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ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

K.25

(05/96)

SERIES K: PROTECTION AGAINST INTERFERENCE

Protection of optical fibre cables

ITU-T Recommendation K.25

Superseded by a more recent version

(Previously "CCITT Recommendation")

FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union (ITU). The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation K.25 was revised by ITU-T Study Group 5 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 8th of May 1996.

NOTES

1. In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

2. The status of annexes and appendices attached to the Series K Recommendations should be interpreted as follows:

- an *annex* to a Recommendation forms an integral part of the Recommendation;
- an *appendix* to a Recommendation does not form part of the Recommendation and only provides some complementary explanation or information specific to that Recommendation.

CONTENTS

Recommendation K.25

PROTECTION OF OPTICAL FIBRE CABLES

(Melbourne, 1988, revised in 1996)

1 Scope and object

The scope of this Recommendation is the protection against lightning of telecommunication lines in fibre optics installations.

The object of this Recommendation is to limit the number of possible primary failures (3.1) occurring in the optical fibre cable in a specified installation within values which are lower than or equal to the limit value, defined as the accepted frequency of primary failures (3.5).

Consequently this Recommendation points out the method for both calculating the possible number of primary failures and choosing the feasible protective measures.

Indication about the accepted frequency of primary failures is given in the Appendix II.

Secondary failures (3.2) are not considered in this Recommendation.

2 References

The following Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision: all users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

[1] *The protection of telecommunication lines and equipment against lightning discharges. Chapter 9: Fibre optic cable lightning damage assessment*, ITU, 1994.

[2] *The protection of telecommunication lines and equipment against lightning discharges* – ITU, 1974 and 1978.

[3] Recommendation K.29 (1992), *Coordinated protection schemes for telecommunication cables below ground.*

[4] UNGAR (S.G): Effects of lightning punctures on the core-shield voltage of buried cable, *The Bell System Technical Journal*, Vol. 59, No. 3, March 1980.

[5] ITU-T Recommendation K.11 (1993), *Principles of protection against overvoltages and overcurrents.*

[6] SUNDE (E): Earth conduction effects in transmission system, *Dover Publications, Inc.*, New York.

[7] BENDAYAN (J): Câbles résistant aux dommages causés par la foudre, *Cables & Transmission*, October 1972.

[8] ITU-T Recommendation K.39 (1996), *Risk assessment of damages to telecommunication sites due to lightning discharges.*

3 Definitions

For the purposes of this Recommendation, the following definitions are given:

3.1 **primary failures**: Primary failures on the optical fibre cable are those which cause the interruption of service (breakage of one or more optical fibres), an unacceptable increase in attenuation of the optical fibre or an interruption in the remote power supply, if the equipment is powered by metallic conductors inside the optical cable.

Primary failures are also those damages to the cable, such as destruction of the protective covering, moisture barrier, interconnecting elements and protective jelly, which, due to other mechanism acting on the damage, will lead to an unacceptable increase in attenuation of the optical fibre.

3.2 secondary failures: Secondary failures on the optical fibre cable are those damages to the cable, such as the puncturing of the plastic protective covering (pinholing) and, in case, also of the metal sheath, which do not cause primary failures.

3.3 frequency of primary failures (N_p) or annual damage rate (ADR): Average annual number of expected primary failures in an optical fibre installation due to direct lightning flashes.

3.4 risk of primary failures (R_d): Probable average annual loss of function in the optical fibre installation due to direct lightning flashes.

3.5 accepted frequency of primary failures (N_a): Maximum value of expected average annual frequency of primary failures in an optical fibre installation not requiring additional protective means due to direct lightning flashes.

3.6 accepted risk of primary failures (R_a): Accepted maximum level of the risk of primary failures (R_d) due to direct lightning flashes.

3.7 direct lightning flash: A lightning to aerial cable or to the ground surface within the equivalent arcing distance D from buried cable.

3.8 direct lightning flash frequency (N_d): Expected average annual number of direct lightning flashes to an optical fibre installation.

3.9 equivalent arcing distance (D): Average distance from buried cable at which a lightning can arc to the cable.

3.10 failure lightning current (I_a): Minimum peak value of the lightning current giving rise to a direct arc on the cable and causing primary failures.

3.11 breakdown sheath current (I_s): Current flowing in the metallic sheath which causes breakdown voltages between metallic elements inside the cable core and the metallic sheath.

3.12 connection current (I_c): Minimum sheath current value, causing primary failures, evaluated with the test for surge current resistibility of the interconnecting elements (5.2.1).

3.13 interconnecting elements: Metallic elements connecting metallic parts of optical fibre cable at joints and cable ends.

3.14 test current (I_t): Current causing primary failures which is evaluated with the test for surge current resistibility shown in 5.2.2 or 5.2.3 for buried or aerial cables respectively.

3.15 impulse current (I_p): Current to be used in the test for surge current resistibility of optical fibre cables. The test generator of this current is under consideration by IEC TC 81.

NOTE – Waiting the IEC TC 81 decision on test generator, information on test currents used in some countries is given:

- double exponential waveform current with a rise time of 10 µs and a time to half value of 350 µs (10/350 µs waveform);
- damped oscillatory current with a maximum time-to-peak value of 15 µs and a maximum frequency of 30 kHz. The time to half value of its waveform envelope shall be 40-70 µs. These values apply to the waveforms measured with the test sample in place.

3.16 breakdown voltage (U_b): Impulse breakdown voltage between metallic components and the sheath of the optical cable.

3.17 protection correction factor (K_d): Correction factor value which allows a conservative evaluation of the frequency of primary failures.

3.18 surge protective device (SPD): A device that is intended to limit transient overvoltages and divert surge currents. It contains at least one non-linear component.

3.19 direct lightning current to aerial cables (J): The minimum lightning current which strikes an aerial cable causing a flashover to ground.

4 Reference configuration

Figure 1 represents the reference configuration for the optical fibre installations, where the connections with optical fibre cables between two Exchanges, between Exchange and Subscriber and between Exchange and line Equipment are shown.

NOTE – For the protection against lightning of the metallic cable installation between Equipment and Subscriber, the requirements requested by the Recommendation K.11 “Principles of protection against overvoltages and overcurrents” [5] shall be considered.

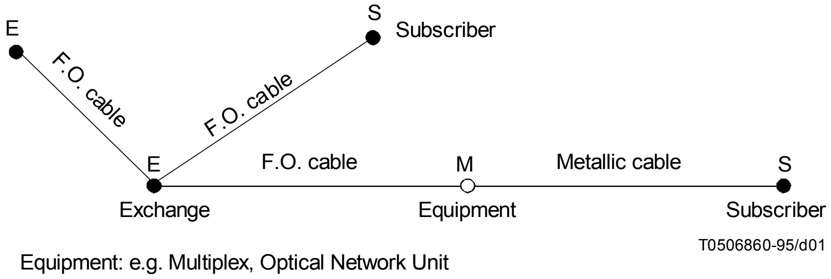

FIGURE 1/K.25

Reference configuration

5 Construction characteristics of the cable and test for surge current resistibility

5.1 Construction characteristics of the cable

This Recommendation applies to the following types of optical fibre cables:

- dielectric, or metal-free, cable: there are no metal elements in the cable;
- cable with dielectric core and metal sheath or sheaths: there are no metal elements in the core of the cable which has a metal sheath (for example the moisture barrier) or a metallic supporting wire;
- cable with metal elements in the core and with or without a metal sheath or sheaths: there are metal elements, such as conductors or strength members, in the core of the cable which has one or more metal sheaths.

For each cable type, except for the dielectric only cable, the possible value of failure lightning current, I_a, shall be evaluated.

The current, I_a, is the lower value between the following values (Figure 2):

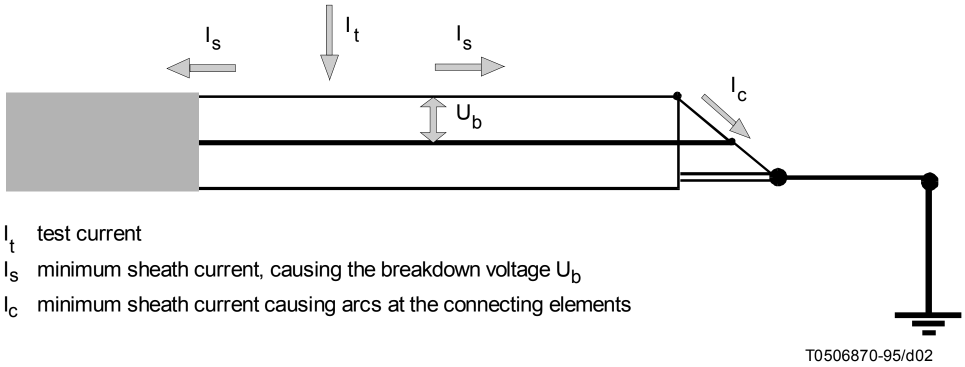

FIGURE 2/K.25

Connector, I_c, and sheath, I_s, currents

a) *buried cables*

- twice the connection current, I_c, evaluated with the test for surge current resistibility of the interconnecting elements (5.2.2);
- the test current, I_t, evaluated with the type test for surge current resistibility shown in 5.2.3 for buried cables [2];
- twice the breakdown sheath current, I_s, flowing in the cable sheath, which causes breakdown voltage between metallic elements inside the cable core and the metallic sheath; the sheath current value, I_s, of the cable with metal elements in the core and with metal sheath(s), with or without an insulating protective covering, may be estimated from the following equation:

$$I_s \cong U_b / (K \cdot R \cdot \sqrt{\rho}) \qquad [\text{kA}] \tag{1}$$

where:

$K = 8$ is the waveshape factor for lightning current (10/350 µs waveform) $[(\text{m}/\Omega)^{0.5}]$

R is the sheath resistance per unit length [Ω/km]

U_b is the breakdown voltage [V] of the optical fibre cable evaluated with the test indicated in 5.2.1

ρ is the soil resistivity (Ω · m)

b) *aerial cables*

- twice the connector current, I_c, evaluated with the test for surge current resistibility of the interconnecting elements (5.2.2);
- the test current, I_t, evaluated with the type test for surge current resistibility shown in 5.2.4 for aerial cables [2];

b1) *aerial cable without earth connections of the metal sheath*

- the direct lightning current, J, (3.19) which strikes the aerial cable causing, as a consequence of the flashover voltage at a pole, a large percentage of the lightning current to ground and a breakdown sheath current, I_s.

  The breakdown sheath current, I_s, is evaluated as follows (with the assumption that the cable is long) [6]:

$$I_s \cong U_b / (250\, K \cdot R) \qquad [\text{kA}] \tag{2}$$

The lightning current, J, can be estimated with the following equation [6]:

$$J = 4\ I_s^2 / k \tag{3}$$

where:

$k = \rho E_o / S^2$

E_o is the soil surface breakdown voltage gradient and is approximately 250 kV/m for $\rho \leq 10$ Ω · m and 500 kV/m for $\rho \geq 1000$ Ω · m

S is the surge impedance of the sheath [1] and [6]

b2) *aerial cable with earth connections of the metal sheath*

- twice the breakdown sheath current, I_s, which, in this case, may be estimated from the following equation (with the assumption that the cable is long):

$$I_s \cong U_b / (K \cdot R \cdot \sqrt{\rho_e}) \tag{4}$$

where:

ρ_e is the effective earth resistivity (Ω · m), and is calculated with equation 11 of [1].

For determining the failure lightning current, I_a, the following procedure is suggested:

a) *buried cables* (Figure 3)

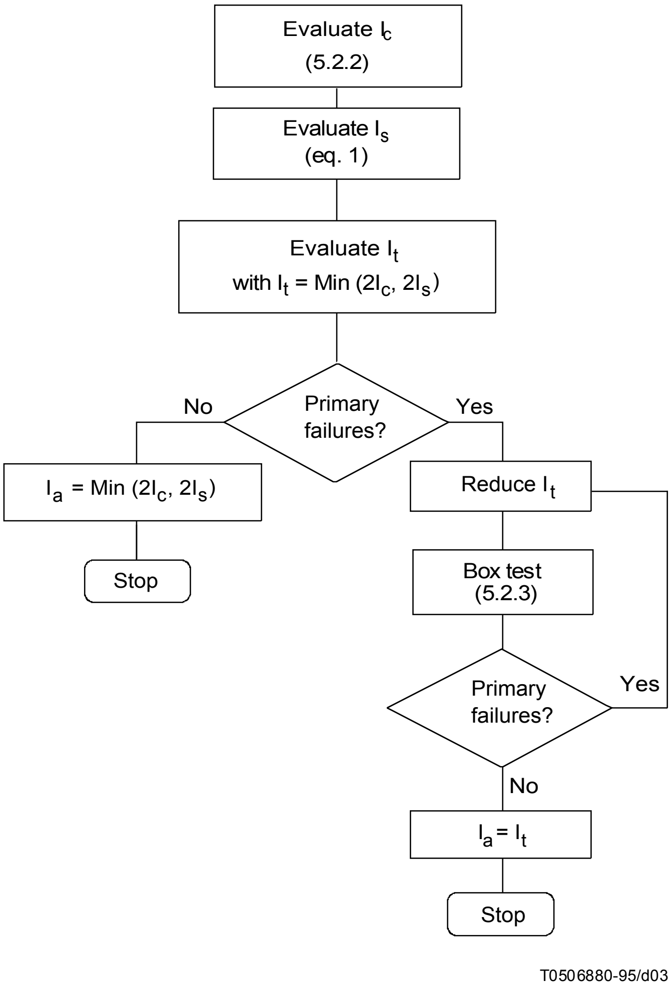

FIGURE 3/K.25

Procedure for determining the failure lightning current for buried cables

1) evaluate the connector current, I_c, and the breakdown current, I_s;

2) use the lower value between $2I_c$ and $2I_s$ as peak current value in the test shown in 5.2.3 for buried cables [2]:

$$I_t = 2I_c \qquad \text{or} \qquad I_t = 2I_s$$

3) if primary failures are not caused during the test shown in 5.2.3, the failure lightning current is the lower value between $2I_c$ and $2I_s$:

$$I_a = 2I_c \qquad \text{or} \qquad I_a = 2I_s$$

if primary failures are caused during the test, the peak current I_t will be reduced in order to determine the minimum peak current causing primary failures; then this new value of I_t will be the failure lightning current:

$$I_a = I_t$$

then:

$$I_a = I_t \quad \text{if} \quad I_t < 2I_s;\ I_t < 2I_c \tag{5}$$

or:

$$I_a = 2I_s \quad \text{if} \quad I_t > 2I_s;\ I_s < I_c \tag{6}$$

or:

$$I_a = 2I_c \quad \text{if} \quad I_t > 2I_c;\ I_c < I_s \tag{7}$$

b) *aerial cables*

b1) *aerial cables without ground connections of the metal sheath* (Figure 4)

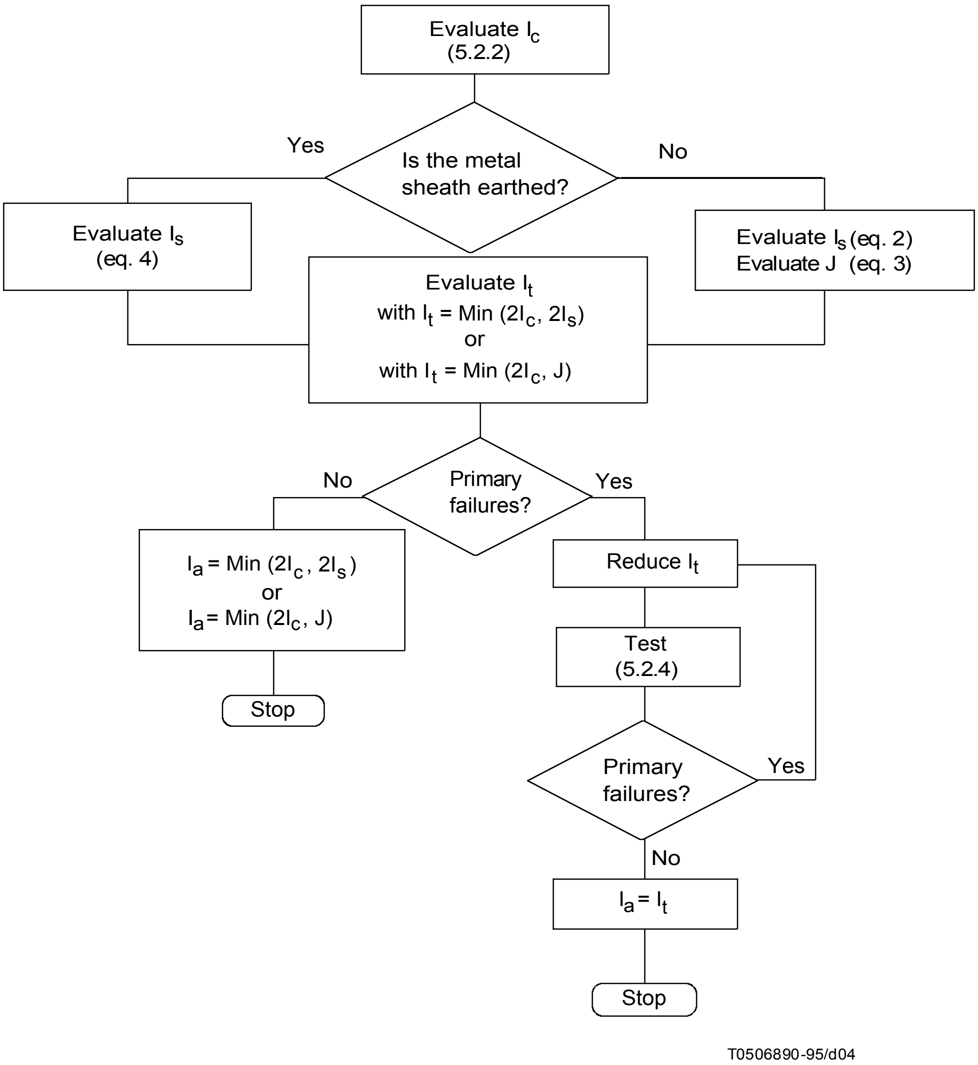

FIGURE 4/K.25

Procedure for determining the failure lightning current for aerial cables

1) evaluate the connector current, I_c, and the breakdown current, I_s with equation (2);

2) use the lower value between $2I_c$ and J, the latter calculated with equation (3), as peak current value in the test shown in 5.2.4 for aerial cables:

$$I_t = 2I_c \qquad \text{or} \qquad I_t = J$$

3) if primary failures are not caused during the test shown in 5.2.4, the failure lightning current is the lower value between $2I_c$ and J:

$$I_a = 2I_c \qquad \text{or} \qquad I_a = J$$

if primary failures are caused during the test, the peak current I_t will be reduced in order to determine the minimum peak current causing primary failures; then this new value of I_t will be the failure lightning current:

$$I_a = I_t$$

then:

$$I_a = I_t \quad \text{if} \quad I_t < J;\ I_t < 2I_c \tag{8}$$

or:

$$I_a = J \quad \text{if} \quad I_t > J;\ J < I_c \tag{9}$$

or:

$$I_a = 2I_c \quad \text{if} \quad I_t > 2I_c;\ 2I_c < J \tag{10}$$

b2) *aerial cables with ground connections of the metal sheath* (Figure 4)

1) evaluate the connector current, I_c, and the breakdown current, I_s with equation (4);

2) use the lower value between $2I_c$ and $2I_s$ as peak current value in the test shown in 5.2.4 for aerial cables:

$$I_t = 2I_c \qquad \text{or} \qquad I_t = 2I_s$$

3) if primary failures are not caused during the test shown in 5.2.4, the failure lightning current is the lower value between $2I_c$ and $2I_s$:

$$I_a = 2I_c \qquad \text{or} \qquad I_a = 2I_s$$

if primary failures are caused during the resistibility test shown in 5.2.4, the peak current I_t will be reduced in order to determine the minimum peak current causing primary failures; then this new value of I_t will be the failure lightning current:

$$I_a = I_t$$

then:

$$I_a = I_t \quad \text{if} \quad I_t < 2I_s;\ I_t < 2I_c \tag{11}$$

or:

$$I_a = 2I_s \quad \text{if} \quad I_t > 2I_s;\ I_s < I_c \tag{12}$$

or:

$$I_a = 2I_c \quad \text{if} \quad I_t > 2I_c;\ I_c < I_s \tag{13}$$

For cables without metallic elements inside the cable core or for cables with more than one metal sheath, the current, I_s, shall not be evaluated.

5.2 Test for surge current resistibility

5.2.1 Breakdown voltage test

A cable sample 5 metres in length shall be used for the test.

The conducting components inside the cable core shall be electrically connected together to form one terminal; another terminal shall be connected to the metallic sheath isolated from the other conducting elements. A surge voltage generator with a 1.2/50 µs waveform shall be placed between the two terminals.

The test voltage is measured during the test.

Following the application of discharge voltages in ascending amplitudes, the test identifies a threshold value of surge voltage which causes a breakdown.

5.2.2 Test for surge current resistibility of the interconnecting elements

All conducting components at one end of the cable shall be electrically connected together to form one terminal; at the opposite end of the cable sample, another terminal shall be connected in the same way. A surge current generator shall be placed between the two terminals (Figure 5).

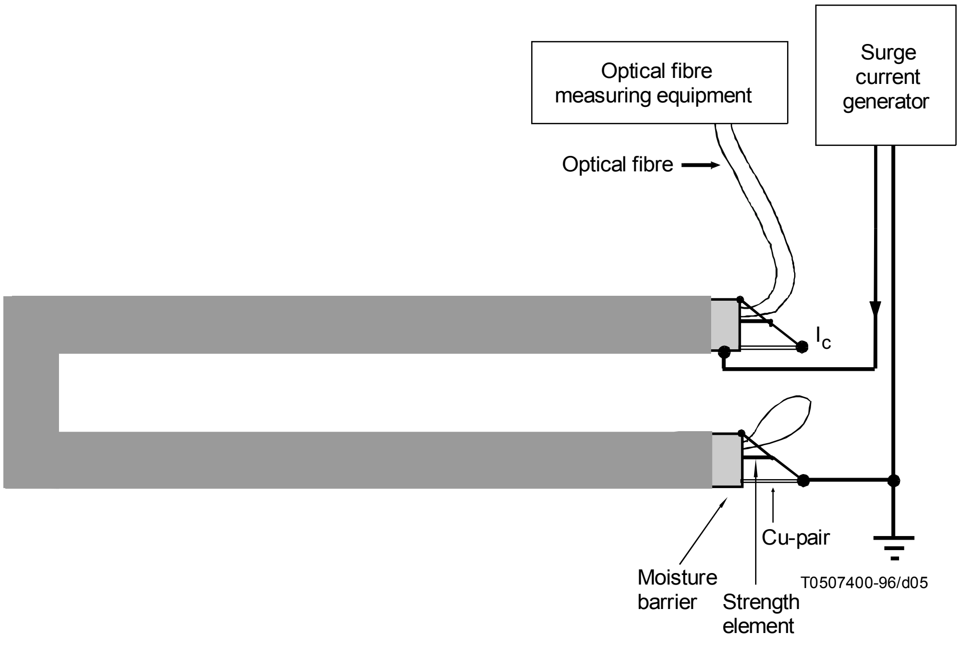

FIGURE 5/K.25

Scheme for surge current resistibility test of interconnecting elements

The test current, I_c, is the impulse current, I_p, (3.15) and it is the only current measured during the test.

Following the application of discharge currents in ascending amplitudes, the sample is tested for loss of its performance according to 3.1. The test identifies a threshold value of surge current which causes primary failures.

5.2.3 Sand box test for buried cables

A cable sample 1 metre in length shall be immersed in wet sand contained in a non-conducting rigid box having a length a minimum of 0.75 m in all inside linear dimensions (Figure 6). The box shall have two holes in the bottom for water drainage, approximately 25 mm in diameter. The sand shall be 20-40 mesh silica sand, and shall be fully saturated for a maximum time interval of 8 hours and drained for at least five minutes before tests. The cable sample shall be placed in the test box and the wet sand tamped around it. The moisture content of the sand in the more critical sand volume is 15% by weight.

A discharge electrode shall be located near the centre of the test box, at a distance of 26 ± 1 mm from the sample. All conducting components in the cable shall be electrically connected together to form one terminal and a test current generator shall be placed between this terminal and the discharge electrode (Figure 6).

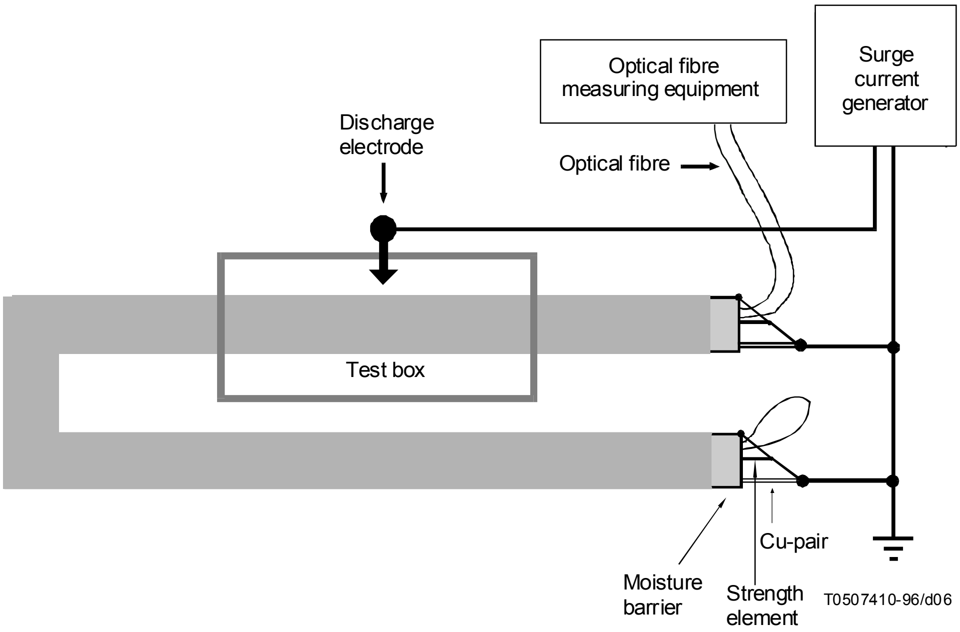

FIGURE 6/K.25

Scheme for surge current resistibility test

It is important for the test current to flow through the sample and to encourage this to occur, any insulating covering over an outer metallic shield or moisture barrier shall be opened with a small slit or hole with a 1 mm diameter tool facing the discharge electrode. If the voltage of the test generator can not breakdown the air-gap, a thin wire shall connect the discharge electrode with an outer metallic shield or moisture barrier.

The test current shall be the impulse current, I_p, (3.15) and it is the only current measured during the test.

Following the application of discharge currents in ascending amplitudes, the sample is tested for loss of its performance according to 3.1. The test identifies a threshold value of surge current which causes primary failures.

5.2.4 Test for aerial cables

A cable sample 1 metre in length shall be in tension according to the manufacturer specifications.

A discharge electrode shall be located near the sample at a distance of 26 ± 1 mm. All conducting components in the cable shall be electrically connected together to form one terminal and a test current generator shall be placed between this terminal and the discharge electrode.

It is important for the test current to flow through the sample and to encourage this to occur, any insulating covering over an outer metallic shield or moisture barrier shall be opened with a small slit or hole with a 1 mm diameter tool facing the discharge electrode. If the voltage of the test generator can not breakdown the air-gap, a thin wire shall connect the discharge electrode with an outer metallic shield or moisture barrier.

The test current, I_t, shall be the impulse current, I_p, (3.15) and it is the only current measured during the test.

6 Need for protection

6.1 General

The need for lightning protection of optical fibre installation depends on the frequency of primary failures, N_p, (3.3) or Annual Damage Rate, ADR, (3.3) and its accepted frequency of primary failures, N_a, (3.5).

The frequency of primary failures, N_p, is given by the following equation:

$$N_p = N_{pb} + N_{pa} + N_{ps} \tag{14}$$

where:

N_{pb} is the frequency of primary failures to buried cables.

N_{pa} is the frequency of primary failures to aerial cables.

N_{ps} is the frequency of primary failures due to direct lightning strokes to exposed structure that the optical fibre cable enters.

If the frequency of primary failures, N_p, is higher than the accepted frequency of primary failures, N_a, protective measures are necessary to reduce N_p and minimize the risk of primary failures, R_d.

Each Network Operator should define the accepted frequency of primary failures, N_a, and the accepted risk of damage, R_a; representative values of N_a and R_a are given in Appendix II.

6.2 Frequency of primary failures or annual damage rate for buried cables

The frequency of primary failures or Annual Damage Rate, ADR, for buried cables, N_{pb}, is estimated by using equation (6) of [1] or with the following equation:

$$N_{pb} = K_d \cdot N_d \cdot p(\geq I_a) \text{ damages/year} \tag{15}$$

where:

$K_d = 3$ is the protection correction factor, defined in 3.17

NOTE – The protection correction factor K_d is introduced in this Recommendation to allow a conservative evaluation of the arcing distance d between a lightning stroke to ground and a buried cable, using an approximated solution based on the concept of the equivalent arcing distance D.

p is the probability for the lightning peak current to be equal or higher than I_a value. The probability distribution of lightning stroke current for both buried and aerial structures is reported in Figure 7 and is expressed by means of the following formula:

$p(i) = 0$ for $i \leq 0$

$p(i) = 10^{-2} \cdot e^{(a-bi)}$ for $i > 0$ (i in [kA])

where:

$a = 4.617$ and $b = 0.0117$ for $i < 20$ kA

$a = 5.075$ and $b = 0.0346$ for $i \geq 20$ kA

I_a is the failure lightning current; e.g. the current which causes primary failures and will depend on the cable design (5.1);

N_d is the expected average annual number of direct lightning flashes to the cable (3.8), calculated with the following equation:

$$N_d = N_g \cdot 2DL/1000 \text{ strokes/year} \tag{16}$$

where:

N_g is the lightning ground flash density expressed in terms of flashes to ground per square km per year; if the map of N_g is not available, it may be estimated by the use of the following relationship (which varies with changes in climate conditions)

$$N_g = 0.04 \cdot T_d^{1.25} \tag{17}$$

where:

T_d is the number of days during which thunder is heard at a specific observation point. T_d can be estimated using isokeraunic maps. More detailed isokeraunic maps of limited areas also exist and can be obtained from national government agencies;

2DL in equation 16 constitutes the area which is susceptible to direct lightning strike or arcing from a stroke point. L is the route length in km. D is the equivalent arcing distance and is calculated using the probability distribution of lightning stroke current to both buried and aerial structures reported in Figure 7 and given in equation (12) of [2]:

$$D = 0.482 \sqrt{\rho} \text{ [m]; for } \rho \leq 100 \ \Omega \cdot \text{m} \qquad (18)$$

$$D = 0.283 \sqrt{\rho} \text{ [m]; for } \rho \geq 1000 \ \Omega \cdot \text{m} \qquad (19)$$

where:

ρ is the soil resistivity in Ω · m, and is the reciprocal of soil conductivity. The value of ρ can be found from soil resistivity maps or it can be measured.

An algebraic or graphical interpolation method which assumes a straight line equation may be used to calculate D for values of ρ between 100 Ω · m and 1000 Ω · m. The following equation gives the algebraic interpolation:

$$D = 0.191 (\sqrt{\rho} - 10) + 4.82 \qquad (20)$$

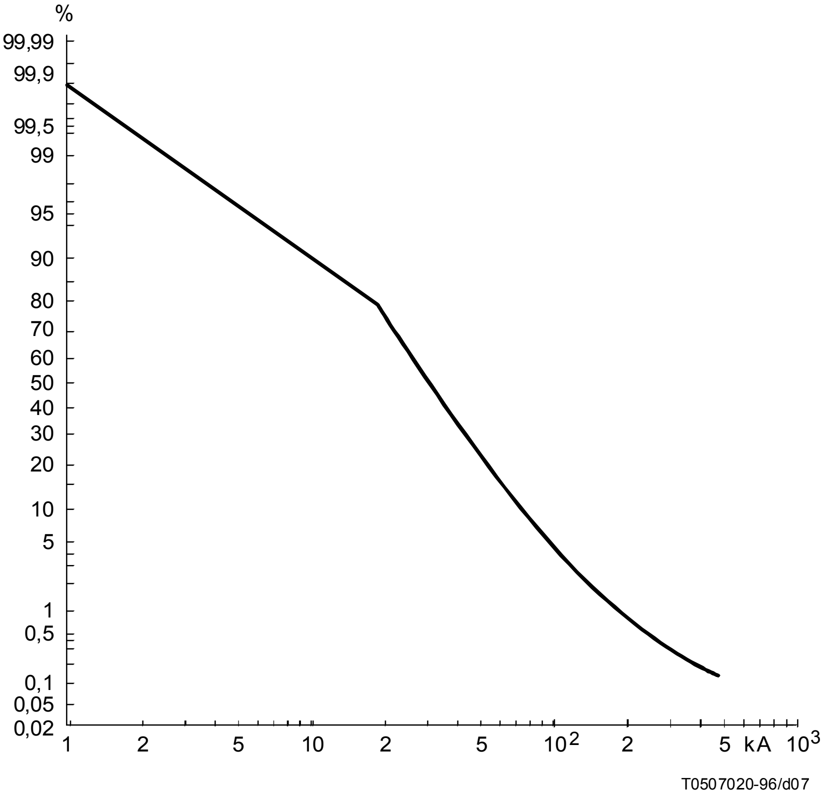

FIGURE 7/K.25

Cumulative lightning peak current distribution to both buried and aerial structures

6.3 Frequency of primary failures or annual damage rate for aerial cables

The direct lightning flash frequency, N_d, for a length of aerial cable can be calculated as follows:

$$N_d = N_g \cdot A_e \tag{21}$$

$$A_e = 2 \cdot 1000 \cdot F_d \cdot H \cdot L \tag{22}$$

where:

A_e is the effective lightning collection area.

$F_d = 3$ is the stroke diversion factor for telephone lines, and all other variables are as defined previously.

The N_{pa} is assessed by multiplying the flashes/year, N_d, by the probability of the failure current, I_a, to aerial cables:

$$N_{pa} = N_d \cdot p(\geq I_a) \text{ primary failures/year} \tag{23}$$

where:

p is the probability for the lightning peak current to be equal to or higher than the I_a value. Figure 7 provides the probability distribution of lightning stroke current to aerial structures.

I_a is the failure lightning current (3.10); e.g. the current which causes primary failures and will depend on the cable design (5.1).

NOTE – The protection correction factor K_d is not introduced because equation (16) allows a conservative evaluation of the number of direct strokes to an aerial cable.

The inverse of the N_p due to lightning will yield the mean time between primary failure in years.

6.4 Frequency of primary failures due to direct lightning strokes to exposed structure that the optical fibre cable enters

The lightning current of a direct stroke to an exposed structure flows into the earthing system of the structure and into the services entering the structure itself. Therefore a part of the lightning current enters the cable connection and the cable sheath of the optical fibre cable.

This current can cause primary failures when it is higher that the sheath current, I_s, or than the connection current, I_c.

Consequently, the frequency of damages, N_{ps}, is estimated by using the following equation:

$$N_{ps} = N_d \cdot p(I) \tag{24}$$

where:

N_d is the direct lightning flash frequency to the exposed structure and to adjacent structures and is calculated using reference [8].

I is the peak value of the lightning current striking the structure which causes a breakdown sheath current, I_s, or the connection current, I_c, in the cable sheath or in the cable connection respectively. This lightning current, I, is estimated assuming that 50% of the lightning current striking the exposed structure flows into the earthing system of the structure and the remaining 50% of the current is shared between several services entering the structure.

p(I) probability of the peak value of the lightning current striking the exposed structure, evaluated using Figure 7.

7 Protective measures

7.1 General

The metallic elements of an optical fibre cable shall be continuous, i.e. it shall be connected across all splices, regenerators, etc., along the length of the cable. The metallic elements shall be connected to the equipotential bonding bar (e.p.b.b.), either directly or through a SPD, at the ends of the cable (Figure 8).

Interconnection of single metallic components such as armouring, moisture barrier or strength member at splices or joints can be avoided in cables which do not use metallic conductors for signals or power (see Note in 7.4).

If the e.p.b.b. of the subscriber building is not available, the metallic elements of the optical fibre cable shall be connected to a dedicated e.p.b.b. inside the Optical Network Termination.

For optical fibre cables with metal elements, the following protective measures are usually considered:

- use of dielectric or metal-free cables;
- choice of the cable type for both buried and aerial cables;
- use of the shield wires for buried cables;
- earthing of the metal sheath along the route for aerial cables only (see 5.1);
- route redundancy for both buried and aerial cables;
- use of surge arresters for the protection of the metallic pairs of both buried and aerial cables.

NOTES

1 For the use of surge arresters on metallic pairs, see the Recommendation K.11 “Principles of protection against overvoltages and overcurrents” [4].

2 Earthing of the metal sheath along the route for buried cables, having metal elements in the cable core, is not considered because the effectiveness of such protective measure is negligible on the reduction of primary failures number.

3 Cables leading to exposed structures [8] can need to be protected by additional protective measures according to [2] in order to reduce N_{ps} (6.4).

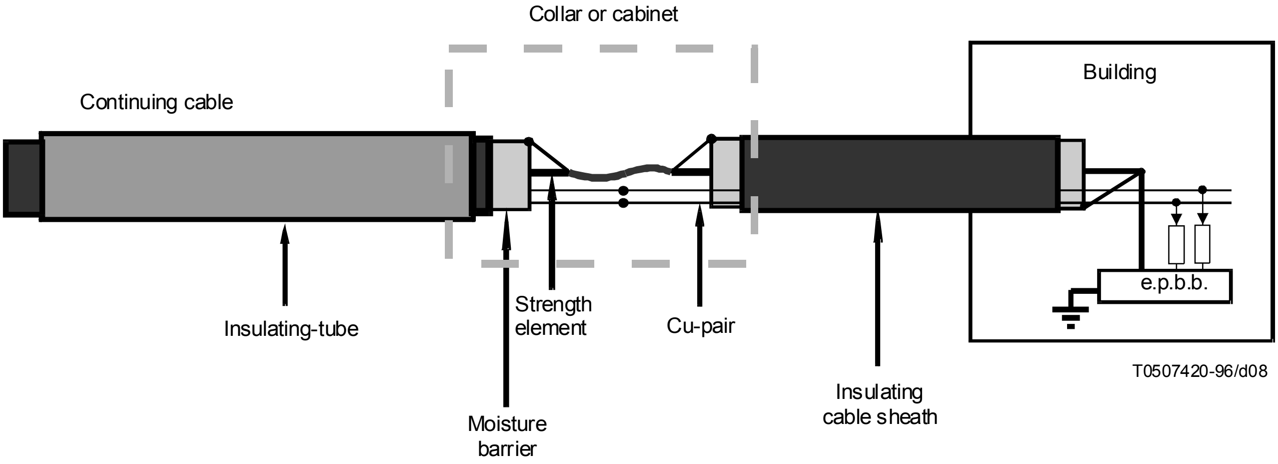

FIGURE 8/K.25

Example of metallic elements connection

7.2 Dielectric or metal-free cables

The use of dielectric or metal-free cables will prevent cable damage due to lightning.

NOTE – For buried cables, the lowered resistance of the cable to moisture penetration and the difficulty of locating them during subsequent maintenance activities should be considered. Moreover metallic cables in the same ditch may be hit by direct lightning strikes and, as a consequence, the optical cable could also be destroyed (such damages are, until now, unknown). The same kind of problem may appear when a metal-free cable is accompanied by a metallic conductor (used to locate the optical cable).

7.3 Choice of cable characteristics for both buried and aerial installations

Each cable type has its own specific value of failure lightning current, I_a, which is evaluated as indicated in 5.1.

The choice of the cable type implies a specific value of failure lightning current, I_a, which must be put into equation (15) or (23) to calculate the frequency of primary failures, N_{pb} and N_{pa} respectively.

The higher the value of I_a, the lower the value of N_p.

7.4 Use of shield wire for buried cables

The probability of damage to buried cable can be reduced by the use of shield wires.

Shield wires intercept a portion of the stroke current thus reducing the amount of current striking the cable.

For properly installed shield wires, the shield factor value, denoted by η, implies that $100\eta\%$ of the stroke current flows on the cable sheath. Shield factor values can be calculated with the method reported in Appendix I.

Improvement to the frequency of primary failures, N_p, due to shield wires can be calculated as follows:

$$N_p = K_d \cdot N_d \cdot p(\geq I_a/\eta) \tag{25}$$

where:

$K_d = 3$ is the protection correction factor, defined in 3.17.

N_d is the expected average annual number of direct lightning flashes to the cable (3.7), calculated with equation (7).

p is the probability for the lightning peak current to be equal to or higher than I_a/η value.

I_a is the failure lightning current.

η is the shield factor.

NOTE – In the case of a metal free-cable core (i.e. there is only one metallic component, the sheath), the protection against induction from electrical lines can be obtained keeping the sheath(s) continuous at splices, providing earthing at repeaters and providing earth electrodes at splices only where required to limit the sheath to earth voltage to a value below the breakdown voltage limits.

The installation of shield wire(s) also allows the use of an another coordinated protection scheme, the interruption of the metallic sheath, i.e. the moisture barrier, at each splice or additionally at intermediate locations as required to keep the induced sheath to earth voltage values below the breakdown voltage limits [3].

7.5 Route redundancy

The overall service availability can be improved by implementing route redundancy using a second parallel route which may be required for other reasons such as the need for increased facilities.

In such a case, the method presented in 3.5 and 4.3 of [1] can aid in deciding the optimal route separation distance to improve the overall service availability for buried and aerial cables respectively.

Appendix I

Shielding factor values

I.1 Definition of the shielding factor

The goal of this appendix is to propose simple formulas able to estimate the shielding factor η mentioned in 7.4.

According to [6], when a direct stroke makes contact with the shield wire or a metallic cable sheath, the voltage between these conductors will be large enough to produce an arcing between them; so, they can be considered interconnected at the arcing point and only a part of the lighting current will flow on the cable sheath thus reducing the probability of a primary failure.

In such a way, if I_{sh} and I'_{sh} are sheath current without and with shield wire respectively, the shielding factor η is defined as:

$$\eta = \frac{I'_{sh}}{I_{sh}} \qquad \text{(I-1)}$$

I.2 Shielding factor with one shield wire

The expression is:

$$\eta = \frac{\log \dfrac{r_{12}}{r_{22}}}{\log \dfrac{r_{12}^2}{r_{11} \cdot r_{22}}} \qquad \text{(I-2)}$$

where (see Figure I.1):

r_{11} is the mean radius of the sheath

r_{22} is the radius of the shield wire

r_{12} is the distance between their axes

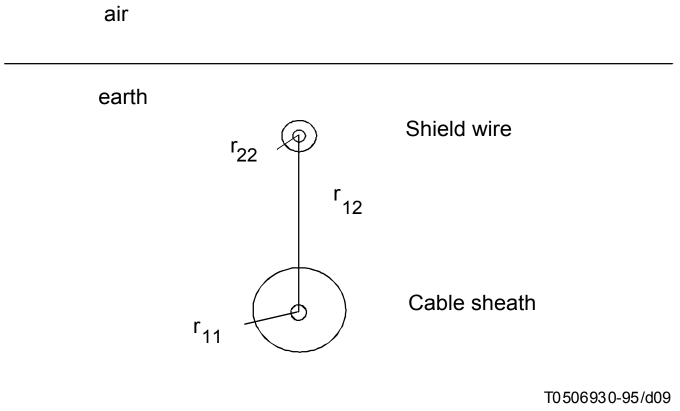

FIGURE I.1/K.25

Cable protected with one shield wire

I.3 Shielding factor expression with two shield wire symmetrically disposed with respect to the axis of the cable

The expression is [7]:

$$\eta = \frac{\log \dfrac{r'_{12}}{r'_{22}}}{\log \dfrac{r'^{2}_{12}}{r'_{11} \cdot r'_{22}}} \qquad r'_{12} > (2 \cdot r_{11} \cdot h)^{0.5} = r'_{11} \qquad \text{(I-3)}$$

where (see Figure I.2):

r'_{12} is the distance between the axis of the cable and one of the shield wires

$$r'_{11} = (2 \cdot r_{11} \cdot h)^{0.5}$$

r_{11} is the mean radius of the sheath

$$r'_{22} = (2 \cdot r_{22} \cdot h' \cdot b \cdot b')^{0.25}$$

r_{22}	is the radius of the shield wire
h	is the buried depth of the cable
h'	is the buried depth of the shield wires
b	is the distance between the shield wires
$b' = \sqrt{b^2 + 4 \cdot h'^2}$	is the distance between one shield wire and the image of the other one with respect to the air-soil interface

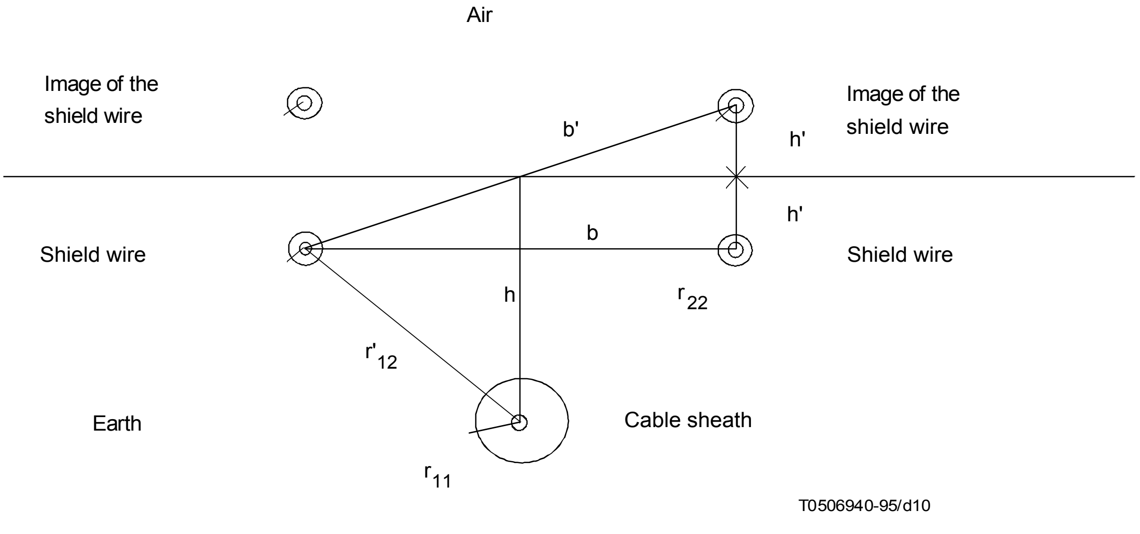

FIGURE I.2/K.25

Cable protected with two shield wires

I.4 Example of application

By considering the following cable data:

$r_{11} = 0.02$ m

$h = 0.5$ m

and the following shield wire data:

$r_{22} = a' = 0.004$ m

$h' = 0.3$ m

$b = 0.4$ m

the following values of η are obtained:

$h = 0.63$ for one shield wire

$h = 0.45$ for two shield wires

Appendix II

Accepted frequency of primary failures (N_a)

The damages caused by lightning to optical fibre installations may produce unacceptable loss of services to the public. In this case, the decision whether or not to provide protective measures should be taken by a comparison of the actual value of frequency of primary failures, N_p, to the optical fibre installation with the limit value of the accepted frequency of primary failures N_a, fixed by each Network Operator.

The value N_a can be estimated with the following equation:

$$N_a = R_a / \delta$$

where:

R_a	accepted maximum level of the risk of damage
$\delta = n' \cdot t'/n \cdot 8760$	relative amount of the expected losses per damage
n'	average number of user effected by the loss of service per damage
t'	yearly time, in hours, of service loss per damage
n	total number of user involved in the service

Representative values of R_a and N_a, suggested by this Recommendation, are:

$$N_a = 0.1 \qquad R_a = 10^{-4}$$

therefore:

$$\delta = 10^{-3}$$

Table II.1 shows the time of service loss per damage for different possible values of the ratio n' n.

TABLE II.1/K.25

Time of service loss per damage (t')

n'/n	t' [hours]
0.1	88
0.2	44
0.3	30
0.4	22
0.5	18
1	9