INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

K.25

(02/2000)

SERIES K: PROTECTION AGAINST INTERFERENCE

Protection of optical fibre cables

ITU-T Recommendation K.25

(Formerly CCITT Recommendation)

ITU-T RECOMMENDATION K.25

PROTECTION OF OPTICAL FIBRE CABLES

Summary

This Recommendation provides a procedure to protect the telecommunication lines using fibre optics against direct lightning discharges to the line itself or to the structures that the line enters. The protection procedure is related to the exposure of the line to direct lightning discharges and includes the selection of cable characteristics/installation, use of shield wires, bonding/earthing of the cable shield, installation of surge protective devices (SPD) and route redundancy.

Source

ITU-T Recommendation K.25 was revised by ITU-T Study Group 5 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on 25 February 2000.

FOREWORD

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

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

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As of the date of approval of this Recommendation, the ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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PROTECTION OF OPTICAL FIBRE CABLES

(Melbourne, 1988, revised in 1996 and 2000)

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 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 tolerable frequency of primary failures.

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

2 References

The following ITU-T 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] CCITT Recommendation K.29 (1992), *Coordinated protection schemes for telecommunication cables below ground*.

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

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

3 Definitions

This Recommendation defines the following terms:

3.1 primary failure: Damage caused by a lightning strike in a telecommunication line that has as consequence the interruption of service.

3.2 frequency of primary failures (F_p): Average annual number of expected primary failures in an optical fibre installation due to direct lightning flashes.

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

3.4 tolerable frequency of primary failures (F_a): Average annual frequency of primary failures in an optical fibre installation not requiring additional protective measures.

3.5 tolerable risk of primary failures (R_a): Maximum level of the risk of primary failures (R_d) due to direct lightning flashes not requiring additional protective measures.

3.6 direct lightning flash: Lightning flash to an aerial cable or to the ground surface near to a buried cable, in which it is assumed that all lightning current is conducted to the cable.

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

3.8 striking distance (D): Distance from a buried cable that, when multiplied by 2, by the line length (L) and the ground flash density (N_g), gives the direct lightning flash frequency (N_d) of the cable.

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

3.10 sheath breakdown current (I_s): Minimum current flowing in the metallic sheath which causes breakdown voltages between metallic elements inside the cable core and the metallic sheath, thus leading to primary failures.

3.11 connection current (I_c): Minimum current flowing in the interconnecting elements that causes a primary failure due to thermal or mechanical effects.

3.12 interconnecting elements: Metallic elements connecting metallic sheath(s) or the metallic strength member(s) of optical fibre cable at joints and cable ends.

3.13 test current (I_t): Minimum current injected by arc in the cable metallic sheath that causes a primary failure due to thermal or mechanical effects.

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

3.15 damage correction factor (K_d): Factor which allows a conservative evaluation of the frequency of primary failures.

3.16 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.

3.17 equipotential bonding bar (E.B.B.): An electrically conductive bar whose electric potential is used as common reference, and to which metallic parts within the installation can be bonded.

3.18 direct lightning current to aerial cables (J): Minimum lightning current which strikes an aerial cable causing a flashover to ground.

3.19 exposed structure: A structure, e.g. telecommunication tower, high building, which needs to be protected against direct lightning strokes.

3.20 keraunic level or thunderstorm days (T_d): Number of days per year in which thunder is heard in a given location.

3.21 ground flash density (N_g): Average number of lightning flashes to ground per square kilometre per year, concerning the region where the structure or the optical fibre cable is located.

3.22 lightning collection area: Area of ground surface which has the same annual frequency of direct lightning as the structure or the line.

4 Reference configuration

Figure 1 represents the reference configuration for the optical fibre installations, where the connections with optical fibre cables between two Switches, between Switch and Line Termination and between Switch and line Equipment are shown.

NOTE – For the protection against lightning of the metallic cable installation between Equipment and Subscriber, the requirements requested by reference [2] shall be considered.

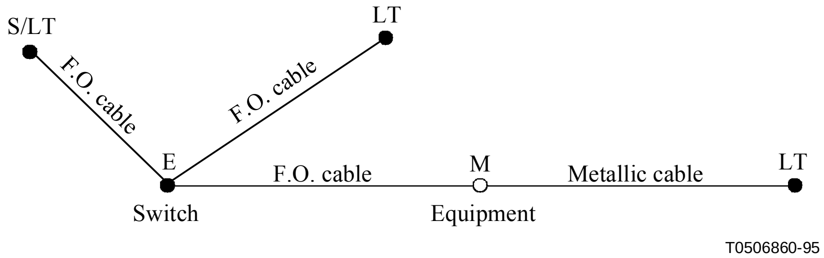


Figure 1/K.25 – Reference configuration

5 Construction characteristics of the cable

5.1 General

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

– type A: cable with dielectric core but having no metal elements (dielectric or metal-free cable);

– type B: 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;

– type C: cable with metal elements in the core and with 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;

– type D: cable with metal elements in the core and without a metal sheath.

For cable types B, C and D, the value of failure current (I_a) shall be evaluated, except for cables with more than one metal sheath.

5.2 Failure current for buried cable or aerial cable with earth connections of the metal sheath

The failure current (I_a) is the lower value among the following values (see Figure 2):

– twice the connection current (I_c) evaluated with the test for surge current resistibility of the interconnecting elements (C.3);

– the test current (I_t) evaluated with the test for surge current resistibility shown in C.4 for buried cables or C.5 for aerial cables (see Bibliography [2]);

– for type C cables, twice the sheath breakdown current (I_s) flowing in the cable metallic sheath (with or without an insulating covering). This current is calculated using the procedure of Annex B.

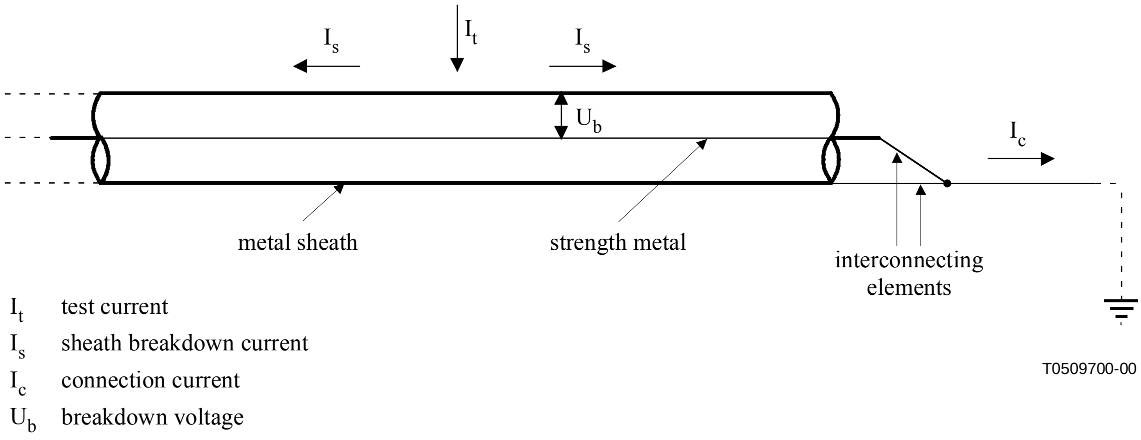


Figure 2/K.25 – Lightning currents in an optical fibre cable

Then:

$$I_a = I_t \text{ if } I_t < 2I_s \text{ and } I_t < 2I_c \tag{1}$$

or:

$$I_a = 2I_s \text{ if } I_t > 2I_s \text{ and } I_s < I_c \tag{2}$$

or:

$$I_a = 2I_c \text{ if } I_t > 2I_c \text{ and } I_c < I_s \tag{3}$$

5.3 Failure current for aerial cable without earth connections of the metal sheath

This type of cable is supposed to be installed in wood poles without ground wires nor shortly spaced guy wires. The failure current (I_a) for such a cable is the lower value among the following values (see Figure 2):

– twice the connection current (I_c) evaluated with the test for surge current resistibility of the interconnecting elements (C.3);

– the test current (I_t) evaluated with the test for surge current resistibility shown in C.5 for aerial cables (see Bibliography [2]);

– for type C cables, the direct lightning current (J) which strikes the aerial cable causing a flashover to ground. This current is calculated using the procedure of Annex B.

Then:

$$I_a = I_t \text{ if } I_t < J \text{ and } I_t < 2I_c \tag{4}$$

or:

$$I_a = J \text{ if } I_t > J \text{ and } J < 2I_c \tag{5}$$

or:

$$I_a = 2I_c \text{ if } I_t > 2I_c \text{ and } 2I_c < J \tag{6}$$

6 Need for protection

The need for lightning protection of optical fibre installation depends on the frequency of primary failures (F_p) and its tolerable frequency of primary failures (F_a). The frequency of primary failures (F_p) is given by the following equation:

$$F_p = F_{pb} + F_{pa} + F_{ps} \tag{7}$$

where:

- F_{pb} is the frequency of primary failures to buried cables
- F_{pa} is the frequency of primary failures to aerial cables
- F_{ps} is the frequency of primary failures due to direct lightning strokes to exposed structures that the optical fibre cable enters

If the frequency of primary failures (F_p) is higher than the tolerable frequency of primary failures (F_a), protective measures are necessary to reduce F_p and minimize the risk of primary failures (R_d).

The risk of primary failures is estimated with the following equation (see Appendix II):

$$Rd = Fp \cdot \delta \tag{8}$$

where δ is the relative amount of the expected losses per primary failure.

Therefore:

$$R_d = F_{ps} \cdot \delta_s + (F_{pb} + F_{pa}) \cdot \delta_d \tag{9}$$

Each Network Operator should define the tolerable frequency of primary failures (F_a) and the tolerable risk of primary failures (R_a). Values of F_a and R_a are suggested in Appendix II.

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.B.B.) either directly or through a SPD, at the ends of the cable (see Figure 3).

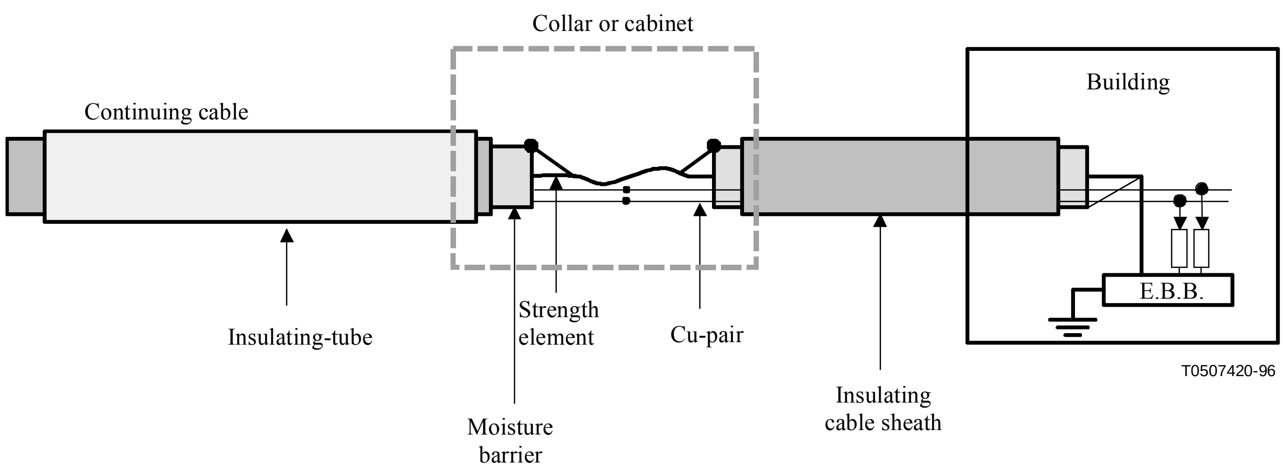


Figure 3/K.25 – Example of metallic elements connection

If the E.B.B. of the subscriber building is not available, the metallic elements of the optical fibre cable shall be connected to a dedicated E.B.B. inside the optical network termination.

For optical fibre cables with metallic 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 (see 5.2);
– 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.

NOTE 1 – For the use of surge arresters on metallic pairs, see reference [2].

NOTE 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 the frequency of primary failures.

NOTE 3 – Cables leading to exposed structures may need to be protected by additional protective measures (see reference [3] and Bibliography [2]).

7.2 Dielectric or metal-free cables

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

NOTE 1 – A non-metallic aerial cable is not directly susceptible to lightning damage. In fact, until now there has been no experience of such damage.

NOTE 2 – 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 current (I_a) which is evaluated as indicated in clause 5. The choice of the cable type implies a specific value of failure current (I_a) and, the higher the value of I_a, the lower the frequency of primary failure, as can be calculated in Annex A.

7.4 Use of shield wire for buried cables

The probability of damage to buried cables 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 shielding 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 shown in Appendix I.

Improvement to the frequency of primary failures (F_p) due to shield wires can be calculated as follows:

$$F_p = N_d \cdot p\left(\frac{I_a}{\eta}\right) \tag{10}$$

where:

N_d expected average annual number of direct lightning flashes to the cable (see Annex A);

p probability for the lightning peak current to be equal to or higher than I_a/η (see Annex A);

I_a failure current (see clause 5);

η shielding factor (see Appendix I).

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 Bibliography [1] can aid in deciding the optimal route separation to improve the overall service availability for buried and aerial cables.

ANNEX A

Frequency of primary failures

A.1 Buried cable

The frequency of primary failures for buried cables (F_{pb}) is estimated with the following equation:

$$F_{pb} = N_d \cdot p(I_a) \quad \text{[damages/year]} \tag{A-1}$$

where:

p is the probability for the lightning peak current to be equal or higher than I_a, which is expressed by the following equation:

$$p(i) = 10^{-2} \cdot e^{(a-bi)} \text{ for } i \geq 0 \quad (i \text{ in } kA) \tag{A-2}$$

where:

a = 4.605 and b = 0.0117 for i < 20 kA

a = 5.063 and b = 0.0346 for i ≥ 20 kA

I_a failure current [kA]

N_d direct lightning flash frequency, calculated with the following equation:

$$N_d = K_d \cdot N_g \cdot Ke \cdot 2DL/1000 \text{ [strokes/year]} \tag{A-3}$$

where:

K_d is the damage correction factor

NOTE – In order to get a conservative evaluation of the striking distance, the damage correction factor shall be set equal to 2.5. Otherwise, it shall be set equal to 1.

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

$$N_g = 0.04 \cdot T_d^{1.25} \tag{A-4}$$

where:

T_d is the keraunic level of the region

K_e is the environmental factor (see Appendix III)

L is the line length in km

D is the striking distance, in metres, and is calculated using the following equations:

$$D = 0.482\ \rho^{1/2}\ [\mathrm{m}]; \quad \text{for } \rho \le 100\ \Omega.\mathrm{m} \tag{A-5}$$

$$D = 0.283\ \rho^{1/2}\ [\mathrm{m}]; \quad \text{for } \rho \ge 1000\ \Omega.\mathrm{m} \tag{A-6}$$

$$D = 0.191\ \rho^{1/2} + 2.91\ [\mathrm{m}]; \quad \text{for } 100\ \Omega.\mathrm{m} < \rho < 1000\ \Omega.\mathrm{m} \tag{A-7}$$

where:

ρ is the soil resistivity in Ω.m, which can be found from soil resistivity maps or measured.

A.2 Aerial cables

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

$$N_d = N_g \cdot A_e \tag{A-8}$$

$$A_e = 6 \cdot K_e \cdot H \cdot L / 1000 \tag{A-9}$$

where:

A_e effective lightning collection area in km^2

K_e environmental factor (see Appendix III)

H line height in metres

The F_{pa} is assessed by multiplying the direct lightning flash frequency (N_d) by the probability of the failure current (I_a) to aerial cables:

$$F_{pa} = N_d \cdot p(I_a) \text{ primary failures/year} \tag{A-10}$$

where:

p probability for the lightning peak current to be equal to or higher than I_a [see equation (A-2)];

I_a failure current [kA].

A.3 Cables entering a structure exposed to direct lightning strokes

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 than the sheath breakdown current (I_s) or than the connection current (I_c).

Consequently, the frequency of primary failures (F_{ps}) is estimated by using the following equation:

$$F_{ps} = N_d \cdot p(I) \tag{A-11}$$

where:

- N_d is the direct lightning flash frequency to the exposed structure and to adjacent structures and is calculated using reference [3].
- 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 equation (A-2).

ANNEX B

Sheath breakdown current

B.1 Buried cable

The sheath breakdown current (I_s) of the cable with metal elements in the core and with one metal sheath, with or without an insulating protective covering, may be estimated from the following equation:

$$I_s \cong U_b / (K \cdot R \cdot \rho^{1/2}) \text{ [kA]} \tag{B-1}$$

where:

- $K = 8$ $[(\mathrm{m}/\Omega)^{0.5}]$ is the waveshape factor for lightning current (10/350 μs waveform)
- R is the sheath resistance per unit length [Ω/km]
- U_b is the breakdown voltage [V] of the cable, evaluated with the test indicated in C.2
- ρ is the soil resistivity (Ω.m)

B.2 Aerial cable

Primary failures in optical fibre cables in aerial routes can occur in cases where metal is present in the sheath and in the core of the cable. The lightning current in the sheath may cause breakdown between the sheath and the core. Fibre damage is possible if the fibres are near or in the path of the resultant arc. The methodology given below assumes that the breakdown voltage between the core and the metal sheath is known.

B.2.1 Aerial cable without earth connections of the metal sheath

When the lightning strikes an aerial cable, a large percentage of the lightning current (J) arcs to ground.

The sheath breakdown current (I_s) is evaluated as follows, with the assumption that the cable is long (see Bibliography [3]):

$$I_s \cong \frac{U_b}{\Phi \cdot R} \quad \text{[kA]} \tag{B-2}$$

where:

$\Phi = 2000$ [m] is the waveshape factor

The lightning current (J) can be estimated with the following equation (see Bibliography [4]):

$$J = 4\frac{I_s^2}{k}\ \mathrm{J} \qquad \text{(B-3)}$$

where:

k = rE_O / S^2

E_O is the soil surface breakdown voltage gradient and is approximately 250 kV/m for $\rho \leq 100\ \Omega$.m and 500 kV/m for $\rho \geq 1000\ \Omega$.m

S is the surge impedance of the sheath (it is approximately 400 Ω for an aerial cable; see Bibliographies [1] and [4] for a more precise evaluation)

B.2.2 Aerial cable with earth connections of the metal sheath

The sheath breakdown current (I_s) for a given breakdown voltage is assessed by the following equation:

$$I_s \cong \frac{U_b}{K \cdot R \cdot \rho_e^{\frac{1}{2}}} \qquad \text{(B-4)}$$

where:

ρ_e is the effective earth resistivity in Ω.m, which is defined as:

$$\rho_e = \frac{\pi d \cdot R_g}{\ln\left(2 \cdot \frac{H}{a}\right)} \qquad \text{(B-5)}$$

where:

d is the spacing between earthing points, in metres (d is assumed to be short, so that reflections occur long before the crest voltage or current is reached)

H is the height of the cable in metres

a is the radius of the cable in metres

R_g is the resistance of the earthing points in Ω

ANNEX C

Tests for surge current resisitivity

C.1 General

The tests reported in this annex are convenient only for risk evaluation associated with lightning in fibre optic installations and are not applicable for the qualification of a cable design. They shall not be repeated unless the cable construction characteristics are significantly changed. Under the cable manufacturer's responsibility, the test results on one type of cable can be used for another cable with similar characteristics from the construction point of view.

The voltage generator for the breakdown voltage test shall have an open circuit voltage with a 1.2/50 µs waveform. The current generator for the test for surge current resistibility of optical fibre cables is under study. The following current waveforms, measured with the test sample in place, are suggested:

– 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 between 40 and 70 μs.

For the tests described in C.3, C.4 and C.5, the occurrence of a primary failure is detected by at least one of the following:

– breakage of one or more optical fibres;
– unacceptable increase in attenuation of the optical fibre;
– interruption in the remote power supply, if the equipment is powered by metallic conductors inside the optical cable.

C.2 Breakdown voltage test

A cable sample 5 m 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 is made by the metallic sheath isolated from the other conducting elements. The sheath termination shall be treated in order to reproduce, as closely as possible, the conditions of a real installation. A surge voltage generator shall be placed between the two terminals. The test voltage is measured during the test. Following the application of test voltages in ascending amplitudes, the test identifies a threshold value of surge voltage which causes a breakdown.

C.3 Test for surge current resistibility of the interconnecting elements

A cable sample 1 m in length shall be used for the test. The metallic sheath(s) and the metallic strength member(s) 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 C.1). The test current is measured during the test. Following the application of currents in ascending amplitudes, the sample is tested for loss of its performance according to C.1. The test identifies a threshold value of surge current which causes primary failure.

C.4 Sand box test for buried cables

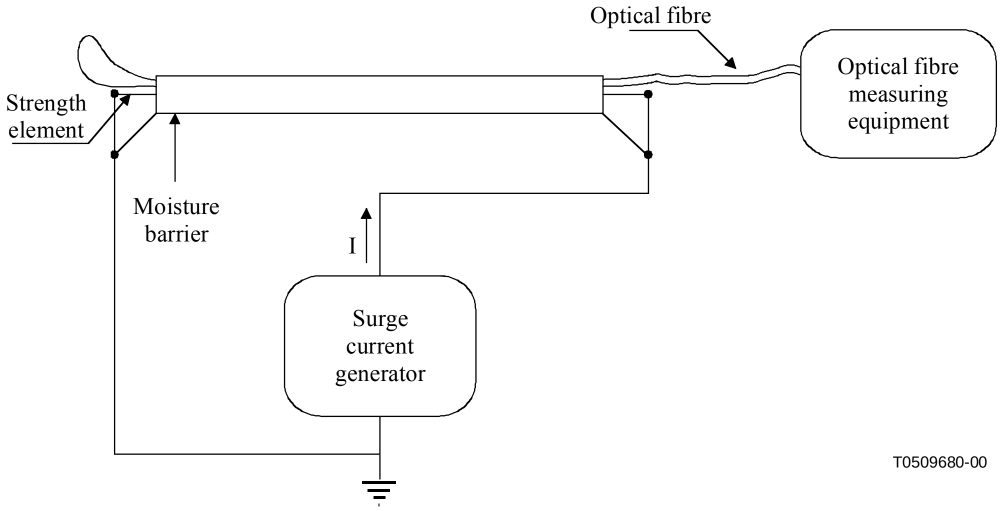
A cable sample 1 metre in length shall be immersed in wet sand contained in a non-conducting rigid box having a minimum length of 0.75 m in all inside linear dimensions (Figure C.2). The box shall have two holes in the bottom for water drainage, approximately 25 mm in diameter. The sand shall be 20-40 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. The metallic sheath(s) and the metallic strength member(s) in the cable shall be electrically connected together to form one terminal and a current generator shall be connected between this terminal and the discharge electrode (Figure C.2). In order to let the test current flow through the sample, any insulation covering the outer metallic sheath 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 cannot break down the air-gap, a thin wire shall connect the discharge electrode with the metallic sheath. The test current shall be measured during the test. Following the application of discharge currents in ascending amplitudes, the sample is tested for loss of its performance according to C.1. The test identifies a threshold value of surge current which causes primary failure.

C.5 Test for aerial cables

A cable sample 1 metre in length shall be in tension according to the manufacturer's specifications. A discharge electrode shall be located near the sample at a distance of 26 ± 1 mm. The metallic sheath(s) and the metallic strength member(s) in the cable shall be electrically connected together to form one terminal and a current generator shall be connected between this terminal and the discharge electrode.

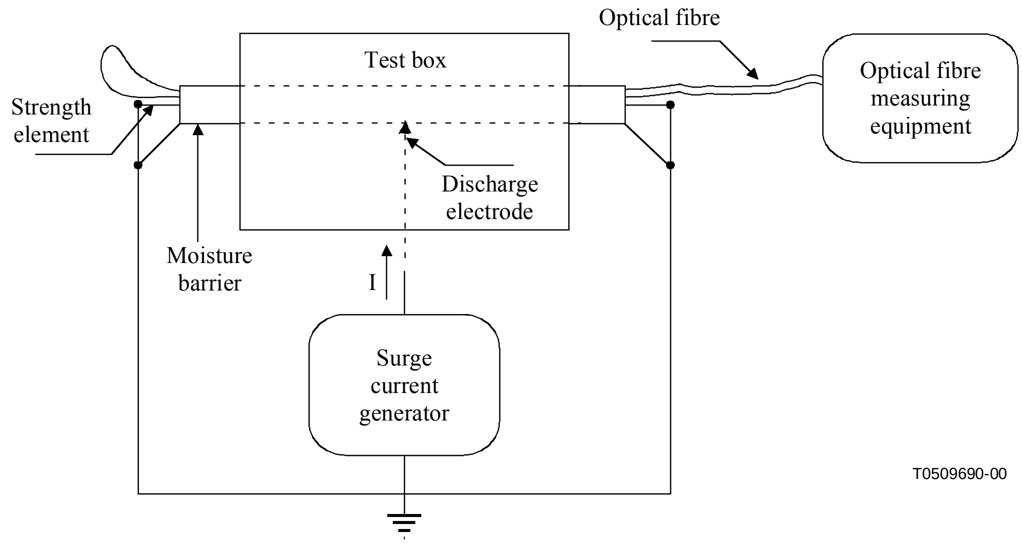
In order to let the test current flow through the sample, any insulating covering the outer metallic sheath shall be opened with a small slit or hole with a 1 mm diameter tool facing the discharge electrode. If the voltage of the test generator cannot break down the air-gap, a thin wire shall connect the discharge electrode with the metallic sheath.

The test current shall be measured during the test. Following the application of discharge currents in ascending amplitudes, the sample is tested for loss of its performance according to C.1. The test identifies a threshold value of surge current which causes primary failure.



NOTE – After the application of the test current, all optical fibres in the cable shall be tested.

Figure C.1/K.25 – Scheme for surge current resistibility test of interconnecting elements



NOTE – After the application of the test current, all optical fibres in the cable shall be tested.

Figure C.2/K.25 – Scheme for surge current resistibility test

APPENDIX I

Shielding factor

I.1 Shielding factor for one shield wire

When there is only one shield wire, the shielding factor is given by:

$$\eta = \ln (x/s) / \ln (x^2/s\ r) \tag{I-1}$$

where [see Figure I.1 (a)]:

- x distance between the axes of the cable and the shield wire
- r radius of the sheath
- s radius of the shield wire

Tables I.1 and I.2 give values of shielding factor for different sizes of conductors and spacing. It can be realized from these tables that the shielding factor for one shield wire is in the range from 0.5 to 0.7. It shall be noted that a shield wire laid over a buried cable also has the function to protect the cable against mechanical damage due to accidental digging.

Table I.1/K.25 – Shielding factor for r = 10 mm

x(m)	s = 2 mm	s = 3 mm	s = 5 mm	s = 8 mm	s = 12 mm
0.15	0.61	0.59	0.56	0.52	0.48
0.25	0.60	0.58	0.55	0.52	0.49
0.50	0.59	0.57	0.54	0.51	0.49
1.00	0.57	0.56	0.53	0.51	0.49

Table I.2/K.25 – Shielding factor for r = 20 mm

x(m)	s = 2 mm	s = 3 mm	s = 5 mm	s = 8 mm	s = 12 mm
0.15	0.68	0.65	0.62	0.59	0.55
0.25	0.65	0.63	0.60	0.57	0.54
0.50	0.63	0.61	0.59	0.56	0.54
1.00	0.61	0.60	0.58	0.55	0.53

I.2 Shielding factor for multiple shield wires

When the number of shield wires increases, the equations become more complex so that it is more useful to compute them in order to make some tables with practical values. The cable and shield wire radius are kept constant with the values r = 10 mm and s = 5 mm. The effect of variations in these parameters is small and can be estimated from Tables I.1 and I.2. Table I.3 shows values of shielding factor for two shield wires disposed in a circle around the cable, where the angle g is with respect to the vertical [see Figure I.1 (b)]. It can be realized that the distance x between the shield wires and the cable has little effect on the shielding factor. For the other tables this value is kept constant as x = 0.25 m.

Table I.3/K.25 – Shielding factor for two wires disposed in a circle around the cable

x(m)	g = 30°	g = 45°	g = 60°	g = 90°
0.15	0.38	0.36	0.34	0.33
0.25	0.38	0.35	0.34	0.33
0.50	0.37	0.35	0.34	0.33
1.00	0.37	0.35	0.34	0.33

The same calculations have been performed for three wires disposed in a circle around the cable, where the angle g is with respect to the vertical [see Figure I.1 (c)]. The values are shown in Table I.4, where x = 0.25 m.

Table I.4/K.25 – Shielding factor for three wires disposed in a circle around the cable

g = 30°	g = 60°	g = 90°	g = 120°
0.33	0.26	0.23	0.22

Table I.5 shows the results for multiple wires disposed symmetrically in a circle around the cable [see Figures I.1 (d), I.1 (e) and I.1 (f)]. The variable n denotes the number of wires and x = 0.25 m.

Table I.5/K.25 – Shielding factor for n wires symmetrically disposed in a circle around the cable

n = 4	n = 6	n = 8
0.16	0.09	0.06

I.3 Minimum length of buried shield wires

In order to protect a telecommunication line in an exposed environment, a buried shield wire shall follow the cable in all extensions of the exposed section and it shall also be continued for a length Y beyond this section. The same procedure applies for the protection of lines entering exposed structures, where the shield wire shall follow the cable route from the exposed structure for a length Y. Naturally, the shield wires shall be bonded to the cable sheath and the structure earthing system.

The length Y can be evaluated by equation (I-2):

$$Y \geq 5 \cdot (\rho)^{1/2} \quad [\mathrm{m}] \tag{I-2}$$

where:

ρ = soil resistivity in Ω.m.

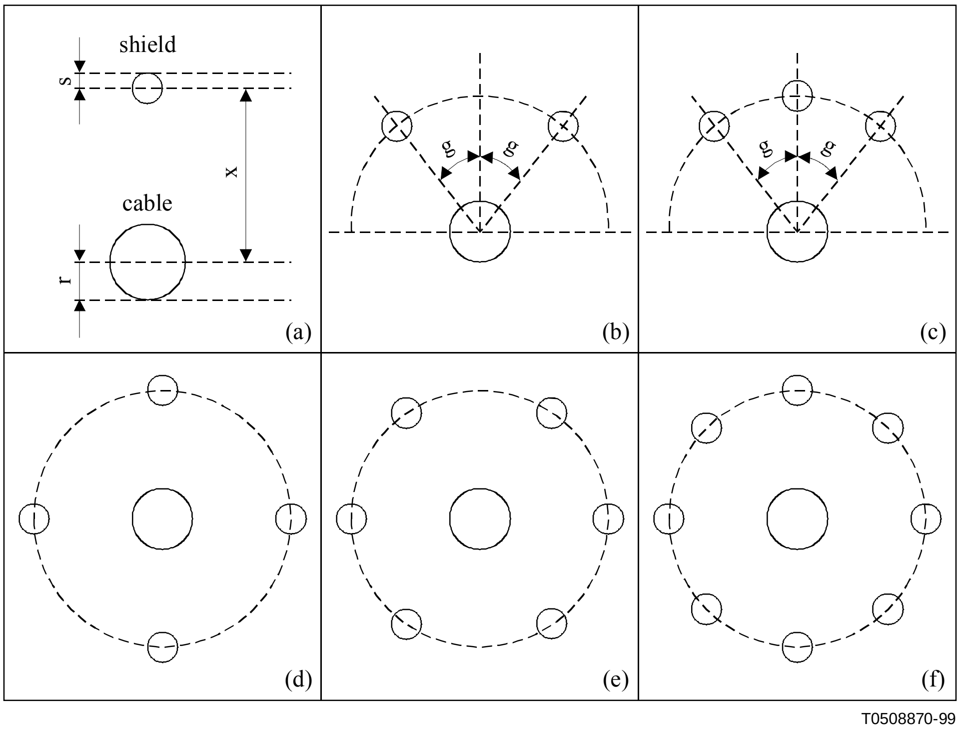


Figure I.1/K.25 – Configurations of shield wires

APPENDIX II

Tolerable frequency of primary failures (F_a)

The damage caused by lightning to optical fibre installations may produce an 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 (F_p) to the optical fibre installation with the limit value of the tolerable frequency of primary failures (F_a), fixed by each Network Operator.

The value F_a can be estimated with the following equation:

$$F_a = \frac{R_a}{\delta} \qquad \text{(II-1)}$$

where:

R_a tolerable risk of primary failures

δ relative amount of the expected losses per damage

The following values of R_a and δ are suggested:

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

$$R_a = 10^{-4}$$

Therefore:

$$F_a = 0.1$$

APPENDIX III

Environmental factor (K_e)

The evaluation of K_e shall be performed based on the typical construction parameters of the region considered:

– Urban area with tall buildings (above 6 floors): $K_e = 0.01$

– Urban area with medium buildings (between 3 and 6 floors): $K_e = 0.1$

– Suburban area with houses (one or two floors): $K_e = 0.5$

– Rural area without constructions (flat ground): $K_e = 1$

– Rural area without constructions (top of hill): $K_e = 2$

APPENDIX IV

Bibliography

[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] 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.

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

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

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Printed in Switzerland
Geneva, 2000