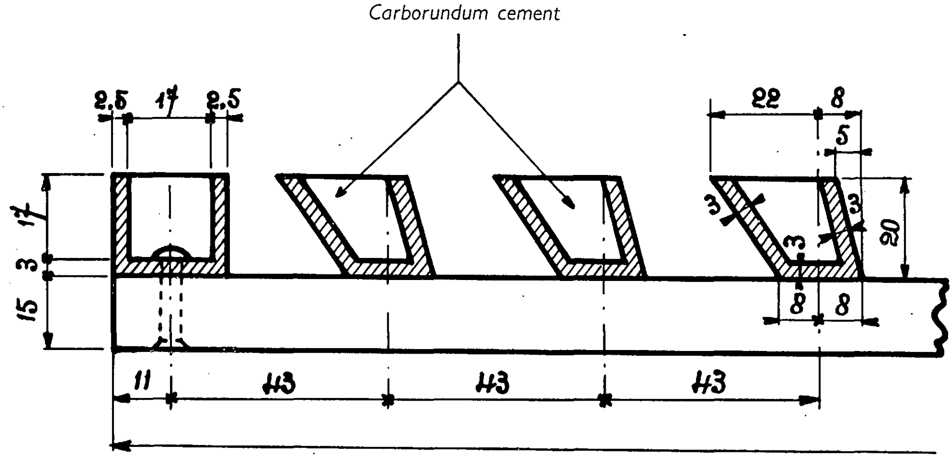
Experiments carried out in closed chambers have shown, in effect, that in the case of a leakage of gas into the interior of the chamber, a mixture with a higher concentration than average, and consequently more dangerous, is first formed in the upper part of the chamber under the ceiling. All things being equal, the initial concentration of the mixture under the ceiling was the greater as the leak was nearer to the ceiling. The percentage at each point in the atmosphere of the chamber became uniform in several hours, according to the law of) mixture of gases. It follows from these observations that it is most important, from a safety point of view, to evacuate the gases from the upper part of the chambers.

These considerations have shown the benefit which would be obtained in taking advantage of the effect of the wind for the special ventilation of the upper part of the chambers.

Instead of attempting to obtain symmetry of the grids in the path of the wind, steps were taken to obtain and create a dissymmetry with respect of the wind. Instead of allowing the pipes to terminate at different heights it is advisable that they both terminate at the top of the chamber so as to ensure the evacuation of the most dangerous gases which concentrate under the ceiling.

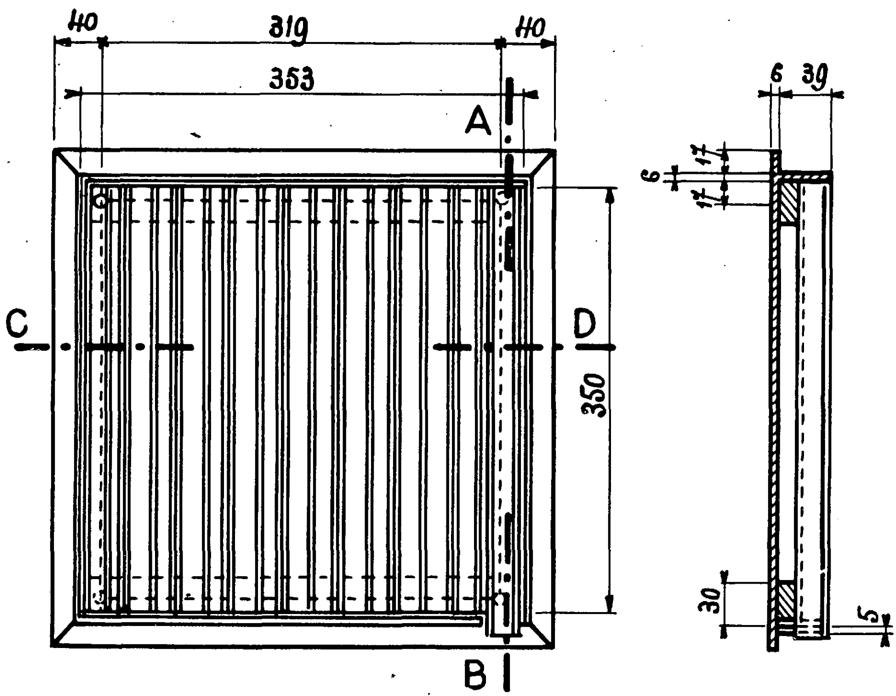
The dissymmetry of the grids can for example be created for cross-road chambers by placing the grids along the two fronts of the buildings on the angle; this procedure is evidently only of occasional use. It was contemplated to slightly incline the grids one to the other or in opposite directions. This procedure is unfortunately impossible on flat pavements. It was then conceived to use grids with inclined bars, which were called "wind traps". The principle of these grids which are arranged in pairs so as to offer their inclined bars in opposite directions, allows the capturing, within the ventilation pipes, of a derived wind whose speed may reach an appreciable fraction, up to 30% of the ground wind.

VENTILATION GRID WITH INCLINED BARS CALLED "WIND-TRAP"
(First model)



Total width = 350 mm

Cross-section of the grid, following CD
(full-size)
(in millimetres)



Plan of the grid in its frame
(scale ¼)

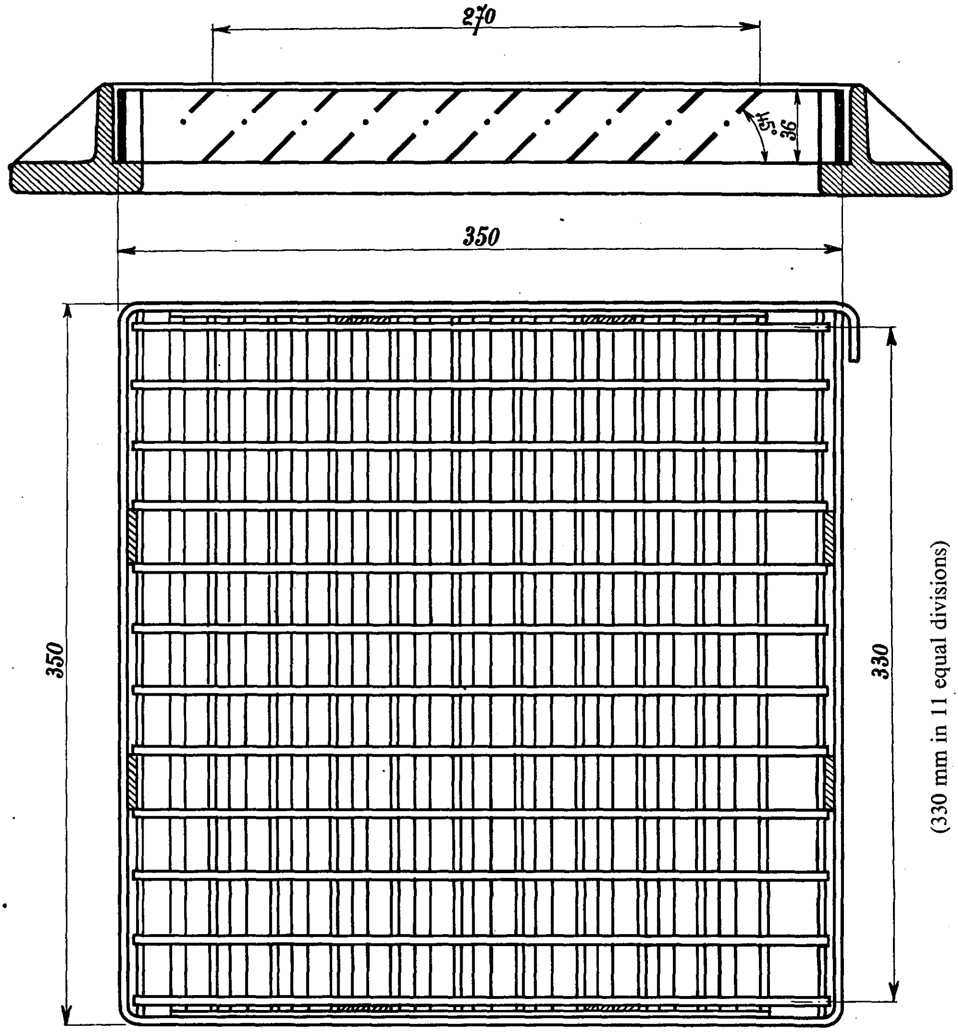
Section following AB
(scale ¼)

Figure 3

VENTILATION GRID WITH INCLINED BARS CALLED "WIND-TRAP"

(Model now used)

270 mm in 9 equal divisions



(330 mm in 11 equal divisions)

Scale 3-10

(Sizes in millimetres)

Figure 4

The model at present used is satisfactory as far as the accumulation of dirt on the grids and the risks of slipping thereon are concerned. The large section which it offers to the passage of gas permits the use of ventilation pipes of only 30 cm interior diameter.

In France the most recent ventilation systems for underground chambers are provided by these devices.

Conclusions.—The static ventilation devices with two orifices* fitted with inclined bar grids and ventilation pipes terminating directly under the ceiling of the chambers and presenting a sufficient diameter (20 to 30 cms) appear to be really efficient for the evacuation of dangerous mixtures of gases.** They contribute, furthermore, to the drying of the chamber when the latter is of watertight construction and does not receive water directly by infiltration along the duct or by the manhole cover, but simply from the humidity due to the porosity of the cement.

They are not, however, of absolutely general use. Under the road the poor mechanical strength of the grids and the filling with dirt of the grids and the sumps render their application very difficult. This is also true in the case of a sanded path when the grids and sumps become filled with dirt and are difficult to maintain. On the contrary they are perfectly satisfactory for pavements (cables in towns).

The use of static ventilating devices, although giving an important complementary safety, in no way affords a dispensation, for the chambers so fitted, from the application of regulation safety precautions for the carrying out of underground work and the periodic checks and supervision of the state of the installations.

In particular, the artificial ventilation which they create is not great enough to allow of the working of several men simultaneously in the chamber if this is not provided with an additional opening (trap door). For gallery sections, even of short length, it is absolutely necessary to allow ventilation grids with a larger surface area (at least 70 × 70 cms).

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* Devices with a single opening are absolutely ineffective and their use should in consequence be condemned.

** For 230 days per year it is possible to count on a wind of 2.50 metres per second; the device is able to evacuate the products of a leak attaining 11 cubic metres per hour before the atmosphere of the chamber reaches the lower limit of inflammability. During the other days of the year satisfactory efficacy can still be expected, due to the effect of the wind, density and the temperature.

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