THE INTERNATIONAL TELEGRAPH AND TELEPHONE CONSULTATIVE COMMITTEE

(C.C.I.T.T.)

FIFTH PLENARY ASSEMBLY

GENEVA, 4-15 DECEMBER 1972

GREEN BOOK

VOLUME IX

Protection

Part 1 — Series K Recommendations and Questions (Study Group V) relating to protection against interference

Part 2 — Series L Recommendations and Questions (Study Group VI) relating to the protection of cable sheaths and poles

Published by
THE INTERNATIONAL TELECOMMUNICATION UNION
1973

THE INTERNATIONAL TELEGRAPH AND TELEPHONE CONSULTATIVE COMMITTEE

(C.C.I.T.T.)

FIFTH PLENARY ASSEMBLY

GENEVA, 4-15 DECEMBER 1972

GREEN BOOK

VOLUME IX

Protection

Part 1 — Series K Recommendations and Questions (Study Group V) relating to protection against interference

Part 2 — Series L Recommendations and Questions (Study Group VI) relating to the protection of cable sheaths and poles

Published by
THE INTERNATIONAL TELECOMMUNICATION UNION
1973

PAGE INTENTIONALLY LEFT BLANK

PAGE LAISSEE EN BLANC INTENTIONNELLEMENT

CONTENTS OF THE C.C.I.T.T. BOOKS APPLICABLE AFTER THE FIFTH PLENARY ASSEMBLY (1972)

(GREEN BOOK)

Volume I — Minutes and reports of the Vth Plenary Assembly of the C.C.I.T.T.
— Resolutions and Opinions issued by the C.C.I.T.T.
— General table of Study Groups and Working Parties for the period 1973-1976.
— Summary table of Questions under study in the period 1973-1976.
— Recommendations (Series A) on the organization of the work of the C.C.I.T.T.
— Recommendations (Series B) relating to means of expression.

Volume II A — Recommendations (Series D) and Questions (Study Group III) relating to the lease of circuits.
— Recommendations (Series E) and Questions (Study Group II) relating to telephone operation and tariffs.

Volume II B — Recommendations (Series F) and Questions (Study Group I) relating to telegraph operation and tariffs.

Volume III — Recommendations (Series G, H and J) and Questions (Study Groups XV, XVI, Special Study Groups C and D) relating to line transmission.

Volume IV — Recommendations (Series M, N and O) and Questions (Study Group IV) relating to the maintenance of international lines, circuits and chains of circuits.

Volume V — Recommendations (Series P) and Questions (Study Group XII) relating to telephone transmission quality, local networks and telephone sets equipment.

Volume VI — Recommendations (Series Q) and Questions (Study Groups XI and XIII) relating to telephone signalling and switching.

Volume VII — Recommendations (Series R, S, T, U) and Questions (Study Groups VIII, IX, X, XIV) relating to telegraph technique.

Volume VIII — Recommendations (Series V and X) and Questions (Study Group VII and Special Study Group A) relating to data transmission.

Volume IX — Recommendations (Series K) and Questions (Study Group V) relating to protection against interference.
— Recommendations (Series L) and Questions (Study Group VI) relating to the protection of cable sheaths and poles.

Each volume also contains, where appropriate:

— Definitions of specific terms used in the field of this volume;
— Supplements for information and documentary purposes.

PAGE INTENTIONALLY LEFT BLANK

PAGE LAISSEE EN BLANC INTENTIONNELLEMENT

PROTECTION

Part 1 — Series K Recommendations and Questions relating to protection against interference

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

PAGE INTENTIONALLY LEFT BLANK

PAGE LAISSEE EN BLANC INTENTIONNELLEMENT

PROTECTION

INTRODUCTORY NOTE

In order to simplify the wording of the Recommendations in this Volume, the expression "Administration" is used, for shortness, to indicate both a telecommunication Administration and recognized private operating agency.

PART 1

SERIES K RECOMMENDATIONS AND QUESTIONS RELATING TO PROTECTION AGAINST INTERFERENCE *

SERIES K RECOMMENDATIONS

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 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).

* See also the *Directives concerning the protection of telecommunication lines against harmful effects from electricity lines,*

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 site 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;

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

— 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 V 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

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 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).

4. Special formal agreements are desirable between the 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 and 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 V 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.

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.

Voltage level at line terminals (Level reference 0.775 V)	Attenuation
Decibels	Decibels
− 17.4	< 0.43
− 8.7	< 0.43
0	≤ 1.7
+ 8.7	> 5.2
+ 17.4	> 10.4
+ 26.1	> 15.6

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-resisitivity, 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 m, 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 m has been used in Sweden under extremely severe soil conditions).

On the other hand, circumstances may exist where a separation of 10 m is not necessary, and a separation of 2 m 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

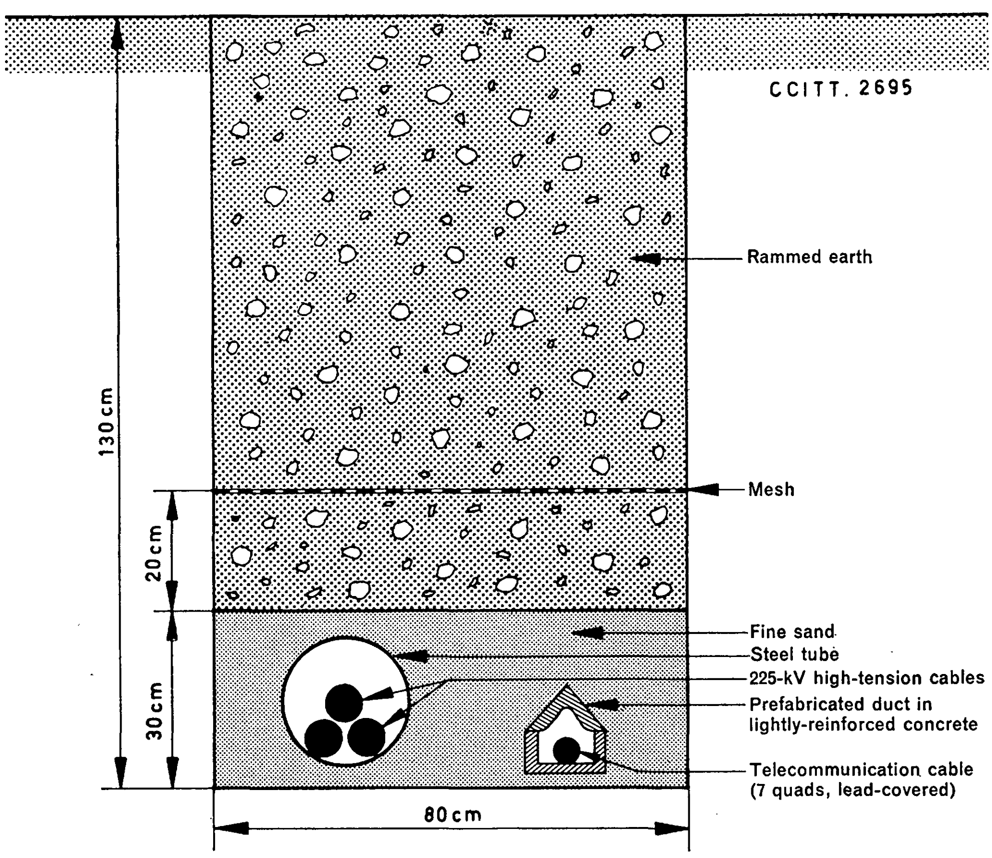
(to Recommendation K.8)

Information supplied by C.I.G.R.E. (1964-1968)

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 m. 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 m) 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 sub-stations 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 telecommunication 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]

Recommendation K.11 (Geneva, 1972)

USE OF GAS-FILLED PROTECTORS AND FUSES

For the protection of equipments from over-voltages on lines, it is recommended that use be made of gas-filled protectors which have a low impulse spark-over voltage to permit some simplification of the protective systems described below.

For telecommunication lines, such protectors should conform to the specification clauses in Recommendation K.12.

The following precautions should be taken:

a) The lightning-protectors should be connected by the shortest possible conductors to the points between which the insulation is to be protected against perforation. (Example: At the transition from an open-wire line to a cable, the protectors must be connected between the conductors and the metal sheath of the cable.)

b) To ensure protection from atmospheric over-voltages, in regions which are not particularly exposed to storms, it is advisable to mount the protectors at the ends of an open-wire line or of an overhead cable having a sheath with low conductivity, either at the transition from the line to underground cable or at the installation in the buildings.

   Fuses contribute in no way to protection from atmospheric over-voltages and reduce the operational safety of the installations.

c) In areas which are highly exposed to storms, it may also be advisable to insert protectors at the points at which the apparatus is connected to the underground cables if there is a substantial difference in the dielectric strength of the apparatus and the cable.

   This is particularly true of cables which have a sheath with low conductivity in contact with earth.

[1] See, in particular, Recommendation Q.45, and also the outcome of further studies by the C.C.I.T.T. in 1973-1976 under Question 13/V.

d) In the case of lines which may come into direct contact with a low-voltage line, it is necessary to use protectors which, in the case of an over-voltage, provide a short-circuit over the widest possible current range.

In the case of uninsulated open-wire lines which may come into direct contact with a low-voltage line, it may happen that the protectors, if they operate, will carry large currents, perhaps over 50 A, which could flow for some time and provoke overheating of conductors. In this special case it may be desired to install fuses on the line side of the protectors. The fuses should have high operating currents (say, over 20 A).

Nevertheless, particularly when the service voltage of the low-voltage network does not cause the protectors to spark over, the best course is to provide the conductors with an insulating covering at the crossing point (Recommendation K.6, Geneva, 1964).

e) In lines subject to magnetic induction effects, the current in the conductors, when there is spark-over of the protectors, may reach substantial values, especially on open-wire lines which are highly induced and whose conductors have a rather low resistance. This must be taken into account in designing the protectors and earths.

f) The dielectric strength of the apparatus and cables connected to the lines must be coordinated with the spark-over voltage of the protectors. Apparatus with highly sensitive components (for example, semi-conductors) must have built-in protection, the protective devices being associated with these components of the circuits in the apparatus.

Recommendation K.12 (Geneva, 1972)

SPECIFICATION CLAUSES FOR THE REQUIREMENTS TO BE MET BY GAS DISCHARGE PROTECTORS FOR THE PROTECTION OF TELECOMMUNICATION INSTALLATIONS

Preamble

Protection of telecommunication lines against external disturbances (atmospheric discharges, exposure to electricity power lines and installations) is becoming more and more important. On the one hand, the introduction of solid state devices has increased the sensitivity of telecommunication installations, and on the other, the inevitable extension of power installations is increasing the risks which arise from this source.

Telephone Administrations and other users of telecommunication systems therefore need to have at their disposal high quality protective equipment of exceptional reliability and complete trustworthiness.

Lightning protectors are among the most commonly used protective devices.

This specification contains the basic requirements to be met by gas discharge protectors for the protection of telecommunication installations.

This specification covers both the performance and the reliability of gas discharge protectors.

Performance requirements may vary according to the use made of the gas discharge protector and tolerances may vary within more or less wide limits, but reliability is the essential factor. Whatever type of gas discharge protector is used, it must have an extremely high reliability.

1. *General*

1.1 Gas discharge protectors (sometimes referred to as rare gas arresters) are used in overhead and underground telecommunication lines to limit over-voltages due to atmospheric discharges or to the effects of electric power installations (magnetic induction, contact with electricity distribution lines), so as to avoid any danger to:

a) the telecommunication lines and the equipment connected therewith;

b) persons in contact with the lines or with part of the telecommunication installation.

In the following, the term "protectors" applies to gas discharge protectors.

1.2 These protectors limit the voltage by making a conductive connection—via an arc discharge in a sealed gaseous medium—between parts of the installation where the over-voltage occurs or with the earthing system, and thus provide a potential-equalizing bond resulting in a residual voltage corresponding to the residual voltage of the over-voltage protector.

The limiting effect is achieved as soon as the over-voltage exceeds the spark-over voltage of the protector with a resulting arc discharge and low residual voltage across the protector.

1.3 The robustness of a protector is characterized by the value of the discharge current and the time of passage of this current (the value of the current being below a certain limit resulting in mechanical destruction).

1.4 When an over-voltage protector is loaded with its rated discharge current, its electrical properties must remain within the specified tolerances after repeated discharges.

2. *Scope*

2.1 The requirements apply to protectors with one or several discharge gaps in a sealed gaseous medium used to limit over-voltages in telecommunication installations.

2.2 The requirements do not apply to protectors which are connected in series with voltage-dependent resistors in order to limit follow-on currents in electrical power systems.

2.3 The general provisions of this specification apply to all protectors in telecommunication systems, but it is recognized that in the case of those used in connection with impedances to reduce the discharge current, certain of the values quoted in the specification may require to be varied, and these must be separately defined by the user.

3. *Definitions*

3.1 *Spark-over* of a protector occurs on electrical breakdown of the respective discharge gap.

3.2 The *d.c. spark-over voltage* is the voltage at which the protector sparks over with slowly increasing d.c. voltage.

It is a quantity which is used to indicate that a protector is suitable for use. This includes testing during its life.

3.3 The *nominal d.c. spark-over voltage* of a protector is the voltage specified by the manufacturer to designate the protector (type designation) and to indicate its application with respect to the service conditions of the installation to be protected. Tolerance limits of the d.c. spark-over voltage are also referred to the nominal d.c. spark-over voltage.

3.4 The *a.c. spark-over voltage* of a protector is the r.m.s. value of the sinusoidal voltage at the frequency of 15 Hz to 62 Hz, the rise of which causes the protector to spark over when the voltage is slowly increased.

It is essentially used to indicate the range of application of a protector in case of direct contact with, or magnetic induction from, a.c. power distribution lines.

3.5 The *impulse spark-over voltage* of a protector is the highest voltage which appears across its terminals in the period between the application of an impulse of given wave shape and the time when current begins to flow.

3.6 The *impulse spark-over voltage/time curve* of a protector is the curve which relates the impulse spark-over voltage to the time to spark over.

3.7 The *alternating discharge current* is the r.m.s. value of an approximately sinusoidal alternating current flowing through the protector.

3.8 The *nominal alternating discharge current* for currents with a frequency of 15 Hz to 62 Hz is the alternating discharge current for which the protector is designed to carry for a defined time.

3.9 The *impulse discharge current* is the peak value of the impulse current flowing through the protector after spark-over.

3.10 The *nominal impulse discharge current* is the peak value of the impulse current with a defined curve shape with respect to time for which the protector is rated.

3.11 The *destruction characteristic* indicates the relationship between the value of the discharge current and its time of flow until the protector is mechanically destroyed (break, electrode short circuit). It is obtained from the average of measurements on several protectors.

For periods of time between 1 μs and some ms, it is based on impulse discharge currents, and for periods of time of 0.1 s and greater it is based on alternating discharge currents.

3.12 The *residual voltage* is the instantaneous voltage appearing across the terminals of a protector during the passage of a discharge current.

A distinction is made between the residual voltage in the case of a glow discharge and the residual voltage in the case of an arc discharge, for it is a quantity which depends upon the type of discharge.

3.13 The *glow current* is the current which flows after spark-over when the electrodes are surrounded by a glow.

3.14 The *arc current* is the current which flows after spark-over when the gap of the protector is bridged by an arc.

3.15 The *voltage/discharge current curve* for alternating currents of a frequency from 15 Hz to 62 Hz indicates the relationship between the instantaneous values of voltage and current during the passage of discharge current.

3.16 The *transverse voltage* of a protector with several gaps is the difference of the residual voltages of the gaps assigned to the two conductors of a telecommunication circuit during the passage of discharge current.

4. *General requirements*

4.1 The protector shall be constructed and rated so that there will be no danger to persons or to the surroundings during normal operation or if it becomes faulty.

In this respect attention should be paid to problems of inadmissible heating, of destruction due to overloading and to the avoidance of radiation in the case of pre-ionization by radioactive matter.

The mechanical construction of a protector, particularly in respect of the seal between metal and the envelope, is most important. In general, this seal should be such as to have a sufficiently large cross-sectional area so that heavy discharges will not shatter or crack the envelope or seal. This applies particularly in respect of feed-through leads.

It is also desirable that the construction of the protector shall be such that mechanical shocks do not alter its electrical characteristics.

4.2 The values of the striking voltages of the protectors shall be selected so that they:

4.2.1 are adapted to the dielectric strength of the insulation of the installation to be protected;

4.2.2 allow for the relevant regulations for the protection of persons against short-term over-voltages;

4.2.3 are well above the highest equipment working-voltage in order to avoid any disturbance to circuits under service conditions.

4.3 The insulation resistance and capacity of the protectors shall be such that the functioning of the telecommunication circuits is not impaired.

4.4 The protector shall not be maintained in operation by the line voltage after the surge has disappeared.

5. *Terms and values designating the protectors*

The electrical characteristics of the various types of protector are indicated by the following terms and values:

5.1 The spark-over voltages as a function of time from the moment when the voltage is applied to the terminals to the moment when the discharge current begins to flow:

Characteristic $U_a = f(t)$. An example is given in Appendix 1.

These spark-over voltages are:

5.1.1 the nominal d.c. spark-over voltage;

5.1.2 the impulse spark-over voltage in the presence of a standard impulse voltage as specified in paragraph 7.

5.2 The discharge-current carrying-capacity as a function of the duration of the discharge.

The current carrying-capacity is indicated by:

5.2.1 the nominal alternating discharge current for a defined time of flow of this current;

5.2.2 the nominal impulse discharge current with an impulse having a standard wave shape as specified in paragraph 7;

5.2.3 the destruction characteristic (characteristic $I_d = f(t)$. An example is given in Appendix 2).

5.3 The residual voltages as a function of the discharge current (characteristic $U_r = f(I_d)$. An example is given in Appendix 3).

These residual voltages are indicated by:

5.3.1 the maximum residual voltage within the range of the glow discharge;

5.3.2 the residual voltage in the case of an arc discharge;

5.3.3 the maximum glow discharge current at which the residual voltage of the glow discharge changes into the residual voltage of the arc discharge.

5.4 According to the kind of over-voltage to be limited, a protector is designated by the following characteristics:

5.4.1 for over-voltages at electrical power frequencies of 15 Hz to 62 Hz, by the nominal values as specified in paragraphs 5.1.1, 5.2.1 and 5.3.3 above.

The characteristics of standard types of these protectors are listed in Table 1.

TABLE 1

Standard type No.	Characteristics		
	Para. 5.1.1. Nominal d.c. spark-over voltage	Para 5.2.1 Nominal alternating discharge current (r.m.s. value)	Para 5.3.3 Maximum glow discharge current
1	Choice of the nominal value with due regard to paragraph 4.2	5 A	< 0.5 A to 1.5 A
2		20 A	
3		50 A	

5.4.2 for over-voltages due to atmospheric discharges, by the values specified in 5.1.1 and 5.2.2 above.

The characteristics of standard types of these protectors are listed in Table 2.

TABLE 2

Standard type No.	Characteristics		
	Para. 5.1.1 Nominal d.c. spark-over voltage	Para. 5.2.2 Nominal impulse discharge current	Para. 5.1.2 Impulse spark-over voltage
4	Choice of the nominal value with due regard to paragraph 4.2	2.5 kA	For upper limits, see Tables 3 and 4
5		10 kA	
6		20 kA	

5.4.3 for over-voltages occurring on the same telecommunication installation due to the effects of electrical power installations (power frequencies) and to atmospheric discharges, by combination of the values in respect of standard types 1 and 4 (standard type 1-4), 2 and 5 (standard type 2-5) and 3 and 6 (standard type 3-6).

5.5 *Tolerance limits of the nominal values*

5.5.1 The upper and lower limits (tolerance) of the d.c. spark-over voltage are determined by the requirement specified in paragraph 4.2. These limits shall be observed even after a repeated flow of discharge currents with values as specified in Table 1 and Table 2 respectively.

5.5.2 As far as the other values are concerned, it is only necessary to state upper *or* lower limits, depending on the characteristics in question.

5.5.3 The limits make allowance for environmental influence and the location (room temperature, polarity, light).

The limits are specified in paragraph 8, *Type tests*.

6. *General information on tests*

6.1 The tests comprise:

6.1.1 type tests as specified in paragraph 8 to determine the electrical and mechanical properties of a type of protector;

6.1.2 acceptance tests as specified in paragraph 9, i.e. sampling of the protector on delivery.

6.2 The electrical properties shall be assessed in accordance with statistical methods, because the physical processes of a discharge in a gaseous medium are subject to statistical variations. Every test shall be made on several specimens.

6.3 In the case of protectors with several discharge gaps in the same discharge envelope, the electrical properties are tested for each gap separately.

6.4 Testing of the mechanical properties includes the checking of the dimensions and of the durability of the connections to the fittings or contact plates attached to the protector. If the protectors are to be used in an environment having a high humidity, it may be advisable to check the corrosion resistance.

6.5 Thermal shock tests may be made on protectors if required by the user.

7. *Standardized test voltages and currents*

7.1 An impulse voltage of the form 5/65 (Definition of the wave shape according to I.E.C. Publication 60/1962) with a peak value of 5 kV is used for the impulse spark-over voltage tests (paragraph 5.1.2).

This impulse voltage may also be replaced by a voltage having a linear increase to 5 kV in 5 μs (voltage of virtual steepness of the impulse wavefront of 1 kV/μs).

Figure 1/K.12 shows an arrangement for testing with a voltage impulse having a wavefront with a virtual steepness of 1 kV/μs.

The test arrangements for impulse voltages must make allowance for the transient phenomena with impulses, such as cut-off frequency of the measuring equipment, matched termination of the test lead, etc.

7.2 An impulse current of the form 8/20 (Definition of the wave shape according to I.E.C. Publication 60/1962) with a peak value as listed in Table 2 above is used for the impulse current carrying capacity tests (para. 5.2.2).

7.3 The voltage used for making the d.c. spark-over voltage tests shall be a slowly increasing voltage having a maximum rate of increase of 10 kV/s.

8. *Type tests*

8.1 *Spark-over voltages*

8.1.1 *d.c. spark-over voltage*

Four measurements are made (two of each polarity) on all specimens used for tests under 8.2.1 and 8.2.2 before those tests are made. Assessment is done in accordance with Table 3.

8.1.2 *Impulse spark-over voltage*

An impulse voltage as specified in paragraph 7.1 is used to measure ten times (five in each direction) the impulse spark-over voltage of each of twenty protectors which have been tested and approved in accordance with paragraph 8.1.1. Assessment is done in accordance with Table 4.

8.1.3 If the envelope is light-transparent, these tests shall be made in darkness after the protectors have been stored in darkness for a sufficient time, to be determined for the type of protector concerned. Between successive measurements a time interval of a few seconds should be allowed.

8.2 *Discharge currents*

8.2.1 *Alternating discharge currents*

The nominal alternating discharge current (within tolerance limits of ±10%) is used to test twenty protectors which have been tested and approved in accordance with paragraph 8.1.1, as follows: the current is applied to each protector ten times for 1 s at intervals of 3 min. After cooling down, the d.c. spark-over voltage is measured and the results are assessed in accordance with Table 3.

If the user considers it to be necessary in case of protection against atmospheric discharges, measurements according to 8.1.2 shall also be made and the results assessed in accordance with Table 4.

8.2.2 *Impulse discharge current*

The nominal impulse discharge current (within the tolerance limits quoted in I.E.C. Publication 60/1962) is used to test twenty other protectors tested and approved in

TABLE 3

Test as specified in paragraph	Spark-over voltage		Percentage (6.2) of the measured values to be within the tolerance
	Nominal value of d.c. voltage (para 5.1.1)	Upper limits of impulse voltage at 1 kV/μs (para 5.5.2)	
8.1.1			95%[b]
8.2.1	Choice of the nominal value with due regard to para. 4.2	± 20%[a]	80%[b]
8.2.2			

TABLE 4

Test as specified in paragraph	D.c. spark-over voltage		Percentage (6.2) of the measured values to be within the tolerance
	Nominal value (para. 5.1.1)	Upper limits at 1 kV/μs (para. 5.2.2)	
8.1.2	< 150 V	< 1 kV	80%[b]
	150 V to 500 V	1 kV to 2 kV	
	500 V to 1500 V	2 kV to 3 kV	

[a] This tolerance can be modified in accordance with the requiiements specified in paragraph 4.2.

[b] In a given batch tested, any individual protector which is outside these tolerances must nevertheless spark over during the test.

accordance with paragraph 8.1.1 and 8.1.2 as follows: an impulse is applied to each protector ten times (five of each polarity) at intervals of 3 min. After cooling down, the d.c. spark-over voltage and the impulse spark-over voltage are measured and the results are assessed in accordance with Tables 3 and 4.

8.2.3 *Destruction characteristics*

The manufacturer shall indicate the destruction curve together with the dispersion of the measured values for every type of protector. If the user wishes the manufacturer to make a check of the destruction curve it shall be sufficient to make a test at one point on the curve, using three protectors. When a protector destroys itself in this test with alternating current it shall fail by short circuit.

8.3 *Voltage/discharge current curve*

The values specified in paragraphs 5.3.1, 5.3.2 and 5.3.3 shall be measured (as shown in Figure 2/K.12) on three other protectors which have been tested and approved in accordance with paragraph 8.1.1. For this purpose use shall be made of power frequency alternating current applied for a period of 3 s. The r.m.s. value of the applied voltage shall be between two and three times the nominal d.c. spark-over voltage, and the current should be limited to a value approximately twice that of the nominal glow discharge current in Table 1.

An oscilloscope with a camera attachment should be used for recording the results. The shutter of the camera should be opened before the current is switched on and should be left open for the full period of 3 s.

8.3.1 The residual voltage in case of a glow discharge is, in general, greater than 60 V. The maximum value shall not exceed 1.3 times the value of the d.c. spark-over voltage.

8.3.2 The residual voltage occurring in the case of arc discharge shall be less than 25 V.

8.3.3 The maximum discharge current occurring in the case of glow discharge (transition from glow to arc discharge) shall not exceed the value listed in Table 1.

The upper limits of these values should be taken from the oscillograms (see also Appendix 3).

8.4 *Transverse voltage of three and more electrode protectors*

The following measurements shall be made between pairs of electrodes assigned to the two conductors of the same circuit and the common earth electrode.

Tests shall be made on ten protectors which have been tested and approved in accordance with paragraphs 8.1.1 and 8.1.2.

8.4.1 *Transverse voltage under a.c. conditions*

The average value of the transverse voltage shall be measured while both discharge gaps are simultaneously carrying an alternating discharge current. The measurement may be made with an arrangement as indicated in Figure 3/K.12. The r.m.s. value of the applied voltage should be between two and three times the nominal d.c. spark-over voltage, and the value of the resistors *R* should be such that the peak value of the current is approximately twice the maximum glow discharge current (transition from glow to arc discharge—paragraph 8.3.3). The duration of the discharge shall not exceed 3 s.

The maximum value of the average transverse voltage shall not exceed 45 V in nine out of the ten protectors tested.

8.4.2 *Transverse voltage under impulse conditions*

The duration of the transverse voltage shall be measured while an impulse voltage having a virtual steepness of impulse wavefront of 1 kV/μs is applied simultaneously to both dis-

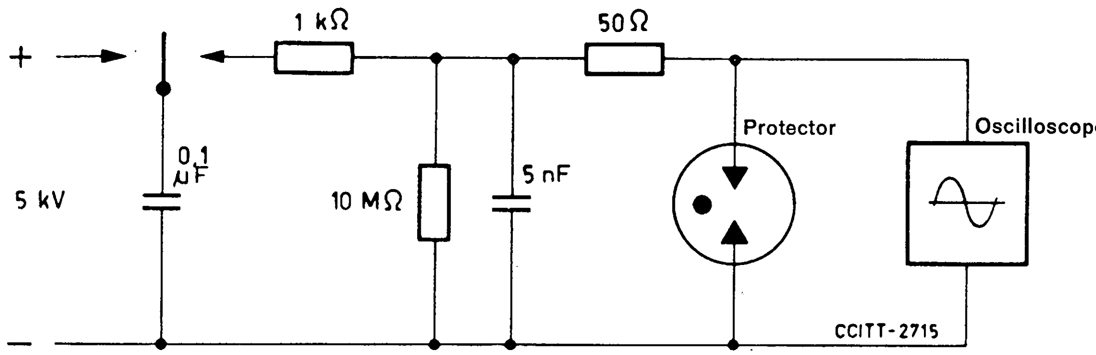


FIGURE 1/K.12. — Testing arrangement producing a voltage impulse having a wavefront with a virtual steepness of 1 kV/μs.

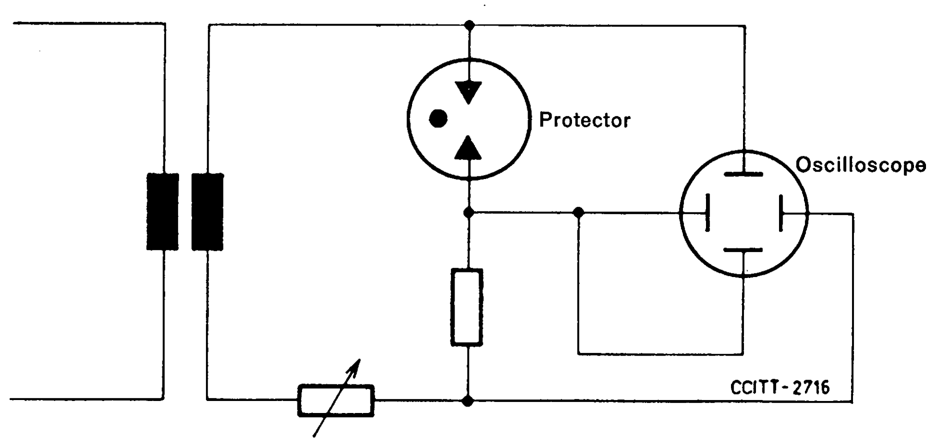


FIGURE 2/K.12. — Testing arrangement for the characteristics mentioned in paragraphs 5.3.1, 5.3.2 and 5.3.3.

charge gaps. Measurement may be made with an arrangement as indicated in Figure 4/K.12. The difference in time between the spark-over of the first gap and that of the second shall not exceed 0.2 μs in nine out of the ten protectors tested.

8.5 *Insulation resistance*

This shall be measured with suitable equipment at a voltage less than the d.c. spark-over voltage of the protectors after they have been in a humid atmosphere for 24 hours (at room temperature and about 83 % relative humidity, for example in a saturated atmosphere over a saturated solution of potassium chloride). The insulation resistance shall be not less than 10^8 ohms after the tests set out in paragraphs 8.2.1 and 8.2.2 have been made. The insulation resistance measurements shall be made on the same protectors used in those tests.

8.6 *Capacity*

The self-capacity shall be measured on three protectors. It shall be less than 10 pF.

8.7 *Radiation*

The emerging radiation from any radioactive matter used to pre-ionize the discharge gaps must be within the limits specified as admissible in the regulations concerning the protection from radiation which are issued by the country of the manufacturer as well as of the user. This provision applies both to individual protectors and to a batch of protectors (for example, when packed in a cardboard box for despatch, storage, etc.).

A type test is not required, provided the manufacturer indicates the kind and amount of the radioactive matter as well as the emerging radiation.

8.8 *Mechanical properties*

Testing of the mechanical properties may be made in accordance with the general indications set out in paragraphs 4.1, 6.4 and 6.5.

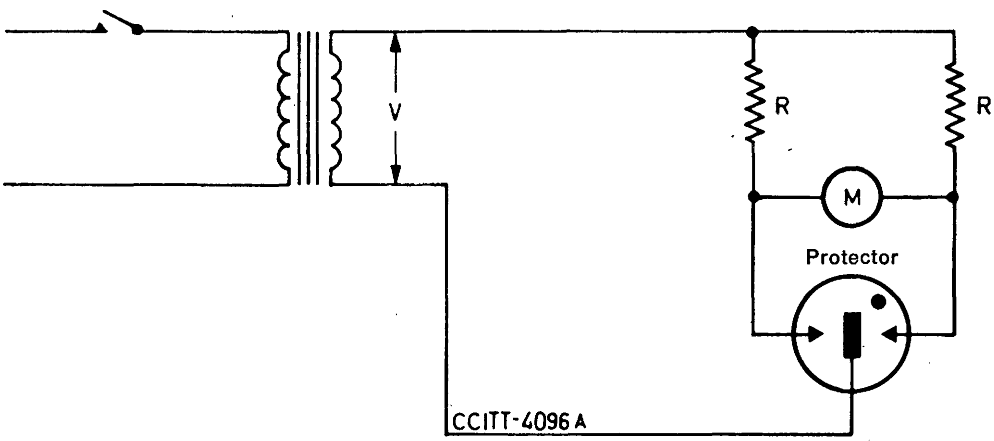
9. *Acceptance testing*

The number of protectors on which acceptance tests are made depends on the respective lot.

The following values apply only as a guide:

Lot	*Acceptance test*
Comprising up to 1 000 protectors	at least 20 protectors
Comprising up to 10 000 protectors	at least 50 protectors
Comprising up to 50 000 protectors	at least 100 protectors

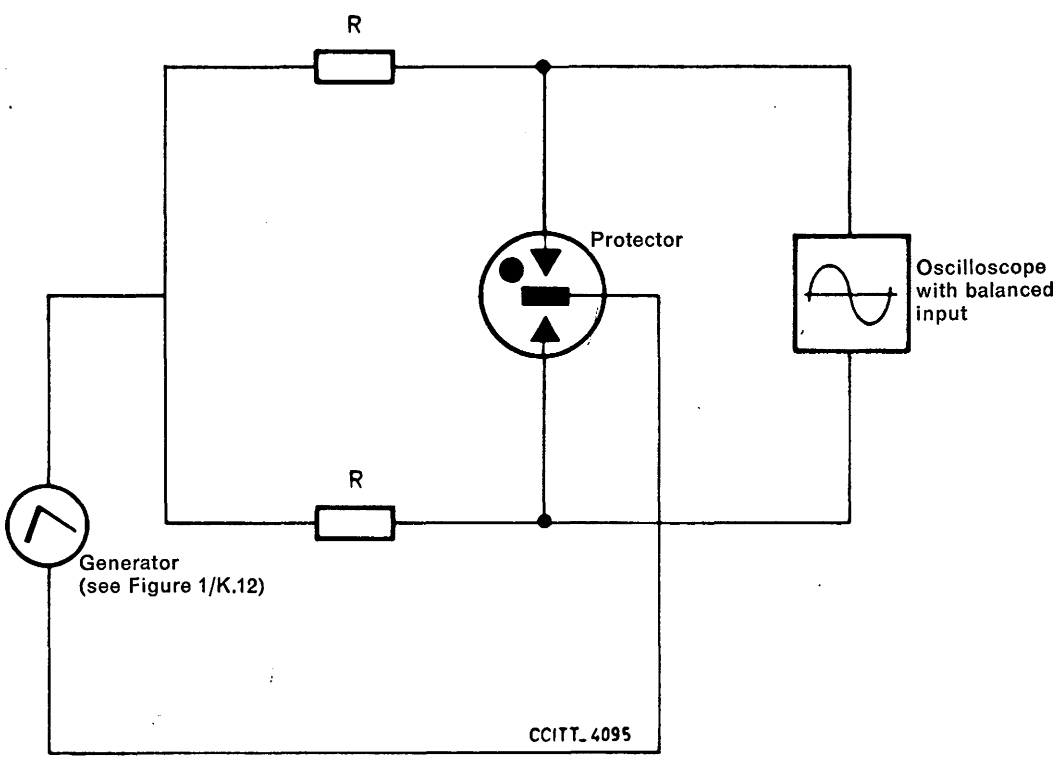
The acceptance test involves the measurement of the d.c. spark-over voltage twice on each sample. Assessment is made in accordance with Tables 3 and 4.



Voltmeter *M* should have a resistance of not less than 20 kΩ and a full scale deflection of 100 V approximately. It should be a moving coil and rectifier instrument, calibrated to read mean values.

Note. — If the meter is calibrated to read the r.m.s. voltage of sinusoidal supplies, the readings should be multiplied by 0.9 to give the mean value.

FIGURE 3/K.12. — **Testing arrangement for the characteristics of 3-electrode protectors referred to in point 8.4.1 (transverse voltage during alternating current discharge).**

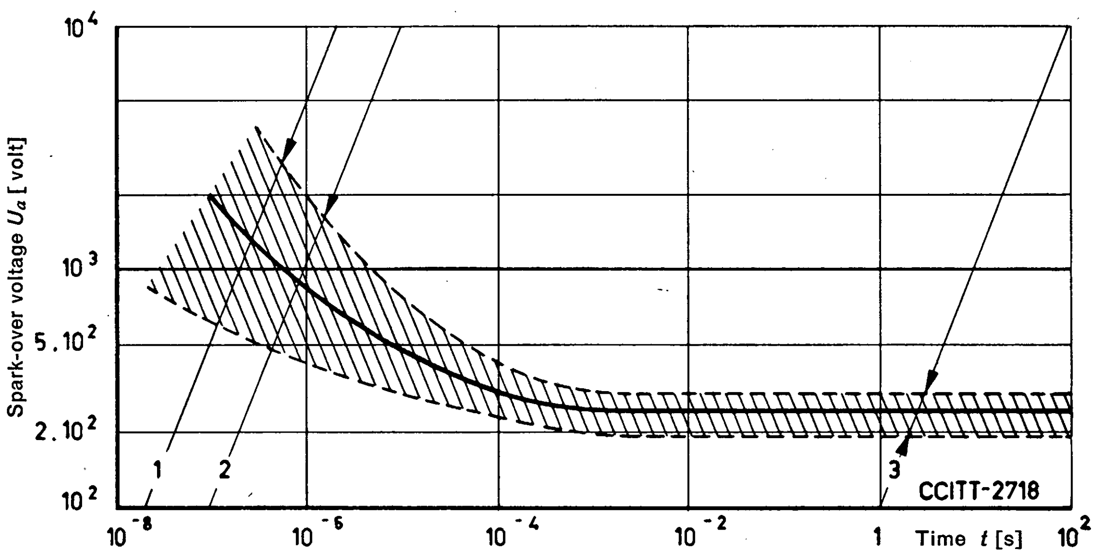


R = Line impedance

FIGURE 4/K.12. — **Testing arrangement for the characteristics of 3-electrode protectors referred to in point 8.4.2 (transverse voltage during an impulse discharge).**

APPENDIX 1

Spark-over characteristic $U_a + f(t)$, paragraph 5.1



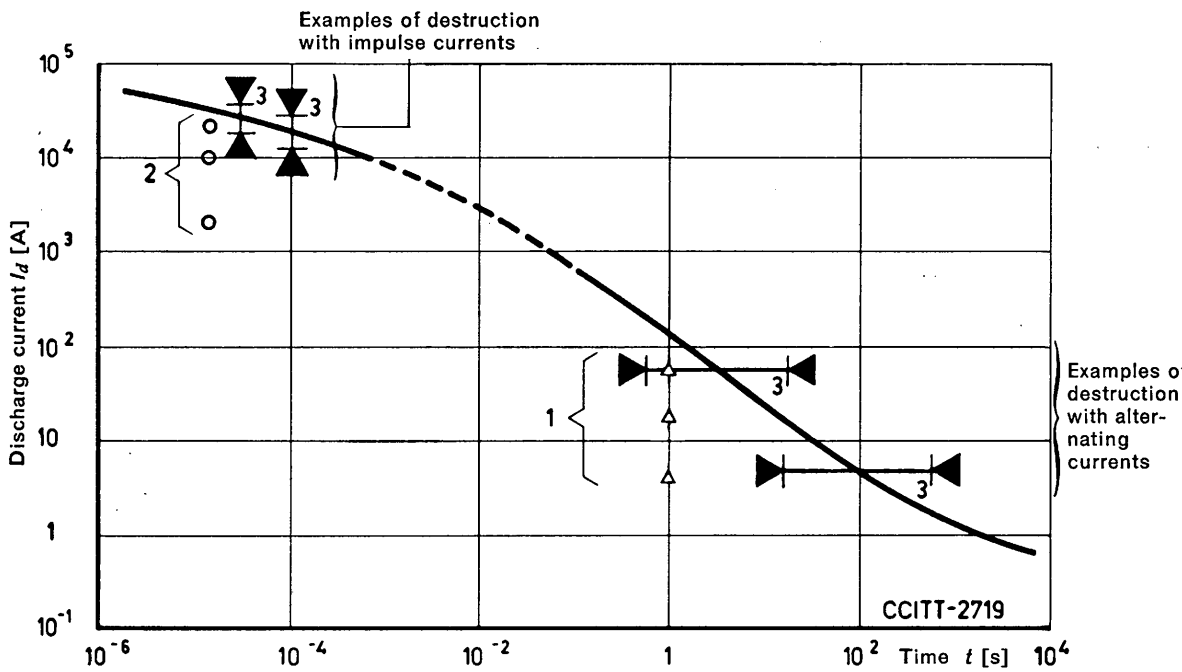
1. Example with 5 kV/μs
2. Example with 1 kV/μs

} Test as specified in paragraph 8.1.2, upper limit

3. Example with 100 V/s — Test as specified in paragraph 8.1.1, tolerance

APPENDIX 2

Discharge currents according to paragraphs 5.2.1 and 5.2.2 and destruction curve $I_d = f(t)$ according to paragraph 5.2.3.



Current carrying capacity:

1. Test as specified in paragraph 8.2.1 with alternating discharge currents △

2. Test as specified in paragraph 8.2.2 with impulse currents ○

Destruction:

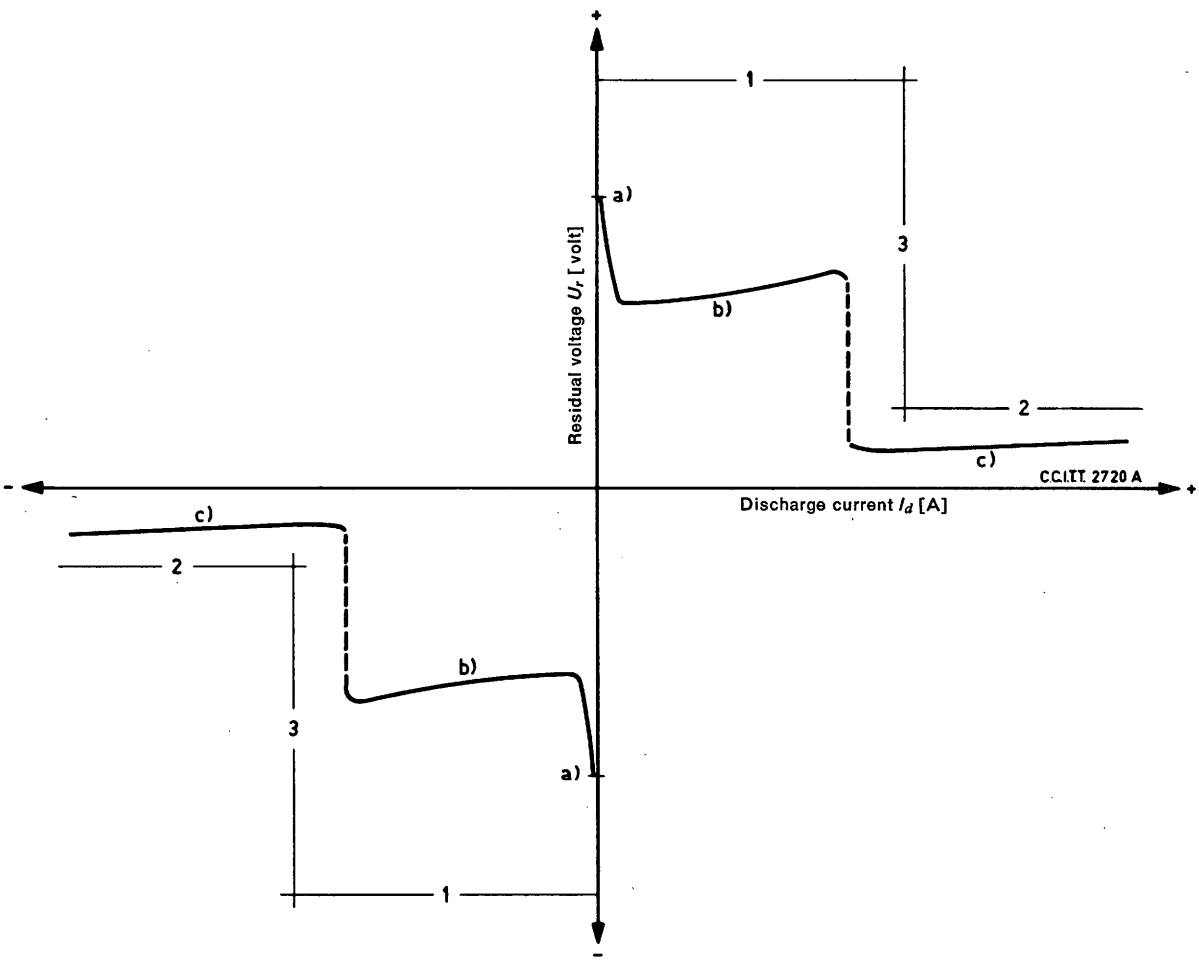
3. Mechanical destruction test as specified in paragraph 8.2.3

Margin of current at destruction by impulse currents

Margin of time at destruction by alternating currents

APPENDIX 3

Voltage discharge current curve $U_r = f(I_d)$, paragraph 5.3



a) Spark-over voltage

b) Residual voltage in the case of glow discharge, paragraph 5.3.1

c) Residual voltage in the case of arc discharge, paragraph 5.3.2

Upper limits:

1. Test as specified in paragraph 8.3.1
2. Test as specified in paragraph 8.3.2
3. Test as specified in paragraph 8.3.3

Recommendation K.13[1] (Geneva, 1972)

INDUCED VOLTAGES IN CABLES WITH PLASTIC-INSULATED CONDUCTORS

According to Chapter IV, Section 2, of the *Directives* (1963 Edition), when a fault occurs on a power line near a telecommunication cable having all its circuits terminated by transformers, the permissible induced longitudinal voltage in the cable conductors should not exceed 60% of the voltage used to check the dielectric strength of the cable, as required by individual specifications for checks of the breakdown strength between the cable conductors and the sheath. This induced voltage is generally 1200 V r.m.s. value for paper-insulated conductors (60% of 2000 V). The *Directives* give no indication of the frequency of occurrence of such a voltage or of its permissible duration. So that such voltages do not endanger line maintenance staff, the safety precautions for staff given in Chapter XX of the *Directives* must be observed.

Plastic-insulated cables can have a much higher dielectric strength than paper-insulated cables. Moreover, this dielectric strength is retained following the mechanical stresses that occur during the laying of the cable. There should thus be no danger of breakdown of the insulation between the conductors and the metal sheath when it is subjected to induced longitudinal e.m.f. sufficiently below the breakdown voltage of the cable. A sufficient safety margin is ensured if induced voltages are kept below 60% of the voltage used for checking the dielectric strength of the cable as given in the individual specifications; this voltage is, of course, related to the breakdown voltage.

At very little extra expense, sleeves and joints can be made to have the same dielectric strength as the insulation between the conductors and the metallic sheath, although transformers and terminal equipments must be suitably protected when their dielectric strength is not up to the conditions concerned.

If the source of the induced longitudinal e.m.f. is a high-reliability power line, as defined in the *Directives*, there is only a very small probability that staff will be in contact with a line at the precise moment when such a voltage of short duration occurs in the telecommunication cable. Any danger to staff is very slight given due observation of the safety precautions for maintenance staff working on telephone lines in which high voltages may be induced by neighbouring electricity lines.

For a cable not having its circuits terminated by transformers the above conditions also apply provided that surge voltages are prevented from reaching the telecommunication equipment by the striking of the lightning protectors installed at the ends of the circuits.

For these reasons the C.C.I.T.T. is unanimously of the opinion that:

1. It is possible to make telecommunication cables with conductors that are insulated from each other and from the metallic sheath by high breakdown strength plastics. For such cables, when there is a fault on a neighbouring electricity line, the value of induced longitudinal e.m.f. that can be allowed is that which does not exceed 60% of the test voltage applied between the conductors and the metallic sheath for checking the dielectric strength (this test voltage, which is given in the individual cable specifications, is related to the breakdown voltage) provided the following conditions are observed:

   a) circuits in such cables are terminated at their ends and at branching points on transformers or are provided with lightning protectors;

[1] This Recommendation may entail subsequent changes to the text of the *Directives*.

b) equipment, joints and cableheads associated with such cables must have a dielectric strength at least equal to that of the insulation between the conductors and the metallic cable sheath of the cable, given that the transformers mentioned in a above must be provided with lightning protectors when their dielectric strength does not meet the required conditions;

c) the power line causing the induction must meet the conditions for high-reliability power lines given in the *Directives*, Preliminary Chapter, sub-section 3.2.3;

d) staff working on telecommunication cables must take the safety precautions specified in Chapter XX of the *Directives*.

2. When the circuits of such a cable are connected direct to the telecommunication equipment, that is, when no transformers or lightning protectors are inserted, and when the condition laid down in paragraph 1.c above is fulfilled, the maximum permissible induced longitudinal e.m.f. should be 650 V.

Recommendation K.14 (Geneva, 1972)

PROVISION OF A METALLIC SCREEN IN PLASTIC-SHEATHED CABLES

A metal sheath provides a cable with electrostatic screening and a degree of magnetic screening. A plastic sheath has no intrinsic screening properties. Some plastic-sheathed cables, for example those with paper-insulated cores, incorporate a metal screen as a water barrier. Such a metal screen, which is usually in the form of a longitudinally applied aluminium tape, provides the same screening properties as a non-ferrous metal sheath of the same longitudinal conductivity. The tape must, however, be connected to the telephone exchange earth electrode systems at its ends and/or to conveniently located earthing points, such as metal cable sheaths, along its length. It is also important that at jointing points the tape be extended through by connections of very low resistance. Although the degree of screening provided by the tape may be small at 50 Hz, it can be considerable at frequencies which give rise to noise interference. The presence of a screen on a cable also reduces the induction arising from the high-frequency components of transients caused by power-line switching and also induced transients from lightning strokes; such transient induced voltages are of increasing importance with the increasing use of miniaturized telecommunication equipment with very small thermal capacity.

On the basis of the above considerations and experience with the use of plastic-sheathed cables, the C.C.I.T.T. recommends that:

1. Since plastic-sheathed subscriber distribution cables without a screen give satisfaction for distribution from the exchange to subscribers, they may be used in localities where there are no alternating current electrified railways. However, account must always be taken of the risk of noise interference that may arise in the vicinity of electric railways, especially those with thyristor controlled equipment in the locomotives. Consideration should also be given to possible interference by radio transmitters which operate in the same frequency range as the circuits in the plastic-sheathed cable.

2. Trunk and junction cables should contain a screen which can be the form of an aluminium-tape water barrier. Cables provided with a screen having a conductance of the order of half that of a cable having the same core diameter, but with a lead sheath, have given complete satisfaction where there are no risks of severe magnetic induction.

3. If a plastic-sheathed cable is provided with a screen of a conductance equivalent to that of a conventional lead-sheathed cable, then in the presence of induction the plastic-sheathed cable can be used in entirely the same circumstances as the lead-sheathed cable.

4. If the effect of the screen according to Items 2 and 3 is not sufficient to limit the magnetic induction at mains frequencies or to these harmonics arising from neighbouring power lines or electric railways to permissible values, the screening factor can be improved by increasing:

   4.1 the inductance of the metal sheath, if necessary, by a lapping of steel tapes;

   4.2 the conductance of the existing screen by additional metal tapes or wires which are arranged below the screen.

   An improved screening effect may also become necessary if there is the risk of noise interference in the vicinity of electric railways equipped with thyristor controlled devices.

5. The screen must be connected to the earth electrode systems of the telecommunication centres. In the case of subscribers' cables the remote end should be connected to a suitable earth. It is also important for the screen of the cable to be extended through at cable joints by means of connections of very low resistance.

6. In view of the increase in the number of electrical installations and the level of harmonics resulting from new techniques, it is to be expected that the effects of interference will become worse. This being so, it may be extremely useful to improve the screening effect of plastic-covered cables as indicated above.

7. If cables have to be laid in areas where there is a danger of atmospheric discharges, attention is drawn to the importance of the metallic screen and of its construction in the protection of cables against lightning and also to the importance of the interconnections between the screen and other structures. (See Chapter IV, paragraph 2.1, of the *Handbook on the protection of telecommunication lines and equipment against lightning discharges* [1]).

Recommendation K.15 (Geneva, 1972)

PROTECTION OF REMOTE-FEEDING SYSTEMS AND LINE REPEATERS AGAINST LIGHTNING AND INTERFERENCE FROM NEIGHBOURING ELECTRICITY LINES

Preliminary recommendation

To minimize interference to the power feeding of repeaters from external sources, 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, and that the circuit in which the power-feeding currents circulate does not provide low impedance paths for longitudinal currents.

Introduction

The presence of components capable of withstanding only moderate excess voltage stress, in particular semi-conductor components (transistors, etc.) in telecommunication equipment necessitates protective measures against over-voltages which may occur at the terminals, even if the over-voltages only slightly exceed the service voltages, as they are still capable of disturbing the functioning of these components and even of destroying them.

[1] In course of preparation.

In addition, the functioning of circuits provided with repeaters may be disturbed by electromotive forces induced by power lines, depending on how the lines are operated; disturbance may be caused even when there is no fault on the lines.

Components, in particular the semi-conductor components of apparatus which is directly connected to the conductors of telecommunication lines, may be damaged since these conductors, whether in cable or in open-wire lines, are exposed to over-voltages due to external sources such as the magnetic induction caused by power lines or atmospheric discharges.

The repeaters inserted at intervals on telecommunication lines belong to this category of equipment. As the remote feeding is by the cable or open-wire conductors which are used for transmission, the over-voltages may reach the terminals of the semi-conductor components and damage them unless protective devices or appropriate circuit designs are provided in order to limit the over-voltages at sensitive points to permissible values or to preclude them altogether.

The protective measures required depend partly on the following:

- the value of the e.m.f. which may occur;
- the composition of the line, particularly when cable pairs are used;
- the arrangements made with regard to the outer conductor of coaxial pairs in relation to the metallic sheath of the cable (floating potential or earth);
- the type of power supply (d.c. or a.c.).

If the over-voltages occurring on conductors used for the power supply are due to magnetic induction caused by neighbouring power lines, one can start by assessing their values by the calculation methods indicated in the *Directives.* Additional calculations are necessary to find what protective measures are required.

When the over-voltages are due to atmospheric discharges, their values can only be reckoned approximately. The protection provided must therefore be tested in the apparatus concerned under the most realistic possible conditions.

The above requirements are met by the measures recommended below. These do not pretend to be complete as the technique is still changing; they will, however, ensure for the manufacturer and the user of such systems a high degree of protection.

1. *Methods of calculation*

1.1 The *Directives concerning the protection of telecommunication lines against harmful effects from electricity lines,* Part 3, 1963 edition, explain, in principle, how to calculate the longitudinal e.m.f. induced in the remote-feeding circuit. The calculation method is applicable both in normal operating conditions and when there is a fault on the electricity line.

1.2 The additional calculation of voltages and currents induced in a coaxial pair is based on the longitudinal e.m.f. reckoned from the information referred to in paragraph 1.1. For this calculation it is advisable to refer to Recommendation K.16. (See also the publication mentioned in point [1] of the References of Recommendation K.16.)

1.3 For the evaluation of voltages and currents (peak value of short impulses) that may occur in remote-feeding circuits following atmospheric discharges, reference should be made to the *Handbook on the protection of telecommunication lines and equipment against lightning discharges* [1]. (See also the publication mentioned in point [2] of the References of Recommendation K.16.)

[1] In course of preparation.

2. *Limit values of over-voltages*

2.1 *Longitudinal voltages caused by magnetic induction*

In principle, the limit values of induced longitudinal voltages indicated in Chapter IV of the *Directives* must not be exceeded when the ability of the material (cables, conductors, equipment) to withstand higher voltages is in doubt. A higher limit may be permitted, however, if a previous examination of the dielectric strength of the insulation of the conductors and the equipment connected to them show that there is no danger of breakdown (see Chapter IV, paragraph 48, of the *Directives*).

If the remote-feeding equipment raises the conductors permanently to a high potential with respect to the metallic sheath of the cable or to earth, it must be borne in mind that the induced voltage is superimposed on the power supply voltage (see Chapter IV, paragraph 53, of the *Directives*).

2.2 *Over-voltages caused by atmospheric discharges*

The permissible limit values of impulse voltages depend mainly on the dielectric strength of the insulation of the conductors and the equipment connected to them unless additional provision is made (e.g. in the systems) to limit the over-voltages to values below the breakdown voltages. The permissible limits at the terminals of equipment including semi-conductor components depend on the characteristics of those components.

3. *Protective measures*

3.1 *Protection against over-voltages*

The protective measures should be designed to function whatever the source of the over-voltages (magnetic induction, atmospheric discharges, etc.).

3.1.1 *Protection of conductors in cables*

If the limit values indicated in points 2.1 and 2.2 above are exceeded, adequate protective measures should be applied. For example, the dielectric strength of the insulation may be increased when new equipments are installed. It is also possible to use cables with an improved screening factor. Furthermore, voltages may be limited by lightning protectors or other voltage limiting devices. In the latter case, care must be taken to ensure that the lightning protector ceases to function once the over-voltage has disappeared and that the power feeding conductor resumes normal operation. Other protective measures are not excluded.

In composite cables in which some pairs are used for power feeding, it is advisable to coordinate the protective measures for all the conductors so as to preclude harmful effects on the cable as a whole.

3.1.2 *Protection of repeaters*

Protection must be provided both at the input and output of the repeater and on the remote-feeding circuit.

It is recommended that protection be incorporated in transistorized repeaters at the time of manufacture so as to prevent damaging magnitudes of over-voltages from reaching the terminals of sensitive elements, e.g. the semi-conductor components.

When lightning protectors are employed to limit over-voltages, it must be borne in mind that certain over-voltages whose amplitude is less than the striking voltage are still high enough to damage some components, e.g. the semi-conductor junctions of components, transistors, etc. present in the equipment. It is therefore advisable to provide protection internally by associating with the lightning protectors other protective components, such as Zener diodes and filtering, (this may already be provided in the equipment). The combination of these elements inside the equipment gives protection that is an integral part of the equipment whereby the over-voltages, whatever their source or value, are reduced by stages to a sufficiently low level as not to cause any harm.

It may happen that the protection of repeaters from voltages induced permanently by power or traction lines requires fewer components and is less expensive when the outer conductor of the coaxial pairs is at a floating potential than when it is earthed. On the other hand, when the outer conductor is earthed, staff working on coaxial pair lines are better protected against accidental contact with the inner conductor which, as it is used for power feeding, is raised to a certain potential. As each system has its advantages and disadvantages, the choice will depend on operating requirements.

3.2 *Measures to ensure the satisfactory functioning of equipment in the presence of a disturbing voltage permanently induced in the cable*

Steps must be taken to ensure that the repeater functions properly in the presence of disturbing voltages and current permanently induced in the cable conductors by power or traction lines. This refers to power lines that cause interference, but which are fault-free. The values of the induced voltages and currents may be assessed by the calculation methods referred to in paragraph 1.1 above.

4. *Testing of power-fed transistorized repeaters*

4.1 *General*

It is advisable that the test conditions simulate real conditions as closely as possible.

They must reproduce not only normal working conditions but accidental circumstances such as obtain when a conductor which is normally insulated happens to enter into contact with the metallic sheath of the cable or with the earth.

4.2 *Testing by impulse voltages*

It is recommended that the information in Recommendation K.17 should be referred to when tests are carried out by means of impulse voltages and currents. With regard to the amplitude of the waveforms, it is not enough to allow it to increase to the maximum; it is also necessary to make the test with an amplitude which is less than any threshold voltage of the protection (e.g. striking voltage of lightning protectors). The effectiveness of the protective devices (diodes, for example) can thus be ascertained in respect of over-voltages whose amplitude is low but whose energy may be high.

When lightning protectors are employed, it is necessary to ensure that their striking voltages are less than the dielectric strength between the conductors and the equipment chassis in order to prevent any breakdown.

4.3 *Testing by alternating voltages*

When repeaters are power fed by symmetric or coaxial pairs whose outer conductors are insulated from earth or from the metallic cable sheath, it is advisable to carry out a test with an alternating voltage to ensure that the strength of the insulation with respect to earth is higher than the values permitted in the *Directives* for voltages due to magnetic induction.

In order to check the behaviour of the repeaters and their power supply path when the lightning protectors strike, an alternating current in accordance with the information given in Recommendation K.17 [1] should be applied to the terminals of the path.

---

[1] Recommendation K.17 has not yet been completed. A draft on which it will be based is given in the Annex to the wording of Question 21/V.

In systems where a permanently induced voltage may be expected due, for example, to the alternating current in railway lines, it is necessary to superimpose on the feed current an alternating current of the same frequency (50 Hz, 60 Hz, $16\frac{2}{3}$ Hz) and strength as that produced in the power-feeding section when the induced voltage has the value specified in Chapter IV, paragraphs 6, 7 and 35, of the *Directives*. During the flow of the induced current the hum modulation must be so small that the values for route sections suggested by Study Group XV in Question 11 are obtained.

Recommendation K.16 (Geneva, 1972)

SIMPLIFIED CALCULATION METHOD FOR ESTIMATING THE EFFECT OF MAGNETIC INDUCTION FROM POWER LINES ON REMOTE-FED REPEATERS IN COAXIAL PAIR TELECOMMUNICATION SYSTEMS

1. *Summary*

A publication mentioned in point [1] of the References in this Recommendation contains a general treatise covering all possible cases of magnetic induction and permitting calculation of the location-dependent variation of the induced voltages and currents for full or partial exposure to induction of a route. This Recommendation gives general information on how to find an equivalent circuit which permits rapid estimation of the maxima of the voltages and currents in cable conductors for any length and location of exposure. The lumped capacitances and the transfer impedance of the equivalent circuit must be appropriately chosen. Only two groups of parameters are required here, depending upon whether the length of the exposed section is shorter than or equal to or greater than half the length of the power feeding section. The manner of switching from the complex formulae given in [1] to the simplified calculation is explained in Annex 1.

To check the usefulness of this universally applicable equivalent circuit, the maxima of the voltages and currents induced on the conductors of a cable when the outer conductors are at floating potential are calculated in Annex 2 for some of the exposure values evaluated numerically in the publication mentioned above. They are also entered in the diagrams. It will be seen that the calculation procedure shown in this Annex 2 gives sufficiently accurate results for practical purposes.

Annex 3 shows how the equivalent circuit must be modified in cases where the outer conductors of the coaxial pairs are earthed at the terminals and at the repeater points.

A similar calculation method for the effects of magnetic induction of power lines on telecommunication systems installed on coaxial pair cables whose outer conductor is insulated is described in the publication mentioned in point [4] of the References in this Recommendation.

2. *Advantages of the equivalent circuit*

One of the reference quantities in the exact formulae given in the above-mentioned papers is the longitudinal voltage induced in the cable. This can be calculated by the usual methods (see the C.C.I.T.T. *Directives*, 1963).

Once it is know, the induced voltages and currents can be numerically evaluated very precisely from the exact formulae, but the results approximate the actual values only in so far as this is permitted by the limited accuracy of the basic parameters used. Experience shows, however, that this accuracy is low since certain factors which cannot be accurately determined—such as the effective conductivity of the soil—play a considerable part.

In view of the unavoidable inaccuracy in calculating the induced longitudinal voltage used as reference quantity, a further error of up to about 20% is tolerated in the remainder of the calculation. The exact formulae can then be considerably simplified for all applications (since in practice $\Gamma \cdot l \leqslant 2$ and $\overline{\Gamma} \cdot l \leqslant 2$ nearly always holds) and corresponding equivalent circuits can be devised for each case. (The quantities Γ and $\overline{\Gamma}$ are the propagation constants of the circuits "cable sheath—outer conductor" and "outer conductor—inner conductor", respectively.)

3. *Statement of the problem*

Equivalent circuits may be considered for the following cases of induction:

1) outer conductor earthed, uniform induction;
2) outer conductor at a floating potential, uniform induction (see Figure 5/K.16);
3) outer conductor earthed, partial exposure on a short length at mid-route;
4) outer conductor at a floating potential, partial exposure on a short length at mid-route (see Figure 6/K.16).

In practice it is much easier to deal with a single equivalent circuit instead of four. Moreover, it would be advantegeous if, using the paper mentioned in point [1] of the References below, a universally applicable uniform equivalent circuit could be devised which furnished sufficiently accurate information on the maxima of the voltages and currents induced on the cable even with an arbitrarily chosen partial exposure to induction of a power-feeding section.

As is shown in Annex 1, such an equivalent circuit can be derived with the aid of the circuit diagrams shown in Figures 5/K.16 and 6/K.16. This circuit is shown in Figure 2/K.16.

4. *Parameters and symbols employed*

On the basis of the general assumption that a power-feeding section with the outer conductors at floating potential (not bonded to the cable sheath or to a grounding system) is exposed to induction along an arbitrarily located section, we can draw Figure 1/K.16 below, which shows the conventions and symbols employed.

The symbols denoting the quantities (E, C, V, I) associated with the circuit "cable sheath—outer conductor" will be written without a bar and all those ($\overline{E}$, $\overline{C}$, $\overline{V}$, $\overline{I}$) associated with the circuit "outer conductor—inner conductor" with a bar.

5. *Universally applicable equivalent circuit*

The arguments in Annex 1 make it possible to define a universal equivalent circuit (Figure 2/K.16).

For all long-distance communication systems with power-feeding sections that are either uniformly exposed to magnetic induction or partially exposed along a short central section, this equivalent circuit furnishes the maxima of the voltages and currents induced in the two circuits in Figure 1/K.16, with an accuracy of about 10%. When this circuit is applied to other cases of exposure, deviations of up to about 20% from the theoretical values must be expected but this error rate may be tolerated in practice in view of the uncertainty in determining the induced longitudinal voltage E and because conditions can then be rapidly estimated.

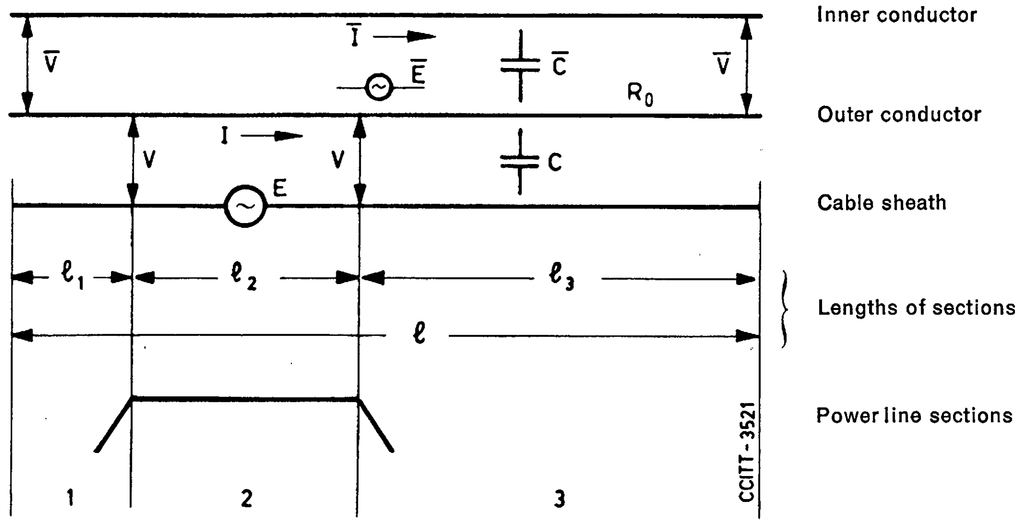


FIGURE 1/K.16. — **Schematic representation of circuits.**

E	= longitudinal voltage induced in the cable (volts)
$\overline{E}$	= longitudinal voltage in the coaxial tube (volts)
l_2	= length of the exposed section (km)
l_1, l_3	= lengths of the unexposed sections (km)
l	= length of the power-feeding section (km) $= l_1 + l_2 + l_3$
$V, \overline{V}, I, \overline{I}$	= maxima of the voltages and currents to be determined
$C, \overline{C}$	= capacitances (F/km) effective per unit length

where

$$C = \frac{C_{os} \cdot l_s + C'_{os}}{l_s} \text{ and } \overline{C} = \frac{C_{io} \cdot l_s + C_f}{l_s}$$

C_{os}	= capacitance per unit length between outer conductor and cable sheath (F/km)
C'_{os}	= capacitance between the outer-conductor and the cable sheath located at the repeater (if any) (F)
C_{io}	= capacitance per unit length between the inner and the outer conductor (F/km)
C_f	= sum of all capacitances between the power-feeding path and the outer conductor in the power separating filters of a repeater (F)
l_s	= length of repeater section (km)
Z_t	= effective transfer impedance per unit length (Ω/km) between the circuit "cable sheath — outer conductor" and the circuit "outer conductor — inner conductor"
R_o	= resistance per unit length (Ω/km) of the outer conductor alone
R_i	= resistance per unit length (Ω/km) of the inner conductor, to which a corrective term is added, which corresponds to the value, per km, of the resistance of the directional filters.

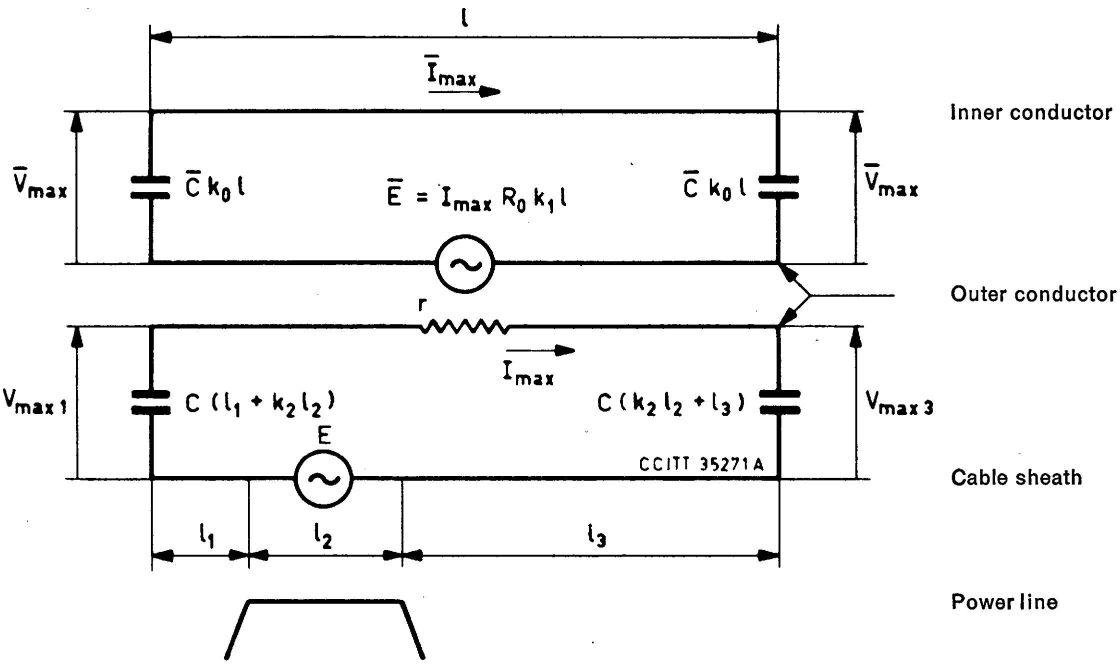


FIGURE 2/K.16. — **Equivalent circuit.**

Value of parameters k			
	k_0	k_1	k_2
for $l_2 \leqslant \frac{l}{2}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$
for $l_2 > \frac{l}{2}$	$\frac{5}{16}$	$\frac{2}{3}$	$\frac{1}{4}$

Note. — The resistance r of Figure 2/K.16 is to be considered only for earthed outer conductors (see Annex 3).

The following comments will help to explain the simplified diagram:

1) All the components of the real transmission lines are assumed to be concentrated, which is acceptable for a short line open at both ends, for a wavelength corresponding to 50 Hz.

2) The conductor resistance is not taken into account in the circuits, except for constituting the inter-circuit transfer impedance; it is introduced weighted by a coefficient k_l which depends on the length of the section exposed and is such that $k_l < 1$.

This implies that the circuits shown in Figure 2/K.16 are in fact open (for induced currents at 50 Hz) at the ends of the remote-feeding section. This may not be the case, particularly if the power supply equipments include filters and balancing devices to fix the inner conductor potentials in relation to the earth. The circuit "inner conductor—outer conductor" is then terminated across high-value capacitors which must be added in parallel at $\bar{C}\,k_0\,l$ at the two ends of Figure 2/K.16. In this case, the inner conductor series resistance cannot now be disregarded. A practical example is given in Annex 3.

3) The capacitances $C\,l_1$ and $C\,l_3$ correspond to the precise terminal beyond the exposed section; the capacitance of the exposed section is introduced weighted by a coefficient k_2 which depends on the length of the exposed section and is such that $2\,k_2 < 1$.

4) The simplified diagram gives rise to dissymmetrical voltages in the circuit "sheath—outer conductor". It can be used to determine the maximum values at the ends. Figure 3/K.16 gives an idea, adequate for practical purposes, of the voltage and current throughout the remote-feeding section. The voltage varies little outside the exposed section and is zero near the middle. The maximum current occurs near the middle of the exposed section; the current is obviously zero at the ends, since the circuit is open when the outer conductor is at floating potential.

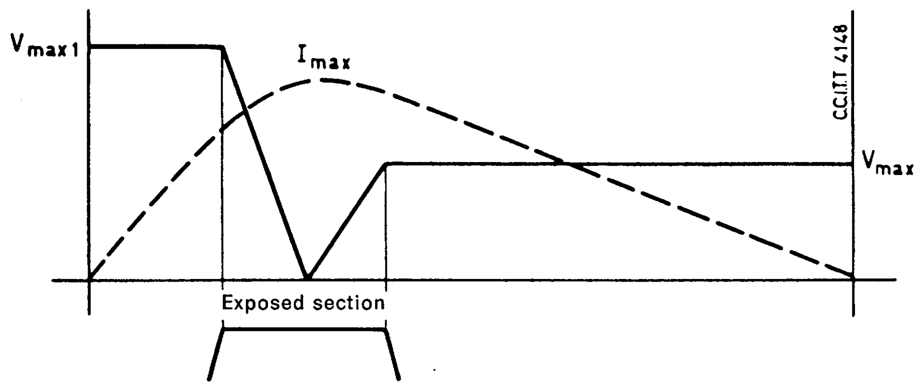


FIGURE 3/K.16. — **Voltage and current throughout the remote-feeding section in the circuit " sheath—outer conductor ".**

5) On the other hand, in the circuit "inner conductor—outer conductor" the voltage and current are much more symmetrical. The capacitance is weighted by a coefficient k_0 which depends on the length of the exposed section and is such that $2\,k_0 < 1$.

6) The simplified diagram makes it possible to calculate, in the same way as in paragraph 4, the maximum voltage and current in the circuit "inner conductor—outer conductor". Depending on the nature of the circuit, these values may be much lower than in the circuit "sheath—outer conductor" Figure 4/K.16 gives an idea, adequate for practical purposes, of the voltage and current throughout the remote-feeding section. The extreme voltages are symmetrical, while the zero voltage and maximum current are always very near the middle of the remote-feeding section, irrespective of the position of the exposed section.

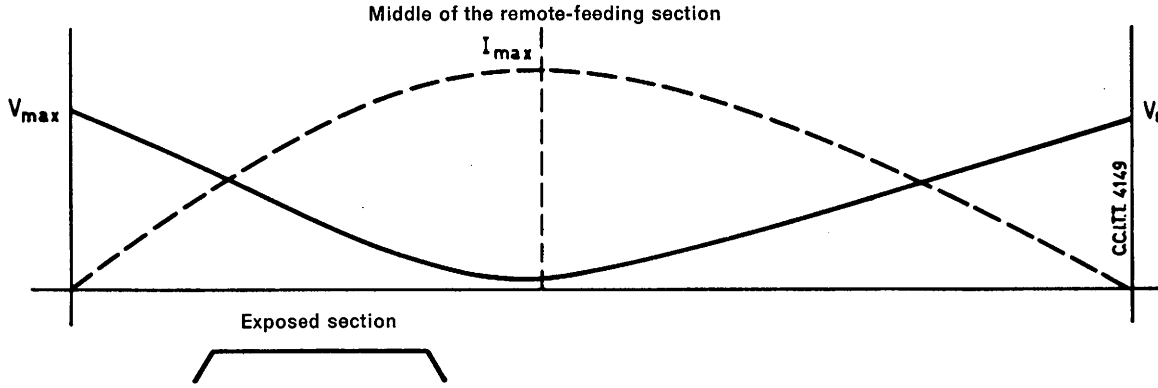


FIGURE 4/K.16. — **Voltage and current throughout the remote-feeding section in the circuit " inner conductor—outer conductor ".**

References

1. Kemp, J., Silcook, H. W., Steward, C. J.: Power frequency induction on coaxial cables with application to transistorized systems, *Electrical Comm.*, Vol. 40 (1965) No. 2, pp. 255-266.
Same text in French in: *Revue des Télécommunications*, Vol. 40 (1965) No. 2, pp. 254-263.

2. Kemp, J.: Estimating voltage surges on buried coaxial cables struck by lightning. *Electrical Comm.*, Vol. 40 (1965) No. 3, pp. 381-385.
Same text in French in: *Revue des Télécommunications*, Vol. 40 (1965) No. 3, pp. 398-402.

3. Popp, E.: Lightning Protection of line repeaters. Conference Proceedings, ICC 68 of the *I.E.E.E.* pp. 169-174.

4. Salzmann, W., Vogel, W.: Berechnung der Starkstrombeeinflussung von Nachrichtenkabeln mit Koaxialpaaren und isolierten Aussenleitern (Calculation of power current interference in telecommunication cables with coaxial pairs and insulated outer conductors) *Signal und Draht 57* (1965) No. 12, pp. 205-211.

ANNEX 1

(to Recommendation K.16)

Justification of the parameters included in the universally applicable equivalent circuit

1. *General case*

The publication mentioned in point [1] of the References in this Recommendation gives equation systems containing the complex transmission parameters of the two circuits in question.

These equations can be used to arrive at a complete solution of the problem of circuits open at both ends. These formulae develop a large number of terms into hyperbolic functions of complex parameters which make them inconvenient to apply in practice. Several approximation stages are required to arrive at a very simple diagram which can be used for an elementary calculation.

2. *First stage—Symmetrical exposure—Full calculation*

The general formulae are applied to two cases of symmetrical exposure, shown in Figures 5/K.16 and 6/K.16; in the first case, the exposure covers the entire remote-feeding section, while in the second case it is confined to a short length in the middle of the section. The curves plotted from the calculations are contained in publication [1] and are also shown in Figure 11/K.16 of Annex 2.

3. *Second stage—Symmetrical exposure—Simplified diagram*

Account is taken of the short electrical length of the lines and of the phase angle near $\pm 45^\circ$ of the secondary propagation parameters. This makes it possible to replace the distributed elements by capacitors and lumped resistances, shown on Figures 5/K.16 and 6/K.16. Coefficients such as $\frac{5}{16}$, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{1}{3}$ derive from the series development of the complex hyperbolic terms.

The equivalent circuits in Figures 5/K.16 and 6/K.16 can be used to calculate the maximum voltages and currents in two cases of symmetrical exposure; since these cases are both extremely exceptional, we should, at the same time, consider the general case of a dissymmetrical exposure of any length. This is the subject of the following stage.

4. *Third Stage—General case—Simplified diagram*

4.1 *Circuit "cable sheath—outer conductor"*

In the exposed section 2, of length l_2, the circuit "cable sheath—outer conductor" can be treated as a two-wire line exposed to uniform induction whose ends are terminated by the line capacitances of the adjacent unexposed sections 1 and 3.

EQUIVALENT CIRCUITS FOR THE DETERMINATION OF THE MAXIMUM VALUE OF THE INDUCED VOLTAGES AND CURRENTS FOR TRANSISTOR TELECOMMUNICATION SYSTEMS ON COAXIAL PAIRS WHOSE OUTER CONDUCTOR IS AT FLOATING POTENTIAL

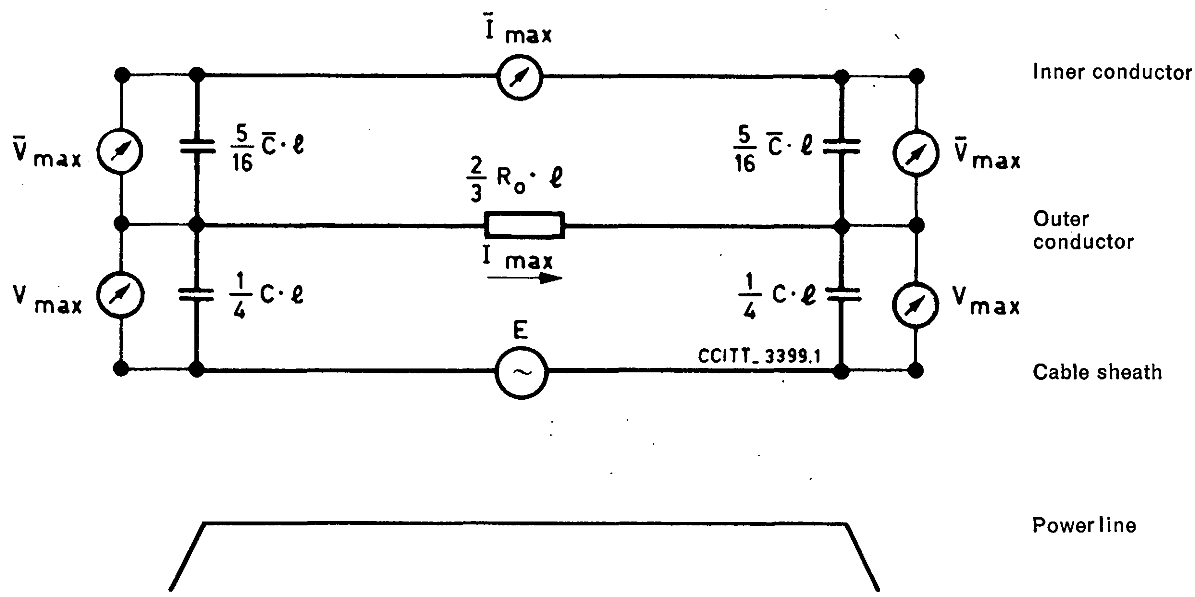


FIGURE 5/K.16. — **Uniform exposure to induction of the power-feeding section.**

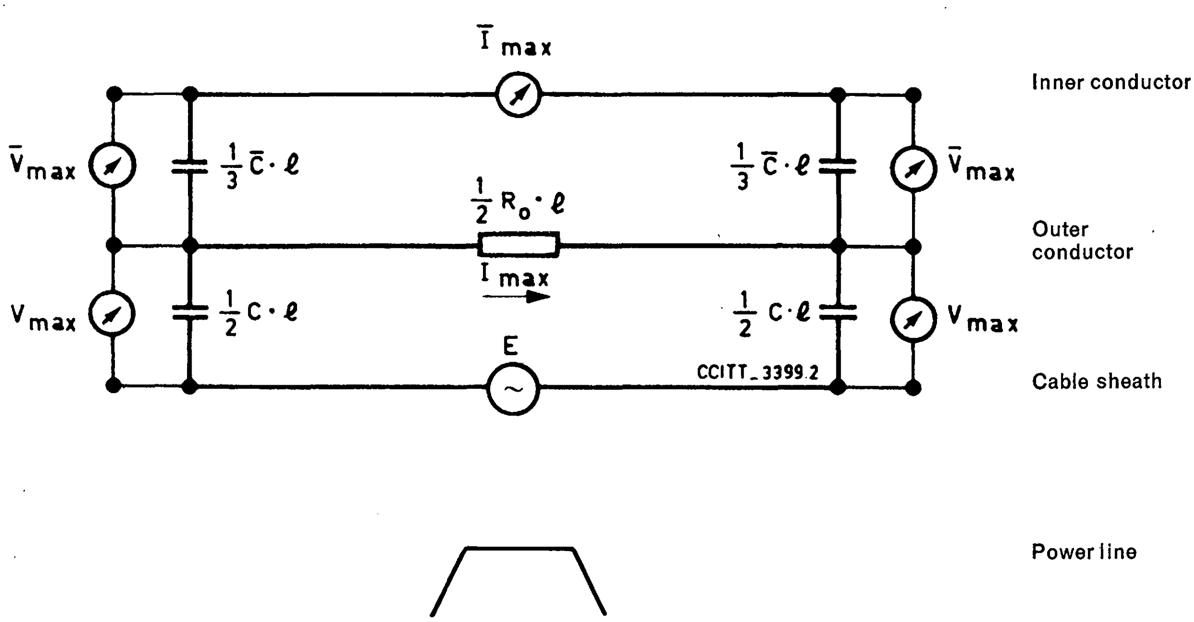


FIGURE 6/K.16. — **Partial exposure of short length in the middle of the section.**

E = Longitudinal voltage induced in the cable (volts)
R_0 = Resistance of the outer conductor (Ω/km)
l = Length of the power-feeding section

If section 2 is far longer than the sections 1 and 3 ($l_2 \gg \frac{l}{2}$), the current and voltage distributions are mainly determined by the exposed section itself and they will therefore be almost or fully symmetrical with reference to the middle of the section. The effective capacitance values shown in Figure 5/K.16 for the uniformly induced two-wire line can then be inserted for section 2. The following arrangement is then obtained for $l_2 \gg \frac{l}{2}$:

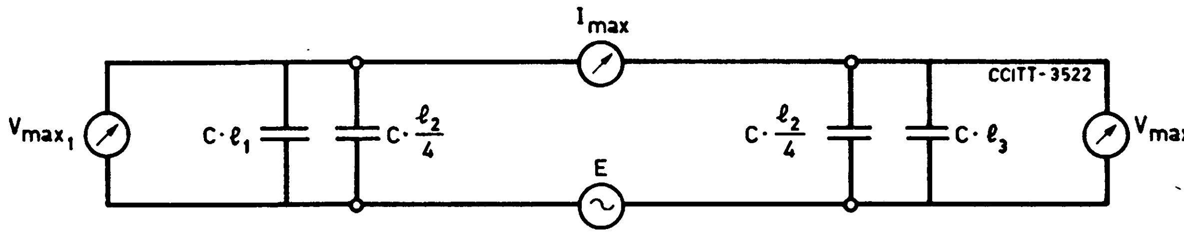


FIGURE 7/K.16. — **Circuit " cable sheath—outer conductor "—long exposed section.**

When, however, the exposed section is far shorter than the unexposed sections ($l_2 \leq \frac{l}{2}$) the current and voltage distribution will be mainly determined by the admittances at the section ends. The induced current maximum moves then towards that end of section 2 that is adjacent to the longer of the two unexposed sections. The largest displacement of the current maximum occurs when the section 2 is located directly at the beginning or at the end of the power-feeding section ($l_1 = 0$ or $l_3 = 0$, respectively). In this limit case, the condition of l_2 approaches that of a uniformly induced two-wire line with a short circuit at one end.

The following equivalent circuit (Figure 8/K.16) will therefore be used to determine the maximum induced current:

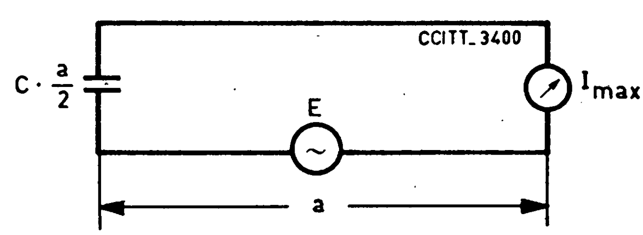


FIGURE 8/K.16. — **Line with a short circuit at one end.**

a = line length

This circuit diagram is obtained from one half of the configuration in Figure 5/K.16, showing a line of length $l = 2\ a$, with uniform induction and with both ends open, when a connection is established at mid-route; this connection does not change the conditions.

Since, however, the end of section 2 is not short-circuited in the limit case under consideration, but is terminated by finite admittance ($\omega\ C \cdot l_3$ and $\omega\ C \cdot l_1$, respectively), the effective lumped capacitance $C \cdot \frac{l_2}{X}$ associated with section 2 in the partial equivalent circuit must range between the limits.

$C \cdot \frac{l_2}{4} < C \cdot \frac{l_2}{X} < C \cdot \frac{l_2}{2}$ at the end with the shorter extension, and

$C \cdot \frac{l_2}{4} > C \cdot \frac{l_2}{X} > 0$ at the other end.

As will be shown subsequently, the assumption of $x = 3$ at each end is a compromise which gives satisfactory results for all locations of the short exposed section. The following configuration (Figure 9/K.16) is then obtained for $l_2 \ll \frac{l}{2}$:

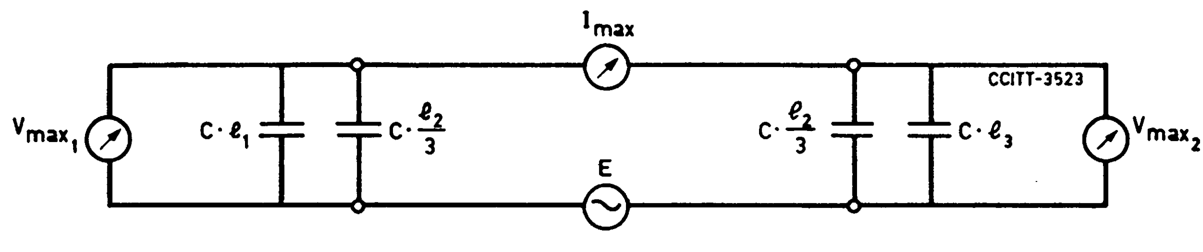


FIGURE 9/K.16. — **Circuit "cable sheath—outer conductor"—short exposed section.**

4.2 *Effective transfer impedance* [1]

The current I flowing in the circuit "cable sheath—outer conductor" produces a longitudinal voltage $\bar{E}$ across the resistance of the outer conductor in the coaxial system. This current I has a maximum in the exposed section and decreases to zero at the ends of the route. An effective resistance to be used with the maximum of I appears in the equivalent circuits derived from the simplified formulae. In the equivalent circuit method an effective resistance is introduced. Once this and the current I are known, it is possible to calculate $\bar{E}$. This effective resistance, designated by $Z_t \cdot l$, is called the effective transfer impedance. It replaces the resistance $R_0 \cdot l$. The value of $\bar{E}$ is given by the equation: $\bar{E} = I_{\max} \cdot Z_t \cdot l$.

With uniform induction over the power-feeding section, as in Figure 5/K.16, the value to be used for the transfer impedance is given by:

$$Z_t \cdot l = \frac{2}{3} \cdot R_0 \cdot l$$

This value can also be inserted where the variation of the current I along the route is largely similar to that occurring with uniform induction ($l_2 \gg \frac{l}{2}$).

With a short partial exposure at the middle of the power-feeding section (see Figure 6/K.16):

$$Z_t \cdot l = \frac{1}{2} \cdot R_0 \cdot l$$

must be used for the transfer impedance.

When the short partial exposure is located at the beginning or end of the power-feeding section, the same value is obtained (as can be proved from the equivalent circuit for a partial exposure at mid-section, by inserting $2 \cdot l$ instead of l).

It can therefore be assumed that, as a first approximation, this value will not vary to any great extent even with an arbitrary location of the short exposed section.

The following values result accordingly for the transfer impedance of the equivalent circuit:

$$Z_t \cdot l = \frac{2}{3} R_0 \cdot l \text{ for } l_2 \gg \frac{l}{2}$$

$$Z_t \cdot l = \frac{1}{2} R_0 \cdot l \text{ for } l_2 \ll \frac{l}{2}$$

[1] The transfer impedance is often also called the coupling impedance of the metallic cable sheath.

4.3 *Circuit "outer conductor—inner conductor"*

In the circuit "outer conductor—inner conductor" the longitudinal voltage $\overline{E}$ extends over the full length of the power-feeding section even in the case of partial exposure. As can be gathered from the Figures in Annex 2 below, the minimum of the voltage $\overline{V}$ between the inner and the outer conductor appears exactly at mid-route in the case of a symmetrical exposure and nearly at mid-route in all cases of unsymmetrical exposures (even with extremely short induced sections at the beginning or end of the power-feeding section). The values calculated for current and voltage in the coaxial pair will therefore not change to any great extent, if it is assumed that the longitudinal-voltage field strength $\overline{E}/l$ is symmetrically distributed irrespective of the length or location of the exposed section.

FIGURES 10/K.16. — **Circuit "outer conductor—inner conductor":**

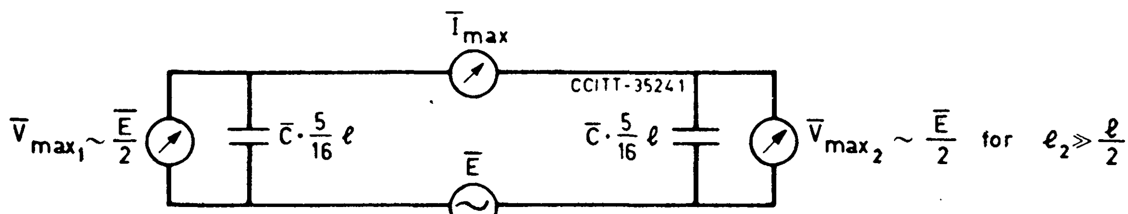


FIGURE 10a/K.16. — **Long exposed section;**

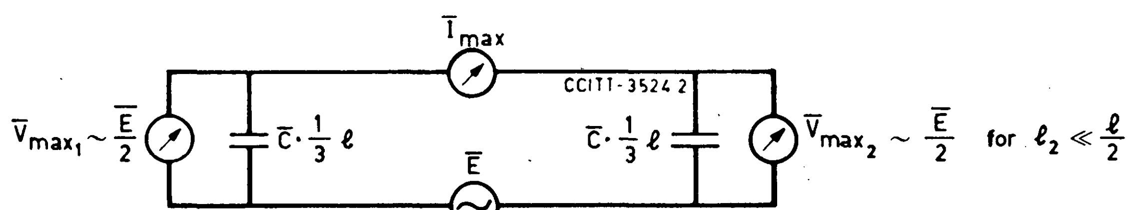


FIGURE 10b/K.16. — **Short exposed section.**

With this assumption the circuit diagrams in Figure 10/K.16 derived from Figures 5/K.16 and 6/K.16 for symmetrical exposure can also be used, as a general rule, for any configuration.

5. *Conclusion of Annex 1*

From the diagrams in Figures 7/K.16 to 10/K.16 of paragraph 4, a generally applicable equivalent circuit can be set up where the numerical values associated with the capacitances and the transfer impedance will vary according to the length of the exposed section:

$l_2 \gg \frac{l}{2}$ and $l_2 \ll \frac{l}{2}$, respectively.

As can be proven with numerical examples, satisfactory results are obtained by keeping the parameters associated with the case $l_2 \ll \frac{l}{2}$ even for $l_2 = \frac{l}{2}$. If then we replace:

$l_2 \gg \frac{l}{2}$ by $l_2 > \frac{l}{2}$ and

$l_2 \ll \frac{l}{2}$ by $l_2 \leqslant \frac{l}{2}$

the full range of all cases of exposure can be covered with two groups of parameters, leaving the error in the transition zone within tolerable limits.

The resulting generally applicable equivalent circuit is shown in Figure 2/K.16 of this Recommendation.

ANNEX 2

(to Recommendation K.16)

Practical examples of complete calculations and of the simplified calculation. Case in which the outer conductors are at floating potential

To check the usefulness of this equivalent circuit for arbitrarily chosen partial exposures, the maxima of the voltages and currents were calculated by means of the equivalent circuit for some cases of exposures completely calculated in [1] and the values determined were entered in the corresponding diagrams reproduced from this publication.

The following values for a 300-channel system on small-diameter coaxial pairs were inserted for the comparative calculation:

$C = 0.12\ \mu\text{F/km};\ R_0 = 6.2\ \Omega/\text{km} \qquad \bar{C} = 0.2\ \mu\text{F/km};\ l = 64\ \text{km}.$

The curves of Figures 11/K.16 to 15/K.16, accurately plotted, show the voltages and currents induced in a 300-channel telecommunication system. These figures correspond to Figures 4/K.16 to 7/K.16 in the paper mentioned in point [1] of the References of Recommendation K.16 except that a longitudinal voltage of $E = 1000$ V, instead of 2000 V, was chosen as reference quantity. The approximate values of the maxima calculated with the equivalent circuit are indicated by black dots. The agreement with the values furnished by the exact analysis is satisfactory in all cases.

Example of calculation for Figure 14/K.16 below

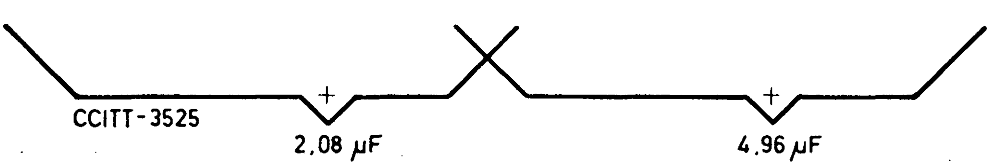
A 64-km power-feeding section of a 300-channel system on small-diameter coaxial pairs, whose outer conductor is at a floating potential, is assumed to be exposed to a power line between the 12th and the 28th kilometre. The longitudinal voltage in the cable is assumed to be 1000 V, 50 Hz. The maxima of the voltages and currents appearing in the cable have to be assessed.

There is thus $l_1 = 12$ km, $l_2 = 16$ km, $l_3 = 36$ km, $\frac{l}{2} = 32$ km. Since $l_2 < \frac{l}{2}$, the following parameters for the equivalent circuit (see Figure 2/K.16) have to be applied:

$$\boxed{\begin{aligned} k_0 &= \tfrac{1}{3} \\ k_1 &= \tfrac{1}{2} \\ k_2 &= \tfrac{1}{3} \end{aligned}} \qquad \text{besides:} \quad \begin{aligned} \bar{C} &= 0.2\ \mu\text{F/km} \\ R_0 &= 6.2\ \Omega/\text{km} \\ C &= 0.12\ \mu\text{F/km} \end{aligned}$$

Calculation scheme

$Cl_1 = 0.12 \times 12$	$Ck_2\, l_2 = 0.12 \times \frac{1}{3} \times 16$	$Cl_3 = 0.12 \times 36$
$= 1.44\ \mu\text{F}$	$= 0.64\ \mu\text{F}$	$= 4.32\ \mu\text{F}$



$\frac{1}{\omega C}$ at 50 Hz: $\quad 1530\ \Omega \quad + \quad 640\ \Omega \quad = \quad 2170\ \Omega$

$$I_{max} = \frac{1000 \text{ V}}{2170 \ \Omega} = 0.461 \text{ A}$$

$$\times \ 1530 \ \Omega = V_{max_1} = 705 \text{ V}$$

$$\times \ 640 \ \Omega = V_{max_2} = 295 \text{ V}$$

$$\times \ 198.5 \ \Omega = \overline{E} = 91.6 \text{ V}$$

$$\frac{1}{2} R_0 \, l = \frac{1}{2} \times 6.2 \times 64 = 198.5 \ \Omega$$

$$\frac{1}{2} \overline{E} \approx V_{max_1} \approx \overline{V}_{max_2} = 45.8 \text{ V}$$

$$\frac{1}{3} \omega \, \overline{C} l = \frac{1}{3} \times 314 \times 0.2 \times 10^{-6} \times 64 = 1.34 \times 10^{-3} \text{ mhos}$$

$$\overline{I}_{max} = 1.34 \times 10^{-3} \times 45.8 = 61.5 \text{ mA}$$

Comparison of the equivalent-circuit determination with the accurately calculated maxima

(Values from Figure 14/K.16)

Maxima	Exact calculation	Equivalent-circuit determination	Deviation from the exact calculation
V_{max_1}	685 V	705 V	+2.9%
V_{max_2}	315 V	295 V	−6.3%
I_{max}	0.455 A	0.461 A	+1.3%
$\overline{V}_{max_1}$	48 V	45.8 V	−4.6%
$\overline{V}_{max_2}$	37.5 V	45.8 V	+22%
$\overline{I}_{max}$	55 mA	61.5 mA	+11.8%

This comparison shows that, with exception of the value of $\overline{V}_{max_2}$, all deviations from the exact calculation remain below 12% and the equivalent circuit values are mostly greater than the exact values. The deviation of 22% in the case of $\overline{V}_{max_2}$ is of no practical importance since this involves the smaller of the two maxima of $\overline{V}$.

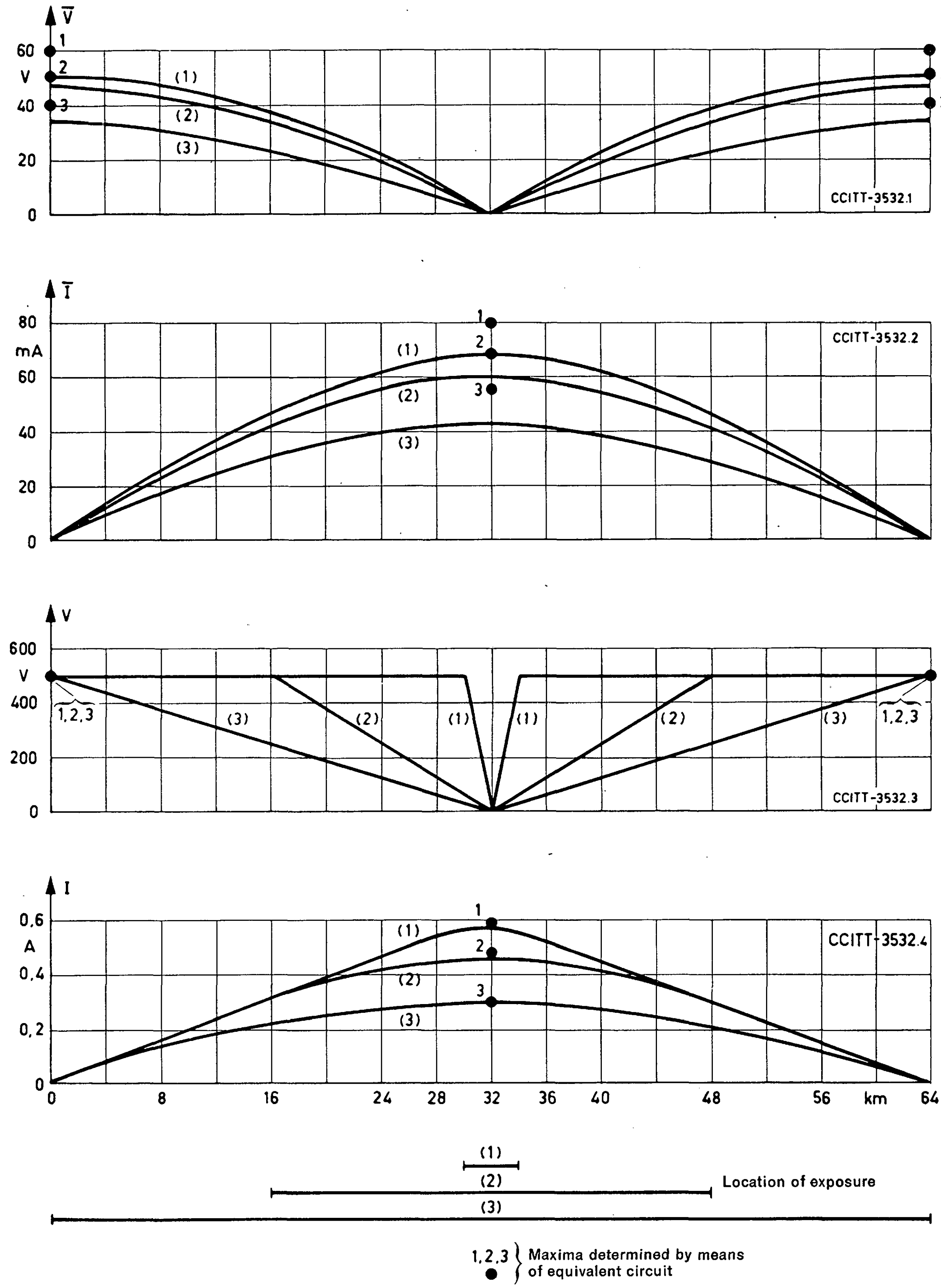


FIGURE 11/K.16. — Voltages and currents for a 300-channel route with symmetrical exposures. Voltage induced along the exposed section: 1000 volts (outer conductors of coaxial pairs at floating potential).

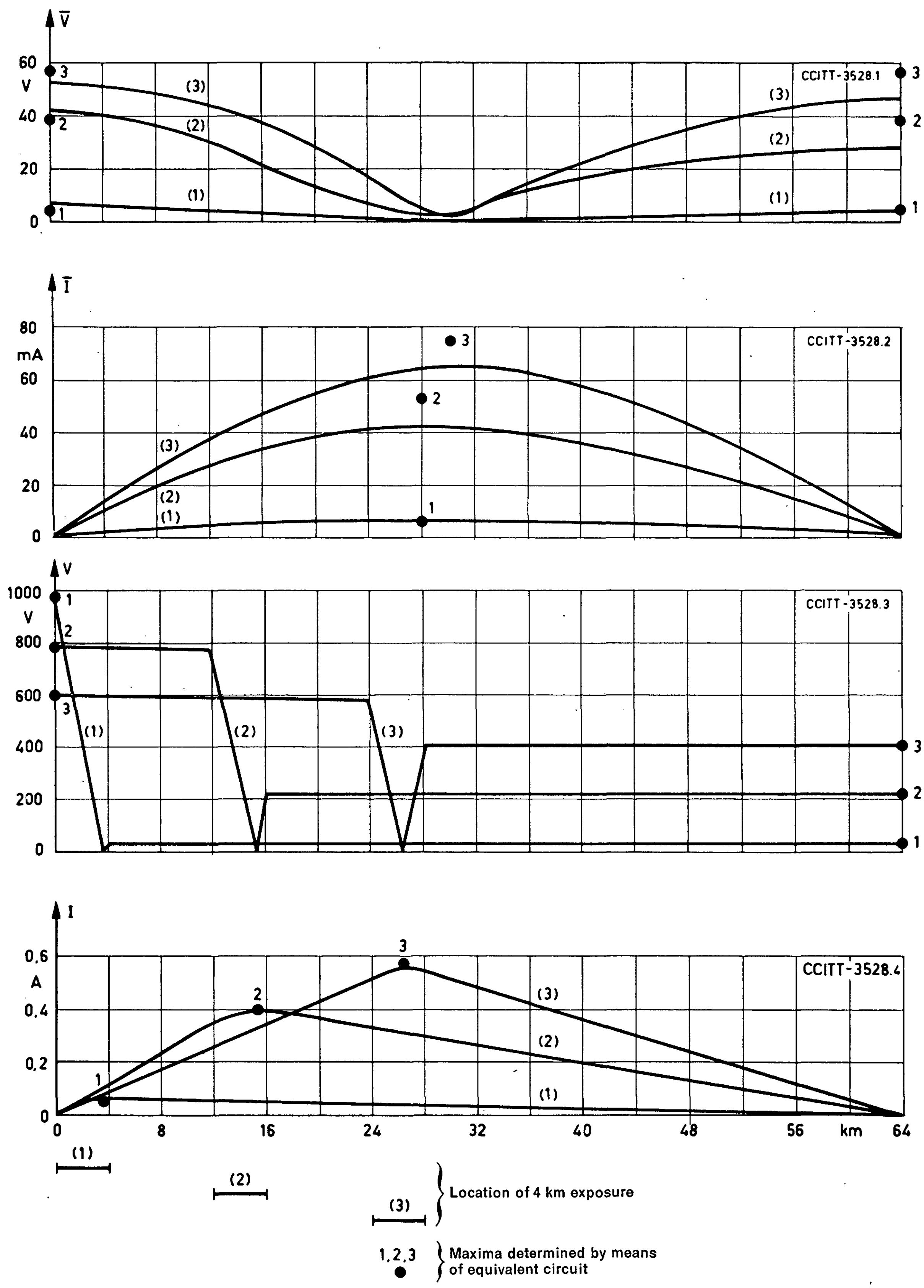


FIGURE 12/K.16. — **Voltages and currents for a 300-channel route with asymmetrical exposures. Length of exposure 4 km. Voltage induced along the exposed section: 1000 volts (outer conductors of coaxial pairs at floating potential).**

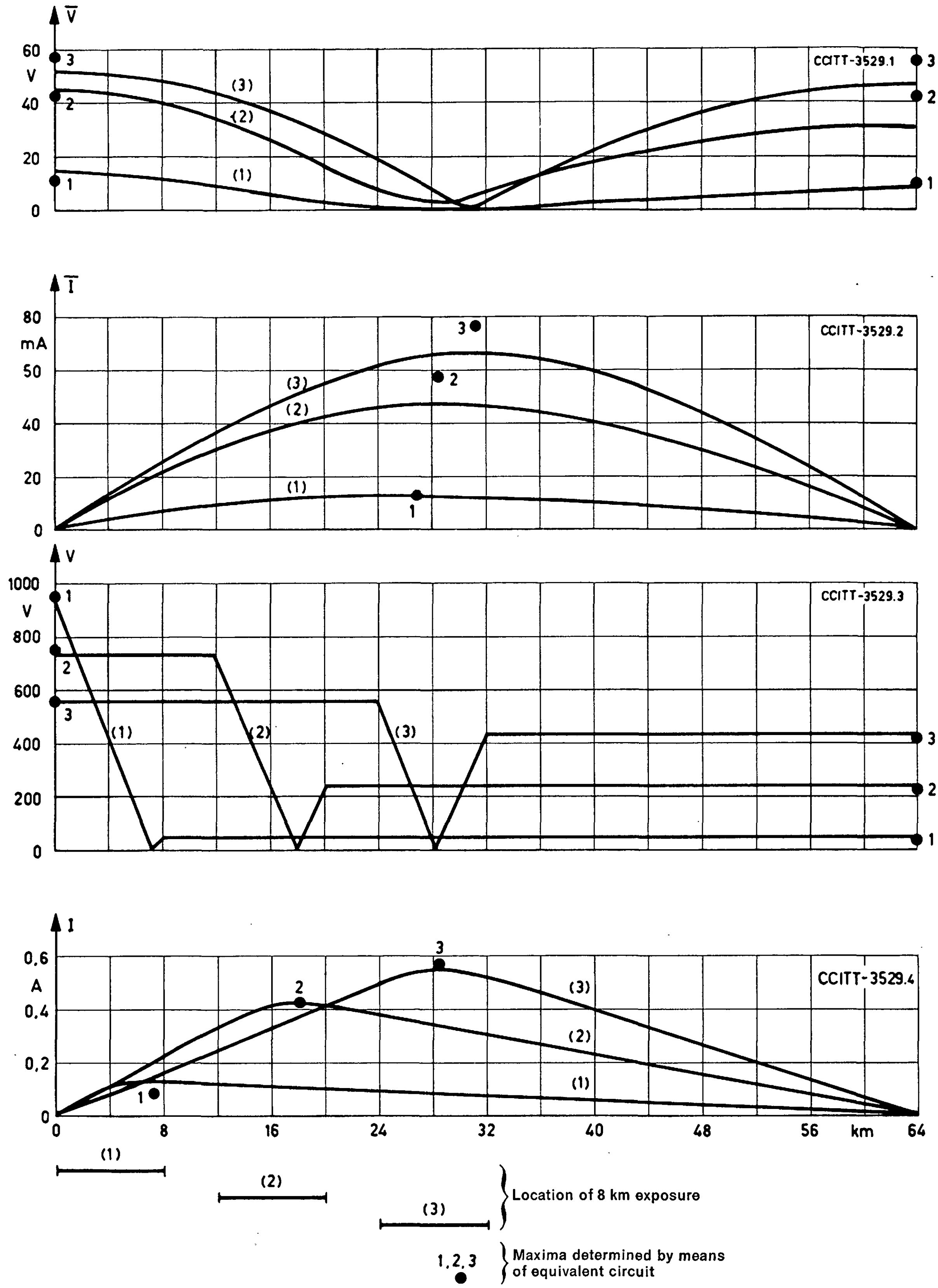


FIGURE 13/K.16. — **Voltages and currents for a 300-channel route with asymmetrical exposures. Length of exposure 8 km. Voltage induced along the exposed section: 1000 volts (outer conductors of coaxial pairs at floating potential).**

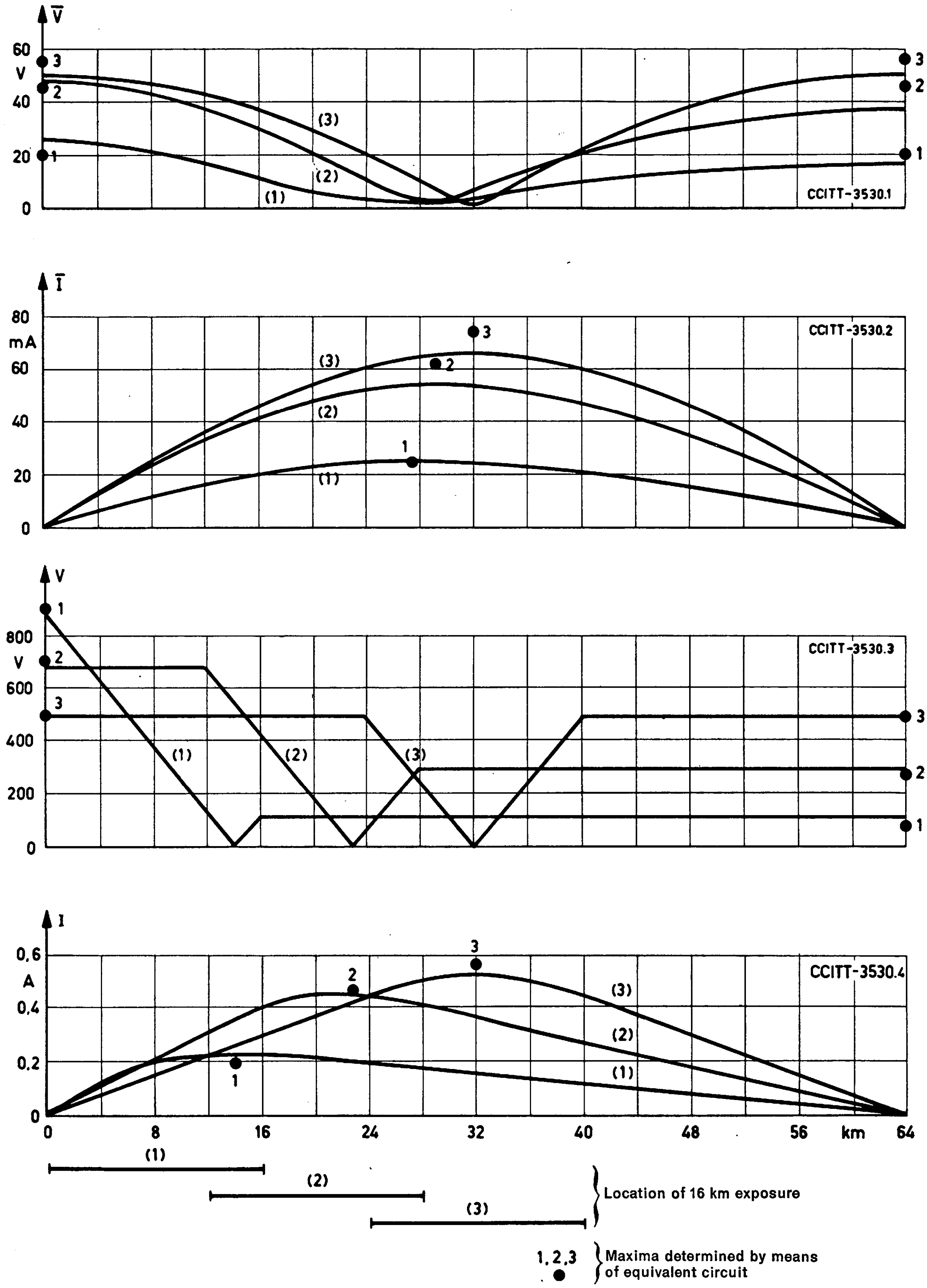


FIGURE 14/K.16. — Voltages and currents for a 300-channel route with asymmetrical exposures. Length of exposure 16 km. Voltage induced along the exposed section: 1000 volts (outer conductors of coaxial pairs at floating potential).

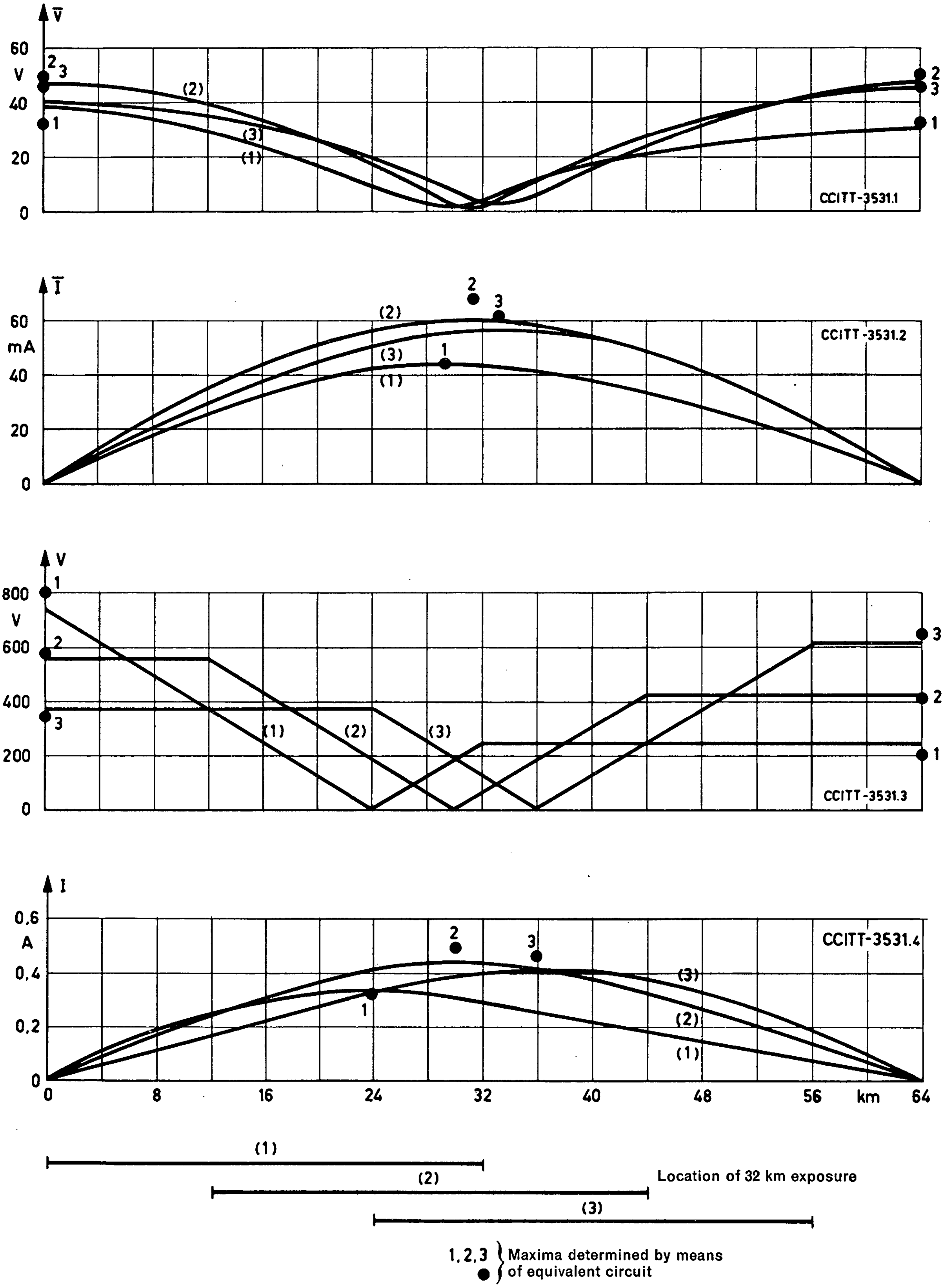


FIGURE 15/K.16. — **Voltages and currents for a 300-channel route with asymmetrical exposures. Length of exposure 32 km. Voltage induced along the exposed section: 1000 volts (outer conductors of coaxial pairs at floating potential).**

ANNEX 3

(to Recommendation K.16)

Practical examples of complete calculations and of the simplified calculation case in which the outer conductors are earthed

1. *Where the inner conductors are at a regulated potential, slightly decoupled*

For the case of earthed outer conductors and inner conductors at a regulated potential with low-value earth decoupling capacitors, only the part of the diagram simulating the circuit "outer conductor—inner conductor" must be considered in the equivalent circuit, inserting logically the capacitance $\overline{C}$ instead of C. The resistance $k_1 R_0 l$ representing the transfer impedance is also omitted. The universal diagram is reduced in this case to the diagram shown in Figure 16/K.16.

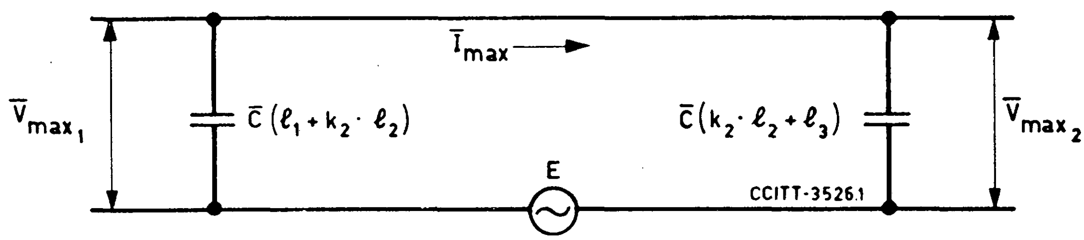


FIGURE 16/K.16. — **Circuit "cable sheath—outer conductor" (long exposed section).**

2. *Where the inner conductors are earthed through a low impedance in the power feeding station*

The universal diagram is reduced in this case to the diagram shown in Figure 17/K.16.

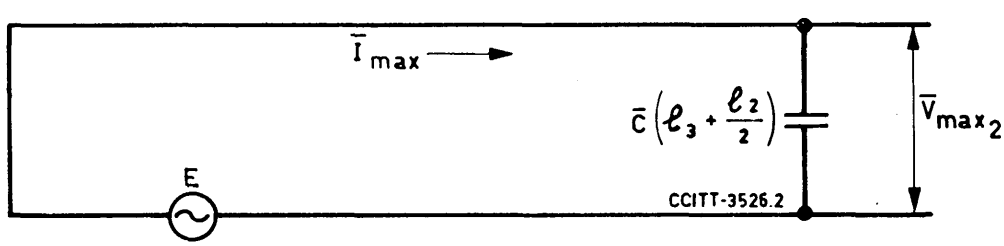
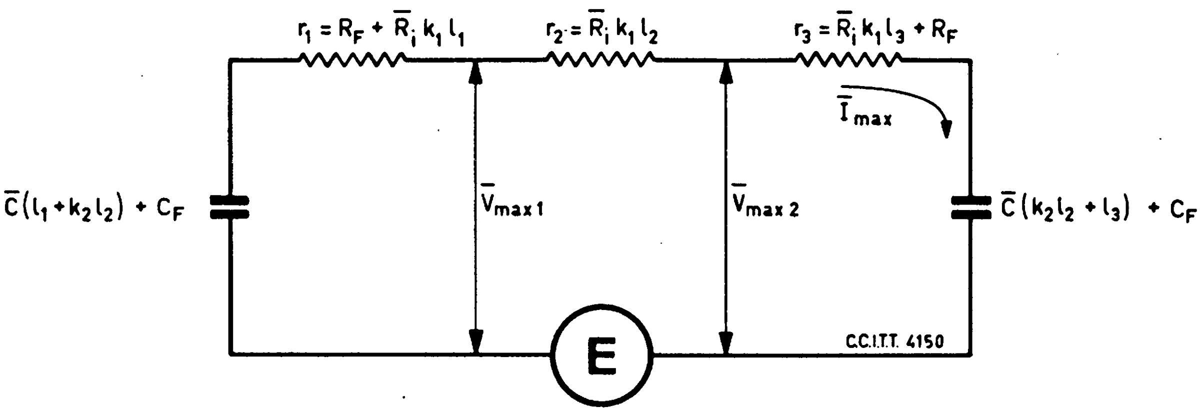


FIGURE 17/K.16. — **Line with a short-circuit at one end.**

3. *Where the inner conductors are at a regulated potential, strongly decoupled*

When the outer conductors are earthed and the inner conductors are connected to a regulated potential with powerful earth decoupling capacitors (several μF), the simplified diagram (Figure 16/K.16) is insufficient. Account must also be taken of the resistance of the centre conductors of the coaxial pairs (possibly resistances in series in repeater power feeds).

To ensure the validity of the equivalent circuit thus modified, a calculation was made using a definite example representing actual service conditions. The systems involved are still 300-channel small-diameter coaxial pair systems, this time involving a circuit 66 km long, with $\overline{C}$ = 0.11 μF/km, R_i = 17 Ω/km, the decoupling impedance the of regulated supply systems being equivalent to a resistance R_F of 50 ohms in series with a capacitance C_F of 15 μF. The diagram is shown in Figure 18/K.16.



Note. — R_i is the resistance per kilometre of the inner conductor plus the total resistance of all the repeater directional filters, expressed as a resistance value per kilometre.

FIGURE 18/K.16. — **Equivalent circuit where the outer conductors of the coaxial pairs are earthed and the inner conductors have a strongly decoupled regulated feed.**

The induced voltage is assumed to be such that, taking account of the screening factor of the cable, the interference voltage to be considered is 100 V (if the voltage could not be restricted to such a value, another solution would be applied, reversion to the floating potential for example). For an induced voltage E of 100 V, after taking the combined screening factor of the cable sheath and the earthed outer conductors into account, Figures 19/K.16 to 22/K.16 below show the values of the voltages and currents obtained in the complete circuit; the points corresponding to the use of the equivalent circuit in Figure 18/K.16 are plotted on these figures. Details of the calculations and measurements are contained in [5] from which the following curves are derived. Agreement between the two series of results is entirely satisfactory.

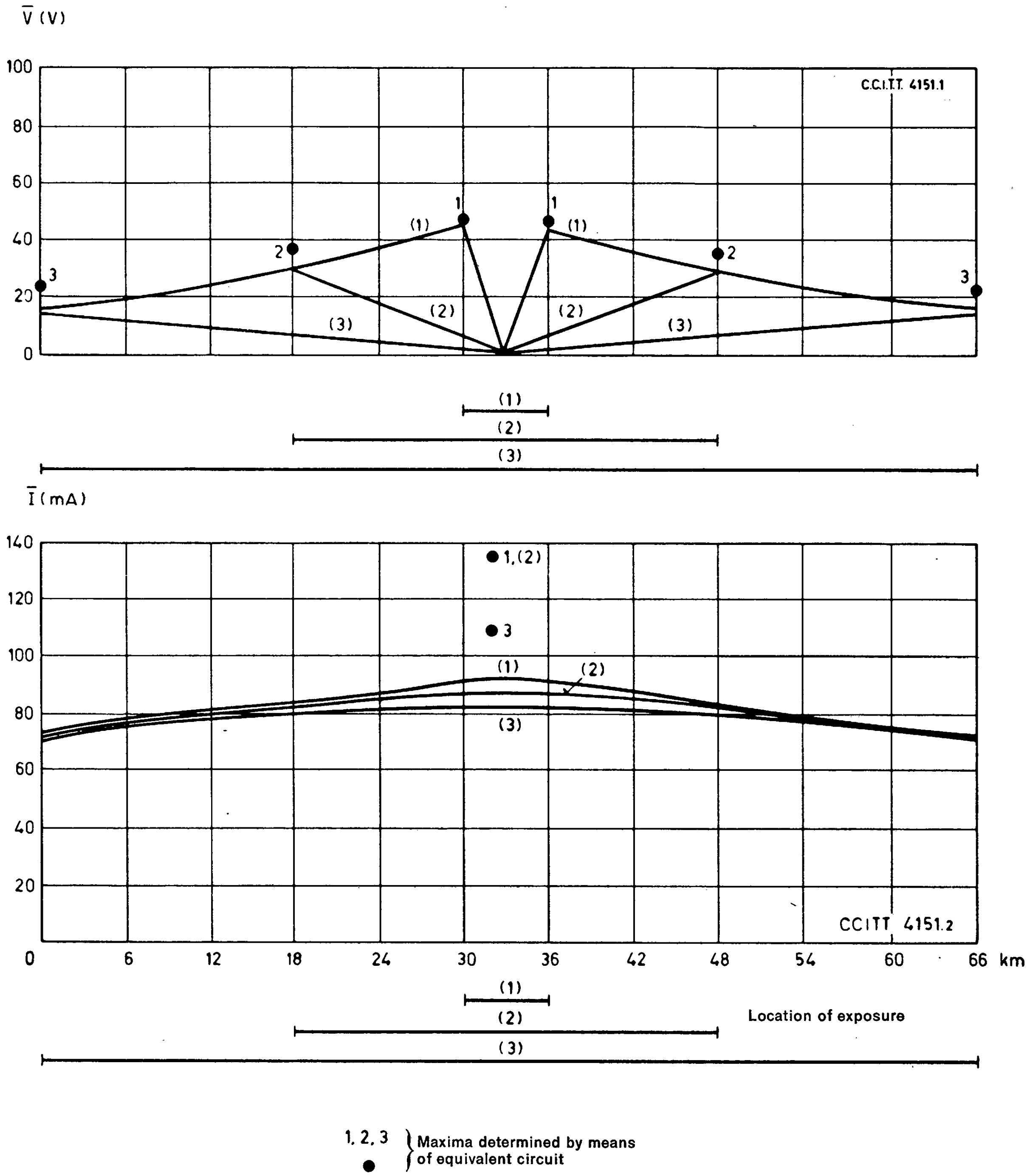


FIGURE 19/K.16. — Voltages and currents for a 300-channel route with asymmetrical exposures (outer conductor of coaxial pairs earthed).

Length of exposure: 6 km, 30 km or 66 km
Inducing voltage : 100 V

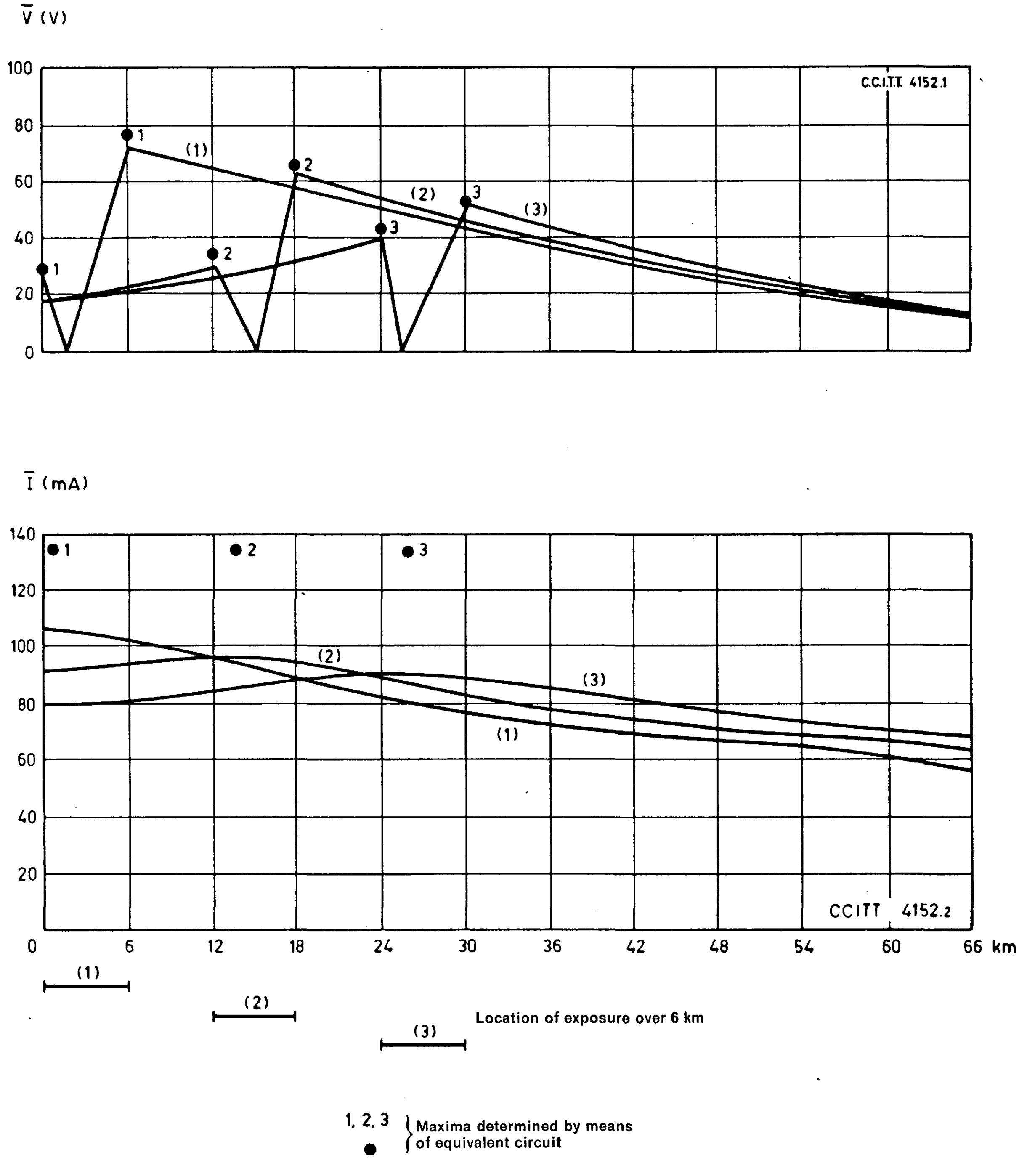


FIGURE 20/K.16. — Voltages and currents for a 300-channel route with asymmetrical exposures (outer conductor of coaxial pairs earthed).

Length of exposure: 6 km
Inducing voltage : 100 V

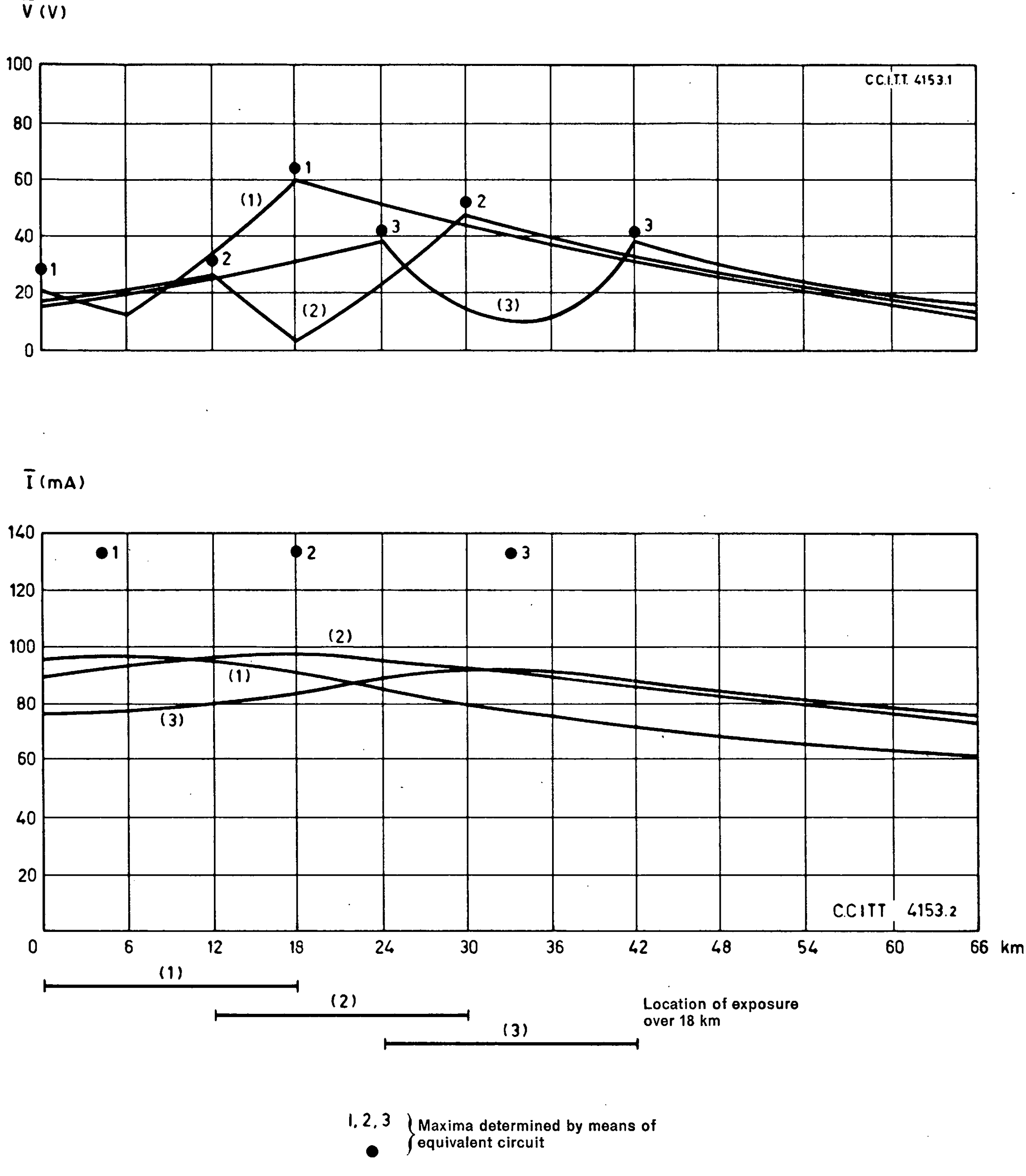


FIGURE 21/K.16. — **Voltages and currents for a 300-channel route with asymmetrical exposures (outer conductor of coaxial pairs earthed).**

Length of exposure : 18 km
Inducing voltage : 100 V

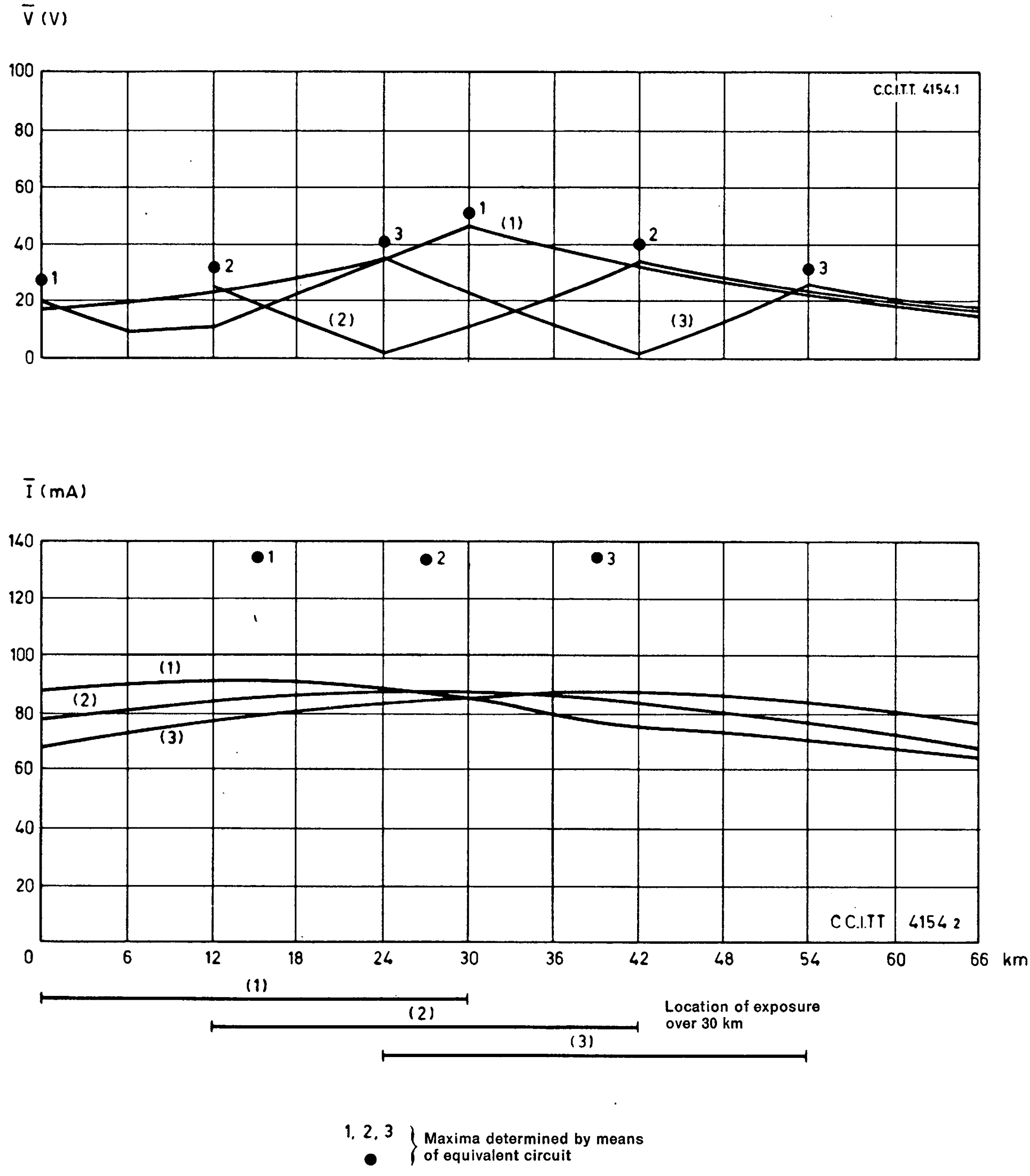


FIGURE 22/K.16. — **Voltages and currents for a 300-channel route with asymmetrical exposures (outer conductor of coaxial pairs earthed).**

Length of exposure: 30 km
Inducing voltage : 100 V

Questions relating to protection against interference allocated to Study Group V in 1973-1976

Question 1/V — Protective devices

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

(new wording)

The use of semi-conductor devices in telecommunication equipment in telecommunication centres, etc., renders such equipment susceptible to damage by over-voltages. Miniaturization of all components, including those used for protection, presents special protection problems that must be further studied. What recommendations can be made in this connection?

Note. — Account must be taken of the amplitude and duration of possible induced voltages, of transverse voltages caused by protectors with unequal striking voltage and of the relatively long duration (a few hundred microseconds) of atmospheric over-voltages.

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

(continuation of Question 2/V, 1968-1972)

(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 — Problems posed by the arrangement of protective devices on telecommunication circuits subject to high induced voltages

(new wording)

Taking account of the method proposed in Recommendation K.11 for the insertion of lightning protectors, at suitable intervals, along the length of an open wire line, how should it be ensured that any degradation of the transmission characteristics of the line consequent on the insertion of lightning protectors, be kept to a minimum?

Note 1. — Degradation of the line transmission characteristics may result from the striking of the protectors.

Note 2. — In this respect, the responsibility of Study Group V is limited to considerations concerning the line. For certain general requirements for the characteristics of open-wire lines, see Recommendation G.521, *Green Book*, Volume III, and Chapter XIX of the *Directives*.

Note 3. — Any information that can be provided concerning the frequency and duration of interruptions caused by the striking of lightning protectors might be of interest to Study Group IV in its study of Question 2/IV.

Note 4. — For the study of this Question the following documents should be considered:

— C.C.I.T.T. — 1961/1964 — Contribution COM V-No. 13 (U.S.S.R. Administration);

— C.C.I.T.T. — 1964/1968 — Contribution COM V-No. 30 (France);

— C.C.I.T.T. — 1968-1972 — Contribution COM V-No. 68 (U.S.S.R. Administration).

Question 4/V — Screening effect of metallic-sheathed cables with a plastic covering

(new question)

(continuation of former Questions 5/V and 7/V 1968-1972)

What problems arise in the earthing, in line, of cable metallic sheaths when they are protected by a plastic covering, and what recommendations should be made on the subject to ensure that the screening effect of the metallic sheath is restored?

Note 1. — A study will be made of the case where the metallic sheath is insulated but has earth connections at intervals along the length of the cable.

Note 2. — The problem of the earthing in telecommunication centres for which it was customary to use metallic sheaths comes under Question 24/V.

Note 3. — In the study of this Question, account should be taken of the information in the following document:

— C.C.I.T.T. 1969-1972 — Contribution COM V-No. 69 (U.S.S.R. Administration).

ANNEX 4

(to Question 4/V)

Information supplied by the French Administration in 1971

To ensure protection of metal-sheathed cables with plastic covering the French Administration, on the basis of calculations and experience, considers that the sheaths of these cables should be earthed as often as possible without involving additional expense even if the resistance of each of the earths is relatively high. For these reasons:

— the metallic continuity of the sheaths is assured at each joint;

— the sheath is connected by a galvanized copper conductor of at least 8 mm^2 cross-section to the cast-iron sleeves protecting the joints or loading coils, which are in contact with the soil;

— all the earths of the exchanges traversed, those of the terminating exchanges, the sheaths of the branch cables, etc., are connected to the sheath of the main cable.

This method is suitable for protection against induction and lightning in moderately exposed regions; in very exposed areas screen wires have to be buried on top of the cable.

These wires are not connected to the earthing points of the sheaths to prevent the lightning current from entering the sheath too directly.

With the sheaths earthed in this way the plastic covering cannot be checked in service for tightness by electrical measuring methods but this slight inconvenience is amply offset by the improvement in the screening factor and by the rapid attenuation of the effects of lightning over a short distance.

(For 1973-1976, there are no questions numbered 5/V, 6/V, 7/V.)

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

(continuation of Question 8/V, 1968-1972)

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. — Information about ordinary lines would be of interest for purposes of comparison with the statistics for high-reliability lines.

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

Note 4. — For the study of this Question the following documents should be considered:

— C.C.I.T.T. — 1968-1972 — Contribution COM V-No. 48 (C.I.G.R.E.);

— C.C.I.T.T. — 1968-1972 — Contribution COM V-No. 55 (C.I.G.R.E., Study Committee 36);

— C.C.I.T.T. — 1968-1972 — Contribution COM V-No. 56 (C.I.G.R.E., Study Committee 36).

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

(continuation of Question 9/V, 1968-1972)

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.

d) Danger to a cable due to a high potential gradient in the following cases:

— 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;

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

Question 10/V — Booster transformers

(continuation of Question 10/V, 1968-1972)

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?

(For the period 1973-1976, there are no questions numbered 11/V, 12/V.)

Question 13/V — Unbalance of telephone installations

(new wording)

From the point of view of noise in telecommunication systems due to interference by electric power systems, is it necessary to specify values and measuring methods of unbalance to earth for:

a) terminal and intermediate equipment;

b) telecommunication lines;

c) the line from subscriber to subscriber within a local network including the exchange?

If so

— Is the method for measuring unbalance of equipment given in Recommendation Q.45, Section 6.4.1, in accordance with Recommendation K.10 and the indications in the *Directives*, Chapter XVI, Section 1?

Which method is suitable and sufficient, to achieve the necessary characteristics?

— Which methods are recommended for unbalance measuring according to b and c?

— Is it necessary to take into account possible changes in the degree of unbalance that occur during the setting-up of a call?

Note 1. — Study Group V considers that for the purpose of evaluation of noise interference it needs to specify values only which can be used for the calculation of noise in a chain of communication.

Note 2. — Study Groups concerned with design of equipment and lines are asked to specify methods for ensuring that the given values are met in practice.

(For the period 1973-1976, there is no question numbered 14/V.)

Question 15/V — Reduction of harmonics in special cases

(new wording)

Study of the characteristics of harmonic currents circulating either in power distribution lines or traction lines and the effects of these currents on telecommunication lines.

Note 1. — The study should include:

— specific arrangements for reducing the significance of harmonic currents circulating in power-lines and traction lines;

— devices enabling a reduction to be made in the noise appearing at the ends of a telecommunication line;

— methods for calculating the harmonic currents circulating in power lines or traction lines and the psophometric voltages appearing at the ends of a telecommunication line exposed to induction from these lines.

Note 2. — The outcome of the study of Question 13/V may contribute to defining methods for reducing noise in telecommunication installations.

Note 3. — Account should be taken of the information on Question 15/V contained in the following document:

C.C.I.T.T. — 1968/1972 — COM V-No. 39, pages 34 to 36.

(For the period 1973-1976, there is no question numbered 16/V)

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

(continuation of Question 17/V, 1968-1972)

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 V 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.T.T. — 1964-1968 — Contribution COM V-No. 34
(concerns the *Directives* Editing Group);

— I.E.E.E. — International Convention Record, 1965, Part 9 — Power;
— Corrosion (L.E. Fiorretto);
— Induction (F.M. Stumpf).

(For the period 1973-1976, there is no question numbered 18/V.)

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

(continuation of Questions 19/V and 20/V, 1968-1972)

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 electro-motive 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 Study Group V of any difficulties encountered and the measures taken to remedy them.

(For the period 1973-1976 there is no question numbered 20/V.)

Question 21/V — Tests to be carried out on power-fed transistorized repeaters to check the efficiency of the protection from external interference

(new text)

For the study of this Question, reference should be made to the information given in the Annex below.

ANNEX

(to Question 21/V)

Unapproved draft drawn up in 1968-1972 for the future study of a Recommendation K.17

Tests on power-fed transistorized repeaters for checking the arrangements for protection from external interference

A. *Introduction*

None of the tests given in this draft of Recommendation K.17 should cause any significant change in the characteristics of the repeaters under test.

The tests consist of:

— prototype tests;

— acceptance tests.

Prototype tests

Prototype tests are designed to check the effectiveness of all the various arrangements made to protect transistorized repeaters.

In deciding what protective measures should be adopted, allowance should be made for the most dangerous e.m.f.s. that may be produced at the inputs and outputs of transistorized repeaters, even where the occurrence of such e.m.f.s. is very rare.

When a transistorized repeater with lightning protectors at its input (or output) terminals is subjected to an impulse voltage, the residual energy capable of reaching semi-conductor components within the time interval from zero to the striking time of the lightning protectors depends among other things on the steepness of the impulse wavefront.

During the prototype test this residual energy should be as large as possible. This is ensured by choosing an impulse wave of suitable steepness and amplitude. It is, however, recommended that the repeater be subjected to an impulse of amplitude less than the striking voltage of the lightning protectors to find out how it responds over the whole of the impulse wave.

Acceptance tests

These tests are carried out on equipment after assembly to check that the protection is working properly. The test is in general less severe than the prototype test in order to avoid exposing certain components to a degradation that might remain undetected by any measuring process. However, users are at liberty to stipulate more stringent tests (such as prototype tests).

The user may decide whether the tests are to be carried out on each equipment or by sampling.

Note. — In certain circumstances, users may consider it worth while to carry out additional tests adapted to their own special requirements. Such tests are not given below.

B. *Measuring methods*

1. *Measuring methods concerning the protection of repeaters against over-voltages resulting from lightning (impulse tests)*

Measurements will be carried out with a device of the type described in Figure 1/K.17. The components of the circuit arrangement have the following values:

C_1 = 20 μF (this capacitor will have to withstand a charging voltage equal to the peak voltage value given in Table 1 below)

C_2 = Value given in the table

R_1 = 50 Ω

R_2 = 15 Ω

The waveforms given in the table are in accordance with the definitions in I.E.C. Publication No. 60/1962 (the voltages and waveforms of Table 1 refer to a generator without load).

The test is carried out with the polarity reversed at consecutive pulses, with a time interval of one minute between pulses; the number of pulses applied to each test point in the different cases is given in the bottom line of Table 1.

Impulse waves should be applied at the following points:

— test 1: at the input of the repeater, with the output terminated by its characteristic impedance;

— test 2: at the output of the repeater, with the input terminated by its characteristic impedance;

— test 3: (longitudinal): between the input side central conductor and the output side central conductor of the repeater (at the terminals of the feeding circuit in the case of symmetric pair repeaters).

Power should be supplied to the repeater during tests 1 and 2 but not for test 3.

2. *Measuring methods concerning the protection of repeaters against disturbances resulting from the presence of alternating longitudinal e.m.f.s. permanently induced by electricity lines*

For satisfactory operation in the presence of steady-state induced voltages (see paragraph 3.2 of Recommendation K.15) the hum modulation characteristics of the repeaters should, as specified in Section 4.3, of Recommendation K.15, meet the recommendations for route sections prepared by Study Group XV for Question 11, when connected to a typical power-feeding circuit in the presence of:

a) an alternating voltage of the corresponding frequency (50 Hz, 16 $^2/_3$ Hz, etc.) applied to either the signal input terminals or the signal output terminals. The source of this alternating voltage shall have at the points of connection to the test circuit such an impedance as not significantly to disturb the transmission frequency characteristics of the circuit;

b) an alternating current of the corresponding frequency superimposed on the power feeding current of the repeater.

The greatest permissible value that the alternating voltage in a can attain is that of the induced voltage in the power feeding section permitted in Chapter IV of the *Directives*, paragraphs 6, 7 and 35, and has a limit of either 60 V r.m.s. or 150 V r.m.s. The superimposed alternating current in b is the maximum value of the current produced in the power feeding circuit by the induced voltage in the most adverse situation (see Recommendation K.16).

C. *Tests to be carried out for the different cases*

1. *Test conditions for repeaters used on coaxial pairs*

The following tests were formulated for the case where the outer conductor is connected to the metallic cable sheath. In this way the case where the outer conductor (normally at a floating potential) accidently comes into contact with the metallic sheath is covered.

1.1 *Prototype tests*

1.1.1 *Tests at the input and output terminals of the repeater*

a) *Impulse tests*

These tests will be carried out with a waveform having the characteristics listed in column 1 of Table 1.

In the case where protection is ensured by "operating threshold" type devices (e.g. lightning protectors) at the input and output of the repeater and they do not strike in the above test conditions, the charging voltage of the capacitor C1 should be gradually increased (though not beyond 7 kV) until they do so.

If the protectors do not strike at 7 kV, or if the repeaters subjected to acceptance tests are not provided with lightning protectors, the waveform suggested above may not be suitable. A pulse shape which simulates a flash-over in the cable can be produced by the test generator already mentioned above when a spark gap of the proper striking voltage is connected across the circuit. In the case that lightning protectors are provided and strike under the above test conditions, the charging voltage of the capacitor C1 should be gradually decreased until they do not strike.

b) *A.c. tests*

An r.m.s. voltage comparable with that likely to be met in practice, but not less than 1200 V, shall be applied for 0.5 s at:

— the input of the repeater, with the output terminated by its characteristic impedance;

— the output of the repeater, with the input terminated by its characteristic impedance.

The impedance of the source of voltage shall be such as to limit any current which flows to 10 A.

c) *Steady-state a.c. induced voltage tests*

These tests should be carried out in accordance with point 2 of Part B.

1.1.2 *Tests at the terminals of the repeater power-feeding circuit*

a) *Impulse tests*

These tests will be carried out with a waveform having the characteristics listed in column 2 of Table 1.

For these tests the circuit arrangement given in Figure 2/K.17 may be found helpful. To couple the impulse generator to the repeater, lightning protectors with a striking voltage of approximately 90 V may be used as illustrated in Figure 3/K.17.

b) *A.c. tests*

If the repeaters under test have lightning protectors and are likely to strike under the effect of longitudinal e.m.f.s. induced by electricity lines, an additional test may be carried out. This consists in passing an alternating current, comparable in intensity and frequency to the alternating currents that are likely to be met with in practice, through the power-feeding circuit. The current should be applied for 0.5 sec but not exceed 10 A.

c) *Steady-state a.c. induced voltage tests*

These tests should be carried out in accordance with point 2 of Part B.

1.2 *Acceptance tests*

1.2.1 *Tests at the input and output terminals of the repeater*

These tests will be carried out with a waveform having the characteristics listed in column 3 of Table 1.

For these tests the circuit arrangement given in Figure 2/K.17 may be found helpful. To couple the impulse generator to the repeater, lightning protectors with a striking voltage of approximately 90 V may be used as illustrated in Figure 3/K.17.

1.2.2 *Tests at the terminals of the power-feeding circuit of the repeater*

These tests will be carried out with a waveform having the characteristics listed in column 4 of Table 1.

In this test the capacitor C1 may be charged either at 3 kV or at a lower voltage provided the peak current in the power-feeding circuit reaches 50 A.

2. *Repeaters used on symmetric pairs*

2.1 *Prototype tests*

2.1.1 *Tests at repeater input and output terminals*

These tests will be carried out with a waveform having the characteristics listed in column 5 of Table 1.

Where the dielectric strength of symmetric pairs is greater than that of paper-insulated pairs, it would be advisable to use a higher peak voltage than that shown in the table.

In the case that lightning protectors are provided and strike under the above test conditions, the charging voltage of the capacitor C1 should be gradually decreased until they do not strike.

Note. — When lightning protectors are placed between the input and output terminals of the repeater and its chassis, one of the terminals should be connected to the chassis before making the transverse voltage test to simulate striking of a lightning protector.

2.1.2 *Tests at the terminals of the repeater power-feeding circuit*

a) *Impulse tests*

These tests will be carried out with a waveform having the characteristics listed in column 6 of Table 1.

For these tests the circuit arrangement given in Figure 2/K.17 may be found helpful. To couple the impulse generator to the repeater, lightning protectors with a striking voltage of approximately 90 V may be used as illustrated in Figure 3/K.17.

In this test the capacitor C1 may be charged either at 5 kV or at a lower voltage provided the peak current in the power-feeding circuit reaches 50 A.

b) *A.c. tests*

If the lightning protectors of the repeaters under test are likely to strike under the effect of longitudinal e.m.f.s. induced by electricity lines, an additional test may be carried out. This consists in passing an alternating current, comparable in intensity and frequency to the alternating currents that are likely to be met with in practice, through the power-feeding circuit. The current should be applied for 0.5 s.

c) *Steady-state a.c. induced voltage tests*

These tests should be carried out in accordance with point 2 of Part B.

2.2 *Acceptance tests*

2.2.1 *Tests at the input and output terminals of repeaters*

These tests will be carried out with a waveform having the characteristics listed in column 7 of Table 1.

For these tests the circuit arrangement given in Figure 2/K.17 may be found helpful. To couple the impulse wave generator to the repeater, lightning protectors with a striking voltage of approximately 90 V may be used as illustrated in Figure 3/K.17.

2.2.2 *Tests at the terminals of the repeater power-feeding circuit*

These tests will be carried out with a waveform having the characteristics listed in column 8 of Table 1.

In this test the capacitor C1 may be charged either at 3 kV or at a lower voltage provided the peak current in the power-feeding circuit reaches 30 A.

TABLE 1

CHARACTERISTICS OF WAVEFORMS TO BE USED FOR THE TESTS

	Coaxial pair repeaters				Symmetric pair repeaters			
	Prototype tests		Acceptance tests		Prototype tests		Acceptance tests	
	Test 1 Test 2	Test 3	Test 1 Test 2	Test 3	Test 1 Test 2	Test 3	Test 1 Test 2	Test 3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Waveform	10/800	100/800	100/800	100/800	10/800	100/800	100/800	100/800
Load	0.1 Coulomb	0.1 Coulomb	0.06 Coulomb	0.1 Coulomb	0.03 Coulomb	0.1 Coulomb	0.03 Coulomb	0.1 Coulomb
Peak voltages ≈	5 kV	5 kV	3 kV	3 kV	1.5 kV	5 kV	1.5 kV	3 kV
Short-circuit current	300 A		200 A		100 A		100 A	
Peak current in the power-feeding circuit		50 A		50 A		30 A		30 A
Short-circuit charge			0.046 Coulomb		0.023 Coulomb		0.023 Coulomb	0.077 Coulomb
C_2	0.2 μF	2 μF	2 μF	2 μF	0.2 μF	2 μF	2 μF	2 μF
Number of pulses	10	2	2	2	10	10	2	2

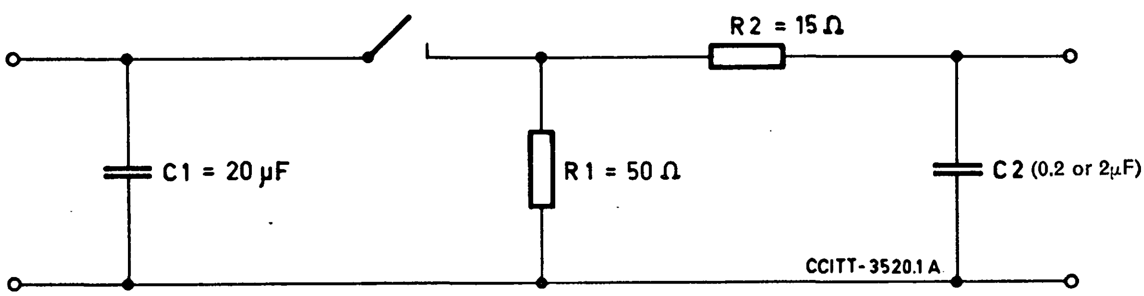


FIGURE 1/K.17. — **Diagram of an impulse generator.**

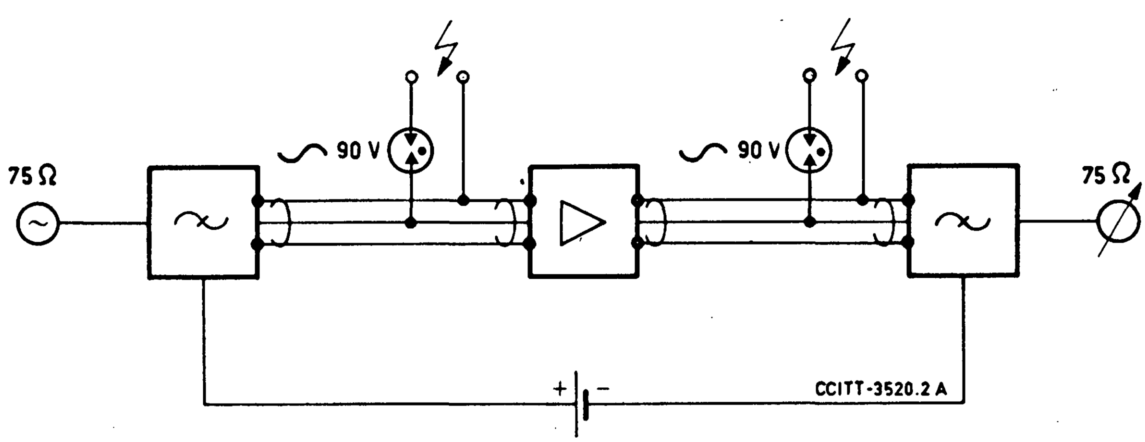


FIGURE 2/K.17. — **Example of an impulse voltage test circuit for power-fed repeaters used on coaxial pair cables.**

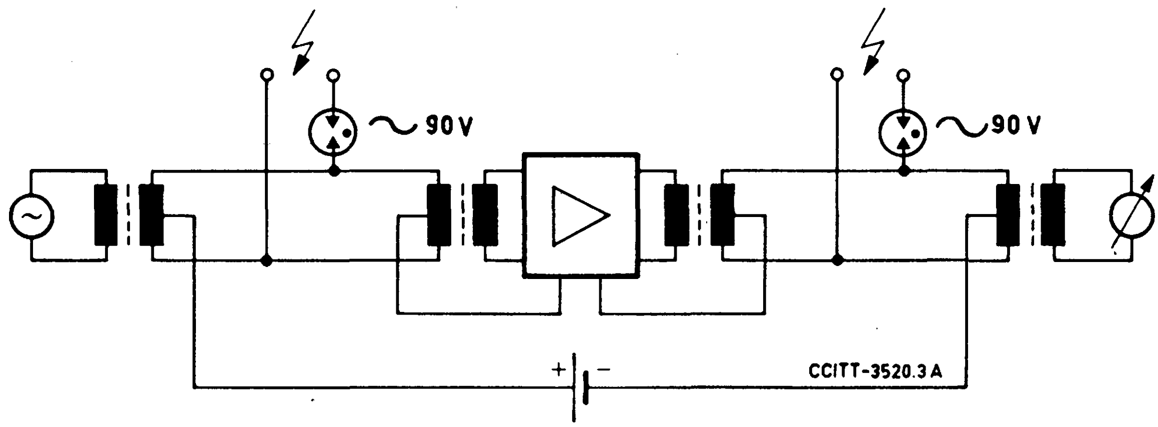


FIGURE 3/K.17. — **Example of circuit arrangement for impulse voltage test for power-fed repeaters used on symmetric pair cables.**

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

(continuation of Question 22/V, 1968-1972, to be studied in 1973-1976 by Joint Working Party CDF of Study Groups V and VI. Study Group V will coordinate 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 1. — This question, which is similar to 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.

Note 2. — At the beginning of 1973, the position concerning the chapters of the *Handbook on the protection of telecommunication lines and equipment against lightning discharges* is as follows:

— the final text of Chapters I to IV will be published by the C.C.I.T.T. Secretariat in accordance with the authorization given to Study Group V by the IVth Plenary Assembly of the C.C.I.T.T. at Mar del Plata;

— the 4th draft text of Chapter V of the Handbook was submitted to and approved by the Vth Plenary Assembly; this will also be published;

— Chapter VI, in its previous form, has been suppressed, since the proposed contents of the Chapter will be dealt with in the Handbook on earthing;

— Chapter VII which now becomes Chapter VI, and will deal with methods of protection, such as the establishment of plans for the routing of the line, bearing in mind all the protective effects resulting from the existence of other structures, the nature of the terrain, etc. The text of the second draft of this chapter will be re-issued as a document in 1973, together with other documentation so that it can be studied in order to draw up a third draft;

— Chapter VIII which now becomes Chapter VII and has been published as a first draft in Contribution COM V-No. 75 1968-1972 and will be re-issued in 1973;

— Chapter IX which now becomes Chapter VIII will contain a bibliography. Some references are already given in a contribution of the 1961/1964 period. This bibliography will also be re-issued in 1973.

The CDF Joint Working Party has been kept in being during the present study period to complete the drafts of the outstanding chapters of the Handbook.

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

(continuation of Question 23/V, 1968-1972)

(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.

Question 24/V — Preparation of a Handbook on earthing

(continuation of Question 24/V, 1968-1972)

(new wording)

Note. — The Vth Plenary Assembly approved, in principle, the publication of a Handbook on earthing to be based on the 2nd draft text in Document AP V-No. 25. The final text will be established during the 1973-1976 study period using a procedure analogous to that of the Special Rapporteur procedure, except that the Secretariat will arrange to centralize the documentation. (This is because any amendments to the draft will have to be made in French, English and Spanish, and the Secretariat will need to arrange for translation.) The experts who will collaborate in completing the final draft will be members of the Administrations of Finland, France, Federal Republic of Germany, Italy, N.T.T. and United Kingdom Post Office only. They will work initially by correspondence either directly between each other or via the Secretariat. The Secretariat will distribute the documentation only to the members of the Administrations named above, in French or English as appropriate. Comments will be receivable from any Administration.

If a point is reached at which problems exist which cannot be solved by correspondence, the group of experts will themselves arrange a meeting (without the C.C.I.T.T. Secretariat) at the invitation of the Administration of one of the members able to obtain authority to convene such a meeting.

Members of Study Group V who wish to collaborate have given to the Secretariat the addresses of the Administrations and rapporteurs to whom the documentation should be sent.

It is hoped that this procedure will enable the Handbook to be published during 1975 or 1976.

Question 25/V — Examination of the existing permissible induced voltage limits and possible amendments to the Directives

(continuation of former Question 6/V, 1968-1972)

The induced voltage limits for short duration earth faults on high voltage power lines have been in operation for some years with no apparent danger to staff and equipment. Various practical and theoretical considerations seem to imply that the present limits are too conservative and that protection is therefore, at present, being provided on a basis that could be modified having regard to the degree of risk.

A re-appraisal of the limits for the magnitude and duration of these voltages is considered appropriate in view of changing technological circumstances. What should these limits be?

What magnitude of induced voltage occurring for a particular time interval can be tolerated for high reliability power lines (as defined in the Preliminary Chapter of the *Directives*, paragraph 3.2.3) and normal power lines?

Note 1. — Such a study should include:

— the physiological effects of induced voltage and resultant current (magnitude and duration);

— the probability of contact of staff with telecommunication conductors during the occurrence of the short duration induced voltage;

— the effects of induced voltage on the equipment.

Note 2. — The outcome of the study of this question could result in a re-arrangement of Chapter IV of the *Directives* so that the allowable voltage and current for a particular time interval are considered separately for:

a) telecommunication staff and telephone users;

b) equipment connected at the terminations of the line (including the amplifiers interposed in the line);

c) particular types of cable conductor insulation.

Note 3. — In the study of this question, information contained in the following documents should be noted:

— Contribution COM V-No. 20 (1969-1972);

— Contribution COM V-No. 35 (1969-1972);

— Contribution COM V-No. 38 (1969-1972);

— C.I.G.R.E. Report No. 36-02 (1970);

— I.T.U. Journal No. 3, 1971: H. Riedel — "The I.T.U. and the protection of telecommunication installations".

Question 26/V — Revision of the Directives

(continuation of Question 26/V, 1968-1972)

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

Note 1. — The IVth Plenary Assembly, Mar del Plata, 1968, gave its approval to the reconstitution within Study Group V of the former *Directives* Editing Group, for the purpose of dealing with amendments to the present *Directives.*

Note 2. — 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).

d) Issuing of a series of "instructions" as a guide to the application of the *Directives* to practical cases. These "instructions" could take the form of simple formulae, graphs, nomograms or slide-rules. Administrations and organizations which already have such "instructions" for their own use are asked to give the C.C.I.T.T. the benefit of their experience.

Note 3. — In its work, the *Directives* Editing Group will take account of all the contributions on this subject (see the reports on Study Group V meetings).

SUMMARY OF QUESTIONS ALLOCATED TO STUDY GROUP V FOR THE PERIOD 1973-1976

No.	Short title	Remarks
1/V	Protective devices	
2/V	Devices reducing the voltage of wires with respect to earth	
3/V	Problems posed by the arrangement of protective devices on telecommunication circuits subject to high induced voltages	
4/V	Screening effect of metallic-sheathed cables with a plastic covering	
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	
13/V	Unbalance of telephone installations	
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	Tests to be carried out on power-fed transistorized repeaters to check the efficiency of the protection from external interference	Of interest to SG XV
22/V	Protection against lightning	For study by GM/CDF (see Q.14/VI)
23/V	Problems of interconnection with carrier systems on power lines	
24/V	Preparation of a Handbook on earthing	
25/V	Examination of the existing permissible induced voltage limits and possible amendments to the *Directives*	
26/V	Revision of the *Directives*	

PART 2

SERIES L RECOMMENDATIONS AND QUESTIONS RELATING TO THE PROTECTION OF CABLE-CHEATHS AND POLES

PAGE INTENTIONALLY LEFT BLANK

PAGE LAISSEE EN BLANC INTENTIONNELLEMENT

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 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, Mar del Plata, 1968 and Geneva, 1972, when it was decided to change the title to *Recommendations concerning the construction, installation and protection of telecommunication cables in public networks*) [1].

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 [2] with a view to providing Administrations, particularly those whose networks are not yet fully developed, with some information on impregnation processes.

This booklet is based on a first draft drawn up in 1968-1972 by the Argentine Administration amended and completed on the basis of information supplied by the Administrations of Australia, Austria, Chile, France, Italy, Federal Republic of Germany, United Kingdom and Switzerland.

[1] Subsequently referred to in these "L" series recommendations simply as the *Recommendations*.

[2] Completely revised, Geneva, 1973.

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 in paragraph 3.

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.

Recommendation L.4 (Geneva, 1972)

ALUMINIUM CABLE SHEATHS

1. *General*

Because of the technological progress made in the use of aluminium, aluminium cable sheaths are being used on an increasing scale and their favourable characteristics can now be fully exploited.

These characteristics include:

— low density (almost a quarter that of lead);

— much higher mechanical strength than lead, so that the sheath is lighter not only because aluminium is lighter than lead, but because the thickness may be less than for lead;

— very high resistance to vibration;

— high conductivity, so that a better screening factor and more effective protection from over-voltages of atmospheric origin can be obtained.

It is now found that the stiffness of an aluminium sheath does not give rise to any additional serious problems during laying. Other difficulties concerning local cables have not yet been completely resolved.

However, because aluminium is more vulnerable than lead to electrochemical and electrolytic corrosive action, aluminium cable sheaths and the joints between individual factory lengths (jointing sleeves and adjacent sections of cable) require a Class II (see 6.3 of the *Recommendations*) outer protective covering of plastic material.

As can be seen from the foregoing, an aluminium sheath has many advantages over a lead sheath. The generalized use of aluminium for sheathing cables is therefore desirable, at least whenever cable costs would not be increased compared with the use of lead, and also whenever aluminium sheaths satisfy the technical requirements to a greater extent. The use of cables with aluminium sheaths is particularly interesting in the case of trunk cables.

2. *Types of aluminium sheath*

2.1 *Extruded sheaths*

This type of sheath is obtained by extruding the aluminium directly around the cable core[1]; the sheath may be corrugated or non-corrugated, depending on the diameter of the cable core, the minimum radius of curvature during laying and on the mechanical characteristics of the aluminium used. (See 5.4.4 of the *Recommendations*.)

As a rough guide it can be stated that the sheath should be corrugated in the case of cables of more than 40 mm core diameter.

As stated above, in paragraph 1, the thickness of the metal used for aluminium sheaths is usually less than for lead sheaths.

The following thicknesses are suggested:

Core diameter (mm)		Metal thickness		
		Non-corrugated sheaths (mm)	Corrugated sheaths (mm)	
more than	up to		*a*	*b*
—	20	1.0		
20	25	1.1		
25	30	1.2		
30	35	1.3		
35	40	1.4	1.4	1.1
40	45	1.5	1.5	1.2
45	50	1.6	1.5	1.2
50	60		1.6	1.3
60	70		1.7	1.4
70	80		1.8	1.5

[a] Thicknesses giving approximately the same screening factor as a corresponding smooth sheath.

[b] Thicknesses that may be used when the screening factor is not of special importance.

[1] The press may be of the "continuous" type or not. If it is not continuous, care must be taken to ensure that no problems are caused in the zones affected by the intermittent nature of the process.

The use of lesser thicknesses than those indicated in the table is not excluded.

In the case of coaxial cables without armouring, the thickness of metal for all sheaths may have to be increased to improve mechanical protection. The increase in the thickness of metal in the case of aluminium is usually about 0.3 mm.

Values different from those given in the table may, of course, be adopted in special cases (for example, if extremely favourable screening factors are required).

2.2 *Welded sheaths*

This type of sheath is made by applying around the cable core an aluminium strip which is longitudinally welded.

The considerations in point 2.1 above on the choice between non-corrugated and corrugated sheaths and on the thickness in relation to the diameter may be considered valid, subject to the maximum thicknesses that can be welded.

3. *Protective coverings*

As stated above, since aluminium used in an underground environment is more liable to corrosion than lead, an impermeable (Class II) covering should be provided in accordance with Chapter 6.3 of the *Recommendations* to ensure the protection of the cable sheath and the jointing sections of individual factory lengths of cable (jointing sleeves and adjacent sections of cable).

Two types of plastic material can be used at present for protective coverings:

a) p.v.c.;

b) polythene.

Polythene is preferable since its general characteristics and its low permeability for water vapour give better protection to the aluminium.

To ensure that moisture which may have penetrated the protective covering (for example, because of a defect in the covering) does not spread along the surface of the sheath, extending the areas of corrosion, it is desirable to apply a leakproof layer consisting mainly of a bituminous mixture.

The leakproof layer must adhere well to the aluminium, especially when p.v.c. is used for the covering, since this material, unlike polythene, does not cling tightly to the sheath after extrusion. Adhesion can be improved by means of plastic tapes wrapped around the sheath after the application of the leakproof layer.

In the case of corrugated sheaths, the bituminous mixture must fill the corrugations sufficiently to allow complete contact with the outer covering.

Special tests should be made of the efficiency of the leakproof layer. A common test[1] consists in removing a part of the protective covering from a sample of the aluminium sheath and submitting it to electrolytic corrosion from an outside source of e.m.f.

After some time, a check must be made to see whether the corrosion is confined to the place from which the protective covering was removed.

The effectiveness of the protective covering can be assessed by means of a test to check the adhesion of the bituminous compound to both the aluminium sheath and the plastic covering. This is normally a type-test.

[1] See for example I.E.C. Publication 229 (1966 Edition and Amendment No. 1 (1970)).

To ensure the permanent effectiveness of the protective covering when cables are laid in areas exposed to lightning discharges (in particular as concerns avoiding perforations due to lightning discharges) the indications given in the handbook on protection against lightning should be taken into account.

4. *Jointing of aluminium sheaths*

Jointing is undoubtedly a more difficult operation for aluminium than for lead sheaths, although these difficulties have been minimized by improved techniques.

There are several methods of jointing aluminium sheaths:
- — jointing by means of lead sleeves;
- — jointing by means of lead rings (cones) pasted with special glue to the aluminium sheath with subsequent soldering to them of lead sleeves (cylinders);
- — other methods, including jointing by means of aluminium sleeves joined to the aluminium sheath by pressure welding (U.S.S.R. so-called "explosion" method).

The methods used for the jointing of aluminium sheaths must meet proper standards of convenience in cable laying and operation.

Generally speaking, lead sleeves, the ends of which are soldered to the aluminium sheaths, are used.

The principal soldering operations are as follows:
- — the aluminium is carefully cleaned;
- — a special alloy to permit soldering by the usual methods is applied immediately (to prevent any oxidation of the aluminium surface);
- — the lead sleeve is soldered on.

Some contractors place lead collars on the ends of the aluminium sheaths of cables which have to be jointed and, during the jointing process, they simply solder a lead sleeve on to the collar. This technique avoids repeated heating of the cable core (which could damage the insulation of coaxial pairs) in work carried out subsequently on the joints.

For a cable subjected to significant temperature variations tensions due to cable contraction should not be borne by the lead wiped joints, as this can lead to joint failure, particularly with non-corrugated sheaths.

5. *Cathodic protection*

There are only a few isolated experimental results available giving experience of cathodic protection of aluminium sheaths. Study of this aspect will be continued by the C.C.I.T.T.

Recommendation L.5 (Geneva, 1972)

CABLE SHEATHS MADE OF METALS OTHER THAN LEAD OR ALUMINIUM

1. *Types of metallic-sheathed cables*

1.1 The most common form of metallic sheath used as an alternative to a lead or aluminium sheath is one of corrugated steel. This consists of a long steel strip, shaped into a tube round the cable core, welded by a suitable process (inert-gas arc, mains frequency or high frequency heating) along the longitudinal seam and then corrugated. Outer protection for the steel sheath is provided by means of a special viscous, anti-corrosion compound enclosing one or more plastic tapes and laid so that the troughs of the corrugations are completely filled. An external plastic covering is then extruded over the compound-protected steel to form a smooth outer-covering.

1.2 For protection against induced currents the cable described in 1.1 may be used with aluminium or copper tapes laid longitudinally or helically beneath the corrugated steel sheath. Alternatively, a corrugated-copper sheath can be used in place of the corrugated-steel sheath.

2. *Construction*

2.1 The metallic strip is shaped into a long tube round the cable core, welded along the longitudinal seam and then corrugated.

2.2 Unprotected steel is particularly vulnerable to corrosion attack and the protection provided usually consists of a layer of compound in which may be embedded plastic tapes so that the corrugations are completely filled. An outer sheath of polythene or similar Class II covering (see Section 6.3 of the *Recommendations*) is then extruded over the compound.

2.3 Armouring of the cable is not normally necessary, but may be provided in special cases.

3. *Uses*

Corrugated steel- or copper-sheathed cables may be used for all types of telecommunication cable and the following are the main considerations influencing their use:

a) taking all factors into consideration (laying costs, duct space, cable cost, for example), and although the total diameter of the cable is greater than in the case of plastic, lead or non-corrugated-aluminium sheathed cables, telecommunication cables with steel sheaths may be more economical than lead-covered cables;

b) a steel sheath is not vulnerable to vibration caused by road or rail traffic;

c) a corrugated metal sheath has good flexibility;

d) a corrugated metal sheath with a smooth outer covering is easy to handle during installation;

e) the same type of cable can be laid direct in the ground or pulled into ducts;

f) such a sheath resists moderate crushing stresses and provides protection against most of the damage caused by stones or digging tools;

g) if the plastic covering of steel-sheathed cables is damaged, rapid corrosion may be expected.

Questions relating to the protection of cable sheaths and poles allocated to Study Group VI for the period 1973-1976

Question 1/VI

(continuation of Question 1/VI, 1968-1972)

— 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} Ωcm.

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 insultation 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/mm², elongation 350%, density 0.920 + 0.935 g/cm³, 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 dexoydized.

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.

ANNEX 5

(to Question 1/VI)

Information supplied by the French Administration in 1972

Since 1961 a large proportion of the long-distance telecommunication cables used by the French Administration have smooth or corrugated aluminium sheaths.

By the end of 1971, 6455 km of aluminium-sheathed cables were in use. In 1970 and 1971 alone, of the 2970 km of new long-distance cables brought into service, 2355 km, or about 80%, had aluminium sheaths, while 4% of the remainder had steel sheaths and 16% had lead sheaths.

The *Société Nationale des Chemins de Fer Français* has 1600 km of aluminium-sheathed cable in operation and 510 km of self-supporting aerial coaxial cables with an aluminium external conductor.

Cable-core wrapping

In the case of cables comprising heat-sensitive elements, such as pairs, quads or polyethylene-insulated coaxial pairs, the wrapping under the sheath must be sufficiently heat-resistant to avoid deterioration of the polyethylene (P.E.) when the sheath is heated for jointing by soldering.

This result is generally obtained by an adequate wrapping of smooth or crêpe paper cloth tape, metalized or graphite-treated paper tape, or by a combination of these two processes.

Composition of sheaths

The aluminium sheath consists of a tube obtained either by extrusion or by longitudinal welding of an aluminium strip.

The cylindrical wall of the tube thus obtained may be smooth or corrugated. The choice is usually left to the manufacturer; some use corrugated sheaths for cables of all diameters, while others make smooth sheaths for narrow cables and corrugated sheaths for thick ones, in which case the maximum drawing-in space required runs from 20 to 35 mm as between the smooth and corrugated varieties.

The metal used is first-fusion aluminium, not less than 99.5% pure. The content of various impurities complies with French standard NF-A-57-101 of May 1961.

The breaking strength of the metal must not be less than 65 N/mm^2 (approximately 6.5 kgf/mm^2) and the elongation at rupture not less than 5%.

Thickness of sheaths

Three thicknesses have been standardized by the French Administration:

— 0.7 mm for smooth sheaths with a diameter less than 10 mm and for corrugated sheaths with a diameter not more than 20 mm;

— 0.9 mm for smoth sheaths with a diameter between 10 and 20 mm and for corrugated sheaths with a diameter between 20 and 35 mm;

— 1.1 mm for smooth sheaths with a diameter of more than 20 mm and for corrugated sheaths with a diameter of more than 35 mm.

However, extruded smooth sheaths must never be less than 0.9 mm thick.

The aluminium-sheathed cables ordered by the *Société Nationale des Chemins de Fer Français* have thicker aluminium to improve the sheath screening factor when this is rendered necessary by extensive parallelism with overhead a.c. traction wires.

These thicknesses vary between 0.9 and 1.4 mm according to the cable diameter and are added to both corrugated and non-corrugated sheaths. The screening factor is further improved by armouring with two steel bands.

Protection of aluminium sheaths

Smooth-walled sheaths receive surface protection against corrosion and a polythene serving.

The furrows of corrugated sheaths are filled with a compound which also forms a thin layer over the ridges and the whole is treated:

— either directly with polythene;

— or with one or two waterproof plastic tapes, which may receive a protective coating and then with the polythene jacket;

— or with one or two tapes as above, then with a second layer of special filling compound and then with the polythene jacket.

Other processes are also permitted, and fine polypropylene cord can be embedded in the flooding compound and wound helically over the ridges of the corrugation to make the protective layer of uniform thickness. The same result can also be obtained if the inside of the polythene cover has longitudinal ribs which rest on the ridges.

The flooding compound, which usually has a bituminous base, is designed to stick fast to the aluminium of the sheath and to be sufficiently flexible and viscous enough to creep if the plastic covering is accidentally damaged. If so, the compound automatically spreads over the base metal and thus provides continued protection against corrosion.

The protective jackets properly so called are made of polythene containing 2% of carbon-black. They are usually made of low-density polythene when they are protected by armouring and of high-density polythene when no additional protection is provided; this has the advantage of higher resistance to puncture and abrasion.

The average thickness of polythene servings is the same for all diameters and must not be less than 2 mm. The minimum thickness must not be less than 1.7 mm at any point.

Impermeability tests

The impermeability of sheaths is tested by pressure or by immersion under pressure. For these tests, dry air is forced into the sheath at a pressure between 20 and 30 N/cm^2 (2 and 3 kgf/cm^2).

In the pressure tests, when equilibrium has been reached, the ends of the sheath are kept sealed for at least 4 hours; at the end of that time, the pressure should not have fallen by more than 2 N/cm^2 (0.2 kgf/cm^2).

In the tests by immersion under pressure, one looks for tell-tale air bubbles escaping from the cable.

Jointing sleeves

Aluminium-sheathed cables are jointed by means of lead sleeves welded to collars, also of lead, fitted and permanently soldered onto the aluminium sheath at the ends of the two lengths of cable (see Figure 1/Q.1/VI).

To prevent seepage of moisture between the collar and the end of the cable covering, this space is covered by a heat-shrinkable sleeve.

The aluminium sheath is first scraped and covered with a zinc-based flux. The collars are then soldered to it with a solder containing 33% tin.

The collars permit easy access to the joints without touching the soldering between the collars and the aluminium sheath. The shrinkable sleeves have an inner covering which cleaves to the polythene cable covering and to the lead collars, thus ensuring impermeability in the space between them.

When buried in earth, the joints are further protected by a cast iron casing filled with a bituminous compound.

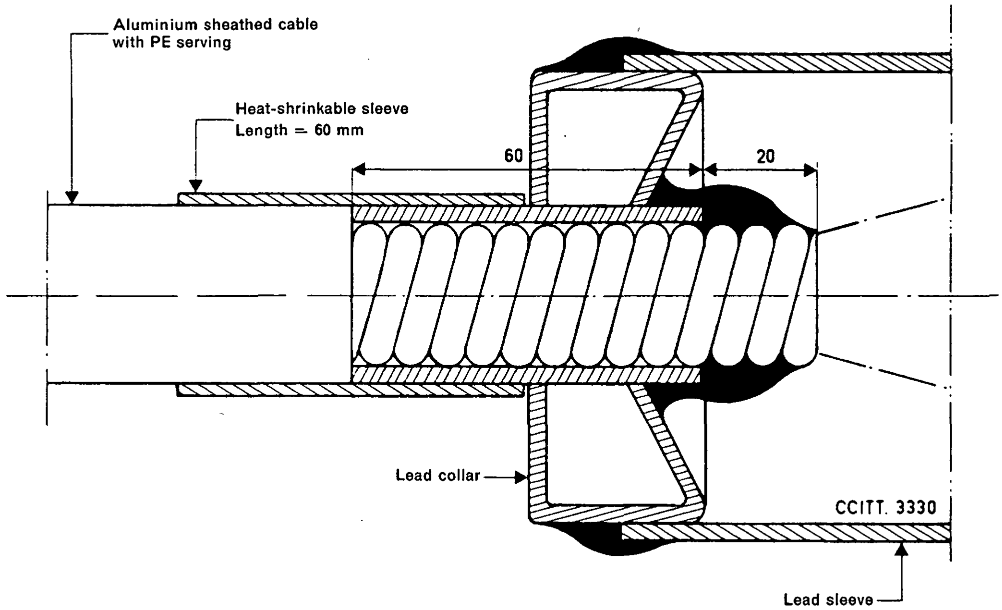


FIGURE 1/Q.1/VI.

ANNEX 6

(to Question 1/VI)

Information supplied by I.T.T. in 1972

For a cable subjected to significant temperature variations, tensions due to cable contraction should not be borne by the lead wiped joints as this can lead to joint failure, particularly with non-corrugated sheaths.

Sheath clamping arrangements are often incorporated in a joint box containing a suitable compound to give protection against moisture.

A newer method of aluminium sheath closure uses an epoxide-resin putty wiped joint between an aluminium sleeve and the cable sheath. The sleeves have "keying" grooves cut into the ends, and with corrugated sheaths no further arrangements are necessary to resist tension arising when the cable is subject to significant temperature variations. An additional internal clamping device is used, when necessary, in the case of plain sheaths.

An advantage of the epoxide-resin putty technique is that it avoids damage by heat which could occur to coaxial cable cores using plumbed lead sleeves. Furthermore, protection boxes are not required; a polythene tube with adhesive lining is heat-shrunk on to the sleeve for corrosion protection.

Question 2/VI

(new question)

Protection of aluminium conductors and joints:

What methods are used to protect aluminium or aluminium alloy conductors of telecommunication cables from corrosion:

1. during cable manufacture (insulation, filling products, etc.);
2. at connection points (connection of conductors, protection of splices, etc.)?

Note. — Aluminium and aluminium alloy conductor cables are being developed in a number of countries. It would be useful if the C.C.I.T.T. considered the problem of the manufacture, jointing and termination of these cables.

Question 3/VI

(continuation of Question 3/VI, 1968-1972)

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

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 ducts 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 dedided 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.

Armoured cables for laying in a trench have a polyethylene insulating layer under the armouring.

Polyvinyl chloride is used for outer coverings because flame travels along it less readily than in the case of polyethylene.

There is a sealing layer between the polyvinyl chloride and the lead.

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 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;

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 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 copolymer 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.

ANNEX 6

(to Question 3/VI)

Information supplied in 1971 by the International Telephone and Telegraph Corporation

Use of plastic materials as protective coverings for metal cable sheaths

The following is a description of some properties, ascertained by experiment, of conductive plastic sheaths based on polythene or p.v.c. The main interest of the conductive plastic sheath is its potential for significant and economic protection of cables against damage by lightning.

Annex 5 to the question, by the Northern Electric Company, provides data on experience over four to five years of some 28 km of such telecommunication cable in Canada.

The best results are achieved with 30 to 35% well-dispersed carbon-black. It is difficult to keep the transverse resistivity, important for lightning protection, within the order of magnitude of the less important longitudinal resistivity of the plastic sheath. When such thermoplastic is extruded, an orientation of the carbon-black particles seems to take place under the control of extrusion conditions. When the filler is a long-chain carbon black, as is appropriate in this case, the chains are longitudinally aligned as an effect of this orientation. This has the effect of reducing the longitudinal resistivity, at the same time increasing the transverse resistivity (in radial direction).

The behaviour of the sheath in the presence of mechanical stress is also of importance. Here it was found that the increase of the carbon-black content up to the optimal value goes hand in hand with a reduction of the breaking elongation and of the tensile strength. Again, extrusion conditions may be an important factor.

An effect worth noting is that on the breakdown voltage of the filled plastic sheath. The resistivity of the sheath was found to decrease with increasing d.c. voltage in the absence of an electrolyte. As the d.c. electric strength of a dielectric decreases with its resistance, the breakdown voltage for a given thickness will also decrease.

If the conductive plastic sheath is buried in soil where stray current could cause electrolysis, no significant increase in transverse resistance is to be expected as a result of such electrolysis; the reduced conductivity of the plastic sheath is compensated by the ingress of the electrolyte into the plastic sheath. However, this process, if continuing, would be detrimental to a metallic screen depending on the conductive plastic for protection against corrosion.

Investigation of the effects of surge voltages, necessary to determine the quality of lightning protection, have not yet been carried out.

When filled plastic sheaths are stored in water for several weeks there is, in the case of polythene copolymers, a decrease of conductivity; initially this is very rapid but eventually there is a levelling-off to a constant value of conductivity. No explanation has been found for this behaviour. The effect is less pronounced in the case of p.v.c. products.

Cables protected against lightning in this way could have an adverse effect on adjacent cables, possibly laid in the same trench. We have not yet investigated this possibility.

It may be concluded that suitable plastic sheaths with low transverse resistance can be provided on the basis either of polythene or p.v.c. with suitable filling compounds; the physical properties greatly depend on the mixing and extruding conditions.

Question 4/VI

(continuation of Question 4/VI, 1968-1972)

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 evaluating 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 Republic of Germany (1961-1964)

1. *Type of cable*

In the Federal Republic of Germany, 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 polysiobutylene 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 225 000 sheath-km, 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 about 18 metres 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 (about 15 km) was experiment. It has a 2.5 mm 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 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 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 24 000 megohm/kilometres; at the same temperature it is now a little under 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 7.5 cm, 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 accomodate 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 cableway 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.

ANNEX 7

(to Question 4/VI)

Study Group VI envisages the establishment of a Recommendation concerning closures for plastic sheathed cables.

First of all, however, following a proposal approved by the Vth Plenary Assembly, a pamphlet will be drawn up and for this, Mr. Nikolski (U.S.S.R.) will act as Special Rapporteur. The pamphlet will give descriptions of the various closures used at present as well as broad recommendations which might indicate the suitability of individual closure principles for particular conditions. The information will take account of "in-line" and "cap-ended" [1] sheath closures and the requirements for cables with few and many pairs of conductors. Methods of reopening sheath-closures will also be noted. In this way, Administrations would be able to choose, from the closures described in the pamphlet, the type best fitted to their own circumstances. The plan for the pamphlet is reproduced in the Appendix to this present Annex. Further information is requested to aid Mr. Nikolski in his task, and this should be provided from as many Administrations and private firms as possible, giving full descriptions of the processes of sheath closure and should be as up-to-date as possible. In particular, information should be given to cover the following points:

1) name of method;

2) country, telecommunication Administration, private operating agency or company;

3) field of use;

4) short statement of technological data;

5) circuits, diagrams, figures and photographs illustrating the basic stages of jointing, dimensions and working operations;

[1] "In-line" sheath closures are those in which one cable end is at one end of the joint and the other cable end(s) is (are) at the other end of the joint. In "cap-ended" closures, all cable ends are at one end of the closure.

6) methods of making reliability tests (precision and quality of jointing);

7) materials and jigs to be used (specifications);

8) estimated time and cost for making a joint (related to cable size).

The associated recommendation will be drawn up when the draft of the pamphlet is sufficiently complete.

It is proposed to publish the pamphlet in the same format as the *Recommendations* and perforated in the same way, so that it can be filed in the same cover.

APPENDIX

(to Annex 7 to Question 4/VI)

Table of Contents for a pamphlet on the jointing of plastic-sheathed telecommunication cables

Introduction

(to be written by Mr. J. R. Walters, United Kingdom Post Office)

Chapter 1

MAIN TYPES OF CABLE SHEATH

1.1 General
1.2 Alpeth sheath (N.T.T., Japan)
1.3 Stalpeth sheath (United States Administration)
1.4 Lepeth sheath (United States Administration)
1.5 Double-screen sheath (N.T.T., Japan)
1.6 Qualpeth sheath (Automatic Electric Company, General Cable Corporation, U.S.A.)
1.7 Polyethylene sheath with watertight barrier (T.C.L., United Kingdom)
1.8 Sealmetic sheath (Anaconda Wire and Cable Company, U.S.A.)
1.9 Copolymer sheath (Automatic Electric Company, General Cable Corporation, U.S.A.)
1.10 Ken-Tel screen sheath (Kennecot-Okonite Telephone Cables, U.S.A.)
1.11 T.I. sheath (Texas Instruments, U.S.A.)
1.12 Welded corrugated sheaths (Hackethal Draht und Kabelwerke AG, F.R. of Germany).

Chapter 2

CLASSIFICATION OF JOINTING METHODS

2.1 General
2.2 Cold techniques
2.3 Hot techniques

$\}$ Classification which it may be desirable to change when all the information is available

Chapter 3 [1]

METHODS OF JOINTING PLASTIC-INSULATED CURRENT CONDUCTOR WIRES

3.1 General
3.2 Jointing by means of plastic sleeves filled with silicone oil (United Kingdom Administration)
3.3 Jointing by means of compression sleeves (F.R. of Germany Administration)
3.4 Jointing by means of plastic sleeves welded to the plastic insulation (Administrations of Italy, Sweden and Hungary)
3.5 Jointing with the aid of a welding pistol (N.T.T., Japan)

[1] See information to be collected under Question 7/VI.

Chapter 4

Methods of jointing plastic and metal-plastic sheaths

4.1 General

4.2 Plastic tape joints (Administrations of Italy, U.K.P.O. and U.S.S.R.)

4.3 Methods for the mechanical jointing of plastic cable sheaths (Administrations of Italy, U.K.P.O. and U.S.S.R.)

4.4 Methods of jointing plastic sheaths by means of potting resins, pastes and glues (Administrations of U.K.P.O., Italy, Austria and Czechoslovakia)

4.5 Methods of welding plastic sheaths with the aid of welding pistols, gas torches, and other heating devices (Administrations of Austria, Australia, Italy and F.R. of Germany)

4.6 Injection-welding method (U.K.P.O.)

4.7 Methods of welding plastic sheaths by means of electrothermic units (Administrations of U.K.P.O. and F.R. of Germany)

4.8 Heat muffle welding method (Administrations of F.R. of Germany and Sweden)

4.9 Lead-sleeve method for jointing plastic sheaths (N.T.T., Japan)

4.10 Method of jointing corrugated-steel sheathed cables in flexible plastic tubing (Austrian Administration)

(See also Contribution COM VI-No. 7 (U.S.S.R.) for information about thermo-shrinkable sleeves.)

Chapter 5

Methods of jointing plastic and metal sheaths

5.1 General

5.2 Method of jointing sheaths made of different materials by means of metal-plastic adapter couplings (F.R. of Germany Administration)

5.3 Method of jointing plastic and metal sheaths by means of a monomolecular layer of stearic acid (United States Administration)

5.4 Method of jointing plastic and metal sheaths by means of lead adapter couplings (Administration of Japan)

5.5 Method for the mechanical jointing of plastic and metal sheaths (U.K.P.O.)

5.6 Method of jointing plastic and lead sheaths by means of connecting cable inserts (Administration of Sweden)

5.7 Adapter coupling method for jointing plastic and lead sheaths (Italian Administration)

5.8 Method of jointing plastic and lead sheaths by means of epoxy resin moulds (Administration of Australia)

5.9 Method of jointing sheaths of different materials by means of mechanical jointing sleeves of the CSS-10 type (U.K.P.O.).

Chapter 6

Installation of aerial telecommunication cables

6.1 General

6.2 Standards for installation of aerial telecommunication cables

6.3 Yugoslav method (Administration of Yugoslavia)

6.4 Swedish method (Administration of Sweden)

Chapter 7

Bibliography

Question 5/VI — Attacks on plastic or metal cable sheaths by insects, rodents or bacteria. Protection against these attacks

(continuation of Question 5/VI, 1968-1972)

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 contamintaed 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 *Synoxylon*, 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-sheathed 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 brought up to date in 1972)

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 (1964-68) being considered as an alternative.

In 1972, Australia reported that trials were continuing to determine the effectiveness of including an insecticide in polythene cable sheathing against attack by termites, ants, etc. The Australian Administration has decided that for its purposes the most effective method of protection is by means of a hard jacket and currently is using nylon. Some difficulties have been encountered with Nylon 11 and these have led to the adoption of Nylon 12, which is easier to obtain and which appears to give equally good results. The use of nylon was originally limited to cable cores of under 1.25 cm diameter. It can now be used for cores of 3.75 cm diameter. It is generally used only in rural areas of Australia where insects, which are not prevalent in towns, are encountered. All single quad carrier cable and approximately 30% of all plastic jacketed cable installed currently (1972) are covered with nylon, and experiments are being are being carried out in an attempt to replace the polythene jacket with nylon on coaxial cables.

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 onto 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, 1968-1972)

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.

Note 5. — Information concerning the jointing of such conductors will be collected under Question 7/VI. (See also Question 4/VI.)

Question 7/VI — Methods for making conductor joints

(new question)

Recent developments in the use of telecommunication cable circuits have emphasized the need for a conductor joint whose electrical and mechanical characteristics are not significantly inferior to those of an equivalent insulated conductor in the cable as manufactured. Information is required on the various jointing techniques at present in use or being developed for copper and aluminium conductors insulated with paper or plastic covering and their performance in service.

Question 8/VI — Corrosion and corrosion protection of wave-guide communication lines

(new question to collect background information).

Question 9/VI

(continuation of Question 9/VI, 1968-1972)

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. — Up to the Vth Plenary Assembly, (Geneva, December 1972), the following studies were carried out under this question:

1. Two aspects of joint protection were dealt with, 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.

2. The question of the nature of interconnecting bonds was examined, and took 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, a study was made to determine how the fault current will divide between the various structures when a fault current on a power system flows through a cathodic protection bond on to other buried structures.

3. Some guidance concerning a possible interconnection of installations associated with high voltage electricity supply systems and those associated with other buried structures is given in 9.3.5. of the *Recommendations*. However, the precautions mentioned in Recommendation K.8 should be noted.

4. In the case of high-voltage lines with tower footings of reinforced concrete a study has been made to see whether it is necessary for such lines to be included in any cathodic protection scheme.

5. 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 have been kept in view:

   a) whether there are 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;

   b) What special arrangements are to be made and what, if any, protective devices should be provided for protection against these phenomena?

(Studies of protective devices have covered the safety of both personnel and plant.)

The conclusions drawn from these studies have not led to any special need to change the text of existing recommendations. However, the question has been retained for study in order that further information may be received and so that it may be possible to draw up an "L series" Recommendation to be read in association with the existing text on Cathodic Protection in the *Recommendations.*

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 Republic of Germany 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 occuring 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

(continuation of Question 10/VI, 1968-1972)

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 VI 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 insuficient cathodic protection does not bring the lead of the cable in a stongly 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, 1968-1972)

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 measurements 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.

Note 5. — The Vth Plenary Assembly gave its approval to a proposal to change the title of this publication to: *Recommendations concerning the construction, installation and protection of telecommunications cables in public networks.*

(For the period 1973-1976 there is no question numbered 12/VI).

Question 13/VI — Corrosion due to direct-current exchange with nearby electrode systems

(continuation of Question 13/VI, 1968-1972)

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.

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. A contribution will be submitted by the United Kingdom Post Office.

ANNEX

(to Question 13/VI)

Design of h.v.d.c. transmission systems

(Information supplied by C.I.G.R.E. in 1972)

H.v.d.c. transmission systems are designed either with two-pole transmission, the two poles (cable or overhead) being isolated from ground, or with single-pole transmission with one conductor isolated from ground and with ground and water used as the second conductor.

With two-pole transmission systems it is possible to provide earthing at one point only so that no current flows through the ground at any time. Normally, however, the mid-point is connected to ground at each substation enabling power to be transmitted via one pole even during interruption of the other pole for repair or maintenance. With such two-pole installations the connections to ground must be made through electrodes that are capable of carrying the full load current although full load current will flow through the ground only when one pole is interrupted.

Possibility of corrosion

Buried metallic plant near either of the electrodes may be exposed to corrosion. The risk of corrosion will be greater for single-pole systems since the electrodes carry full load current continuously. In the case of extensive buried structures the corrosion risk occurs particularly near the electrode that is acting as a cathode.

In the two-pole system the electrodes carry full load only during short periods although unbalance can give rise to some current flowing through the soil at other times. The corrosion risk in such cases requires special consideration.

The integrated and not the instantaneous values of ground current should be the basis for assessing any harmful effects on other structures. It follows that the maximum allowable value of ground current and of any associated effects can be greater with intermittent operation of ground return than for continuous operation.

Measures to be taken

The risk of corrosion can be reduced by careful selection of electrode sites and positions for the installation of metal structures in soil or water near the high voltage direct-current transmission electrodes. The area in which there is risk will be minimized if the electrodes are located so that their resistance, measured to distant ground, is low. This can be achieved by siting the electrodes to take advantage of sea-water, iron ores or low resistivity soils.

Investigations concerning the risk of corrosion should be made with the objective of preventing serious damage to nearby structures during their expected foreseen lifetime. Account should be taken of the variations of the ground resistivity, the dimensions, material, and coating of the buried structure, the distance from the electrodes and the depth of corrosion that is tolerable.

Before the final design of the electrode is settled, a basis for judgment of suitable distances to buried objects can be obtained by field test measurements of electrical conditions using a current-carrying test electrode placed at the intended electrode site. It will normally be impossible to test with the full operating current but the effect on the structures, for example calculated on the basis of the potential distribution in the ground, can be estimated approximately by assuming it to be proportional to the test current.

It follows from the foregoing that it should not be assumed that recommendations relating to the assessment of the effects of interaction between cathode protection installations and neighbouring structures are applicable to the effects of d.c. transmission installations. Although the two cases are in many ways similar, a major difference is that, in the case of d.c. transmission, the small number of cases where harmful effects may be considered possible justify making detailed investigations and considering each case in relation to the local conditions and to the high capital cost of the d.c. transmission system.

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

(continuation of Question 14/VI, 1968-1972, studied by Joint Working Party CDF 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 1. — Study of this question (which is similar to Question 22/V) is to be continued during 1973-1976 by Joint Working Party CDF of Study Groups V and VI.

Note 2. — Study Group VI should ensure that its own recommendations cover the special requirements, and meet the required conditions, in respect of cables that are going to be called for in the Manual. A few examples are:

- the adequacy of various sorts of bonds (between structures, across cable joints);
- jointing methods and the compatibility of breakdown voltages at various points, referring particularly to the filling of cables and joints with products such as petroleum jelly.

Question 15/VI — Protection of screens and armouring

(continuation of Question 15/VI, 1968-1972)

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 — Degradation of plastic sheaths

(continuation of Question 16/VI, 1968-1972)

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 — Stray alternating currents

(continuation of Question 17/VI, 1968-1972)

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 the wording of Question 17/VI)

Conclusions by Study Group VI on a.c. corrosion (up to 1972)

Laboratory experiments and the results of examinations of industrial installations show that stray alternating currents can cause corrosion.

Other experiments on lead to compare the effects of direct current and alternating current by weight loss show that the corrosion effect due to a.c. is very slight compared with corrosion by d.c. A.c. corrosion appears in the form of pitting.

The following points should nevertheless be noted:

— the corrosion, although rare, occurs more readily with decreased frequencies below the usual mains frequency of 50 Hz or 60 Hz;

— another factor to be considered is possible rectification due to the nature of the soil or to the presence at the surface of the metals of oxides or polluting substances.

At present, there is no practical way of finding out the current densities at which corrosion occurs. The individual pitting that is usual, the fact that anodic and cathodic reactions occur on the same surface of the metals, and variations in the chemical characteristics of the environment make it impossible for any accurate concept or definition of critical current density to be worked out at present.

Information on how corrosion occurs at a given potential in a given environment and in a known metal could be specified, subject to future checks and experiments.

It seems reasonable to suggest that a.c. at low-voltage is not usually harmful to steel but may corrode lead and especially aluminium in some cases. For aluminium the critical voltage is much lower—about 1 volt.

Question 18/VI — Requirements when armouring is used

(continuation of Question 18/VI, 1968-1972)

(Question Asia 9 from the Asia Plan Committee C.C.I.T.T. 1964)

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

(continuation of Question 19/VI, 1968-1972)

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.

SUMMARY OF QUESTIONS ALLOCATED TO STUDY GROUP VI FOR THE PERIOD 1973-1976

No.	Short title	Remarks
1/VI	Aluminium cable sheaths. Protective covering for these sheaths	
2/VI	Protection of aluminium conductors and joints	
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 or metal cable sheaths by insects, rodents or bacteria. Protection against these attacks	
6/VI	Cables with plastic-insulated conductors	
7/VI	Methods for making conductor joints	Documentary question to lead to drawing up a Handbook
8/VI	Corrosion protection for wave-guides	To be studied with point 1.8 of Question 23/XV
9/VI	Joint cathodic protection of several networks	
10/VI	Unusual cases of corrosion	
11/VI	Amendments to the Recommendations against corrosion	
13/VI	Corrosion due to direct-current exchange with nearby electrode systems	
14/VI	Protection against lightning	For study by GM/CDF (see Question 22/V)
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	