THE INTERNATIONAL TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE
(C.C.I.T.T.)

# IVth PLENARY ASSEMBLY

MAR DEL PLATA, 23 SEPTEMBER - 25 OCTOBER 1968

WHITE BOOK

# VOLUME IX

## Protection

Published by
THE INTERNATIONAL TELECOMMUNICATION UNION
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## Protection

Part 1 — Series K Recommendations and Questions on protection against interference

Part 2 — Series L Recommendations and Questions concerning the protection of cable sheaths and poles

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PART 1

# SERIES K RECOMMENDATIONS AND QUESTIONS ON PROTECTION AGAINST INTERFERENCE

# SERIES K RECOMMENDATIONS

## Protection against interference [1]

RECOMMENDATION K.1 (New Delhi, 1960)

### CONNECTION TO EARTH OF AN AUDIO-FREQUENCY TELEPHONE LINE IN CABLE

*Introduction*

The present state of technique is such that cables can now be so manufactured that the capacitances of the various circuits at audio-frequencies, with respect to the sheath, are very exactly balanced.

This balance of the capacitances is adequate in the case of circuits having no unbalanced connections to earth.

On the other hand, every connection to earth, even with apparent balance, is likely to involve the inductance and resistance unbalances of each of the circuits to which such an earth connection is made.

The dielectric strength between the conductors of a cable is appreciably less than that between the conductors and the sheath, and consequently, the connection to earth of some of these conductors would create a danger of breakdown of the dielectric separating the conductors when the cable is subjected to severe induction.

When a loaded cable is subjected to a high induced electromotive force, the presence of connections to earth would permit a flow of current the value of which could, in some cases, exceed the limit for avoiding deterioration of the magnetic properties of loading coils.

*For these reasons the C.C.I.T.T. makes the following unanimous recommendations :*

No earth connection should be made at any point whatsoever on an audio-frequency circuit, unless all the line windings of the transformers are permanently connected to the sheath by low resistance connections at one or both ends of the cable.

As a general rule, it is desirable not to make any earth connection at any point whatsoever on an installation (telephone or telegraph) connected metallically to a long-distance line in cable.

However, if, for special reasons, an earth connection must be made to an installation directly connected to audio-frequency circuits, the following precautions should be taken :

a) The earth connection must be made in such a manner as not to affect the balance of the circuits with respect to earth and 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

[1] See also the *Directives concerning the protection of telecommunication lines against harmful effects from electricity lines.*

highest voltage which, owing to induction from neighbouring electricity lines, could exist between these conductors and those of the circuit connected to earth.

c) When the installation connected to the cable is a telegraph installation, it is also necessary to conform to C.C.I.T.T. Recommendations concerning the conditions for co-existence of telephony and telegraphy (Series H Recommendations in Volume III of the C.C.I.T.T. *White Book*).

## RECOMMENDATION K.2 (New Delhi, 1960)

### PROTECTION OF REPEATER POWER-FEEDING SYSTEMS AGAINST INTERFERENCE FROM NEIGHBOURING ELECTRICITY LINES

To avoid interference to the power feeding of repeaters, either by magnetic induction from a neighbouring electricity line or as the result of resistance coupling with a neighbouring electricity line, the C.C.I.T.T. recommends that, whenever possible, the repeater power-feeding system should be so arranged that the circuit in which the power-feeding currents circulate (including the units connected to it) remains balanced with respect to the sheath and to earth.

## RECOMMENDATION K.3 (New Delhi, 1960)

### INTERFERENCE CAUSED BY AUDIO-FREQUENCY SIGNALS INJECTED INTO A POWER DISTRIBUTION NETWORK

In the event of the use by electricity authorities of audio-frequency signals injected into the power distribution network for the operation of remote control systems, such signals may cause interference to neighbouring telecommunication lines.

Calculation of such interference may be carried out, using the formulae in the *Directives*, and finding the values of the equivalent disturbing voltages and currents for these audio-frequency signals.

## RECOMMENDATION K.4 (Geneva, 1964)

### DISTURBANCE TO SIGNALLING

In order to reduce interference to direct current signalling or to alternating current signalling at mains frequencies on telecommunication lines on open wires, in aerial or underground cables, or on composite lines, arising from neighbouring alternating or direct current electricity lines, the possibility should be examined of adopting one or more of the following methods in each case where such interference appears liable to be produced or where it has been observed to exist:

— development and use of telecommunication systems: a) in which the balance to earth [1] of the signalling circuit is maintained in all circumstances, even during switching operations; b) in which, besides being balanced, interference in such systems due to longitudinal currents arising from direct or indirect earth connections is avoided.

— choice of sites for telephone exchange earths so that, as far as possible, they are, in particular, remote from electric traction lines and also from the earth electrodes of power systems.

— adoption of measures for reducing induced currents (use of telephone cables with a low screening factor, use of booster transformers in single-phase traction lines, etc.) to facilitate the use of existing signalling systems.

— use of neutralizing transformers in telecommunication circuits to compensate currents produced by induced voltages.

— use of tuned circuits to provide a high impedance at the frequency of the interfering current.

*Note.* — The *Directives concerning the protection of telecommunication lines against harmful effects from electricity lines* mention a limit of 60 volts for the voltage induced into telecommunication lines. This limit of 60 V concerns only the safety of personnel and should not be taken to be a limit for the purpose of ensuring that there is no interference to signalling systems. In the case of unbalanced signalling systems, such interference may be caused by much lower voltages, as is mentioned in the *Directives* (1963 edition, Chapter V, section 3, No. 45).

## RECOMMENDATION K.5 (Geneva, 1964)

### JOINT USE OF POLES FOR ELECTRICITY DISTRIBUTION AND FOR TELECOMMUNICATIONS

Telecommunication administrations that wish to adopt joint use of the same supports for open-wire or aerial cable telecommunication lines and for electricity lines are recommended, when national laws and regulations permit such an arrangement, to take the following general considerations into account:

1. There are economic and aesthetic advantages to be derived from the joint use of poles by telecommunication administrations and electricity authorities.

2. When suitable joint construction methods are used, there is, nevertheless, some increased likelihood of danger by comparison with ordinary construction methods, both to staff working on the telecommunication line and to the telecommunication installation connected thereto. Special training of personnel working on such lines is highly desirable and especially when the electricity line is a high-voltage line.

3. The rules given in the *Directives* in connection with danger, disturbance, and staff safety should be complied with (see Chapters IV, V and XX of the *Directives*, 1963).

[1] See *Directives*, 1963, Chapter XVI.

4. Special formal agreements are desirable between the telecommunication administration and the electricity authority in the case of joint use of poles in order to define responsibilities.

5. If joint use is applied on short sections (of the order of 1 km), in most cases a few simple precautions may be enough to ensure that disturbances due to electric and magnetic induction are tolerable.

## RECOMMENDATION K.6 (Geneva, 1964)

## PRECAUTIONS AT CROSSINGS

*Introduction*

Crossings between overhead telecommunication lines and electricity lines present dangers for persons and for equipment.

A number of arrangements have been made by the responsible authorities in various countries, resulting in national regulations. These regulations are sometimes rather inconsistent and the effectiveness of the arrangements made varies somewhat.

Bearing in mind the stage now reached in technique and the experience gained in the various countries, it now seems possible for the C.C.I.T.T. to issue a recommendation advocating the arrangements which seem to be the most effective, on the basis of which countries might draw up or revise their national regulations.

It is therefore recommended that, when an overhead telecommunication line has to cross an electricity line, either of two methods may be used : namely, to route the overhead telecommunication line in an underground cable at the crossing, or to leave it overhead.

1. *Line routed underground*

This method is not always to be recommended because if a conductor of the electricity line breaks, the underground cable may be in a region where the ground potential is high. This situation is dangerous if the cable has a bare metallic sheath ; the higher the voltage of the power line, the shorter the length of the cable section, and the higher the resistivity of the soil, the greater is the danger. This dangerous situation also arises whenever an earth fault occurs on a pylon near the cable.

If circumstances require the overhead line to be routed in a cable, special precautions will have to be taken at the crossing, for example :

— the use of an insulating covering round the metal sheath of the cable ;

— the use of a cable with an all-plastic sheath.

2. *Line left overhead*

The method whereby the power line is separated from the telecommunication line by a guard-wire or a cradle cannot generally be recommended.

In any case, regardless of the circumstances, a minimum vertical distance has to be kept between telecommunication conductors and power conductors, in conformity with national regulations.

There are, moreover, a number of arrangements that could be introduced to reduce the danger :

2.1 *Use of a common support* at the crossing-point, provided the insulators used for the telecommunication line have, if necessary, a high breakdown voltage.

2.2 *Insulation of the conductors*, preferably the telecommunication conductors, provided that such insulation is properly adapted to the conditions existing.

2.3 *Reinforcement of the construction* of the power line where the crossing takes place, so as to minimize the risk of a break.

3. *Circumstances in which the various arrangements in 2.1, 2.2, 2.3 above are applicable*

The application of these methods depends primarily on the voltage of the power line. The voltage ranges to be taken into account are not related to the International Electrotechnical Commission (I.E.C.) standardization, because of the special features of the problem raised.

3.1 *Systems using voltages of 600 volts or less*

Arrangements to be as in 2.1 and/or 2.2.

3.2 *Systems using voltages of 60 kV or more*

(In particular the "high reliability" system referred to in the 1963 *Directives*—preliminary chapter, section 3.2.3.)

Arrangements to be as in 2.3, if necessary.

3.3 *Intermediate voltage systems*

For the 600-V to 60-kV range, because of the variety of voltages, the mechanical characteristics of lines and the operating methods encountered, it is impossible to issue precise recommendations.

However, one or more of the arrangements described above might be applicable, although certain special cases call for thorough examination in close collaboration with the services concerned.

## RECOMMENDATION K.7 (Geneva, 1964)

### DEVICES FOR PROTECTION AGAINST ACOUSTIC SHOCK

In unfavourable circumstances, sudden voltage bursts may occur across a telephone receiver and produce such strong sound pressure that there is danger to the ear and to the nervous system. Such bursts are most likely to occur when lightning protectors are inserted in the two conductors of a telephone line and do not function simultaneously, so that a compensating current flows through the telephone. The C.C.I.T.T. therefore recommends the use, particularly on lines equipped with vacuum lightning protectors, of protection devices against acoustic shock arising from inadmissibly high, induced voltages (see Chapter I/6 of the *Directives*, page 16).

The fitting of a device consisting of two rectifiers, in parallel and with opposite polarities, or other semi-conductor elements, has proved to be an effective and inexpensive means of eliminating sudden voltage surges in a telephone receiver and the consequent risk to the ear. In this case, both rectifiers are connected directly in parallel to the telephone receiver.

To conform to the design exigencies of other equipment, to enable a rapid check to be made of the performance of protective devices against acoustic shock, and to avoid excessive impairment of telephone transmission quality, it is recommended that these devices should have the following characteristics :

1. It is desirable for the protective device against acoustic shock to be designed so that it occupies a small space (so that it can be placed, for example, in the case of the operator's or subscriber's telephone receiver).

2. The device must be well made. Its electrical characteristics should not show significant changes under the temperature and humidity conditions to which it is subjected in service.

3. The design of the device must be adapted to the characteristics of the telephone receivers with which it will most often be associated, so that it does not overheat in service.

4. The device should be designed so that, when the protective device against excess voltages on the lines operates (e.g. striking and operation of gas-filled protectors), the amplitude of the sound pressure caused by the diaphragm of the telephone receiver should not exceed about 120 dB above $2 \cdot 10^{-4}$ microbar at 1000 Hz.

*Note.* — Tests have shown that protective devices of the type mentioned above have properties such that this condition can be met without difficulty, if only pulses and not continuous overvoltages are concerned.

5. For certain protective devices used in association with a particular telephone set, the table below gives limits for the attenuation measured with a sinusoidal signal of 800 Hz that should be achieved for various voltage levels applied to the line terminals of the telephone set concerned. The line impedance is assumed to be 600 ohms. For the purpose of these measurements, the receiver is replaced by a pure resistance of value corresponding to the modulus of the impedance of the receiver at 880 Hz, and the attenuation is given in terms of the ratio of the voltages, expressed in transmission units, across the terminals of that resistance, with and without the protective device in position across the resistance.

| Voltage level at line terminals (Level reference 0.775 V) | | Attenuation | |
|---|---|---|---|
| decibels | nepers | decibels | nepers |
| − 17.4 | − 2.0 | < 0.43 | < 0.05 |
| − 8.7 | − 1.0 | < 0.43 | < 0.05 |
| 0 | 0 | ≦ 1.7 | ≦ 0.2 |
| + 8.7 | + 1.0 | > 5.2 | > 0.6 |
| + 17.4 | + 2.0 | > 10.4 | > 1.2 |
| + 26.1 | + 3.0 | > 15.6 | > 1.8 |

The measurements should be carried out by means of an instrument indicating r.m.s. values (or, possibly, rectified average values).

In testing any new type of device, it may be advisable to carry out similar measurements at frequencies between 200 Hz and 4000 Hz, to ensure that the average insertion loss is of the same order.

6. Administrations that so desire can determine the acceptance test limits to be specified for the supply of a device that they have found to be suitable for their own telephone sets and which meets the requirements of paragraph 5 above, by themselves making measurements of the insertion loss of a sample of that device between resistances representing the receiver and the associated circuit of their own telephone sets, and quoting the measurement results as limiting values of insertion loss measured between the resistance values used.

7. It should be noted that the harmonics produced while the device is operated as in paragraph 4, and resulting from the non-linearity of its characteristic, may contribute to the sound pressure. However, harmful effects from the harmonics do not appear so long as the conditions in paragraph 5 are met.

## RECOMMENDATION K.8 (Mar del Plata, 1968)

## SEPARATION IN THE SOIL BETWEEN TELECOMMUNICATION AND POWER INSTALLATIONS

The magnitude of possible voltages in the soil in the vicinity of telecommunication cables depends on a number of factors, for example, the power-system voltage, the fault-current level, the soil-resistivity, the layout of both the power system and the telecommunication installations and other local conditions. It is, in consequence, impossible to suggest general rules regarding the minimum separation to be recommended. In principle, the effect of the power system on the telecommunication installation should be established by tests whenever conditions indicate the possibility of excessive voltages. In many cases, however, such tests may require such a large amount of work that they could not be justified. Experience has shown that problems do not arise if the minimum separation admitted between telecommunication plant and pylon footings is 10 metres, provided that the earth resistivity is not unduly high (of the order of a few hundred ohm-metres) and that there are no other known or suspected conditions that might make this distance insufficient. Such known or suspected conditions may necessitate an increased separation (a separation of up to 50 metres has been used in Sweden under extremely severe soil conditions).

On the other hand, circumstances may exist where a separation of 10 metres is not necessary, and a separation of two metres or even less is found sufficient in some countries under stated circumstances. (See the following annex.)

If local conditions do not permit the adoption of a requisite separation, the sheath of the telecommunication cable could be provided with suitable insulation (for example, by being placed in ducts or provided with an insulating covering) within the area of possible excessive soil-voltage.

# ANNEX

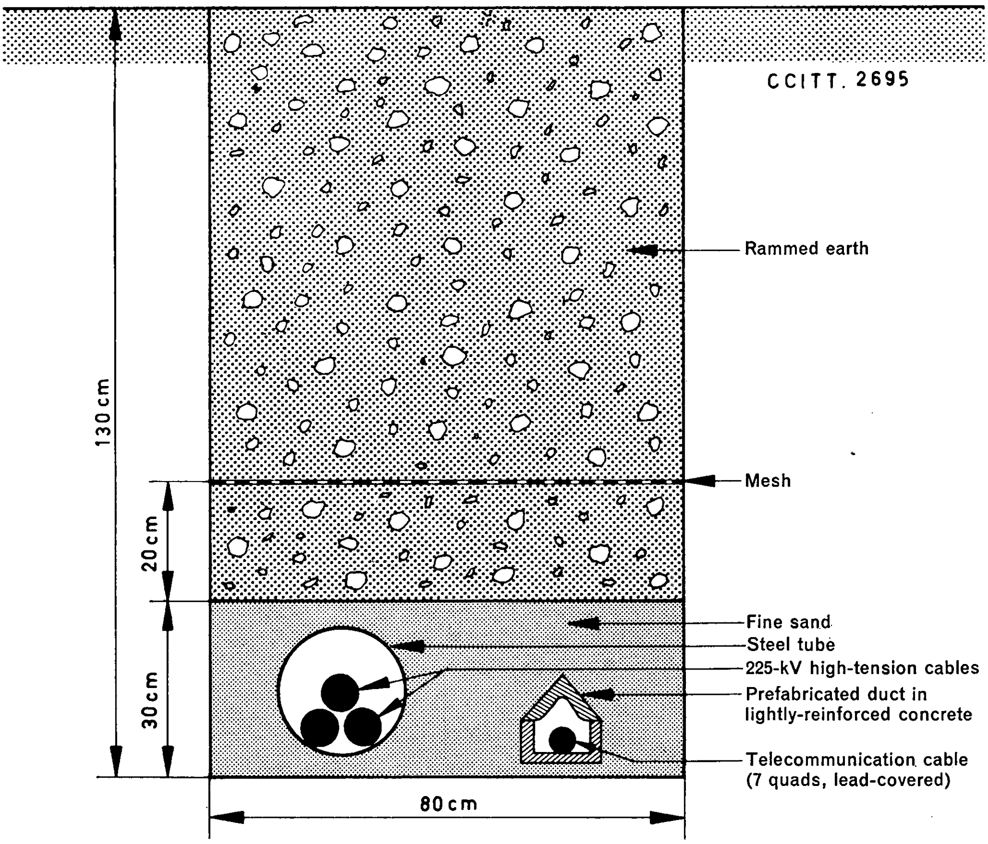
(to Recommendation K.8)

**Information supplied by C.I.G.R.E.**

The following diagram shows a practical example in the Paris area where a telecommunication cable has been laid in the same trench as a 225-kV high tension cable over a length of 4911 metres. The three single-phase power cables are in a steel tube which is carefully earthed at its ends and the telecommunication cable (7 quads, lead-covered) is in a lightly reinforced, prefabricated, concrete duct.

Measurements of induction made for several values of short circuit current over the total length of the telecommunication circuit (4911 metres) have given the following induced electromotive forces.

| | | | |
|---|---|---|---|
| Short-circuit current (in amperes) . . . . . . . . . . . . | 100 | 200 | 400 |
| Induced e.m.f. (in volts per ampere) . . . . . . . . . . . | 0.055 | 0.046 | 0.036 |




**Common trench for a power cable and a telecommunication cable**

RECOMMENDATION K.9 (Mar del Plata, 1968)

# PROTECTION OF TELECOMMUNICATION STAFF AND PLANT AGAINST A LARGE EARTH POTENTIAL DUE TO A NEIGHBOURING ELECTRIC TRACTION LINE

*General*

From the technical standpoint the precautions taken on electrified railways to protect staff and plant may differ according to a number of factors, the chief of which are :

— ground resistivity ;

— electrical line equipment (track circuits), which, though necessary for railway safety installations, may prevent the systematic connection to rail of metal structures near the railway ;

— the characteristics of the protective devices required which, with a.c. electric traction systems, may be to some extent affected by the presence (or absence) of booster-transformers ;

— the degree of insulation of the contact system, which may also affect the nature of the protective devices, particularly in the case of relatively low-voltage electric systems such as 1500 V d.c. lines ;

— the means to be recommended for linking a metal structure to the rail in case of overvoltage without making a permanent connection (one method is to make the connection via a spark gap).

*A.c. electric traction lines*

It is recommended that neighbouring metal structures, for example, all those within a certain distance from the line, be connected to rail, provided that there are no safety installations which make this impossible.

If the structures cannot be connected to rail, it is recommended that they be earthed to an earth-electrode having a sufficiently low resistance.

*D.c. electric traction lines*

Protective measures should also take account of the need to avoid any risk of electrolytic corrosion. Such measures may amount to connecting to rail only such metal structures as are sufficiently insulated from the ground or linking them via a spark gap, or, in the case of metal structures carrying an adequately insulated contact system or lines with a sufficiently low service voltage, connecting neither to rail nor to earth.

*Telecommunication cables*

In new installations, it is recommended that cables near rails, at the entry to substations or over metal bridges should have an outer plastic covering, possibly of high dielectric strength, where it is necessary to prevent contact between the cables and such structures.

If, on the other hand, cables with metal sheaths already exist, a good solution, at least in the case of large railway stations, may be to connect the sheaths to rail.

*Conditions to be fulfilled by P.T.T. installations in the neighbourhood of electric traction lines*

The following are the main precautions taken to protect such installations :

— placing them outside the danger zone,
— screening,
— substituting insulating components for metal components, in particular the sheaths or covering of cables or in the construction of repeater cabinets or boxes.

*Note.* — The above recommendations are inspired solely by technical considerations which are to be carefully weighed up in each case. It goes without saying that every administration must comply with the laws and regulations in force in its country.

## RECOMMENDATION K.10 (Mar del Plata, 1968)

### UNBALANCE OF TELECOMMUNICATION INSTALLATIONS

In the interests of maintaining an adequate balance of telecommunication installations and of the lines connected to them, it is recommended that the minimum permissible value for the balance of telecommunications installations should be 40 dB (from 300 to 600 Hz) and 46 dB (from 600 to 3400 Hz). This is a general minimum value and does not exclude the possibility of higher minimum values being quoted for particular requirements in other Recommendations of the C.C.I.T.T. [1]

[1] See, in particular, Recommendation Q.45, and also the outcome of further studies by the C.C.I.T.T. in 1968-1972 under Question 13/V.

## IMPORTANT NOTICE

1. An asterisk indicates that a question is urgent, i.e. that the study of the question has to be completed before the Vth Plenary Assembly.

2. Since Special Study Group D was set up by the Plenary Assembly, all questions relating to pulse code modulation (p.c.m.) have been assigned to this Study Group for the time being.

The Chairman of Special Study Group D will make arrangements with the other Chairmen for effecting liaison with the other Study Groups concerned as work progresses.

3. When a question is of interest to more than one Study Group and no joint study group has been set up to deal with it, the mention of the other Study Group(s) concerned is intended for the information of the members of the Study Group to which the question has been assigned, to enable them to arrange for the necessary co-ordination *within their national* administrations, in accordance with a decision of the IVth Plenary Assembly.

# Questions concerning protection against danger and electromagnetic interference allocated to Study Group V in 1968-1972

## Question 1/V — Protective devices

*(continuation of Question 1/V, 1964-1968 to be studied during 1968-1972 by Joint Working Party PAR of Study Groups V and VI and C.I.G.R.E.) — (wording modified)*

a) Should the protection principles at present in use be modified ?

b) What are the characteristics to be met by protective devices and what methods should be used to measure these characteristics ?

c) Protection of components having a small thermal capacity (for example, components using semi-conductors).

(See Chapter XIX of the *Directives*.)

*Note.* — In studying this question, the following points should be noted :

1. It is desirable to see whether it is possible to simplify the protection arrangements by eliminating certain elements from them and also to specify in what conditions it is appropriate to use :

— a protection arrangement comprising three elements (fuse, lightning protector and heat coil) ;
— a protection system with two elements (fuse and protector) ;
— a protection system with a single element (protector).

It would also be useful to examine the operating conditions of the various elements of a protection arrangement when they are used on a circuit entering the exchange by means of a cable and to take various lengths of cable into account.

2. It is desirable to associate the study of lightning protectors (dischargers), used in normal conditions, with that of the fuses used in the protection arrangement employed. The use should be considered of lightning protectors capable of discharging greater currents than some existing models, reaching, for example, several tens of amperes during one or a few seconds.

3. Lightning protectors having great regularity and stability of operation would be very useful.

4. The following points are given as the fundamental requirements for lightning protectors with respect to excess voltages at mains frequencies :

4.1 Striking voltage as constant as possible even after several successive discharges.

4.2 The transition from glow to arc discharge must occur with the weakest possible current ; the value should be markedly less than one ampere. Arc discharge, once established, must be very stable, and spontaneous transition from arc to glow discharge must never occur.

4.3 The arcing voltage must be as small as possible so as to lower both the residual voltage and the energy dissipated within the lightning protector.

4.4 The lightning protector must be capable of carrying strong currents (of several tens of amperes) for periods of the order of one second. It must be able to repeat such an operation several times at very short intervals without its characteristics being affected.

4.5 If, in exceptional circumstances, the above values are exceeded (in strength or duration) the lightning protector should "fail-safe" ; this should be achieved through final short-circuiting of the electrodes. The lightning protector must on no account be destroyed by shattering of the envelope in such a way as to leave the electrodes exposed, or by breakage of an internal connection, since in such cases the circuit is no longer protected and no warning of the fact is given.

5. The relation between operation (glow discharge or arc discharge) and heating of the lightning arrester under service conditions (with or without fuse) should be observed.

6. The greater use of semi-conductor devices in telecommunications equipment, particularly in electronic exchanges, may render such equipment more and more susceptible to damage. At the same time there is a general requirement for miniaturization of all components, including those used for protection. These two conflicting considerations present special problems.

7. A study should be made of the use of three-electrode protectors.

8. Previous contributions of interest in the study of this question are:

— C.C.I.F.—1955-1956—Document No. 11 (Federal Republic of Germany).
— C.C.I.T.T.—1957-1960, Study Group V—Contribution No. 4 (Italy).
— C.C.I.T.T.—1957-1960, Study Group V—Contribution No. 15 (United Kingdom).
— C.C.I.T.T.—1961-1964, Study Group V—Contribution No. 52 (Sweden).
— C.C.I.T.T.—1961-1964, Study Group V—Contribution No. 13 (U.S.S.R.).

9. Some manufacturers of over-voltage protectors may find it convenient to take into account the requirements of both telecommunication lines and of power lines, so that, in certain cases, a protector can be suitable for use on both sorts of line. Specification requirements for over-voltage protectors should therefore be drawn up within the framework of this question. The work should be done by the Joint Working Party PAR of Study Groups V and VI and C.I.G.R.E.

## Question 2/V — Devices reducing the voltage of wires with respect to earth

*(continuation of Question 2/V, 1964-1968)*
*(documentary question)*

Study of devices, other than lightning protectors and discharge tubes, that may be inserted in telephone lines exposed to severe induction, so as to reduce the voltage between wires and earth.

*Note.* — Two points should be studied in connection with the use of neutralizing or reducing transformers:

a) how should the best position be found for such a transformer for the purpose of compensating voltages induced on telecommunication lines during a short circuit in a neighbouring electric power line? and

b) within what limits can this device be used in such cases?

## Question 3/V* — Tolerable induced voltage in telecommunication circuits protected by special devices

*(continuation of Question 3/V, part b), 1964-1968) — (new wording)*

When high induced electromotive forces cannot be avoided in an overhead telecommunication line, how should a protection method be defined that would consist in the insertion along the line, at suitably chosen points, of lightning protectors or gas discharge tubes? What conditions should be met (number of such devices, their position, etc.) in order that no difficulties should be caused, particularly transmission difficulties?

*Note 1.* — Although a line may be made secure against danger by the fitting of lightning protectors in such a number as will not *cause* transmission difficulties, transmission difficulties associated with the same induction effects that gave rise to the danger, for example a high level of induced noise, will not be *removed* by fitting lightning protectors.

*Note 2.* — In the study of this problem, the conditions of use given in Chapter XIX of the *Directives* should be noted.

*Note 3.* — The following documents should be taken into consideration:

— C.C.I.T.T.—1961-1964—Study Group V—Contribution No. 13 (U.S.S.R.).
— C.C.I.T.T.—1964-1968—Study Group V—Contribution No. 30 (France).

## Question 4/V — Danger to a cable due to a high potential gradient

*(continuation of Question 4/V, 1964-1968)*

To what risks are persons, equipment and the insulation of a telephone line, on open wires or in cable, exposed when :

1. a high earth potential relative to a distant earth electrode occurs at the site of a power station or sub-station where that line terminates or near which it passes ;

2. a high earth potential or a large earth potential gradient occurs near the route of such a telecommunication line (due for example to a short circuit to earth, perhaps via a metallic support fixed in the ground, of the contact wire of an electric traction line or of one phase of a power transmission line).

What protective arrangements and what protective devices should be used to guard against these dangers ? How should the requisite calculations and measurements be made ?

*Note 1.* — Special attention should be given to the following:

a) a cable serving telephones in a power station or sub-station where the neutral is directly connected to earth ;

b) cables serving telephones in a power station or sub-station where the neutral is earthed through an arc suppression coil ;

c) an open-wire line serving telephones in a power station or sub-station, entry being made by means of a cable section ;

d) an open-wire line directly serving (without intermediate cable section) the telephones of a station or sub-station ;

e) lines near to the earthing connections of pylons on a power line in a network with a directly earthed neutral, or to buried conductors interconnecting all the pylons on such a line ;

f) a contact or arc occurring between a telephone cable and an electricity cable, due to an accident to the latter.

*Note 2.* — In studying this question, allowance should be made for the presence of the protective devices normally used to protect telecommunication systems against high voltage due to lightning.

*Note 3.* — Further study of the question should take account of the question of the usefulness of connections to rail.

## Question 5/V* — Protection of telecommunication cables against induction

*(continuation of Question 5/V, 1964-1968)*
*(documentary question)*

What modifications or extensions can be made to the formulae given in the *Directives* for the calculation of electromotive force that is :

— induced in a telecommunication cable having a metallic sheath by a neighbouring electricity line ;

— induced in a telecommunication line by a neighbouring electricity cable having a metallic sheath.

The following conditions should be considered:

a) the resistance between the telecommunication cable sheath and earth is uniformly distributed ;

b) the cable sheath is insulated and has earth connections of finite resistance at intervals along the length of the cable ;

c) two or more telecommunication cables with insulated sheaths are laid side-by-side and share a common earthing system ;

d) the metallic sheath of the telecommunication cable is completely insulated from earth throughout its length by an insulating covering. (This includes cables having a metallic sheath that is electrically continuous and those having a sheath whose electrical continuity is interrupted by insulating joints.)

*Note 1.* — It will be useful to consider, in particular, a cable sheath that has a good screening factor and has high conductivity, but has to be insulated from earth (for example, a sheath made of aluminium) and where it is necessary to arrange connection to earth electrodes having comparatively low resistance.

*Note 2.* — In some cases the way that a cable is laid may make it necessary to consider the effect of distributed capacitance between the metallic sheath and earth, particularly at harmonic frequencies of the main power supply.

*Note 3.* — A theoretical solution to this problem can now be obtained from Chapter XII of the *Directives.* It should first be checked whether that solution is complete enough. It might be desirable to make tests to see whether the results confirm the theory or show that it should be extended. Finally, it needs to be seen whether this study can be made to yield some practical rules which may lead to modifications or additions to the *Directives.*

*Note 4.* — In the study of this question, replies contained in the following documents should be noted :

— Contribution COM V—No. 15 (1961-1964) C.C.I.T.T. (S.A.T—Mr. Collet) Reply to Question 22/V—part b).

— Contribution COM V—No. 26 (1961-1964) C.C.I.T.T. (Chile Telephone Company) Reply to Question 22/V—part d).

— Contribution COM V—No. 81 (1961-1964) C.C.I.T.T. Reply to Questions 22 and 23 by the Câbleries de Brougg (Switzerland).

— Contribution COM V—No. 8 (1964-1968) C.C.I.T.T. (H. Pech) Reply to Question 5/V.

— An article in Câbles et Transmission, Volume 16, No. I—1962, entitled *Protection des câbles de télécommunication contre l'induction.*

— Woodbridge, A. W. and Klewe, H. R. J. : Inductive interference and its measurements on electrified railways ; *The Institute of Railway Signal Engineers,* Proceedings, 1962, pp. 23-65.

## Question 6/V* — Permissible voltage between sheath and plastic-insulated conductors and possible amendments to the Directives

*(continuation of Question 6/V, 1964-1968)*

The use of plastic insulating materials makes possible the economical design of telecommunication cables with high dielectric strength between conductors as well as between conductors and metallic sheath (if provided).

What modifications, if any, should be made in the 1963 *Directives* to take account of the introduction of such cables ?

In view of the higher voltages that may be permitted when plastic-insulated cables are used, questions concerning the safety of staff must also be studied.

## References

NICKOLAS, A. C.: Assessment of probability of personal danger. *Australian Telecommunication*, Monograph No. 3, November 1964.

TODD, B. C.: *Probabilities of personal danger.*

Contribution COM V—No. 32 (1964-1968): Methods of making joints having a high dielectric strength (United Kingdom).

## Question 7/V* — Earthing problems associated with the use of plastic-sheathed cables

*(continuation of Question 7/V, 1964-1968)*

What earthing problems arise in connection with the use of plastic-sheathed cable or lead cable with a plastic covering (for example, where lead-sheathed cables would have contributed to the earthing of a telephone exchange), and what recommendations should be made concerning these problems?

## Question 8/V — High-reliability power-line fault-statistics

*(continuation of Question 8/V, 1964-1968)*

Statistical study of faults affecting high-reliability lines and study of the repercussions on telecommunication lines or installations.

Nature and gravity of such repercussions.

*Note 1.* — The drawing-up of these statistics will require close collaboration between telephone administrations and power-supply authorities, particularly in connection with simultaneous recording of voltages and currents on the respective installations.

*Note 2.* — It would be of interest to compare the statistics for high-reliability lines with those for ordinary lines.

*Note 3.* — This study will show whether the present definition of high-reliability lines needs modifying or extending.

## Question 9/V — Joint use of supports and trenches, etc., by telecommunication lines and power lines

*(continuation of Question 9/V, 1964-1968)*

a) Joint use of the same supports to accommodate open-wire or aerial cable telecommunication lines and electricity lines;

b) 1. — Joint use of the same trench, pipe, single- or multiple-way duct, or cable to accommodate underground telecommunication lines and electricity lines. Would it be economic and prudent to extend such joint use to water and/or gas services?

2. — Joint use of the same earth electrodes.

*Note.* — This part b) of the question is directed to:

— determining which joint uses are inadmissible;

— establishing recommendations for those joint uses that are admissible.

c) What is the basis of the calculations necessary in connection with electromagnetic induction to take account of interference and danger in such cases of joint use under both points a) and b) ?

*Note.* — See Recommendation K.5.

## Question 10/V* — Booster transformers

*(continuation of Question 10/V, 1964-1968)*

Interference to telecommunication lines by railways fitted with booster transformers. The fundamental principles are covered by Chapter XVIII of the *Directives*, but the following questions of particular interest require further study :

a) What are the magnitudes and waveforms of the currents in the various parts of a traction system under overload and short-circuit conditions ?

b) What is the effect of non-uniform distribution of current in the contact wire ?

*Note.* — This may be due :

1) to the presence of more than one train in a supply section, or
2) to the use of different sizes and/or spacing of the booster transformers.

c) What conventions should be recommended for the calculation of dangerous and disturbing voltages when there is more than one train in the supply section ?

## Question 11/V — Devices for reducing noise

*(continuation of Question 11/V, 1964-1968)*

Study of the devices to give, in special cases, a reduction of noise observed at the ends of a telephone line exposed to electromagnetic or electrostatic induction.

*Note* 1. — If the literature provided about such devices is to be used to best advantage, their description will have to be accompanied by the following information :

- nature of the signalling current ;
- diagrams of the complete circuit in which the device is to be installed, showing the various elements in the speech position and also in the various signalling and switching positions ;
- the type, characteristics and location of the elements which cause unbalance and favour the appearance of noise ;
- principle, method of use, and location of the device ;
- ease of installation of the device and limits on its use, reduction of noise achieved, etc.

*Note 2.* — See pages 15 and 16 of the 1963 *Directives*, Chapter I, for prescriptions concerning the construction of balanced lines.

## Question 12/V — Sensitivity coefficients

*(continuation of Question 12/V, 1964-1968)*

a) Statistical study of the values of sensitivity coefficients for electromagnetic and electrostatic induction (such as those defined in Chapter XVI of the 1963 *Directives* for short sections of telephone circuits).

b) Study of the possibility of specifying sensitivity coefficients for cables, in terms of distance and any other factors such as propagation coefficient.

*Note.* — For making measurements of sensitivity coefficients and for interpreting the results of such measurements, the detailed recommendations given in Chapter XVI of the 1963 *Directives* should be taken into account.

## Question 13/V — Unbalance of telephone installations

*(continuation of Question 13/V, 1964-1968)*

What limits should be specified for the amount of unbalance :

a) of subscribers' installations ;

b) of telephone exchange installations, when their circuits are in the speech position ?

*Note 1.* — To achieve an answer to this question it is first necessary to assemble information based on measurements made by the method described in Chapter XVI of the 1963 *Directives*.

*Note 2.* — It would be interesting to associate with such measurement results, in particular those giving abnormal values, an explanation of their causes.

*Note 3.* — For a given exchange, it is necessary to make individual unbalance measurements for the various types of call likely to pass through the exchange, in particular :

— a subscriber-to-subscriber call within the local network of that exchange ;
— various sorts of call between that exchange and others in which automatic operations are carried out under control of that exchange, due to the use of a particular switching system.

*Note 4.* — Recommendation K.10 gives 46 decibels as a minimum value to be recommended for the unbalance of installations. Values better than this limit are often obtained in practice.

C.C.I.T.T. Study Group V has said that the value of 46 decibels as a limit should be used for calculation only. It might, for example, be used when assessing the transverse noise voltage at the end of a balanced line along which there is a known (or calculated) longitudinal noise voltage and at the end of which the telephone installation is assumed to have an unbalance of 46 decibels.

This limit may have to be approved also by other Study Groups and it could, therefore, be put forward for comment as a value applicable over the whole audio-frequency band, and applying generally to subscribers' installations and to telephone exchange installations. It is proposed that the limit should apply to measurements made at line terminals across a 600-ohms pure resistance.

*Note 5.* — See the article : "A comparison of techniques for measuring longitudinal balance" by J. C. Mau in the *Automatic Electric Technical Journal*, January 1964, Volume 9, No. 1.

*Note 6.* — See Recommendation Q.45, in which attention is directed to the fact that at least two methods of measurement are in common use :

a) that given in C.C.I.T.T. *Directives*, Chapter XVI, section 2 (Figure 13 of Recommendation Q.45) ;

b) that given in Figure 14 of Recommendation Q.45.

These two methods differ in respect of the presence or absence of an earth at the mid-point of the termination and can give different results according to the nature of the unbalance, and it is necessary to apply both methods (i.e. with and without the earth at the mid-point of the termination). However, the C.C.I.T.T. in 1968 recommended that only one set of limit values should be specified, which must be met by both measuring methods.

Recommendation Q.45 also observes that some administrations guided by their knowledge of local conditions, may feel a need to specify a figure for a lower frequency, for instance, 50 Hz.

## Question 14/V* — Necessity for a screen in plastic-sheathed cables

*(continuation of Question 14/V, 1964-1968) — (new wording)*

The metal sheath commonly used to protect a cable core against moisture provides also electric screening and a degree of magnetic screening. Sheaths using plastics only, which have no intrinsic screening properties, and other sheaths incorporating a metal screen as a moisture barrier, but which have very little screening properties are now coming into general use. Under what circumstances is it then necessary to add other screening or provide alternative means of limiting the longitudinal voltages, noise or transients?

*Note 1.* — The increasing use of miniaturized telecommunication equipment with very small thermal capacity (as in integrated circuits) makes the transients from power switching and lightning of increasing importance.

*Note 2.* — To preserve the electromagnetic properties of a moisture barrier it must be extended through at jointing points by connections of very low resistance.

## Question 15/V — Reduction of harmonics in special cases

*(continuation of Question 15/V, 1964-1968)*

Arrangements to reduce harmonics from a.c. electricity transmission or distribution lines in certain special cases (e.g. lines with a large rectifier load from industrial or traction installations or for feeding a.c./d.c. converting installations) and a.c. traction lines.

*Note.* — See pages 26 to 28 of Volume IX of the *Blue Book*.

## Question 17/V — D.c. power lines at very high voltage

*(continuation of Question 17/V, 1964-1968)*

Conditions for co-existence of very high voltage d.c. power transmission lines and neighbouring telephone lines.

*Note 1.* — The following points should be studied:

1. The character of the transients on the high voltage line which arise in normal operating circumstances at the instant when the voltage is applied and in abnormal conditions such as breakage of a conductor, accidental earth faults, etc.

2. The effect of these transients on neighbouring telecommunication lines.

3. The possibility of specifying a limiting peak value for the longitudinal e.m.f. developed when there is a sudden change of voltage, under abnormal conditions. If found possible it might be considered whether the 1000-volt limit adopted for d.c. traction lines is applicable also to this present case.

4. The noise which may arise in the telecommunication lines as a result of the current fluctuations.

5. Increase in harmonics in the power lines feeding the sub-station which converts the direct current into alternating current or in the lines fed by that sub-station.

In the case of d.c. submarine power cables, attention is drawn to the fact that the principal effect to be investigated appears to be that arising from aerial lines extending the submarine cable to the current-supplying sub-stations.

It would be useful to determine what method could be recommended for the calculation of interference and danger to which telecommunication circuits may be subject because of neighbouring d.c. power lines of very high voltage.

Moreover, it would be desirable to investigate the best methods of reducing the fluctuations of the direct current in these power lines.

6. It would be of interest to know the range and amplitude of the harmonics present in the d.c. power lines and the associated a.c. power lines.

*Note 2.* — In studying this question, consideration should be given to the following documents :

— C.C.I.F.—1955-1956—Study Group I—Document No. 14 (United Kingdom).

— C.C.I.F.—1955-1956—Study Group I—Document No. 20 (U.S.S.R.).

— C.C.I.T.T.—1957-1960—Contribution COM V—Nos. 9 and 11 (U.S.S.R.).

— C.C.I.T.T.—1961-1964—Contribution COM V—No. 31 (United Kingdom).

— C.I.G.R.E.—Report No. 331 (Meeting, May 1962).

— I.E.E.E. International Convention Record, 1965, Part 9,
  — Power corrosion (L. E. Fioretto)
  — Induction (F. M. Stumpf).

## Question 19/V — Effect of radio station emissions on telecommunication circuits

*(continuation of Questions 19/V and 20/V, 1964-1968) — (new wording)*

Effect of radio station emissions on telecommunication circuits on open-wire lines or in aerial or underground cables.

The following points should be studied in particular :

a) Under what conditions (e.g. distance between radio station and telecommunication lines, transposition scheme, sensitivity coefficient of the circuit) does noise arise in carrier channels ?

b) By what method can the noise caused in a telecommunication circuit by a radio station be calculated ?

c) What methods can be recommended for the reduction of this noise :

1. On existing lines ?
2. On new lines being planned ?

(Attention is drawn to the prescriptions concerning the construction of new lines already given in the *Directives*. Additions to these prescriptions might be proposed.)

d) What precautions are to be taken to avoid other troubles, such as interference due to the characteristics of non-linear elements ?

e) What precautions are to be taken to avoid danger due to strong induced electromotive forces (in particular in the case of lines passing near to or serving powerful radio stations) ?

*Note.* — In 1964-1968, Study Group V concluded that no great inconvenience is caused to (cable) telecommunication by interference from radio stations. A large number of administrations either do not experience such interference or find it easy to overcome. Before a recommendation is drawn up, administrations are again asked to inform the Study Group of any difficulties encountered and the measures taken to remedy them.

## Question 21/V — Protection of power-feeding installations and transistorized repeaters

*(continuation of Question 21/V, 1964-1968)*

a) What arrangements should be made to avoid power-feeding installations and amplifiers on coaxial and symmetric cables being rendered unserviceable or being subjected to interference due to :

1. electromagnetic induction from a neighbouring electricity or traction line ;
2. high earth potential in the neighbourhood of such a line ;
3. or atmospheric disturbances (lightning) ?

b) A special study should be made of power-feeding systems for repeaters using transistors on small-diameter coaxial cables.

c) What are the upper limits of e.m.f. of external origin which may be superimposed on the d.c. power-feeding voltage from the standpoint of danger ?

Such e.m.f.s of external origin may arise from any of the causes given in a). When they are due to magnetic induction from electricity and traction systems it would be useful to determine upper limits under both fault and normal working conditions.

What special procedures are necessary to avoid danger to personnel working on cables or equipment ?

d) What means of protection are to be recommended to reduce e.m.f.s of external origin so that they lie within the limits arrived at from the study of point c) of this question ? It is important that any protective devices, once operated, should not be kept in operation by the power-feeding voltage alone.

e) Should a testing device be recommended which would simulate an e.m.f. of external origin and which would enable service protection arrangements to be checked ?

What should this device be ?

*Note by the Secretariat.* — The study of this question will be carried out jointly with designated representatives of Study Group XV in Joint Working Party PFP. The following Administrations have said they will appoint representatives (from Study Group XV) : France, the Netherlands, People's Republic of Poland, the Federal Republic of Germany, the United Kingdom, Switzerland, Czechoslovakia. Representatives from Study Group V will be sent by the United Kingdom, France, Italy, Switzerland, the Federal Republic of Germany, the U.S.S.R., Sweden, Poland and Denmark.

This Working Party will have to fix permissible limits for induced longitudinal and transverse voltages and study the protection measures to be taken :

- — if these values are exceeded ;
- — if there is an increase in the earth potential in the neighbourhood of electrical installations (C.C.I.T.T. Directives for the protection of telecommunication lines) ;
- — in the case of surges due to lightning.

A Group of Experts to deal with induced voltage calculations will consist of Dr. Riedel, Mr. Köpping (Federal Republic of Germany) ; Mr. Howard (Standard Telecommunication Laboratories Ltd.) ; Dr. Rosen (Central Electricity Generating Board) ; Mr. Schultz (Siemens A.G.) ; Dr. Widl, Mr. Vogt (Standard Elektrik Lorenz) ; Mr. Fielding (United Kingdom).

## Question 22/V (Question 14/VI) — Protection against lightning

*(continuation of Question 22/V, 1964-1968, to be studied by Joint Working Party CDF of Study Groups V and VI. Study Group V will co-ordinate the study)*

A. a) Study of electromagnetic phenomena likely to appear on the inside or outside of either a buried or aerial cable, when lightning strikes in the vicinity.

b) Possibility of calculating the protection given by buried or aerial earth conductors, trees either singly or in groups, buildings fitted with a lightning conductor, etc.

c) Some radio or television transmitters on mountain tops exposed to frequent storms have to be connected with underground telecommunication cables containing audio-frequency circuits earthed at their extremities, and/or coaxial-pair cables. In such circumstances, the cables, their conductors and the equipment connected to them may be damaged by lightning striking the aerial or the top of the mountain.
What can be done to protect such cables, conductors, and the associated equipment against damage by lightning?

B. a) Liability of damage affecting the sheath or core of an underground or overhead cable if lightning strikes in the vicinity.

b) Effect of the various cable construction and laying data (cable core, sheath, different coverings, armourings, etc.) on this liability.

*Note.* — This question, which is the same as Question 14/VI, is being studied by Joint Working Party CDF of Study Groups V and VI; Part A was proposed at the Plenary Assembly in 1960 by Study Group V, and Part B by Study Group VI.

## Question 23/V — Problems of interconnection with carrier systems on power lines

*(continuation of Questions 18/V and 23/V, 1964-1968)*
*(former Asia Question No. 12, 1964, proposed by the Plan Sub-Committee for Asia)*

What problems arise, and what standards and specifications should apply, when carrier telecommunication channels on power lines are interconnected with other telecommunication channels belonging to public or private networks?

*Note.* — From its study of Question 18/V in 1964-1968, Study Group V concluded that the frequency spectrum of interference resulting from corona effect and bad contacts in power lines is now well known. If the frequencies used in telecommunication circuits do not exceed 100 kHz there is no serious risk of interference as, at such frequencies, field strength values are very low.

### Bibliography

A.I.E.E.-Committee Report: Guide to application and treatment of channels for power-line carrier, *A.I.E.E. Transact.* 73 (1954), Part III-A, pp. 417-436.

Fleischer, H.: Zur Einstrahlung von Funksendern in Trägerfrequenzverbindungen auf Hochspannungsleitungen (Radio interference in carrier systems on high tension lines); *Elektr. Wirtschaft 53* (1954), pp. 159-161.

FLEISCHER, H.; GRAFF, G.: In Hochspannungsleitungen durch das Feld von Funksendern eingestrahlte Störspannung (Interfering voltage, radiated by the electromagnetic field or radio transmitters, on high tension lines); *Elektr. Wirtschaft 57* (1958), pp. 201-203.

FLEISCHER, H.; GRAFF, G.: Kompensation von Störungen durch Funksender bei Trägerfrequenzverbindungen auf Hochspannungsleitungen (Compensation of radio interference in carrier systems on high tension lines); *Elektr. Wirtschaft 57* (1958), pp. 141-145.

GROSSKOPF, J.: Die Beeinflussung des trägerfrequenten Sprechverkehrs auf Hochspannungsleitungen (Disturbances caused to calls over carrier systems on high tension lines); *Fernmeldetechn. Zeitschrift 7* (1954), pp. 623-636.

PODSZECK, H. K.: *Trägerfrequenz-Nachrichtenübertragung über Hochspannungsleitungen* (Communication by carrier systems on high tension lines); Springer-Verlag (Edition Springer) Berlin, 1962.

— *Empfehlungen für die Planung und den Betrieb von TFH-Anlagen unter Berücksichtigung der Fremdpegeleinflüsse durch Funksender.* Technische Empfehlung Nr. 4 (Recommendations on the planning and operating of carrier installations on high tension lines with special reference to radio interference. Technical recommendation No. 4); Verlags- und Wirtschaftsgesellschaft der Elektrizitätswerke, Frankfurt/Main, 1961.

## Question 24/V — Interconnection of earthing installations

*(continuation of Question 24/V, 1964-1968. To be studied by Joint Working Party TER of Study Groups IV, V, VI, XI, and XV. Study Group V will co-ordinate the study)*

Interconnection of earthing installations.

Under what conditions and in what circumstances is it desirable or not to use in telephone exchanges and repeater stations a shared earthing system for:

— batteries,

— the earth of power equipment,

— the screening of telecommunication apparatus,

— lightning-protectors of telephone equipment.

Is it permissible to connect the shared earthing system as above with the neutral conductor of a low-voltage power network, with the lightning-arrestor installation of a building, the sheaths of telecommunication and power cables and other metallic underground structures?

*Note.* — On a proposal by Study Group V, the IVth Plenary Assembly decided that a special joint group composed of members of Study Groups IV, V, VI, IX and XV should be given the responsibility for drawing up a handbook dealing with earthing, and that this group should take as the basis for this work the text submitted in Contribution GAS 1—No. 45 (COM IV—No. 132; COM V—No. 16), together with the outcome of the work at present done by Study Group IV in 1964-1968 under its Question 18/IV.

(The text of Contribution GAS 1—No. 45 was published as Document AP IV—No. 41.)

The work of drawing up the handbook is to consist of drafting work to be carried out by a small number of experts, taking the GAS 1 text as a basis and amending it or adding to it to take account of the work of the other Study Groups concerned. The experts could probably work mainly by correspondence.

REFERENCE

Contribution COM V—No. 36 (1964-1968) (Belgium).

## Question 26/V — Revision of the Directives

*(continuation of Question 26/V, 1964-1968)*

Revision of the *Directives concerning the protection of telecommunication lines against the adverse effects of electricity lines.*

*Note 1.* — It would be of particular interest to carry out the following studies:

a) Following developments in technique, the collection of information, necessary to check the suitability of the values given in the *Directives* for calculating equivalent disturbing voltages and currents, when measured results are not available.

b) Check of the necessity to take into account, when calculating short-circuit currents, the fact that lines are of finite length and that certain effects, not previously allowed for, appear at the ends (see Contribution COM V—No. 80, 1961-1964, from the U.S.S.R. Administration).

c) Development of the formulae to be applied in the case of a line having permanently earthed conductors (see the 1963 *Directives*, pages 54, 61, 64 and 81).

*Note 2.* — In 1968, the IVth C.C.I.T.T. Plenary Assembly gave its approval, in principle, to the reconstitution within Study Group V of the former *Directives* Editing Group, for the purpose of dealing with amendments to the present *Directives* and to provide supplements in the form of a series of "guide-lines" to indicate the application of the *Directives* to practical cases. The "guide-lines" might take the form of simplified formulae, graphs, nomograms and slide-rules. The Study Group hopes that work already begun by C.I.G.R.E. will be available to serve as a basis for the work of the Editing Group. Meanwhile, administrations etc., having already prepared such guide-lines for use in their own organizations, are asked to send the results to the C.C.I.T.T.

The initial membership of the Editing Group would consist of experts from the following countries and organizations: Denmark, Finland, France, Italy, Japan, Federal Republic of Germany, United Kingdom, U.S.S.R., Sweden, C.I.G.R.E./U.N.I.P.E.D.E.

Other countries wishing to take part and able to contribute to the work either by positive contribution or by a statement of requirements in the guide-lines are asked to inform the C.C.I.T.T. Secretariat.

*Note 3.* — In its work, the *Directives* Editing Group should take account of the following Study Group V contributions for the 1964-1968 period: COM V—Nos. 22, 23, 24, 26, 28, 29, 31, 34, 35, 38.

*Summary of Questions allocated to Study Group V for the period 1968-1972*

| Question No. | Title | Remarks |
|---|---|---|
| 1/V | Protective devices | To be studied by Joint Working Party PAR of S.G.s V and VI and C.I.G.R.E. |
| 2/V | Devices reducing the voltage of wires with respect to earth | |
| 3/V* | Tolerable induced voltage in telecommunication circuits protected by special devices | |
| 4/V | Danger to a cable due to a high potential gradient | |
| 5/V* | Protection of telecommunication cables against induction | |
| 6/V* | Permissible voltage between sheath and plastic-insulated conductors and consequent amendments to the *Directives* | |

| Question No. | Title | Remarks |
|---|---|---|
| 7/V* | Earthing problems associated with the use of plastic- sheathed cables | |
| 8/V | High reliability power-line fault-statistics | |
| 9/V | Joint use of supports and trenches, etc. by telecommunication lines and power lines | |
| 10/V* | Booster transformers | |
| 11/V | Devices for reducing noise | |
| 12/V | Sensitivity coefficients | |
| 13/V | Unbalance of telephone installations | |
| 14/V* | Necessity for a screen in plastic-sheathed cables | |
| 15/V | Reduction of harmonics in special cases | |
| 17/V | D.c. power lines at very high voltage | |
| 19/V | Effect of radio station emissions on telecommunication circuits | |
| 21/V | Protection of power-feeding installations and transistorized repeaters | To be studied in co-operation with S.G. XV in the existing Joint Working Party PFP |
| 22/V | Protection against lightning | (Also Question 14/VI). To be studied by Joint Working Party CDF of S.G.s V and VI. S.G. V will co-ordinate the study |
| 23/V | Problems of interconnection with carrier systems on power lines | Addition of a bibliography. Includes studies coming under former Question 18 (1964-1968) |
| 24/V | Interconnection of earthing installations | To be studied by Joint Working Party TER of S.G.s IV, V, VI, XI and XV. S.G. V will co-ordinate the study |
| 26/V | Revision of the *Directives* | Editing Group |

PART 2

# SERIES L RECOMMENDATIONS AND QUESTIONS CONCERNING THE PROTECTION OF CABLE SHEATHS AND POLES

# SERIES L RECOMMENDATIONS

## RECOMMENDATION L.1

### PROTECTION AGAINST CORROSION

The C.C.I.T.T.,

*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,

*unanimously recommends*

that, when cables are laid, administrations and private operating agencies will find it to their interest to comply with the "Recommendations for the protection of underground cables against corrosion" (New Delhi, 1960 amended and completed Geneva, 1964 and Mar del Plata, 1968).

## RECOMMENDATION L.2

### IMPREGNATION OF WOODEN POLES

The C.C.I.T.T. draws attention to the economic importance of impregnating the wooden poles carrying overhead telecommunication lines.

The C.C.I.T.T. has issued a booklet [1] with a view to providing administrations, particularly those whose networks are not yet fully developed, with some information on impregnation processes. This booklet takes account of the information supplied on preservation processes by the administrations or recognized private operating agencies of the following countries:

| | |
|---|---|
| Australia | Greece |
| Austria | Hungary |
| Canada | India |
| Chile | Italy |
| Czechoslovakia | Japan |
| Denmark | Sweden |
| Federal German Republic | Switzerland |
| Finland | Union of Soviet Socialist Republics |
| France | United Kingdom |

[1] To be revised during 1969-1972 under Question 12/VI.

## RECOMMENDATION L.3

# ARMOURING OF CABLES

### 1. *Type of armouring*

1.1 The most common forms of armouring are :

a) *tape armouring* — This consists of overlapping steel tape or tapes, applied in helical form with a short lay, over the cable sheath ;

b) *wire armouring* — This is formed from round, flat or trapezoidal steel wires applied helically around the cable sheath with a relatively long lay.

1.2 These two types of armouring are used in combination with other protective layers (jute, plastic) for constructional, or mechanical reasons, or for protection against corrosion.

### 2. *Choice of armouring*

In deciding whether or not to use armouring and in choosing between the various types of construction, very careful consideration should be given to the local conditions of installation, such as :

a) whether the cables are laid in duct or direct in the soil ;

b) whether the cables are laid in a trench alongside a road or on private land ;

c) what material is used for the cable sheath ;

d) whether other cables are or may be laid along the same run ;

e) the nature of the soil : rocky, sandy, corrosive or not ; presence of micro-organisms ;

f) the depth of the trench, which in any case should not be less than 50 cm, and for large cables 80 cm ;

g) the risk of induction ;

h) the risk of attack by rodents or insects ;

i) the degree of exposure to lightning ;

j) whether the size and importance of the link justifies special precautions, in which case steel-wire armouring provides additional protection, particularly in manholes ;

k) whether a long draw-in is required, e.g. crossings under rivers (as cases of this are infrequent, no need is envisaged for a new design of land cable incorporating a central strain wire).

### 3. *Protection provided*

With cables laid directly in the soil, armouring contributes to safe installation and reliability of operation by ensuring protection of the cables against :

a) mechanical damage caused by stones and excavation equipment or tools ;

b) rodents and insects ;

c) chemical or electrolytic corrosion ;

d) effects of atmospheric discharges ;

e) induction phenomena due to the proximity of power lines.

4. *Tape armouring*

Tape armouring is to be preferred for protection against damage by pointed digging tools, sharp stones, etc., and is useful for providing magnetic screening for circuits within the cable, for which wire armouring is much less effective because the air gaps between the individual steel wires, which are arranged circumferentially around the cable, greatly reduce the magnetic coupling between the armoured sheath and the conductors within the cable.

5. *Wire armouring*

Wire armouring gives considerable additional tensile strength to a cable and is useful where pulling-in stresses are high (long draw-in) or where high stresses arise from conditions of use, for example, where there is ground subsidence in mining districts and where cables are run in water and bogs or in shafts leading to deep level locations.

6. *General type of armouring*

For cables with a metallic sheath of lead or aluminium, the type of armouring in most common use consists of two helical windings of steel tape between layers of impregnated paper and jute with an external protection of jute yarn or other fibre. This type of armouring ensures good protection in all five cases listed above.

For plastic-sheathed cables, a light armouring may be used, formed of metallic tapes (steel, aluminium or copper) between two coverings of plastic material (polythene or p.v.c.). Cables of this design are protected chiefly against the hazards mentioned in 3.b) and 3.c) and to a certain extent against hazards 3.a) and 3.d).

7. *Armouring for main cables*

The major cables in a long-distance network are certainly best protected by a watertight metallic sheath and the conventional armouring described above but the price of such protection is relatively high.

The cost of cables can be reduced by using a thin welded steel sheath protected against corrosion by a bituminous compound and a plastic covering. This protects the cable, though to a lesser degree, against hazards 3.a), b), c), d) ; some protection against induction may be obtained by inserting conductor elements or copper or aluminium bonds under the steel sheath.

8. *Cables in ducts*

Experience shows that symmetric-pair, coaxial pair or composite cables without armouring of any kind can be drawn into ducts in lengths of up to 300 metres, provided that the tensile stress is spread between the conductors and the components of the sheath. Thus, the steel-wire armouring formerly used may be dispensed with, except in certain special cases (important links, long draw-in, for example river crossings).

9. *Corrosion considerations—cables with metal sheaths*

Both tape and wire armouring are useful in mitigating corrosion attack ; largely because they tend to keep the impregnated coverings lying beneath them in good order and so safeguard the metal sheath from the effects of differential aeration, etc.

10. *Rodents and insects*

Damage from rodents tends to be rather high in some areas ; either tape or wire armouring will provide a safeguard, but this is an expensive method and the C.C.I.T.T. is studying the possibilities of some form of cheaper sandwich construction, say polythene—thin aluminium—coated steel—polythene. Insects might penetrate the outer polythene layer, but would then come up against the metal. Assuming this stopped them, the metal would probably later fail by corrosion, but this would be of little importance if the metal were bonded to the inner and outer polythene tubes. Besides providing protection against most rodents and insects, such a type of construction might provide some measure of extra strength relatively cheaply.

11. *Tropical countries*

In tropical countries special attention must be paid to points 6 and 7 and to the danger from micro-organisms.

In general, it is safe to dispense with armouring only when :

— cable is laid in duct ;
— no magnetic screening is required, or where this is provided by some other metallic layer included for the purpose ;
— when there is no risk of corrosion or where corrosion protection is provided by some other layer included for this purpose ;
— in the case of directly buried cables, where the soil is homogeneous and contains no flints or rocks likely to damage the cable, and where there is no danger of damage by rodents and insects.

However, special local conditions may still make armouring necessary, even in the above cases.

# Questions concerning the protection of cable sheaths allocated to Study Group VI for the period 1968-1972

## Question 1/VI

*(continuation of Question 1/VI, 1964-1968)*

— Aluminium cable sheaths.
— Protective covering for these sheaths.

*Note.* — The following points should be dealt with in the study of the protection of aluminium cable sheaths against corrosion.

1. What coverings are found to offer adequate protection to the sheaths against corrosion ?

*Note.* — For the study of this part of the question, the following points should be examined :
- — effects of purity of metal and method of sheath formation ;
- — use of the covering for preserving the armouring as well when the latter serves for screening purposes;
- — effect of induced currents when the cables are installed along a.c. electrified railway tracks ;
- — special precautions at joints and at earthing points (to maintain the effect of an electromagnetic screen).

2. What sort of tests are applied to finished cables to check the protection given by protective coverings ?

3. How can the choice of any type of covering be correlated to results of soil tests ?

4. Can cathodic protection be employed as an additional protection if, for example, it is considered that the perfection of the protective covering cannot be maintained ? In applying cathodic protection to aluminium, the potential difference between the metal and the soil must be maintained between limits, which need to be defined. Cathodic corrosion occurs at strongly negative potentials. For similar reasons special care may be needed if aluminium sheaths form part of a cable sheath system which is being connected to a cathodically protected structure to prevent harmful interaction.

ANNEX 1

(to Question 1/VI)

### Conclusions reached by Study Group 6 in 1957-1960

1. In 1957-1960, Study Group 6 paid particular attention to :
— the jointing of aluminium cables ;

— the use of aluminium sheaths for long-distance cables placed alongside power lines when a more favourable screening factor is required;
— the protection of aluminium sheaths against corrosion.

2. S.G. 6 would like to be informed of any experience acquired regarding the cathodic protection of aluminium-sheathed cables. There was some discussion at the meeting in June 1960 about the cathodic protection of cables. It is too early to define exact figures for the negative potential to be applied. Excessively negative potentials might give very heavy corrosion. Cathodic protection might conceivably be practicable between potentials of 0.8 and 1.2 or 1.4 V. Hence if cathodic protection is desired for aluminium, it must be done with extreme circumspection.

3. The discussion emphasized the effect on the corrosion of aluminium of the purity of the metal and the mechanical handling it has undergone. The purer the metal, the less will be the risks of corrosion; the more stretched and rolled it has been, the greater the risk of corrosion.

4. Damp and air seeping into the plastic sheath, between sheath and cable, actively encourage corrosion, hence the importance of ensuring that the plastic sheath adheres to the cable. A plastic sheath is not as effective on aluminium as on lead. Cathodic protection should not be necessary with a plastic sheath on lead, whereas plastics on an aluminium sheath may call for cathodic protection.

## ANNEX 2
## (to Question 1/VI)

**Information supplied by the Federal Republic of Germany in 1968**

1. *Aluminium sheaths*

Whenever cables with aluminium sheaths are employed by the Federal German Postal and Telecommunication Administration, non-corrugated aluminium sheaths on cables less than 50 mm in diameter are used and must be jointed by means of direct pressure, without soldering. On cables more than 50 mm in diameter, corrugated aluminium sheaths are used. The aluminium must be at least 99.5% pure.

2. *Protection from corrosion*

2.1 The anti-corrosion protection prescribed for non-corrugated aluminium sheaths consists of:
— a layer of soft material, covered by a strip of polyisobutylene or butyl 0.6 mm thick with an overlap;
— a strip of impregnated cloth;
— finally, a protective sheath of polythene jointed by pressure, without soldering.

2.2 The anti-corrosion protection prescribed for sheaths of corrugated aluminium consists of:
— a layer of soft material which fills the corrugations;
— a plastic sheet covering with an overlap;

— another layer of plastic material (if necessary, another plastic sheet with an overlap);
— finally, a protective polythene sheath jointed by pressure, without soldering.

The following applies to both types of sheath:
— The polyisobutylene or butyl strip must be soldered at the overlap points;
— The specific resistance of the strip must be at least $10^{10}$ Ω cm.

3. *Jointing sleeves*

Jointing of the aluminium sheaths is effected by soldering on lead sleeves. By using a new liquid flux, tinning of aluminium sheaths with a special solder (90% zinc and 10% tin) is greatly simplified and made much more reliable. After the aluminium sheath has been scraped white with a steel brush, the flux is applied to the sheath which is then tinned by a lamp with a special solder (90% zinc and 10% tin). The lead sleeve is soldered with soldering tin.

4. *Tests*

Tests are made on the aluminium sheath, the anti-corrosion protective material and the polythene sheath.
Normal processes are used for the prescribed tests, which include bending tests, testing the water-tightness of the metal sheath, thermal testing of the anti-corrosion protective material and of the polythene sheath, determination of the dew-point and of the softening point.

ANNEX 3
(to Question 1/VI)

**Aluminium cables tested in the United Kingdom**
(Information brought up to date in 1968)

1. The Inverness-Nairn (16 miles) 96 pair/20 lb (0.9 mm) paper-insulated, argon-arc seam-welded aluminium-sheathed cable (non-corrugated) with extruded polythene covering was installed in May 1957 to gain experience in the use of aluminium cables. There is no adhesive between the aluminium and polythene sheaths and the lead jointing sleeves plumbed to the aluminium sheath are protected with polythene sheeting overwrapped with layers of impregnated tapes. Because of the possibility of water gaining ingress to the aluminium sheath two magnesium reactor anodes were connected to give cathodic protection. Insulating gaps are provided at terminal stations to isolate the cable from the lead-sheathed cable network in order to avoid a galvanic couple between the lead and aluminium. Several joint failures have occurred due to deterioration of the bond between the solder and the aluminium sheath resulting in low insulation on the cable pairs. It is proposed to pressurize the cable to guard against joint failure. The overwrapping of the lead sleeves has failed to prevent the ingress of water to the jointing sleeves, which has resulted in a reduction in the overall sheath/earth resistance. In April 1967 this measured 280 ohms. Split polythene sleeves heat welded with epoxy resin wipes are being provided as joint closures in order to improve the sheath/earth insulation resistance. The sheath potential in April 1967 was between

$-1.30$ V and $-1.37$ V to a saturated copper/copper-sulphate electrode. No corrosion faults have been reported.

Dimensions (approx.) : Overall diameter, 34 mm ; polythene thickness, 1.7 mm ; aluminium thickness, 1.4 mm.

2. The Droitwich-Worcester (7 miles) 216 pair/20 lb (0.9 mm) paper-insulated, corrugated aluminium-sheathed cable produced by the argon-arc welding process was installed in November 1959. In this case bitumen is provided between the aluminium sheath and the p.v.c. covering. The depth of corrugation is 2.4 mm. The cable lengths are jointed by means of plumbed lead sleeves provided with protective coverings. The overall insulation resistance sheath/earth is now of the order of 10 000 ohms. Cathodic protection is not provided. No corrosion faults have so far occurred.

Dimensions (approx.) : Overall diameter, 54 mm ; p.v.c. thickness, 2.2 mm ; aluminium thickness, 2.2 mm.

3. The Beeston-Nottingham (4.2 miles) 300 pair/10 lb (0.6 mm) paper-insulated cable was installed in June 1960. It has a sheath of super-pure aluminium, 99.99%, extruded directly over the paper core (non-corrugated) and the aluminium is protected by an extruded polythene sheath. There is no adhesive between the polythene and aluminium sheaths. Insulating gaps are provided at the terminating exchanges to avoid contact with lead cable sheaths. At about the end of 1962 cathodic protection was applied by means of one magnesium anode. The potential of the sheath in March 1967 was $-1.36$ V to a saturated copper/copper-sulphate electrode. The sheath/earth insulation resistance was 150 000 ohms. No corrosion faults have so far been reported.

Dimensions (approx.) : Overall diameter, 42 mm ; polythene thickness, 1.5 mm ; aluminium thickness, 1.5 mm.

These experimental cables are to remain in use and the United Kingdom will continue to give further information in the light of later experience.

## ANNEX 4

(to Question 1/VI)

### Information supplied by the Administration of Italy in 1968

The Italian Administration is now beginning to lay the first aluminium-sheathed cable in connection with the establishment of an important connection 200 km long.

The cable, which has already been manufactured, consists of four 2.6/9.5 mm coaxial pairs; it has a non-corrugated aluminium sheath (purity 99.8%, thickness 2 mm, nominal screening factor 0.23), an anti-moisture protective layer (mixture of bitumen and rubber) and a polythene covering of low-density and high molecular weight (thickness 3 mm, breaking load 10 $N/mm^2$, elongation 350%, density $0.920 + 0.935$ $g/cm^3$, melt flow index $0.2 + 0.3$, carbon black content $1.5 + 2.5$%).

The aluminium sheath was applied by extrusion at 400°C. The choice of grade of aluminium and impurity content (Fe 0.15%, Cu 0.01%, Si 0.15%, Zn 0.06%, other 0.02%) was dictated by the following considerations : resistance to corrosion, mechanical strength, ease of extrusion and cost.

Polythene was chosen for the outer covering instead of p.v.c. because its properties, particularly its relative impermeability to water vapour, give better protection to the aluminium against corrosion.

The cable is not armoured and no cathodic protection of the aluminium is provided.

Jointing will be ensured by means of lead sleeves soldered on the aluminium, which will first be carefully deoxydized.

In view of the high temperature reached inside the coaxial pairs during the soldering operation (about 105°C), the polythene discs (14 for each coaxial pair) will be replaced by polytetrafluoroethylene discs.

## Question 2/VI

*(continuation of Question 2/VI, 1964-1968)*

Cable sheaths made of metals other than lead or aluminium.

*Note.* — The following are the main considerations influencing the use of telecommunication cables with corrugated steel sheaths:

a) In certain circumstances, telecommunication cables with steel sheaths may be more economical than lead-covered cables.
b) A corrugated steel sheath remains unaffected almost indefinitely by traffic shocks. The intercrystalline cracks caused by fatigue which appear in lead sheaths do not occur.
c) Such cables are flexible enough to be drawn through small manholes.
d) The smooth non-adhesive nature of the plastic covering permits of clean work.
e) One and the same type of cable may be used for laying either direct in the ground or in ducts.

### ANNEX 1

(to Question 2/VI)

**Information from the Federal German Republic (1961-1964)**

Telecommunication cables with corrugated steel sheaths are used by the Federal German Administration.

The steel sheath is welded longitudinally and given roughly sinusoidal corrugations so as to obtain better cable flexibility. Until now, the joint has been lap-welded; in future it will be butt-welded. At least two layers of a special plastic substance based on tar, of sufficient thickness, are placed on the corrugated steel sheath as protection against chemical or electrolytic corrosion. These layers are separated from each other by a thermoplastic lapping. Mechanical protection is ensured by special plastic material. A covering made of a polyvinyl chloride mixture or of polythene is used as an additional protection against corrosion. Cables provided with such steel sheaths can at present be made for cable cores of 13-70 mm.

Specifications for telecommunication cables laid outside buildings, including those for corrugated steel-sheathed cables, are published in Instructions 0816 of the *Verband Deutscher Elektrotechniker*.

By 1964, 10 000 km of cable with corrugated steel sheath had been laid in the Federal German Republic, and was giving satisfactory service. There is some susceptibility to atmospheric discharges since the sheath is not in direct contact with the soil.

## ANNEX 2
## (to Question 2/VI)

### Information from the Austrian Administration (1961-1964)

The Austrian Administration has been using corrugated-steel sheathed cables for some time now on sections exposed to strong vibrations. Information about the steel sheath and the protective coverings is given below:

1. *Corrugated-steel sheath*

This sheath consists of non-alloyed steel according to DIN 1624; it is made with a longitudinal lapped or butted welded seam. At the same time, it is given a helical corrugation of which the depth is 2.5 mm for cables having a diameter of 20 mm (measured without sheath). For cables of greater diameter, the depth of corrugation increases roughly proportionally to the diameter. The steel tape has a thickness of 0.3 mm for cables having a diameter of 15 to 20 mm, measured under the metal sheath, and of 0.5 mm for stronger cables. To increase the adhesion of the outside of the sheath it can be subjected to an appropriate chemical treatment.

2. *Internal protective coverings against corrosion*

These coverings consist of a special viscous substance ("polyment") enclosed in one or more covering plastic tapes.

3. *External plastic covering*

This is made of polyvinyl chloride. The thickness of the covering depends on the diameter of the cable core, lying between 1.0 and 2.9 mm.

4. *Protection against induction*

In order to create some protection against induction (to achieve a lower screening factor) a layer of round or flat copper or aluminium wires can be applied between the cable core and the steel sheath; these bare wires may be covered, if necessary, by steel tape windings.

The Austrian Administration has published some "Instructions for the preparation of sections of corrugated-steel cables and their assembly" ("Anweisung für das Vorbereiten der Kabelenden und für die Montage von Stahlwellmantelkabeln"), dealing with cable-laying procedure, assembly methods, and especially the protection of joints.

## ANNEX 3
## (to Question 2/VI)

### Information supplied by the American Telephone and Telegraph Company (1961-1964)

*Bell System experience with stalpeth sheath*

Stalpeth sheath as made by Western Electric Company consists of a layer of corrugated aluminium, a layer of corrugated and soldered steel, a flooding of hot thermoplastic compound, and an outer polyethylene jacket.

We recommend stalpeth sheath for use in conduit and in aerial plant. Our experience with stalpeth for these uses has been excellent. We have had no indication of corrosion of the aluminium or steel except at points where the outer sheath has been damaged and water has entered the cable. The bulk of the Bell System pulp-insulated feeder plant is now made with stalpeth sheath.

We do not recommend the use of stalpeth in buried plant because the outer polyethylene jacket is vulnerable to lightning punctures in most sections of the U.S.A. The plastic sheaths recommended for buried use are as follows:

1. *On pulp-insulated cables* — PASP (polyethylene, aluminium, soldered steel, flooding compound and outer polyethylene). With this design, lightning may puncture the outer sheath, but there is rarely any damage to the polyethylene jacket under the metallic shield.

2. *On polyethylene-insulated cables* — PASP, as in pulp cables, or PAP (polyethylene, aluminium and polyethylene). These sheaths are equally effective in protecting the cable against lightning damage.

## ANNEX 4
(to Question 2/VI)

### Information supplied by the French Administration in 1967

The French P.T.T. Administration has established a specification for steel-sheathed cables which are cheaper than conventional trunk cables with lead sheath, steel tape armouring, and impregnated jute backing.

The cable core is the same as that of lead-sheathed trunk cables. One or more conducting tapes of aluminium or copper are wrapped helically or lengthwise on the core, after it has been covered with several layers of paper. The manufacturer is free to choose the number and thickness of the tapes, the only condition being that the screening factor must be better than that of lead-sheathed cables with conventional armouring[1].

The metallic sheath consists of a steel band curved in the shape of a tube, which is welded lengthwise and corrugated to make the cable flexible. The thickness of the steel band is:

— 0.4 mm for cores with a diameter of $\leq 48$ mm;
— 0.5 mm for cores with a diameter of $> 48$ mm.

The steel sheath is protected from corrosion by a bituminous coating which fills the grooves, possibly one or more polyester tapes, and by a polythene sheath 2 mm thick. These cables are buried in the earth direct or they can be drawn into cement or plastic ducts in towns.

## Question 3/VI

*(continuation of Question 3/VI, 1964-1968)*

Use of plastic materials as protective coverings for metal cable sheaths:

[1] *Reference:* Article by H. PECH, *Revue des Câbles et Transmissions*, No. 3, July 1966.

1. for protection against corrosion ;
2. for protection against high potentials, however caused.

*Note 1.* — Studies under this question should be directed to deciding :

a) If mechanical protection of a plastic sheath by armouring is necessary when the cable covered in this way is buried in the earth direct.

b) If not, whether periodic measurements of the insulation between the sheath and earth should be recommended to ensure that the protective covering continues to be in good condition. This procedure would imply that the splicing sleeves and loading coil pots—which are normally connected to the sheath electrically—should be insulated with respect to the earth.

*Note 2.* — Studies under this question should take into account the studies by Study Group V relative to coverings which, while providing protection against corrosion, have a low resistivity so as to enable a suitable resistive coupling between the earth and the metal sheath to be maintained.

ANNEX 1

(to Question 3/VI)

**Summary of the information given to Study Group 6 in 1957-1960 and brought up to date in 1968, regarding plastic protective coverings**

The Federal German Administration recalls the use of plastic materials as protective covering for steel- or aluminium-sheathed cables and mentions a covering made of polyvinyl chloride mixture placed on a plastic layer of a special tar-based substance (cables with stiffened lead sheaths) used when the lead sheath and/or the steel armouring have to be protected against aggressive soil compounds (the soil of swamps, etc.).

The United Kingdom Administration reports that protective coverings for metal cable sheaths are used less frequently than in the past because most cable sheaths are themselves now made from plastics. For the present, lead sheathing is, however, still specified for cables containing coaxial pairs and in this case there is a polythene covering over the lead.

On the periphery of local exchange networks small polythene-insulated and polythene-sheathed cables are in common use. About half these are in earthenware duct and the remainder directly buried in the ground. A small proportion of those directly buried are covered with wire armouring to minimize the risk of damage from digging and similar operations. This wire armouring has a plastic covering to safeguard it against corrosion. In this instance the plastic used is polyvinyl chloride because of the greater resistance to abrasion it affords.

In the United Kingdom there has always been a preference for polythene rather than polyvinyl chloride for external cables, both for coverings and for sheaths. This applies except where resistance to abrasion has to be specially catered for as in the circumstance referred to above. The reasons for this preference are largely historical and are outlined below.

Lead was in short supply during the war and for some years after and as a result the standard lead-thickness for conventional paper-lead cable was reduced somewhat in 1942 and again in 1946. A little later seemingly authoritative reports suggested that world resources of this metal were becoming limited and might in a comparatively short time become insufficient. This stimulated a further reduction in lead thickness and the introduction in 1947 of thin-lead and hessian-protected cables. Further, it was thought expedient at that time to examine the practicability of using a sheath entirely of plastic as an alternative to lead for paper-core cable. The choice of plastic fell naturally on polythene as it was a British development and had a very good moisture permeability constant, much better than that of polyvinyl chloride.

As little was known about the behaviour of extruded polythene it was decided to proceed cautiously and to manufacture about 10% of the thin-lead and hessian-protected cable requirement as thin-lead and polythene. Searching tests were made on the "polythene over thin-lead" and the results were very good. So good that confidence was built up in polythene and a sheath entirely of polythene was considered practicable. In the event there was no lead shortage but a complete change-over to entirely plastic sheathing, either with or without a 0.15 mm aluminium tape water-barrier, has now become standard practice for multi-pair audio cables.

Owing to the low coefficient of friction of polythene a lead cable covered with this material pulls-in very well. It is better in this respect than one covered with polyvinyl chloride. It is true that the polythene covering is the more inflammable but no adverse effects from this have materialized. The same remarks, of course, apply to cables with sheaths made entirely of plastic.

There is some small economic advantage and convenience in using one material both for protective coverings and for entire sheaths and on balance there is considered to be advantage in continuing to use polythene for both purposes.

The text of specifications laid down by the Italian Administration as regards thermoplastic coverings laid over the lead of telephone cables is given in Contribution COM 6—No. 12 in the 1957-1960 series.

These specifications were still valid in 1963. During the period 1958 to 1963, about 1100 km of coaxial pair cables with thermoplastic covering were laid in Italy and have proved satisfactory. Moreover, balanced pair cables of considerable length provided with such a protective covering have been laid without giving rise to any reports of faults.

Quite recently (1964), a reduction in the thermoplastic sheath has been introduced into the specifications by the Italian Administration; it now has to meet the formula:

$S = 1.0 + 0.032$ Dp ($S$ thickness in mm, Dp diameter over the lead sheath in mm).

It is added, by way of information, that about 1000 km of coaxial pair lead cable with thermoplastic covering is now being laid, this cable complying with the same specification. It may be of interest to note that since 1959 considerable lengths of balanced pair lead cables provided with a thermoplastic protective covering have also been used by the Italian State Railways with satisfactory results.

The Austrian Administration, in general, envisages the use of plastic coverings for lead-sheathed cables only if the cables are exposed to harmful effects due to:

1. Very high earth potentials, due to the earthing of electric installations by a short circuit;
2. attacks by soil components or liquids;
3. electrolytic corrosion.

Polyvinyl chloride is generally used for the protective covering, because it possesses favourable mechanical characteristics (especially as regards abrasion) and can be applied in close windings round the lead sheath. As an intermediate layer, bitumen is used, with a lapping of polyvinyl-chloride tape or bitumenized cotton tape.

If the cable has an external plastic covering, a reduction in the thickness of the lead sheath is considered sufficient.

The thickness of the polyvinyl chloride covering must be adequate to ensure a dielectric strength of 20 kV for 50 Hz alternating current and it should in no case be less than 3 mm.

ANNEX 2

(to Question 3/VI)

**Steps taken by the French Administration to protect metal sheaths against electrochemical or electrolytic corrosion**

(Information supplied by the French Administration in 1964-1968)

| Type of sheath | Risk of corrosion | Laid in ducts or conduits | Laid in the earth |
|---|---|---|---|
| Lead | Normal (general case) | None | Armouring of metal strips and impregnated jute |
| | Very high risk | 2-mm extruded polythene sheath | ditto + 2-mm polythene sheath for strictly necessary distance |
| Aluminium | Normal (general case) | Proofing compound and 2-mm extruded polythene sheath | Compound + 2-mm polythene sheath + metal strips + impregnated jute |
| | Very high risk | ditto | ditto + 2-mm polythene sheath for strictly necessary distance |
| Steel | In all cases | Proofing compound + 2-mm extruded polythene sheath | |

ANNEX 3

(to Question 3/VI)

**Summary of information supplied by the U.S.S.R. Administration in 1964-1968**

To protect the metal sheaths of its underground telecommunication cables against corrosion, the Soviet Administration applies various types of insulating coverings—their specifications depending on the type of metal, the cable operating conditions, and the degree of attack of the surrounding medium.

In the case of lead-sheathed cables,

— either a normal protection composed of successive layers of paper, bitumen and jute,

— or reinforced protection which includes in addition, above the first bitumen layer, two p.v.c. tapes overlapping by at least 20% between the sheath and the armouring.

The aluminium sheaths are always protected by a layer of bitumen compound, and then a polythene sheath.

If the cable is not likely to be subjected to a high level of a.c. induction, this covering is considered sufficient, its thickness being between 2 and 2.5 mm.

Otherwise, or in regions where there is a high keraunic level, the polythene sheath—whose thickness is then reduced to about 1 mm—is covered by alternate layers of bitumen and crêpe paper, or sometimes by p.v.c. tape overlaid with steel strips and jute.

If the degree of attack is likely to cause rapid corrosion of the steel strips, the armouring is protected by a plastic covering between 1.5 and 2 mm thick.

## ANNEX 4
(to Question 3/VI)

### Protective coverings for metal sheaths of telecommunication cables used in Czechoslovakia
(Information supplied by the Czechoslovak Administration in 1964-1968)

In Czechoslovakia, metal sheaths of telecommunication cables are protected against corrosion in accordance with the C.C.I.T.T. Recommendations and the directives prepared by the Administration in respect of specific local conditions.

Telecommunication cables are protected against corrosion only at those points on the route where a general exploration has clearly shown that a risk of corrosion exists. Examination of old and new cable routes shows that the classical steel-armoured telecommunication cable corrodes only on short lengths in certain places (provided the cable does not run parallel with d.c. electric railway lines). The greater part of all cables is not subject to heavy corrosion. These sections of cable usually last for more than 30 years.

On the basis of this examination, it has been agreed that only the vulnerable sections of low-current cables should be protected against corrosion and that passive and active protection methods should be used.

Passive protection methods include various types of insulating coverings placed on metal sheaths and insulating sleeves at the joints. Active protective methods comprise cathodic protection, drainage installations, active anodes and the earthing of metal sheaths.

At present, only three main types of passive protection are used in Czechoslovakia :

1) simple,
2) reinforced, and
3) special.

1. Simple passive protection consists of a layer of bitumen placed over the lead sheath which is wrapped in impregnated paper. If the cable has no armouring, a layer of impregnated jute is added to the paper layer.

2. Reinforced passive protection consists of a layer of bitumen placed over the lead sheath with another protective layer made up of three plasticized p.v.c. tapes with 35% overlap. A third layer of two impregnated paper tapes is placed over these first two layers. If the cable has no armouring, a layer of impregnated jute is placed over the paper. If the cable is armoured, the armouring is protected in a similar way.

3. Special passive protection may be applied in three ways :

3.1 Type C consists of bitumen covering over the lead sheath which is wrapped in five rubber tapes with 20% overlap. A binder is used between the second and third and between the third and fourth tapes. Another plasticized p.v.c. tape with 15% overlap or two rubberized cloth tapes are placed over the insulating layers. If the cable has no armouring, another impregnated paper layer is wrapped around these layers (two tapes with 35% overlap) and an impregnated jute covering is applied to the surface. If the cables are armoured, the armouring is wrapped around the final paper layer and protected by a layer of bitumen and an impregnated jute covering.

3.2 Type Y consists of a continuous plasticized p.v.c. covering, 2.5 mm thick, applied by pressure over the lead sheath. Two impregnated-paper tapes are wound around this covering. If the cable has no armouring, an impregnated jute layer is wrapped around the final paper layer. In armoured cables, the armouring is placed over the final paper layer and protected by three more layers. The first layer consists of a coat of bitumen around which three impregnated paper tapes are wound with 25% overlap, and over the whole an impregnated jute covering is applied.

3.3 Type S is applied to cables whose route offers a particular corrosion hazard for metal sheaths ; it is also used for cables with an aluminium sheath. On the whole, the insulating layers are constructed in the same way as for type Y, the only difference being that an intermediate layer consisting of a special type of paraffin (containing a bactericidal substance) is applied between the metal sheath and the continuous p.v.c. layer. The purpose of this intermediate layer is to limit the penetration of air and damp should the compactness of the continuous insulating layer deteriorate. The armouring of these cables, moreover, is very carefully protected by a layer of asphalt and four plasticized p.v.c. tapes. A covering of impregnated jute is placed over the final layer. As type S protection is still in the testing stage, detailed information will be supplied later. The directives specifying at which points and over which lengths passive types of protection should be applied in the various cases are described above.

These types of passive protection have been used in Czechoslovakia for four years and, so far, no particular disadvantages have been observed. As it is relatively expensive to make cables with such passive protection (1-4% more expensive than the classical method), it is extremely important to limit their use to areas where it has been definitely proved that corrosion is possible. Cables provided with such protective coverings are manufactured in Czechoslovakia ; they are used mainly when new cables are required or when routes are repaired. In addition to the protective coverings mentioned above, another kind of tape and protective paste known as "PLU" are used. These protective tapes and paste are applied by hand over the jute covering of the traditional type of cable when general repairs are carried out and when defects are remedied, but only if the existing cables are exposed to corrosion for a length of 50 metres at least. The protective tape is made of very fine glass fibre liberally impregnated on both sides with petroleum jelly paste. The paste coating is fungicidal and contains 50-60% of finely ground mineral substances and at least 5% of alkaline chromate. After this has been applied to the cable sheath, after the protective wrapping has been applied and after the surface has been slightly reheated with an oil lamp, during which time the surface is constantly smoothed, a compact insulating covering is formed which prevents humidity from penetrating to the cable sheath and absorbs the humidity which already exists in the insulating coverings. This type of passive protection is used also in cases where the protective covering on the jointing sleeves has to be renewed during the assembly of the classical type of cable.

The problems presented by such passive protection are always related to the preservation and measuring of the insulated condition after the cable has been laid. The Czechoslovak Administration is now working out methods for preserving and measuring the insulated condition of Types S and Y passive protection, but reliable results will not be available for another year.

*Conclusion*

The following conclusions were arrived at after four years' experience of the protection methods described above:

a) The correct use of cables with passive protection depends mainly on the care with which the soil examination work has been carried out.

b) The plasticizing agents used in the p.v.c. composition must strictly accord with the standards adopted in each case.

c) The defects so far observed on insulating layers were caused by faults in manufacture or by incorrect handling of the cable during laying.

d) The cost of constructing cable routes using cables equipped with the above-mentioned types of protection is from 1 to 4% more than the cost using classical lead-sheathed cable.

e) Laboratory tests of the durability of protective coverings show that these can be relied upon to last for more than 15 years.

## ANNEX 5

(to Question 3/VI)

### Conductive plastic sheaths

(Information supplied by the Northern Electric Company)

*Summary*

Conductive plastic-sheathed cable has been buried in numerous locations and evaluated in comparison with normal plastic-sheath cable. The results indicate a significant improvement in the incidence of damage and consequently the ease of location of faults, if any.

*Cables*

The various cables used in the field trial comprised 25 to 200 pairs of conductors of 0.91 mm or 0.64 mm diameter. The cable core was wrapped with a longitudinal tape of plastic or rubber-and-plastic laminate, and shielded with a 0.22-mm soft aluminium tape which in most instances was corrugated transversely. The outer jacket of conductive plastic had a conductivity of approximately 100 ohm/cm and is commercially available.

The jacketing material is a co-polymer of ethylene/ethyl-acrylate with up to 50% of carbon black. Such material, if properly compounded and well dried, exhibits good extrusion qualities and good tensile, impact and cut-through strength. Flexibility at low temperatures and stress-crack resistance are also good. Waterproofing flooding compound under the jacket was omitted as no suitable electrically conductive material was available.

*Environment*

The cable was installed in areas having an isokeraunic level of 20-30 thunderstorm days per year.

*Test application*

A total length of 28 km of cable has been in service for periods of 4 to 5 years in eastern Canada. Seven locations were involved, each of which had a continuing history of high incidence of cable faults due to lightning.

*Results*

Only two cases of cable damage have been reported over the duration of the trial and in each case the damage was highly localized. Other cables with non-conductive sheaths in the area, either running parallel to or spliced in series with the test cables, have exhibited the usual damage —that is, numerous pinholes scattered over long lengths of the cables. The faults found in the conductive sheathed cables, being localized, were easier to repair in comparison.

*Comment*

Heavy stray direct currents in the earth can adversely affect this type of sheath, much as would be the case on a lead-sheathed cable with jute or other non-insulating protection. In areas where this condition is not a problem a conductive plastic sheath over a metallic shield appears to significantly reduce cable damage due to lightning.

## Question 4/VI

*(continuation of Question 4/VI, 1964-1968)*

Cable sheaths made of plastics :

i) where the sheath is entirely of plastics ;

ii) where a metallic water-barrier is included.

*Note 1.* — Information is requested on methods of locating faults in plastic cables. A fault may occur at a considerable distance from the point where water has penetrated the cable sheath, particularly when the conductors are sheathed in plastic material.

*Note 2.* — Information should be given on methods for appreciating the expected life of cables with plastic sheaths and the reliability of joints made by various means : for example, welding or moulding, mechanical devices, tapes, epoxy resin compounds, etc.

### ANNEX 1

(to Question 4/VI)

**Information from the Federal German Republic (1961-1964)**

1. *Type of cable*

In the Federal German Republic, cables have been laid, on a trial basis, which have paper-insulated conductors as in lead-sheathed cables. The core of the cable has a static screen consisting of an uninterrupted lapping of aluminium tape, and over that a seamless sheath, made of a mixture of polyisobutylene and carbon-black. This kind of sheath is exceedingly plastic and malleable, so we have protected it with textile lappings and with several lappings of paper-bedding between layers. The whole is lapped with steel tape armouring and, externally, there is an impregnated jute protective covering.

The polyisobutylene used for the mixture is a high-polymer thermoplastic hydrocarbon, which has a high molecular weight and is very resistant to penetration by water vapour. At normal temperatures it resists acids, solvents, saline solutions, etc. It remains plastic down to a minimum temperature of −50°C. Its tensile strength is very low. Its resistance to ageing seems good.

2. *Jointing*

A joint between two cable ends is covered by a polyisobutylene-mixture sleeve, made in one piece and with a longitudinal seam. The longitudinal seam is pressure-welded at about 200°C by means of a propane gas-heated welding tool. The two ends of the sheath are welded to the polyisobutylene sheath in similar fashion. When the two superimposed layers of polyisobutylene are welded together, the joints are fully watertight. The soft plastic sheath made of polyisobutylene mixture with welded joints is protected by a protective coupling of cast-iron in the shape of two half-shells. The empty space between the polyisobutylene sheath and the cast-iron protective coupling is filled with a compound having a maximum melting-point of 150°C.

## ANNEX 2
(to Question 4/VI)

**Cables with sheaths made entirely of plastic materials used in the United Kingdom**
(Information brought up to date by the United Kingdom in 1968)

1. *Polythene-insulated and polythene-sheathed local cable*

A considerable quantity of this cable, estimated at 140 000 sheath-miles, is giving very good service in the distribution part of the local network. Possibly rather over half is in duct and the remainder buried direct. The costs of such cables are estimated to be slightly less than those of equivalent cable with lead sheath and paper-covered copper, but their flexibility and reliability confer an added economic advantage. Since April 1960, all distribution cables up to a capacity of 100 pairs are of this kind. Some cables were fitted with discrete water-blocks at intervals of 20 yards to restrict the passage of water in the event of sheath damage, but the latest cables are completely filled with petroleum jelly, their conductors being enclosed in foamed polythene insulant to offset increase in capacitance due to the jelly. Aluminium conductors in this type of cable are now coming into use.

2. *Large local cable with polythene sheath*

For the larger exchange cables the cost pattern differs and the polythene-insulated and polythene-sheathed type would be more expensive than paper-lead. It is here that paper-insulated and polythene-sheathed cable is economical to use. From April 1964 it has been used for most subscribers' cable ranging from above 100 to 3000 pairs. In this cable a thin but wide aluminium foil tape, precoated on one side with a strongly adherent film of polythene, is laid lengthwise over the paper core of the cable before sheathing, the polythene surface of the tape being outermost. Hot polythene from the extruder welds to the polythene surface of the tape and firmly bonds the aluminium to the inside surface of the sheath. This aluminium tape barrier reduces the effective area over which water vapour can diffuse into the paper core by at least 50 times and in practice the resulting rate of ingress is so slow that it can be disregarded.

Large polythene-insulated and polythene-sheathed cable lends itself to direct termination on a frame, and to save a joint, cable of this type is largely used in place of paper-insulated cable for the last length entering an exchange.

3. *Trunk and junction cable* (audio)

The Dover-Deal junction cable (9 miles) was an experiment. It has a 100-mils polythene sheath, without carbon black, over paper-insulated aluminium conductors. The core is fairly loose to facilitate the passing of dry gas through the cable if required. The diameter is 1.27 inch (32 mm). The cable is kept under permanent gas pressure and is fully described in the *I.P.O.E.E. Journal*, Volume 48, page 224, and Volume 49, page 22, January and April 1956.

The cable was brought into service in June 1955 and for 13 years has given very good service.

There is a difference of some 12°C (22°F) between the winter and summer cable temperatures and the insulation resistance for any year at minimum winter temperature is about three times that for the corresponding maximum summer temperature. When laid, the insulation resistance at maximum summer temperature was 14 500 megohm/miles (24 000 megohm/kilometres) ; at the same temperature it is now a little under 2000 megohm/miles (3000 megohm/kilometres).

A number of audio trunk and junction paper-polythene cables have been laid and are now regarded as standard construction. They all have copper conductors. All these cables incorporate the aluminium tape barrier bonded to the inside of the polythene sheath and in consequence the slow fall of insulation with time exhibited by the Dover-Deal cable is substantially eliminated.

## ANNEX 3

(to Question 4/VI)

**Technique used in Italy for jointing cables having plastic sheaths**

1. *Method of jointing polythene-insulated conductors and the conductors of thermoplastic-sheathed cables*

The insulation of the conductors of thermoplastic-sheathed cables consists generally of solid or cellular polythene ; sometimes polythene having a star-shaped cross-section is used. In the first two cases, the insulation of the conductors is made watertight by inserting a small polythene sleeve at the junction point, this sleeve being heat-welded to the polythene of the conductors on each side of a joint. Another method is to ensure the adhesion of the small polythene sleeve by means of two cones. Whatever method is used, the aim is to make the insulation of the conductors completely watertight so that operation is not affected even if water penetrates under the sheath at the splicing points.

When polythene having a star-shaped cross-section is used, the technique applied consists of covering the end of the twisted wires with a cap filled with silicone grease.

2. *Methods of jointing thermoplastic sheaths*

a) *Cables with p.v.c. sheath*

After all the conductors have been wrapped with polythene tape, two half-sleeves made of p.v.c. are inserted on the splice and these half-sleeves are then welded together and to the sheath by means of a suitable solvent. To support the half-sleeves while they are being welded, a rigid sleeve (made of p.v.c., for example) is first placed over all the conductors.

b) *Cables with polythene sheaths*

The conductors are spliced as described above. As regards the sheath, a cylindrical sleeve of polythene is heat-welded to the sheath on each side of the splice. This is done with the aid of an appropriate tool which is heated to a given temperature. A cast-iron casing filled with low-melting-point pitch in the case of underground cables or a piece of metal, as described under point a) for aerial cables, is used for the outside of the joint. Such a joint in an aerial cable is then protected by a piece of metal which is also used for attachment to the suspension cable.

c) *Cables with a polythene sheath plus an additional p.v.c. sheath*

This type of cable is being used more and more in Italy, and the jointing of the polythene sheath and the p.v.c. sheath is effected separately by means of the procedure described under a) and b).

3. *Joint between a thermoplastic sheath and a lead sheath*

A prefabricated device is used, consisting of a watertight plastic plug—which is pierced by a number of conductors corresponding to those of the cables to be connected—and equipped, on either side, with sleeves for connection to the lead and thermoplastic sleeves respectively.

4. *Self-supporting overhead cables with moulded-in suspension wire*

To avoid the drawbacks of rigid suspension of self-supported overhead cables traversing stormy regions of areas exposed to fairly violent winds, a device has been developed in Italy for suspending the cable from the pole, which enables the cable to move somewhat in the longitudinal direction. Although this device does not prevent the cable from vibrating under the effect of the wind, it greatly reduces the harmful effects at the supports.

For lengths that are particularly exposed to the wind, use is made exceptionally of a "catenary" suspension by means of a supplementary suspension cable, from which the cable is suspended by means of the devices described above.

With cables of this type, laid along an electric railway, and suspended from the posts bearing the contact wire, use has often been made of the guard wire already existing, the cable being fixed to it at intermediate points so as to reduce the length of free span.

## ANNEX 4

(to Question 4/VI)

### Joints in plastic-sheathed cables

(Information from the Australian Administration (1968))

The Australian Administration has been using plastic-insulated plastic-sheathed cables for some time and has carried out field trials with a number of different jointing methods. The predominant method at present in use for joints housed underground involves complete encapsulation of the joint with an epoxy resin.

The conductors are jointed with bare wire twists soldered and protected with plastic sleeves. A plastic mould is placed around the joint, and the mould is then filled with an epoxy resin mixture. The resin is supplied in a field pack consisting of:

a) A thin-walled clear polythene bottle containing a mixture of a base epoxy resin (Epikote 834: Epichlorohydrin—Bisphenol A) plus a reactive diluent (Cardura E: an epoxidized synthetic fatty acid);

b) a tin-plated lead tube with a spout, containing "polymid 75" (a polyamine-polyamide resin) fatty agent;

c) three plastic bags, two of which are used to protect the hands during mixing and pouring the resin and the other to contain the used pack and waste material for subsequent disposal.

The contents of the hardener tube are emptied into the plastic bottle containing the resin, the contents are thoroughly mixed together in the bottle and are then poured into the mould and allowed to set.

For above ground joints, the soldered bare wire twisted conductor joints are protected with polythene sleeves filled with silicone grease. The joints are placed in a pole mounted box to give protection but no attempt is made to provide a sheath seal.

A re-openable joint enclosure for underground use comprising a premoulded plastic base has been developed and extensive field trials have now commenced. The cables are sealed into the base with epoxy resin and the conductors are bare wire twisted, soldered, and then insulated with polythene sleeves filled with silicone grease.

## ANNEX 5
(to Question 4/VI)

### Method of jointing polythene-insulated and p.v.c.-sheathed local cable, employed by the Federation of Malaya and Singapore (1961-1964)

1. The various types of joint may be grouped as follows:

1.1 *The taped joint*

In this type of joint, plastic tapes are used for sealing. In joints on cables larger than two-pair, a plastic cable sleeve is drawn over the joint and the plastic tapes are wound over the sleeve and the cable sheath, where the cable emerges from the sleeve, to provide a moisture-proof seat. In the smaller joints on one-pair and two-pair cables, where the length of the joint does not exceed 3″, a plastic sleeve is not used, and the joint is protected and sealed by an overall lapping of plastic tapes.

The tape joint is used when a simple straight joint is to be made between two plastic cables of the same size. For a "Y" or multiple joint, the plugged joint technique is used.

1.2 *The plugged joint*

In this type of joint, a lead (or brass) sleeve or pot is used to house the joint, and sealing is effected by means of an expanding plug.

The plugged joint may be of a single-ended "U" type or the double-ended type. In the single-ended type, all the cables enter the jointing pot via holes, provided for the purpose, in the expanding plug inserted at the open end of the pot. Where the number of holes in an expanding plug is insufficient to accommodate all the cables that are to be jointed, a double-ended joint is used.

In this type, two plugs are used with a sleeve having both ends open. One plug is inserted into each end of the sleeve and the cables enter the sleeve via the plug at either end. The single-ended type is used where possible as only one expanding plug is required.

1.3 *The plastic cable to lead cable joint*

Where the lead-covered cable is of a size that can be satisfactorily accommodated in one of the holes or cableways of an expanding plug, together with the plastic cables, no plumbing is required and the joint is similar to the plugged joint, as described above. Where, however, no suitable cable-way is available, plumbing is required and the lead-covered cable is arranged to enter the sleeve at the end remote from that at which the plastic cables enter, and the cable is plumbed to the sleeve.

2. *Use of water barriers*

If water enters a plastic cable through a puncture or absorption in the sheath, it is possible for the water or water vapour to pass along the cable, and, provided that the conductor insulation has not been damaged, the normal working of the cable will not be affected until the water enters a joint. To prevent this happening, water barrier sleeves are fitted at all lead-to-plastic cable joints. The following types of water barrier fittings are used:

2.1 *Water barrier couplings*

This type of water barrier can be installed near an existing joint if it is not possible to fit water barrier sleeves to the cable ends within the joint. They can also be fitted at a point where damage to the cable sheath has occurred. The coupling comprises two identical parts made of thermosetting plastic which, when fitted together, form a cylindrical body around the cable sheath. Each part of the coupling is provided with a thin wafer of material which can be knocked out from the uppermost half of the coupling to form the hole through which the sealing compound can be poured.

2.2 *Water barrier sleeves*

These consist of synthetic rubber sleeves which can be fitted over the butts of cables and filled with compound to seal the interstices between the conductors.

## ANNEX 6

(to Question 4/VI)

**Information supplied to Study Group VI during 1964-1968**

*Federal Republic of Germany*

Cables with plastic insulation and plastic sheath are under trial in the local network. Jointing is carried out using polythene sleeves. Seams in the sleeves, and the joints between the sleeves and the cable ends, are welded the heat being provided by passing electric current through wire encased in the polythene. The power is obtained from a 12-volt motor-car battery.

The cables are kept under air pressure as it is difficult to remove water if it gains access to the core. A type of cable using solid polythene around the conductors but having the usual air space filled by a type of foamed plastic is under trial.

*Netherlands*

Upwards of 28 000 km of polythene-insulated and polythene-sheathed cable have been installed, containing about 400 000 km pairs. About three-quarters of this cable is in the ground, unprotected, at a minimum depth of about 50 cm. The jointing method generally used employs epoxy-resin. More than 500 000 joints have been made.

Compared with armoured cable the faults in the polythene cable itself are some six times more frequent, but the polythene joints are far more reliable than soldered lead-sleeve-joints in steel-armoured cables. Taking both cable and joints into consideration the unprotected polythene cable has only 1.4 times the fault rate of the armoured lead cable.

*Japan*

Plastic-insulated conductors are used for both toll and subscribers' lines. If water penetrates into the core there is no immediate failure of service, but after a time failure of conductors due to corrosion may arise. Quick repair is therefore necessary. When the section affected by water is short it is dried out with nitrogen gas and when it is long, over say 30 metres, the length is replaced. The approximate location of the faulty length is first found by a bridge type of test, accurate location is made by a pulse echo test and then the actual length in metres which is wet is determined by another pulse echo test. Although great accuracy is not claimed the pulse echo test is helpful in deciding which of the two methods of repair must be adopted.

Some five and a-half thousand kilometres of stahlpeth-sheathed paper-insulated cable containing roughly fifty thousand sheath joints are also in service in Japan. The "improved auxiliary lead-sleeve method of jointing" used on this cable behaves well.

## Question 5/VI

*(continuation of Question 5/VI, 1964-1968)*

Attacks on plastic materials by insects and rodents.

### ANNEX 1
### (to Question 5/VI)

**Information assembled by Study Group 6 in 1957-1960**

The extent of the damage caused to telecommunication cables by insects and rodents varies greatly with the geographical region. In temperate zones, the damage is more of a nuisance than a real danger.

In warm climates, the attacks can be much more serious and may necessitate special precautions. Statistics submitted by the Australian Administration during the period 1954-1956 show that about 3% of cable breakdowns are due to insects, termites and rodents.

*Insects*

1. According to information sent to the C.C.I.T.T., one of the most active insects in causing damage is the *Sinoxylon sexdentatum*, which attacks lead-covered aerial cables in the Mediterranean region and in Japan. In some parts of Japan, it is responsible for about 10% of cable breakdowns.

The perforations made by the *Sinoxylon* usually occur next to the cable suspenders, probably because the insect supports itself on them while perforating the cable. It may be assumed also that its activity is facilitated by the support it finds on any roughness in the surface of the lead covering. The cables most frequently damaged are those of small diameter ; cables whose diameter exceeds 25 mm are rarely attacked.

2. Damage caused by insects has been observed on cables while they are still coiled on drums. This is due to the fact that the wood used for the drums is not sound enough. Among the insects identified are the *Sirex juvincus*, of the hymenoptera family, and the pine wasp (*Hylotropes bajulus*), of the coleoptera family. These insects lay their eggs in resinous trees, whether standing or felled ; the larvae grow in drums made of the contaminated wood and produce the insects which, to get out of the drum, sometimes pierce the lead sheath of the surrounding cable.

3. It is only in special cases that protection against insects should be considered.

4. For protection against the *Sinoxylon*, recourse was had to a thermoplastic sheath. This type of sheath provides protection so long as it remains sufficiently soft and pliable.

5. One protective measure consists of smearing the cable sheath with an insecticide solution or, better still, with a chemical solution repulsive to insects. The insects do not always eat the sheath material and only attack it so that they can lay their eggs in it.

For some years, in Cuba, the protection of cables by applying an enamel coating containing DDT has been under test and has given good results.

The Australian Administration is studying insect damage to plastic-sheath cables and the effect of incorporating various insecticides in the plastic material.

Among substances repulsive to insects are those with a copper base, such as copper naphthenate, which is also a very strong fungicide.

The only really efficient way of protecting a cable with plastic material against insects is, in fact, to cover the plastic cable sheath with a light metallic armouring.

6. To prevent damage to cables on wooden drums, the drums should be seasoned or impregnated. This is unnecessary when the wood of the drums is sound.

*Rodents*

Damage caused by rodents occurs mainly in cables laid in ducts and in buried cables without armour. The places attacked by rodents are several centimetres long and more or less oval in shape. Their walls are clearly defined and toothmarks can be seen.

In large towns most of this damage is caused by rats.

It is difficult to eliminate rodents because the places where the damage is noted are very far apart. No protective measure, therefore, such as the incorporation of substances repulsive to rodents, is systematically applied in the case of ordinary telecommunication cables.

## ANNEX 2

(to Question 5/VI)

### Attack on plastic cable by insects and rodents

(Information from the Australian Administration (1964-1968))

Field testing and service experience by the Australian Administration since 1951 has clearly indicated that severe damage due to termite and ant attack can be expected with both p.v.c. and polythene sheathed cables. The following genera have been definitely connected with attacks on cables and wiring:

Termites: *mastotermes, coptotermes, nasutitermes.*

Ants: *pheidole, iridomyrmex, monomorium, pheidolegeton.*

In addition, isolated attacks on cables by rats, mice, rabbits and bandicoots are being reported from widespread areas.

In an effort to develop an insect-resistant cable sheath, the Australian Administration has been conducting a succession of controlled field trials on various sheathing materials, including many where an insect repellant was incorporated in the sheathing. These trials have shown that the inclusion of up to 1% of such insect repellants as Dieldrin, Gammexane or Aldrin will not confer a sufficiently high level of immunity to the cable, and that the inclusion of up to 5% of finely divided silica is also not fully effective. Various alternative sheathing materials have been investigated, and it has been shown that polypropylene, high-density polythene and polyurethane, whilst reducing the probability of attack, cannot be regarded as fully satisfactory. However, extensive trials have indicated that nylon and also probably acetal, applied as an outer jacket (0.075 cm thick) over a polythene sheath will give complete protection from insect attack. Earlier work had shown that Nylon 6 tended to delaminate and blister, and that the cracking of a blister could allow ants to gain access to the underlying polythene sheath. Therefore, a change to Nylon 11 has been made with entirely satisfactory results, and Nylon 12 is presently being considered as an alternative.

Two other methods which have given good results in field experiments are a single lapping of 0.01-cm brass tape over an inner polythene sheath with an outer jacket of low-grade polythene, and polythene incorporating 1% of the carbamate insecticide "Sevin". The former method is, however, expensive and presents manufacturing difficulties, whereas the latter method still requires further study regarding its long-term effectiveness.

The treatment of the soil surrounding the cable with Dieldrin during cable-laying operations is being carried out in one area of Australia with good results and appears to give protection for several years. Further studies are presently being made to ascertain the duration of effective protection of various concentrations of insecticides in both tropical and temperate climates.

## ANNEX 3

(to Question 5/VI)

### Information from the Federation of Malaya and Singapore (1961-1964)

1. The Telecommunication Department of the Federation of Malaya makes wide use of plastic telephone cables in its subscribers' distribution network and has also employed plastic cable on certain junction cables on routes not exceeding 20 miles. Plastic-covered cables are also used for river crossings and undersea crossings in estuaries, and they are also used to a limited extent as overhead aerial cables. Insect attack on these cables has been quite severe.

2. *Type of attack*

The most frequent attacks are to cables buried directly in the ground, although there have been isolated instances of attacks to aerial-suspended cables.

In most of the attacks, the insects have eaten through polyvinyl chloride sheaths, the aluminium tape and the conductor insulation. Almost all the attacks reported were made radially (towards the centre of the cable).

3. *Types of insect*

So far, the following species have been identified as being responsible for these attacks :

a) *macrotermes,*
b) *kolotermes,*
c) *pheidologeton diversus,*
d) *campanotus* spp.

This list is not necessarily comprehensive. The identification of the insects concerned has proved very difficult because of difficulty in obtaining specimens of the insects responsible.

4. *Experiments in progress*

Experiments are in progress at various sites throughout the country to determine methods of preventing insect attacks to cables. All these experiments are directed towards establishing a form of protection which can be built into the cable, either in the form of insecticide or insect repellant impregnating the polyvinyl chloride sheath, or in the form of a special barrier incorporated in the make-up of the cable. There is some indication that nylon sheaths are more resistant to insect attack than polyvinyl chloride.

A second series of experiments is aimed at discovering a method of treating or laying cable in such a way as to minimize attacks of this kind. These are discussed in the following paragraphs.

4.1 *Use of bitumen.* There was an indication that bitumen itself served as an insect repellant. A number of cables were therefore painted with bitumen paint before being laid. In some cases, the attacks stopped, in others they continued. This experiment is therefore inconclusive at present. In other experiments in this series, bitumen was mixed with Gammexane or other insecticides before being painted on to the cable. Again, some of these experiments were successful, others not.

4.2 *Arsenite protection.* Arsenite is widely used in rubber estates as an insecticide to protect crops and to destroy weeds. A successful experiment was carried out in 1959 when 2 miles of cable were laid underneath the open roadside drain in a rubber estate. This cable has not been attacked since, and it is thought that the soil around the drain is kept continually impregnated with arsenite washed away from the rubber estate by rain. It is difficult to devise an experiment to check the validity of this test as this would involve asking the estates to stop using arsenite for a period of time which would probably be harmful to their crops.

4.3 *Depth of laying.* It is customary to lay plastic cables at a depth of 18 inches. In certain areas, it has been found that insect attack was reduced by digging trenches deeper and laying cables at a depth of 3 feet. In this connection, it might perhaps be added that attacks have been reported up to a depth of 24 inches.

*Reference :* K. Lapkamp, D. Magnus : Bleimantelschäden durch Käferlarven (Damage to lead sheaths caused by the larvae of beetles)—*N.T.Z.*, 1956, No. 9, pages 415-420.

## Question 6/VI

*(continuation of Question 6/VI, 1964-1968)*

Cables with plastic-insulated conductors.

The following points are to be studied :

a) what are the thermoplastic materials recommended for the insulation of telephone conductors in the case of :

i) conductors for local or trunk cables ;

ii) insulated conductors without sheaths for subscribers' distribution ;

iii) conductors for internal telephone installations ?

b) What conditions should be imposed on the thermoplastic materials used to insulate the conductors ?

c) What tests can be made to verify that these conditions are met ?

d) What conditions attach to the laying of cables having plastic-insulated conductors ?

*Note 1.* — The aim is to collect information about the specifications used by administrations for these conductors and about the standards imposed on the thermoplastic materials mentioned in these specifications.

*Note 2.* — If necessary, separate mention will be made of copper conductors and of conductors of other metals (steel, aluminium).

*Note 3.* — Where there has been ingress of water through a cable sheath, and it has penetrated along the cable, what methods can be recommended for removing the water ?

*N.B.* — The presence of moisture on the polythene-insulated conductors can cause very large increases in attenuation especially in loaded trunk cables, even where the insulation resistance is satisfactory.

*Note 4.* — See in the *Review of the Electrical Communication Laboratory*, Volume 9, Nos. 11-12, November-December 1961, published by the Nippon Telegraph and Telephone Public Corporation, an article by Mr. Mituru Rokonohe describing a cable with small-diameter conductors insulated with foamed polythene.

## Question 7/VI

*(continuation of Question 7/VI, 1964-1968)*

Methods of keeping cable sheaths under gas pressure.

To check the continuity of cable sheaths, trunk and junction cables are maintained under permanent gas pressure in a number of countries. Modified gas pressure systems using a fairly high gas flow are sometimes adopted, particularly on local cables. Methods of application and of feeding-in the dry gas supply differ considerably and administrations are requested to supply information about the salient features of gas systems which are being operated successfully in their countries.

*Note.* — During 1964-1968, the C.C.I.T.T. completed the draft of a handbook on methods of keeping cables under gas pressure. The final editing work is to be done early in the 1968-1972 study period and in consequence, the IVth C.C.I.T.T. Plenary Assembly decided to retain the Question for study meanwhile.

## Question 8/VI

*(continuation of Question 8/VI, 1964-1968)*

Classification of non-electrolytic corrosion.

ANNEX 1

(to Question 8/VI)

**Conclusions by Study Group VI (1968)**

1. Study Group VI has come to the conclusion that phenol is not harmful to cable sheaths. This view is based on careful studies, particularly those made in Switzerland, Denmark and Hungary.

The Research and Tests Laboratory of the Swiss Administration tried to determine the nature of the corrosion previously attributed to phenol:

a) by examining meticulously all cases of this type of corrosion observed,

b) by field tests, taking samples of buried cables and verifying the degree of corrosion,

c) by laboratory research and by trying to reproduce the conditions which give rise to this type of corrosion.

2. A comparison of samples of such corrosion in Switzerland and the United Kingdom revealed that different types of corrosion had been classified under the same name.

In Denmark, studies were concentrated mainly on the effect of the decomposition of impregnating oils by microbes and revealed the part played by certain bacteria particularly the *Pseudomona oleovorans*. The recovery of a trunk cable, some sections of which had shown faults attributed to phenol corrosion, provided the opportunity to prove from samples taken all along the cable that there was no connection between the presence of phenol in the cable covering and the corrosion of the cable.

3. Furthermore, modern electrochemical theory recognizes today that phenol must act rather as an inhibiting than a catalytic agent of corrosion. It is only with a solution containing 5% of phenol in toluene or xylene that an attack on lead in the presence of air has been observed in the laboratory. This condition is not encountered in cables.

4. The main characteristic of the type of corrosion formerly attributed to phenol is a corrosive attack usually advancing along the grain edges.

5. The hypothesis that corrosion is caused by phenol having been rejected, an attempt was made to find other reasons for the type of corrosion previously attributed to phenol.

Besides the aggressive products in the ground, electric potentials have considerable influence on intercrystalline corrosion. Such corrosion is accelerated by anodic potentials, but equally well, as experience has shown, it can be guarded against by cathodic protection.

An explanation of such corrosion was sought in the action of bacteria which cause jute to rot, in the action of bacteria which destroy the oil in impregnation substances, in the small quantities of nitrate and/or nitrite in soil waters, in the effect of differential aeration, etc. So far no conclusive analysis of the basic reasons for this kind of corrosion has been reached, and the study of this question must therefore be pursued by Study Group VI.

Once the cause of this corrosion has been determined, it may be possible to provide more effective protective measures than those now employed. Meanwhile, in view of the quality of protection obtained from oils and pitch on cables of the old type, there is no objection to retaining the classical mode of protection using distilled coal products. Whether used alone or in conjunction with petroleum derivatives, distilled coal products should ensure that the covering is firmly attached to the lead sheath so that electrochemical reactions have no chance to occur.

In the Hungarian People's Republic (see also Annex 2) it has been found that:

a) for external layers of jute, better protection (more than 40 years' life as against 15-20 years) against decomposition by micro-organisms in the soil is provided by impregnation with coal-tar products than by impregnation with bituminous material;

b) there is little difference in decomposition, when the jute is beneath a layer of armour, whether coal tar or bitumen is used;

c) bitumen is to be preferred to coal tar beneath a layer of armouring because of its more favourable plasticity.

However, although coal tar may have some advantages, the continued use of bitumen in all cases may be preferred since the small degree of trouble to which it is likely to give rise is known. It is necessary to take precautions concerning the coal tar used, such as specifying the appropriate distillation fraction. Limiting values for ammonia and acetic acid content need to be specified.

## ANNEX 2

(to Question 8/VI)

### Information supplied by the Hungarian Administration

The standpoint of the Hungarian Administration concerning this Question is the following:

"Y" corrosion of the lead sheaths of cables can be eliminated by using armoured cables. The armouring isolates the lead sheath well from the environment, prevents the formation of galvanic couples of differential aeration and the development of "Y" corrosion on the lead sheath.

The steel armour can ensure a lasting protection against influences from electricity lines and can ensure the stability of the screening factor only as long as it does not become rust-eaten and if its protecting covering of jute remains intact for decades.

The impregnation with coal-tar product preserves the covering of jute from rotting and at the same time decreases the rusting of the armouring material. In armoured cables the tar product impregnating the jute covering above the armour cannot reach the lead sheath, as it is prevented by many layers of bituminous protective coverings.

The Hungarian Administration agrees that the quality of the coal tar to be used for impregnating cable coverings should be specified. For this purpose the specification * given by the Hungarian Administration, as well as the coal-tar product specified by the Swiss Administration for impregnation of paper strips and jute yarns, may be suggested.

The Hungarian Administration also agrees that the coal-tar product should not contain acetic acid. The coal-tar products suggested above very likely do not contain acetic acid owing to their

* See C.C.I.T.T. 1964-1968 contribution, COM V—No. 29.

high boiling-points. The specification could prescribe that the coal-tar product should not contain any acetic acid, or the permissible quantity of it should be given.

There is no objection to giving the method for quantitative determination of acetic acid content. The Hungarian Administration would like to draw attention to the fact that jute yarn used for manufacturing cables—even in its original condition—contains about 0.02% of volatile organic acid of which a considerable quantity is acetic acid. (Reference: Dr. K. Ipolyi: *Technische Mitteilungen PTT* 42/1964, pages 273-279.)

In the jute yarn the volatile organic acids result from the preparing operation, the retting.

Thus acetic acid gets into the cable-protecting covering even in the case where the impregnating coal-tar material was entirely free from acetic acid.

## Question 9/VI

*(continuation of Question 9/VI, 1964-1968)*

Joint cathodic protection of several networks.

Should special arrangements be made when telecommunication cables, power cables, gas and water mains, electrified railway tracks, pipelines, and other metallic structures are to be interconnected with the object of achieving electrical protection, particularly in the case where other considerations make it desirable to keep some of these installations separate?

What should these arrangements be?

What special precautions need to be taken when a cable with an aluminium sheath is included in a joint protection scheme including cables having sheaths made of metals other than aluminium?

*Note 1.* — Two aspects of joint protection should be dealt with under this question, namely protection schemes designed on a joint basis from the outset and those that become joint schemes as a result of the extension to other structures of a scheme originally installed as a single protection scheme.

The question of the nature of interconnecting bonds should be examined, and should take into account the full range of structures that might have to be interconnected (telecommunication lines, electricity lines, traction lines, gas-pipes, oil-lines, etc.). Also, when a fault current on a power system flows through a cathodic protection bond on to other buried structures it would be useful to know how the fault current will divide between the various structures.

It has been reported that where joint protection schemes have been planned, they have been put into service without any misgiving on the part of those concerned. However, it seems that there exists some apprehension concerning the possible interconnection of installations associated with very-high-voltage power lines and those associated with vulnerable structures such as gas-pipes and oil-pipe lines.

Some guidance ought to be given in such cases. Also, in the case of high-voltage lines with tower footings of reinforced concrete the Recommendation should say whether it is necessary for such lines to be included in any cathodic protection scheme.

*Note 2.* — In the case of joint protection schemes for power cables, telecommunication cables, gas or water mains, pipe-lines, etc., using electrical protection, the following points should be kept in view:

a) Are there, either permanently or during a short-circuit on a power cable included in the electrical protection scheme, any possible disadvantages, such as: danger of gas explosion, fire risks, deterioration of cable sheaths, danger resulting from the rise in potential of these sheaths, etc.?
b) What special arrangements are to be made and what, if any, protective devices should be provided for protection against these phenomena?

Any protective devices should cover the safety of both personnel and plant.

## ANNEX 1
(to Question 9/VI)

### Information supplied to Study Group VI in 1961-1964

In the U.S.S.R., where cathodic protection schemes are widely used, it is found that the greatest danger in such schemes is due to current arising from differences of potential produced by galvanic pairs, and the current exchange that takes place if the protection system fails in the neighbourhood of tramways and direct current traction systems.

To prevent this current exchange and to prevent the subsequent corrosion of lead coverings, rectifier elements are inserted near the joint protection scheme. These rectifiers are usually germanium or silicon type depending on the type of protection.

Such schemes, which have been in use since 1954 in the U.S.S.R., have given good results for both telecommunication cables and underground pipes.

In Milan (Italy) an organization exists which co-ordinates the different protection arrangements and proposals. This is particularly necessary in Milan because the tramway network is very extensive. The organization includes a committee that meets once a month and there is a central technical office. These are supported by the municipality especially when joint action is to be taken by several authorities. Certain definitions in connection with protection have been drawn up and there are regulations governing joint measurements and joint protection schemes.

Neither in the Federal German Republic nor in the Union of Soviet Socialist Republics is cathodic protection applied to cables having aluminium sheaths. Cathodic protection applied by the United Kingdom on the Inverness-Nairn cable, which has an aluminium sheath, was for the express purpose of providing information for Study Group VI and is not normal U.K. practice for this type of cable.

## ANNEX 2
(to Question 9/VI)

### Conclusions reached by C.C.I.T.T. Study Group VI in 1961-1964

When, to obtain joint electrical protection, telecommunication cables are directly connected to the sheath of a power cable, it is necessary to take into account the risks to personnel working on the telecommunication cables in the event of short-circuit to earth of one phase of the power cable. These risks are especially to be feared when the power network is a high voltage network with neutral connected to earth.

In the vicinity of the point of connection of the power cables and the telecommunication cables, it is necessary then to determine what will be the rise of potential of the telecommunication cable sheath with respect to the potential of this same cable at a distant point, when a short-circuit occurs on the power cable, and then to ascertain if this rise potential can be permitted.

Also, it appears desirable to recommend that workmen likely to work on the telecommunication cables where the sheath is connected to that of a power cable, should first provide a shunt, using a conductor of sufficient cross-section, joining the two parts of the telephone cable between which a cut is to be made.

Consideration should be given to the design of suitable devices to be connected between the sheaths of power cables and the sheaths of telecommunication cables when cathodic protection is applied jointly to both structures, or when such devices are provided as a method of avoiding harmful interaction. The devices should be capable of permitting the required direct current to flow, but should limit both the value of the alternating current flowing under normal working conditions and that liable to flow in the event of an earth fault occurring on the power supply system. Practical considerations may require the devices to be installed in the ground at points where the use of fuses or circuit breakers would be undesirable. The power handling capacity for which the devices should be designed will depend on the proportion of fault current liable to flow on to the network of telecommunication cable sheaths in the event of a power supply earth fault. It would be of interest to examine whether different precautions are required for devices to be connected to high voltage and to medium voltage supply systems.

The advice of Study Group V might be sought on these considerations.

## Question 10/VI

*(revised wording) (continuation of part a) of Question 10/VI, 1964-1968)*

Unusual cases of corrosion concerning observed cases of corrosion of lead sheaths of underground cables, even though these sheaths were at cathodic potentials.

*Note.* — See Question 17/VI for studies concerning corrosion by alternating current.

### ANNEX

(to Question 10/VI)

**Conclusions reached by the C.C.I.T.T.**

1. Study Group 6 has received lead corrosion diagrams submitted by Cebelcor (diagrams by Professor Pourbaix, which are given in the *Recommendations*).

An examination of Professor Pourbaix's diagram shows that corrosion is thermodynamically possible when very negative potentials are applied to the lead.

Cebelcor laboratory experiments and field tests gave cathode corrosion at a potential of less than −2.1 V for densities of about 10 mA/cm$^2$; this density is a thousand times higher than that which was proved necessary to obtain cathodic protection in the laboratory, and 1500 to 5000 times higher than the density normally used in practice for the cathodic protection of cables.

The lead is not permanently attacked at very negative potentials except in the case of pure lead in the presence of an aqueous solution ; in the case of lead alloys in the presence of solutions or wet soils, the attack is a transient and superficial phenomenon.

Twenty-five years' experience of the cathodic protection of cables has not revealed any drawbacks due to the application of very low potentials.

Nevertheless, some countries, including the U.S.S.R., fix an upper limit on the protection potential, although it is recognized that in ordinary soils the cathode potential may reach a few volts.

2. Another form of cathodic corrosion is to be feared much more in practice, as was apparent from information supplied by Italy, the United Kingdom, Belgium and the U.S.S.R. The corrosion in question occurs in strongly alkaline surroundings (pH $> 10$) when the lead is subjected to a *low* cathodic potential.

The curves of Professor Pourbaix and of the Administration of the U.S.S.R. are comparable ; they recommend that the lower limit of the protection potential should be raised, as soon as the pH of the soil or conduits becomes higher than 10 (either naturally, or by reason of works in the neighbourhood).

It should therefore be ensured that an insufficient cathodic protection does not bring the lead of the cable in a strongly alkaline environment to a lower potential than the corrosion limit. The result could be a more rapid corrosion than if the cathodic protection had not been applied ; such protection is to be recommended because the cable would be corroded in any case.

3. A study was undertaken in the laboratories of the Italian Administration to ascertain the process giving rise to certain cases of corrosion in lead cable sheaths when the cables were distinctly negative.

The characteristics of the corrosion observed were as follows :

a) the cables were negative in relation to the surrounding earth ;
b) in each case, a compact and adherent layer of lead monoxide (PbO) in tetragonal form was found. This substance was very porous ;
c) in each case, the presence of a strongly alkaline medium was observed, and sometimes a variation of pH from 7.7 at 1 metre from the cable to 10 at 1 centimetre from the cable.

Laboratory tests made it possible to ascertain the nature of the electrochemical phenomena. They were carried out at constant current. It is interesting to note that the cathodic corrosion faults mentioned above occurred at points where the negative potential was variable.

The foregoing observations are similar to the case mentioned in Question 10, studied in 1957-1960, about cathodic corrosion observed in Great Britain. This corrosion occurred in rather special conditions, in an asbestos-cement duct where there was free lime. The corrosion was evident when the negative potential to earth was from 1 to 1.5 V (potential measured with an impolarizable electrode $Cu/CuSO_4$) ; when the negative potential was 10 V, cathodic corrosion was no longer observed.

## Question 11/VI

*(continuation of Question 11/VI, 1964-1968)*

Amendments and additions to the *Recommendations for the protection of underground cables against corrosion.*

*Note 1.* — Studies under this question should be directed to keeping the *Recommendations* up to date.

*Note 2.* — Attention is directed to the interest of fixing a criterion for harmful interaction between cathodic protection schemes and of methods of measurement suitable for finding whether particular schemes respect this criterion in practice.

*Note 3.* — Further studies should be made in connection with methods of protection against toxic gases, for example when using liquid gas burners for jointing processes.

*Note 4.* — Studies should be made, with a view to additions to Chapters V and VI of the *Recommendations*, concerning the general design of cable sheaths and coverings for protection against high voltages due to induction lightning, etc..

## Question 12/VI

*(new Question)*

Revision of the booklet on the impregnation of wooden poles.

## ANNEX
(to Question 12/VI)

### Comment by the Argentine Administration

Study of the booklet mentioned in Recommendation L.2 ("Impregnation of wooden poles") shows that this booklet needs bringing up to date in view of the period which has elapsed since its publication, the technical advances made and the omission of a number of concepts useful from the point of view of improving and maintaining the technical quality of the information provided.

In the opinion of the Argentine Administration, which would wish to take part in this work, a thorough revision of Sections III and IV is particularly necessary. Attention is also drawn to the need for including a section on the service-life statistics of poles treated with various substances. This is the only practical way of providing members of the C.C.I.T.T. with reference material, which it is difficult to obtain even in specialized publications, on the behaviour and effectiveness of the various treatments available as a function of the requirements, climate and types of trees.

This section should be a compilation of information supplied by administrations on each type of tree or on related groups of trees used as poles including data on years of service, the preservative used and retention properties. Additional data should also be supplied on such items as the treatment process employed, climatic conditions and species of fungi and insects isolated or discovered in impregnated poles.

From every point of view it is desirable to have as much information as possible from tropical and sub-tropical areas, since in our experience, which we believe to be similar to that of Australia, New Zealand and India, some types of modern water-soluble products, which are distributed and promoted throughout the world, do not work when used with the retention values recommended by their manufacturers.

The following observations are submitted in connection with the various sections of Recommendation L.2.

*Section I*

*Types of trees used in the manufacture of poles*

There seems little point in having such a general text. If it is retained, it should cover the main types of trees in the Northern and Southern Hemispheres subdivided into the two main groups of coniferous and broad-leaf trees.

There are some inaccuracies in the Spanish text. It is not correct, for example, to classify eucalyptus poles as one of the world's most decay-resistant types under natural conditions. This is not true of most types and only a small number of Australian varieties, popularly called "iron bark" (*Eucalyptus sideroxylon*, *E. crebra*, etc.), can match the natural durability of other tropical hardwoods such as our red quebracho (*Chinopsis*) or conifers with highly-toxic resins (*Thuja plicata*).

*Climatic conditions*

To underline the importance of the variations in biological effects with climatic conditions and modifications in the types and conditions of treatments used, emphasis should be placed on the retention values and the substances applied and all ambiguous material should be deleted.

*Inspection after erection*

The specialized nature of the inspections that have to be carried out to determine the type and degree of biological attack makes it useless to consider this point superficially. It might be more useful to indicate the basic rules for inspecting parts of poles that have been treated and to list the fundamental requirements of proper purchasing specifications.

*Section II*

The normal practice would appear to be for administrations as users to buy poles on the timber market rather than to exploit forestry reserves themselves. This being so, the important thing is to specify the permissible defects of the poles and their technical characteristics, e.g. moisture and sapwood content—i.e. to specify those requirements that are needed to enable the necessary mechanical quality of the poles to be maintained and to provide technical conditions compatible with the impregnation product and process used and likely to guarantee proper standards of efficiency. In accordance with this suggestion, there should be no reference to requirements of specific interest to suppliers (e.g. season for felling, transport), which are based on normal forestry practice.

*Section III*

An up-to-date approach is required based on the present nomenclature with the deletion of some substances and the addition of others. Thus amended, and with the relevant information on the definitions and concepts involved, this section could then be included in the recommendation, consideration being given to the following groups of impregnation products :

a) *Oily substances :* creosote, solutions of creosote and petroleum fuel oils, solutions of creosote and pentachlorophenol, emulsions of creosote and arsenic.

b) *Oil-soluble substances :* chlorophenols and naphtenates.

c) *Water-soluble substances :*

   i) used singly : mercuric chloride, copper sulphate ;

   ii) used in mixtures : combinations of salts of fluorine, arsenic, chromium and phenol derivatives (fluorine arsenic chromate mixtures) ; combinations of salts of copper, arsenic and chromium (copper arsenic chromate mixtures).

*Section IV*

The impregnation processes should be dealt with generically on the basis of the technique employed. References should be omitted to processes which merely constitute regional variations ; this also applies to processes that are based on patented methods involving the use of special techniques (Cobra, osmosis, etc.) or do not guarantee proper penetration of the wood (surface treatments). Rules should be laid down for selecting treatments and determining the general technical conditions of the material with regard to treatment.

It is absolutely necessary to provide clear, concise and technically valid information in order to avoid improvisation and to counteract the influence of purely commercial promotion techniques in use on the world market to propagate the use of processes not suited to regional peculiarities.

The following examples could be included in the criteria to be borne in mind in selecting impregnation processes :

1) the impregnation process should be adapted to the impregnation product used and to the characteristics of the timber and the conditions under which it is made available commercially ;

2) the impregnation process should be capable of providing a given impregnation efficiency, established in advance with due consideration of the biological risk involved, in terms of retentiveness (in kg of impregnation product per $m^3$ of wood) and minimum penetration of the diameter of the pole ;

3) it should be possible to carry out checks at the impregnation plant during the impregnation process ;

4) the relationship between the volume impregnated and the time required should be compatible with sound commercial practice.

Data on the treatment processes, techniques and technological requirements of the materials used could be presented more or less in accordance with the outline proposed in the table below.

It would be convenient and practical if this brochure, which is subject to periodical amendments, could be published in the form of a loose-leaf handbook to avoid the necessity for preparing a new brochure whenever modifications are made.

In accordance with the above, the Argentine Administration therefore proposes:

1) that Recommendation L.2 *Impregnation of wooden poles* be revised;
2) that, if this proposal is adopted, special attention be paid to the points made in connection with Sections III and IV;
3) that, if the above proposal is adopted, a section on the service life of impregnated poles be added;
4) that the recommendations be published in future in the form of a loose-leaf handbook.

TABLE 1

| Method of treatment | Duration | Possible preservatives | Retentivity check | Technical condition of the material |
|---|---|---|---|---|
| Vacuum-pressure (Bethell, Lowry & Rüping) | 1.5-3 hours | Oily, oil-soluble and water-soluble | Simple calculation | Moisture below fibre-saturation point (open-air poles) |
| Hot and cold baths | Generally 24-hour cycles | Ditto, but limited to oily and oil-soluble products for practical reasons | Ditto, subject to corrections | Ditto |
| Sap displacement (Boucherie) | Generally 24 hours for each 2-3 m of length | Water-soluble | Difficult with simple calculation | Moisture above fibre-saturation point (undried poles) |
| Immersion | Days to weeks | Water-soluble products generally used singly | Analytical techniques generally used | Generally moisture above fibre-saturation point (undried poles) |
| Diffusion and osmosis | Weeks to months | Water-soluble | Ditto | Moisture above fibre-saturation point (undried poles) |

## Question 13/VI

*(continuation of Question 13/VI, 1964-1968, studied by a joint working party of Study Group V and Study Group VI)*

Corrosion of buried structures due to the passage of direct current into or out of nearby electrode systems provided.

a) For high-voltage direct current transmission systems, or

b) For direct-current power supplies to repeaters installed in land and submarine telecommunication cables.

*Note 1.* — Contribution COM VI—No. 13 (1961-1964) from the U.S.S.R. Administration should be studied under this question. Further information has been promised by the Administration of the U.S.S.R. Further contributions under this question will be sent by the United Kingdom and by Italy.

*Note 2.* — Although it is outside the scope of this question, the study of the design of electrode systems to pass direct current into or out of the earth (including the sea) for this and other purposes would be useful.

## Question 14/VI (also Question 22/V)

*(continuation of Question 14/VI, 1964-1968, studied by a joint working party of Study Group V and Study Group VI)*

### Part A

a) Study of electromagnetic phenomena likely to appear on the inside or outside of either a buried or aerial cable, when lightning strikes in the vicinity.

b) Possibility of calculating the protection given by buried or aerial earth conductors, trees either singly or in groups, buildings fitted with a lightning conductor, etc.

c) Some radio or television transmitters on mountain tops exposed to frequent storms have to be connected with underground telecommunication cables containing audio-frequency circuits earthed at their extremities, and/or coaxial-pair cables. In such circumstances, the cables, their conductors and the equipment connected to them may be damaged by lightning striking the aerial or the top of the mountain.

What can be done to protect such cables, conductors, and the associated equipment against damage by lightning?

### Part B

a) Sensitivity to disintegration affecting the sheath or core of an underground or overhead cable if lightning strikes in the vicinity.

b) Effect on this sensitivity of the various cable construction and laying data (cable core, sheath, sundry coverings, armourings, etc.).

### Part C

Possibility of using coverings having conducting qualities to meet the requirements of both protection against lightning and protection against corrosion.

*Note.* — This question (which is the same as Question 22/V) is to be studied during 1968-1972 by Joint Working Party CDF of Study Groups V and VI.

## Question 15/VI

*(continuation of Question 15/VI, 1964-1968)*

Protection against corrosion of steel or other ferrous materials which are used in the construction of cables for the purpose of reducing their susceptibility :

— to electromagnetic induction,
— to mechanical damage.

## Question 16/VI

*(continuation of Question 16/VI, 1964-1968)*

Evaluation of degradations in the properties of plastic sheaths and coverings, particular consideration being given to :

— their composition, the nature of their constituents, their preparation and use ;
— surroundings (storms, sunlight, pollution, bacteria) ;
— mechanical constraints ;
— contacts, if any, with substances that might act as catalysts. Any deterioration suffered as a result should be described with all possible detail ;
— evaluation of the quality of plastic sheaths with time.

*Note*. — Page 500 of Volume I of the C.C.I.T.T. *Red Book* gives the results of a bibliographical study made on the behaviour of polythene in the presence of certain substances.

## Question 17/VI

*(continuation of Question 17/VI, 1964-1968)*

Stray alternating currents and their possible effects on the corrosion of buried structures.

Investigations of the corrosion of buried metallic structures are generally carried out using instruments which are insensitive to alternating currents. As a result, there is doubt as to the effect of alternating current on corrosion rates. It is therefore of interest to know :

a) What methods may be used for measuring the density of alternating current interchanged between a structure and the soil.

b) Whether the densities of alternating current which occur in practice are such as to affect the corrosion rates of buried structures.

c) If corrosion rates are affected by alternating current, whether the effect of the alternating current is accompanied by a corresponding change of the direct current, potential difference between the metal and the soil or whether, on the other hand, measurement other than that of direct current potential is necessary to detect the effect of alternating current.

## ANNEX
(to Question 17/VI)

**Conclusions reached by the C.C.I.T.T. in 1960-1968**

In 1960 Study Group 6 took note of a study carried out at Turin (Italy) by Stipel on the corrosion caused by alternating currents. The results of this study, which was made in laboratory, revealed the existence of corrosion due to alternating currents in certain conditions.

This type of corrosion is characterized by perforations in the form of craters with steep walls. The effect of frequency on the degree of corrosion is dealt with in a supplementary study [1].

The attention of S.G. 6 was also drawn to a study made by Mr. L. Amy and Mr. C. Mounios, which appeared in the *Revue générale de l'Electricité* (March 1957) [2]. This study, based on laboratory tests, concludes that corrosion due to alternating currents does exist, even in the absence of any direct component. It also indicates the possibility of a direct current component resulting from rectification caused by a wet contact between two metals (iron/lead).

In 1964 an investigation in the Departmental Research Laboratories in Australia into the effect of alternating current on the direct current corrosion of lead in an electrolyte of 0.2 molar sodium chloride has been studied for current densities of 0-100 $mA/cm^2$ for direct current and 0-180 $mA/cm^2$ for alternating current.

When the lead was anodic there occurred a 5-10% increase in the rate of corrosion but reproducibility in these experiments was not good, probably due to circuit problems.

For lead acting as a cathode with a direct current of 10 $mA/cm^2$ reaching the lead surface through the electrolyte, the superimposition of alternating current from 10 $mA/cm^2$ to 150 $mA/cm^2$ caused slight corrosion.

In these experiments, the superimposition of alternating current on a lead surface corroding by the loss of direct current to the electrolyte caused the formation of a corrosion product of different appearance and probably also of composition from that formed when alternating current was absent.

Further laboratory research [3] has tended to confirm that alternating current causes accelerated corrosion of lead when the latter is an anode.

This later research shows that the corrosion of lead by alternating current:

— would cause only a small loss of metal in cable sheaths, but would give rise to damage comparable to that caused by direct current. This arises from the localized character and perforating nature of the craters which are rounded and have very steep sides.

— increases in efficiency with a reduction in frequency and also with a decrease in current density. However, it has not been possible from the experimental results to fix a safety limit for the minimum value of current.

— does not permit of a certain diagnosis of corrosion danger from measurement of potential difference to earth.

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[1] See article by Dr. Ing. Carlo Enrico GALIMBERTI entitled "Corrosion of lead by alternating current", in *Corrosion*, Vol. 20, No. 5, May 1964.

[2] See also the *Revue générale de l'Electricité*, April 1960, pp. 228-231.

[3] See the article by Professor GALIMBERTI: "Corrosion of lead by alternating current" published in the May 1964 issue of the N.A.C.E. Journal, *Corrosion* (Vol. 20, No. 5, pp. 150-157); and also the article by F. WILLIAMS in *Materials protection*, Volume 5, No. 2, 1967.

It seems that alternating current corrodes lead at about 1% of the rate corresponding to direct current. The phenomenon is made greater even at small current densities, by anodic polarization, but is cancelled by cathodic polarization. Galvanic association with less noble metals than lead (magnesium, iron, zinc) usually results in a reduction of corrosion, but in the case of magnesium it may increase if the current flows through the metal and becomes rectified in consequence.

The corrosion has two distinct forms depending on whether the anions present in the solution give rise to soluble salts or to protective films.

Tests have referred to high values of current density because, in practice, exchange of alternating current in the soil is generally concentrated on small areas where the insulating covering has been damaged.

This research leads to the conclusion that before protecting a lead-covered cable, an examination should be made not only of the distribution in the soil of direct current, but also of the possibility of galvanic coupling between the lead and alternating current existing in the soil.

When the presence of alternating current alone is detected, the question whether or not to apply protection becomes one of economics.

The above findings have been supported by an investigation carried out by the International Union of Railways (U.I.C) with the Italian State Railways as Rapporteur. This investigation concerned tests made on telecommunication cables laid alongside a.c. electric traction lines.

The research was conducted in conjunction with the SIP and with the co-operation of SIRTI. It revealed : a) the non-aggressivity of the soil, as demonstrated by physical and chemical soil analysis, and b) the existence of strong alternating currents, varying with the rail traffic, superposed on weak invariable direct currents.

Corrosion was observed and the conclusion drawn from the investigation is that the corrosion observed appears to be mainly due to alternating current.

The U.S.S.R. Administration has observed that the corrosive action on steel armouring of cables by alternating current at industrial frequencies is equal on the average to 1% to 2.5% of the action of direct current of the same strength but that for lead and even more for aluminium this percentage is certainly higher.

The Swiss Administration has made laboratory tests with samples of lead cable sheath either bare or protected by four different types of covering with bitumen or coal-tar impregnation.

To these samples, immersed in a tank of drinking-water, alternating voltages of 4 V r.m.s. at 50 and $16\,^2/_3$ Hz were applied, with or without superposition of a d.c. voltage of 100 mV ; d.c. voltages were also applied without superposition of an a.c. voltage.

The value 100 mV roughly corresponds to the d.c. voltage normally met with on cables in practice. All tests lasted two months.

The Swiss Administration concludes that the effects of alternating current are so minor compared with those of direct current that a variation of about 100 mV towards positive, in the case of d.c., is more dangerous than the effect of 4 V r.m.s. a.c.

The C.C.I.T.T. therefore decided in 1964-1968 that there should be a series of controlled experiments to give a conclusive answer to the work already done in this connection. When the order of corrosion likely to result from particular values of alternating current has been finally established, a suitable text should be drawn up for inclusion in the "Recommendations". Both of these tasks were entrusted to a Working Group consisting of:

Mr. Cabrillac (C.I.G.R.E.), Chairman ; Dr. Vögtli (Switzerland) ; Professor Galimberti (Italy) ; Mr. Dimario (Italy) ; Mr. Ronzani (Italy).

## Question 18/VI

*(continuation of Question 18/VI, 1964-1968)*
*(Question Asia 9 from the Asia Plan Committee C.C.I.T.T. 1964)*

Requirements when armouring is used.

a) For directly buried cables, in what way does armouring contribute to safe installation and reliability of operation ?

b) Under what conditions can armouring be dispensed with for directly buried cables ?

c) If, under certain conditions, tensile strength of the cable is the essential reason for armouring, would an alternative form of cable be more economical, e.g. an unarmoured cable with a central strain wire ?

*Note 1.* — Information should be given on the relative strength of a cable, reinforced with extra thicknesses of plastic covering by comparison with the strength of a cable protected with a conventional metallic sheath and armouring. It is desirable to know the relative strength of the cables as regards their ability to withstand tensile stresses and to resist impulsive and crushing stresses such as might be imposed during laying and in normal service. The relative resistance to vibration and subsidence of the earth in the case of the two types of cable is also important.
How should these properties of resistance to stress and damage be measured ?

*Note 2.* — See Recommendation L.3.

## Question 19/VI

*(new question)*

Corrosion and earthing problems consequent upon the use of non-conducting water-pipes, and of non-conducting cable sheaths for power and telecommunication purposes.

*Note 1.* — Consumers' low-voltage power supplies often demand a low impedance protective earth so that in the event of an insulation fault a fuse or circuit breaker will operate. The necessary "good" earth may not be readily available if the water-pipe and the supply cable sheath are not sufficiently conducting. In some countries the electricity authorities therefore connect the neutral of the power supply to a number of earth electrodes along its length, so that it may be used as the protective earth. Multiple earthing of the neutral in this way permits some part of the load current to circulate via the earth and if this current has any appreciable direct current component it may be necessary to safeguard nearby telecommunication cables having metal sheaths against corrosion.

*Note 2.* — The impedance of an earthing system at a telecommunication station is often largely dependent upon the metal sheaths of the telephone cables entering the station being in contact with the earth along their lengths. If such cables are wholly or partially replaced by others having non-conducting sheaths the impedance of the station's earth-electrode system will rise and it will be necessary to consider the effect upon its protective and other functions.

Study of this question should be pursued in conjunction with other interested Study Groups.

## Question 20/VI

*(new question)*

Is it possible to recommend protective substances, arsenic compounds in particular, for application as a paste on the surface of underground cables that are liable to damage by the attacks of beetles and termites ?

## ANNEX
(to Question 20/VI)

### Comment by the Argentine Administration

Analysis of the information obtained by Study Group VI in the period 1957-1960 and the information contained in Annexes 2 and 3 of Volume IX of the *Blue Book* (reproducing reports by the Administrations of Australia and the Federation of Malaya and Singapore) indicate that biological attacks on cable coverings are due mainly to termites and coleoptera.

There is an obvious parallelism between this type of attack and the effects observable in wood, in which considerable damage is caused by these same organisms. Indeed, one of the organisms mentioned in the above reports, *Hylotropes bajulus* L.—like some species of termites—is among the worst destructive agents of wooden houses in European countries.

A branch of wood technology of direct relevance to this problem is the preservation of wood against the action of biological agents. Hundreds of substances with fungicide and insecticide properties have been tried out and used as wood preservatives under a variety of service conditions. The latest available data indicate that among these substances inorganic arsenic compounds are the most effective from the point of view of checking attacks by termites and coleoptera.

The Argentine Administration has proposed:

1) that compatibility tests be carried out to try out the possibility of incorporating arsenic compounds such as arsenic trioxide and pentoxide into the sheathing of cables;
2) that experiments to test the effectiveness of these products and determine recommendable doses be stepped up.

*Summary of Questions allocated to Study Group VI for the period 1968-1972*

| Question No. | Short title | Remarks |
|---|---|---|
| 1/VI | Aluminium cable sheaths. Protective covering for these sheaths | |
| 2/VI | Cable sheaths made of metals other than lead or aluminium | |
| 3/VI | Use of plastic materials as protective coverings for metal cable sheaths | |
| 4/VI | Cable sheaths made of plastics | |
| 5/VI | Attacks on plastic materials by insects and rodents | |
| 6/VI | Cables with plastic-insulated conductors | |
| 7/VI | Methods of keeping cable sheaths under gas pressure | |
| 8/VI | Classification of non-electrolytic corrosion | |
| 9/VI | Joint cathodic protection of several networks | |
| 10/VI | Unusual cases of corrosion | |
| 11/VI | Amendments to the *Recommendations* | |
| 12/VI | Revision of the booklet on the impregnation of wooden poles | |
| 13/VI | Corrosion due to direct-current exchange with nearby electrode systems | |
| 14/VI | Protection against lightning | (Also Question 22/V). To be studied by Joint Working Party CDF (S.G.s V and VI) |
| 15/VI | Protection of screens and armouring | |
| 16/VI | Degradation of plastic sheaths | |
| 17/VI | Stray alternating currents | |
| 18/VI | Requirements when armouring is used | |
| 19/VI | Corrosion and earthing problems consequent upon the use of non-conducting water-pipes, and of non-conducting cable sheaths for power and telecommunication purposes | |
| 20/VI | Is it possible to recommend protective substances, arsenic compounds in particular, for application as a paste on the surface of underground cables that are liable to damage by the attacks of beetles and termites ? | |