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PART II

Series L Recommendations

CONSTRUCTION, INSTALLATION AND PROTECTION OF

CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

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CONSTRUCTION, INSTALLATION AND PROTECTION OF

CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Recommendation L.1

CONSTRUCTION, INSTALLATION AND PROTECTION OF

TELECOMMUNICATION CABLES IN PUBLIC NETWORKS

(Melbourne, 1988)

The CCITT,

considering

(a) that the location of faults on underground cables and the repair of these faults can entail great expense,

(b) that the interruptions to service likely to be caused by the occurrence of these faults must be avoided with the greatest care,

(c) that the occurence of these faults, other than by outside factors, is mainly determined by the construction, installation and protective measures applied,

unanimously recommends

that, when selecting and installing cables, Administrations will find it in their interest to comply with the CCITT manual *Outside plant technologies for public networks* .

This manual replaces the CCITT *Recommendations concerning the construction, installation and protection of telecommunication cables in public networks* , ITU, Geneva, revision 1974, amendments and additions 1977 and 1986. The manual consists of the following five parts:

Part I: Basic information about the construction of telecommunication cables

Part II: Installations and assemblage of telecommunication cables and their supporting structure

Part III: Pressurization of telecommunication cables

Part IV-A: Protection of telecommunication cables and associated hardware against corrosion

Part IV-B: Protection of telecommunication cables supports and underground structure against other hazards

Part V: Fault location and repair of telecommunication cables.

Recommendation L.2

IMPREGNATION OF WOODEN POLES

The CCITT draws attention to the economic importance of impregnating the wooden poles carrying overhead telecommunication lines

The CCITT has issued a manual entitled *The preservation of wooden poles carrying overhead telecommunication lines* , ITU, Geneva, 1974, with a view to providing Administrations, particularly those whose networks are not yet fully developed, with some information on impregnation processes.

This manual 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.

Recommendation L.3

ARMOURING OF CABLES

(Mar del Plata, 1968; modified at Melbourne, 1988)

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. It is also 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 in § 3 above.

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

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 3a), b), c), d) above; some protection against induction may be obtained by inserting conductor elements or copper or aluminium bonds under the steel sheath.

8 Through-connection of armouring

In case long-distance cables or similar cables are provided with metal armouring, this should be through-connected electrically at the splicing points. This should be done to obtain maximum protection against the effects of atmospheric discharges and protection against induction.

Metal armouring on cables forming part of the distribution network should also be through-connected in case such protection is needed.

In case metal-armoured cables are also provided with a metal sheath, it may be desirable to through-connect the sheath and the armouring electrically at the splicing and/or repeater points. This should be done to neutralize any differences in potential between the armouring and metal sheath, and to obtain maximum protection against magnetic interference. Through-connection may create corrosion problems, which will usually reduce the lifetime of the metal armouring.

9 Omission of armouring

On directly buried cables, metal armouring can be dispensed with in case the cable is provided with a strong plastic sheath, for example of polyethylene conditions should be favourable.

Additional protection, for example of optical fibre cables, may be obtained by providing the cable sheath with an external layer of polyamide (thickness 0.4 - 0.5 mm). This has a favourable effect as a wearing surface when drawing the cable over long distances. Moreover, the layer gives a certain degree of protection against light mechanical attacks.

10 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.

11 Rodents and insects

Damage from rodents and insects to direct buried cables may be high in some areas. In those locations, it may be advisable to consider the application of some type of armouring. For detailed information regarding armour protection against rodent and/or insect attack, the reader is directed to Part IV-B, Chapter II of the CCITT manual *Outside plant technologies for public networks* , mentioned in Recommendation L.1.

12 Tropical countries

In tropical countries special attention must be paid to §§ 6 and 7 above 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

ALUMINIUM CABLE SHEATHS

(Geneva, 1972; modified at Geneva, 1976, Malaga-Torremolinos, 1984 and Melbourne, 1988)

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 overvoltages 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.

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 [1]) 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. 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.

2.2 *Welded sheaths*

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

2.3 *Quality of sheath material*

In order to make the means of protection against corrosion effective, great care has to be taken concerning the quality of the sheath. In case pure aluminium is used, the purity of aluminium for the sheath should not be lower than 99.5% grade, for both the extruded sheath or the welded sheath.

2.4 *Choice of sheath shape and thickness*

After the sheath has been extruded or welded it may either be shrunk on to the cable core (noncorrugated sheath) or corrugated by a variety of methods (corrugated sheath).

The sheath may be corrugated or noncorrugated, 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 [2]). 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 in § 1 above the thickness of the metal used for aluminium sheaths is usually less than for lead sheaths.

The thicknesses given in Table 1/L.4 are suggested although the values given in this table apply to both extruded and welded sheaths; however, extruded sheaths may not be less than 0.9 mm and welded sheaths may not be more than 1.4 mm, that being the maximum thickness which can be welded by existing methods.

The use of lesser thicknesses than those indicated in Table 1/L.4 is not excluded and, conversely, 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 may be as much as approximately 0.3 mm.

Values different from those given in Table 1/L.4 may, of course, be adopted in certain cases (for example, if extremely favourable screening factors are required).

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 reference [1] 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) polyvinylchloride (PVC);

b) polyethylene.

Polyethylene 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 essential to apply a leakproof layer consisting of an adhesive tape or a suitable mixture.

The leakproof layer must adhere well to the aluminium, especially when PVC is used for the covering, since this material, unlike polyethylene, does not cling tightly to the sheath after extrusion.

The protective covering on the aluminium sheath should be sound. One form of test with the cable on the drum is to measure the insulation resistance of the covering.

H.T. [T1.4]
TABLE 1/L.4
Suggested thickness

Core diameter (mm)	Metal thickness (mm)		
Minimum Corrugated sheaths | ua) }	Maximum	Noncorrugated sheaths	{
—	10	0.7 to 1.0	0.5 to 0.9
10	15	0.7 to 1.0	0.6 to 0.9
15	20	0.9 to 1.0	0.7 to 0.9
20	25	1.1	0.8 to 0.9
25	30	1.1 to 1.2	0.9
30	35	1.1 to 1.3	0.9 to 1.0
35	40	1.1 to 1.4	1.1
40	45	1.5	1.1 to 1.2
45	50	1.6	1.1 to 1.2
50	60	.	1.1 to 1.3
60	70	.	1.1 to 1.4
70	80	.	1.3 to 1.5

a) If it is intended to obtain approximately the same screening factor with a corrugated sheath as with a noncorrugated one, the thickness should be the same as with a noncorrugated sheath.

TABLE 1/L.4 [T1.4], p.

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 consists in removing a part of the protective covering from a sample of the aluminium sheath and submitting it to electrolytic attack using 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.

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 manual cited in [3] should be taken into account.

If a test of the protective covering is necessary in the manufacturing process, an electric spark detect method or a voltage resistance test method with the cable submerged in water is effective. In the process of installation and operation, if the factors that might cause damage to the protective covering or decrease the protective covering's insulation resistance are to be found, the test should be carried out and the faults should be eliminated.

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 or cones which are plumbed using a normal method or fixed with special glue to the aluminium sheath to permit subsequent soldering to lead sleeves;

— jointing by means of aluminium sleeves joined to the aluminium sheath by pressure welding (explosion, pressure or cold welding);

— other methods including the use of adhesive tapes and epoxy pastes.

The methods used for the jointing of aluminium sheaths must meet the conditions recommended in the booklet cited in [4].

For an aluminium-sheathed cable subjected to significant temperature variations, tensions due to cable contraction should not be borne by the joints as this can lead to joint failure, particularly with noncorrugated sheaths.

5 Cathodic protection

The corrosion protection of aluminium sheaths depends mainly on a high quality anti-corrosion protective cover. However, if there is serious risk of damage to the protective cover, and particularly if it is not possible to re-establish the protective cover to its original specifications after repair, the cover should be protected with special measures such as sacrifice anode electrical chemical protection. Aluminium alloy sacrifice anode, which has the advantage of a higher current capacity per unit weight, an appropriate protective potential, an abundant raw material resource base, and ease of manufacture, is an effective measure to protect aluminium sheathed cables. Tests show that good results can be obtained if the protected aluminium sheath potential value with respect to ground is limited within the range of —0.85 to 1.20 V (relative to a Cu/$CuSO_4$ electrode).

6 If there are no special requirements in using aluminium sheaths for optical fibre cables, the same sheath material and manufacturing process may be used as for metallic conductor cables.

References

[1] CCITT manual *Outside plant technologies for public networks* , Part IV-A, Chapter III, § 1.2.2, ITU, Geneva 1988.

[2] *Ibid.* , Part I, Chapter III, § 6.2.2.

[3] CCITT manual *The protection of telecommunication lines and equipment against lightning discharges* , ITU, Geneva, 1974, 1978.

[4] CCITT manual *Jointing of plastic-sheathed cables* , ITU, Geneva, 1978.

Recommendation L.5

CABLE SHEATHS MADE OF METALS OTHER THAN LEAD OR ALUMINIUM

(Geneva, 1972)

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 above may be used with aluminium or copper tapes laid longitudinally or helically beneath the corrugated steel sheath 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 polyethylene or similar Class II covering (see reference [1]) 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 noncorrugated-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.

Reference

[1] CCITT manual *Outside plant technologies for public networks* , ITU, Geneva, 1988, Part IV-A, Chapter III, § 1.2.2.

Recommendation L.6

METHODS OF KEEPING CABLES UNDER GAS PRESSURE

(Geneva, 1972)

The CCITT draws attention to the improvements in service made possible by protecting telecommunication cables against the ingress of moisture when the sheath is perforated or damaged. To ensure that the circuits remain free of interruption until repairs can be completed, the CCITT recommends that Administrations recognize the utility of following the advice given in the manual *Protection of telecommunication cables by pressurization* , ITU, Geneva, 1970.

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Recommendation L.7

APPLICATION OF JOINT CATHODIC PROTECTION

(Geneva, 1976)

1 General

By joint cathodic protection of several underground metallic structures is meant corrosion protection of these structures by means of common protective devices.

A joint protection system for several underground metallic structures is composed of electrical bonds between the structures and of common protective devices complying with cathodic protection and electrical drainage requirements.

Joint protection techniques enhance the reliability of buried structures, improve efficiency of cathodic protection devices and also reduce total investment and maintenance costs of the protective system.

2 Conditions for application of joint cathodic protection

It is practicable to apply joint cathodic protection of underground metallic plant when several different structures approach or cross each other and when it is necessary to avoid the harmful effects of the protected structure on neighbouring unprotected structures, provided that it is economical and there is no better means to avoid this influence. The harmful influence of cathodic polarization or protected plant on the neighbouring metallic structures occurs when:

a) measured potentials are lower or higher than the values recommended;

b) the danger of corrosion on neighbouring underground metallic structures is increased.

Joint protection of telecommunication cables with other structures can be reasonably applied in the cases when:

a) nearby underground structures are at a distance generally not exceeding 50 metres;

b) the buried plants cross each other;

c) the ground beds or reactive anodes of a cathodic protection system have a harmful influence on nearby unprotected plants.

Joint protection of telecommunications and power cables in accordance with reference [1] may be considered when the potential to earth of the telecommunications cable does not exceed the safe voltage required by local or national safety rules in the event of an earth fault or short circuit on the power supply system.

Joint cathodic protection should provide on the protected plants potentials which are within the values indicated in reference [1].

In the case of joint protection it may be possible to use devices which automatically control the current output of the cathodic protection equipment.

3 Conditions for electrical bonds

Special bonds are used to provide electric contact between jointly protected plants. Bonds may be direct, or provided with a resistor (to limit the current) or polarized.

Direct bonds may be used in the following cases:

a) when underground metallic structures of the same type are crossing or approaching each other;

b) when the provision of bonds between structures of different types does not reduce the efficiency of the primary cathodic protection system.

Resistor bonds which control the current applied to different types of plant should be used when potentials on these structures should be controlled.

Polarized bonds should be used:

a) for joint drainage and cathodic protection systems ;

b) to prevent current flowing from a pipeline to telecommunication plant;

c) to protect against failure of the cathodic protection equipment

Bonds should not be installed between buried structures and power supply cables and equipment unless it is safe to do so in the event of a fault on the power supply system and it is in accordance with local and national safety rules.

4 Monitoring the performance of joint cathodic protection devices

The performance of joint cathodic protection devices should be monitored by means of:

a) routine examination of protective devices and equipment;

b) routine measurements of interaction potential differences with the protection equipment switched on and switched off at all the plants incorporated in the joint protection system, in compliance with local accepted procedures.

When tests or changes are made on the joint cathodic protection system, the presence or agreement of the representatives of operating agencies whose underground structures are incorporated in the joint protection system is recommended.

Reference

[1] CCITT manual *Outside plant technologies for public networks* , ITU, Geneva, 1988.

Recommendation L.8

CORROSION CAUSED BY ALTERNATING CURRENT

(Geneva, 1976)

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

However, 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 frequencies below the usual mains frequency of 50 Hz or 60 Hz;

— rectification may occur due to the nature of the soil or to the presence at the surface of the metals of oxides or polluting substances.

There is no practical way of finding out the current densities and the voltages 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.

It seems reasonable to suggest that a.c. at low voltage is not usually harmful to steel or lead but may corrode aluminium in some cases.

Recommendation L.9

METHODS OF TERMINATING METALLIC CABLE CONDUCTORS

(Melbourne, 1988)

1 General

Metallic cable conductor terminations are installed at various locations within the cable network. The type of terminal and termination device utilized at these locations is dependent on various factors relating to the specific installation:

— type of cable and conductor being terminated;

— location and purpose of the termination;

— number or quantity of terminations required;

— type of service or transmission link involved;

— flexibility and protection requirements.

Basically, all exchange, repeater (amplifier or regenerator), and major cross-connection point terminations are of the ‘‘fixed’’ type utilizing wrapping, soldering of insulation displacement connection (IDC) techniques.

Local distribution and customer terminations utilize a mixture of ‘‘fix’’ and ‘‘temporary’’ (screw terminal) type terminations depending on individual conditions. Where required, over-voltage protection may be provided as an integral component of the terminating device or a separate ‘‘add-on’’ facility.

Within a cable network, two methods of terminating cables are available. These may generally be referred to as the direct and indirect methods.

Direct termination implies that the conductors associated with a particular cable connected directly to the terminal forming the ‘‘end’’ of the cable circuit, e.g. the cable conductor and terminal are directly coupled.

Indirect termination implies that the cable conductor is connected to the end terminal via a device that incorporates a preformed or manufactured termination.

Direct terminations are usually utilized in end terminals such as at the exchange main distribution frame (MDF) and customer premises, although some direct terminations are used in the customer distribution cable area. In most other mid-point terminations (distribution cabinets and pillars, repeater housings and termination points for trunk carrier and coaxial cables), indirect terminations utilizing devices with pre-terminating tail cables are spliced into the basic bearer cables.

The electric conducting parts of terminating devices will be of metal such as copper, brass or other similar alloys suitably plated to resist corrosion and other environmental effects and provide good electrical connection, either by contact, pressure, soldering or wrapping.

Various insulating materials (plastic extrusions and resin moulding) provide the mechanical mounting and electrical insulation of the metallic components.

2 Termination types

2.1 *Termination types for symmetric pair conductors*

2.1.1 *Wire-wrapping type*

In this type the conductor is wire-stripped and cut, inserted in a wire-wrap tool and wire-wrapped around the terminal point.

2.1.2 *Solder-on-type*

In this type the conductor is wire-stripped and cut, then inserted in the terminal slot and soldered.

2.1.3 *Wrap-and-solder type*

In this type, after wrapping, the conductor is soldered to the cut end of a terminal.

2.1.4 *Binder-post type*

There are different forms of this type:

a) Termination by means of screws. The conductor is wire-stripped, cut and fastened with screws by means of a screwdriver.

b) Termination by means of nuts. The termination consists of a fixed threaded brass post containing washers and a threaded hex nut. The conductors are terminated between the washers.

2.1.5 *Insulation displacement contact (IDC) type*

In this type, generally the conductor is installed and pressed into a U-element contact by means of a special tool.

The U-element contact has different forms and is the most frequently used terminating type.

2.1.6 *Termination for unused conductors*

This termination is made by means of plastic connectors without U-element contacts and is used for the protection of unused conductors in a pedestal or splice closure.

2.2 *Termination types for coaxial conductors*

2.2.1 *Connectors types*

Coaxial pairs are terminated in connectors mounted on a metallic diaphragm for accessing the repeater housing of the terminal equipment.

The connector joins the stiff coaxial tube to the flexible one leading into the housing or exchange, and is provided with a device for pneumatic insulation.

2.2.2 *Direct-joint type*

A joint between the air core tube and the flexible coaxial cable is made at times.

3 Termination use

The types of termination mentioned above are used in different devices and locations for terminating cables in all their applications: main distribution frame, regenerating equipments, cabinets, terminal boxes and subscriber's premises.

These devices present some physical characteristics which may vary greatly from country to country, although their technical features (i.e. electrical and environmental requirements) are very similar.

4 Requirements for MDF terminating devices

The basic requirements of the exchange MDF terminating device include the provision for:

— fixed termination of external cable conductors, in multi-pair units (usually 100), and associated jumper cross-connection leads;

— ease of termination, and retermination where necessary, of cable and jumper cross-connection conductors;

— overvoltage protection by add-on or plug-in triode gas protectors;

— circuit isolation by insertion or removal of an appropriate device;

— independent circuit accessing and testing, on equipment and line sides;

— circuit paralleling;

— earthing points or buses;

— ratio of O/G (outgoing) to I/C (incoming) circuit terminating capability of at least two;

— multi-point pair access connection (plugs and leads);

— colour coding of special circuits;

— fanning strips and jumper guides;

— permanent circuit indentification numbering;

— good visibility.

4.1 *Technical requirements*

The design, construction and materials utilized in the terminating device must provide for an expected service life of up to 40 years. Devices must be compatible with the existing MDF construction and utilization practices, interchangeable with the existing termination devices, and maintain or increase current circuit density per unit area.

The line side terminals shall be required to terminate the existing range of copper external cable conductors extending from 0.32 mm to 0.90 mm diameter, plastic insulated with solid or cellular forms of insulation. The terminals on the equipment side shall be required to terminate the existing range of copper internal cable conductors.

Reliable retermination of conductors in the order of 100 to 200 times over the life of the system shall be possible. Prior termination of larger conductors shall not affect the subsequent termination of a second thinner wire.

The line side terminating device on which line cables terminate should allow for the installation and acceptance testing of external cables (automatic simultaneous access, via the MDF termination, to all pairs of a 100-pair, or other, terminating unit.).

Terminating equipment shall be able to withstand the effects of normal concentrations of moisture, sodium chloride, hydrogen sulphide, sulphur dioxide, ammonium chloride and formic acid which may penetrate or originiate in buildings.

Terminating equipment shall be expected to operate satisfactorily in temperatures ranging from —10 | (deC to 50 | (deC with daily ambient fluctuations of up to 15 | (deC. Upper temperature limits shall be assumed to prevail for 25% of total time. Yearly average relative humidity of 75% is to be assumed with maximum values not exceeding 95%.

In addition to the above, terminating equipment will be required to satisfy the following test requirements:

— cold;

— dry heat;

— damp heat;

— accelerated damp heat;

— vibration;

— storage;

— mould growth;

— corrosion test;

— robustness of terminals.

4.2 *Safety requirements*

Terminating systems will need to be designed with safety and security in mind. To this end, designs should:

— minimize the likelihood of unintended electrical contact and/or accidental dislocation of wires;

— use plastic materials with an oxygen index of at least 28, determined in accordance with international standards;

— use plastic materials which do not emit hazardous fumes or smoke when heated;

— avoid sharp corners and edges.

4.3 *Electrical requirements*

All the terminating blocks should have proper electrical characteristics in order to minimize the risk of personal injury to staff, customers and public from electrical causes, arising from the installation, operation, and maintenance of the devices.

If necessary, proper values should be recommended for:

— insulation resistance;

— voltage-proof test;

— capacitance between pairs of terminals.

5 Requirements for cable termination devices

5.1 *Electrical characteristics of terminations*

The main electrical characteristics for termination devices specified by most Administrations are:

— dielectric strength;

— insulation resistance;

— reflection index (coaxial only);

— contact resistance.

These characteristics are different for coaxial-pair terminations, long-distance symmetric-pair cables and local symmetric-pair cables.

5.2 *Environmental requirements of terminations*

The requirements should be specified for at least 20 years of field operation in stationary use at partially weather-protected locations. The IEC Standards should be followed in the areas of:

— temperature cycling, lower and upper limits;

— change of temperature;

— damp heat, steady state;

— standard climatic sequence;

1) dry heat,

2) damp heat, cyclic,

3) cold,

4) damp heat, cyclic,

— gas-tightness;

— shock or vibration.

Recommendation L.10

OPTICAL FIBRE CABLES FOR DUCT, TUNNEL, AERIAL AND | fR BURIED APPLICATION

(Melbourne, 1988)

Introduction

With the recent progress in optical fibre cable technology, optical fibres for telecommunication use have been applied to trunk and subscriber networks, indoor wiring and submarine sections. There are various kinds of installation, such as aerial, duct, cable tunnel, buried, on-premises and underwater. Thus, optical fibre cables are exposed to natural and man-made external factors.

There is a need to establish the mechanical and environmental characteristics of optical fibres which will satisfy operational requirements and to advise on suitable testing methods.

This Recommendation advises on optical cables to be used in certain installation conditions. Cables for underwater and in-building applications require further study.

1 Scope

This Recommendation:

— refers to multi-mode graded index and single-mode optical fibre cables to be used for telecommunications networks in duct, tunnel, buried and aerial installations;

— deals with mechanical and environmental characteristics of the optical fibre cables concerned. The optical fibre dimensional and transmission characteristics, together with their test methods, should comply with Recommendations G.651 and G.652, which deal with multi-mode graded index and single-mode optical fibres respectively;

— deals with fundamental considerations related to optical fibre cable from the mechanical and environmental points of view;

— acknowledges that some optical fibre cables may contain metallic elements, for which reference should be made to the manual, *Outside plant technologies for public networks* (see Recommendation L.1), and other L-Series Recommendations;

— recommends that an optical fibre cable should be provided with cable end-sealing and protection during cable delivery and storage, as is common for metallic cables. If splicing components have been factory installed they should be adequately protected;

— recommends that pulling devices can be fitted to the end of the cable if required.

2 Characteristics of the optical fibres and cables

2.1 *Mechanical characteristics*

2.1.1 *Fibre microbending*

Severe bending of an optical fibre involving local axial displacement of a few micrometers over short distances caused by localized lateral forces along its length is called microbending. This may be caused by manufacturing and installation strains and also dimensional variations of cable materials due to temperature changes during operation.

Microbending can cause an increase in optical loss. In order to reduce microbending loss, stress randomly applied to a fibre along its axis should be eliminated during the fiber's incorporation into the cable, as well as during and after cable installation.

2.1.1 *Fibre macrobending*

Macrobending is the resulting curvature of an optical fibre after cable manufacture and installation.

Macrobending can cause an increase in optical loss. The optical loss increases if the bending radius is too small.

2.1.3 *Cable bending*

Under the dynamic conditions encountered during installation, the fibre is subjected to strain from both cable tension and bending. The strength elements in the cable and the installation bend radius must be selected to limit this combined dynamic strain. Any fibre bend radius remaining after cable installation shall be large enough to limit the macrobending loss or long-term strain limiting the lifetime of the fibre.

2.1.4 *Tensile strength*

Optical fibre cable is subjected to short-term loading during manufacture and installation, and may be affected by continuous static loading and/or cyclic loading during operation (e.g. temperature variation). Especially in the case of aerial application, continuous loading during the full lifetime of the cable may be present. Fibre strain may be caused by tension, torsion and bending occurring in connection with cable installation and/or type of installation (e.g. aerial) and/or environmental conditions (e.g. wind, ice).

Excessive cable tensile loading increases the optical loss and may cause increased residual strain in the fibre if the cable cannot relax. To avoid this, the maximum tensile strength determined by the cable construction, especially the design of the strength member, should not be exceeded.

Note 1 — Where a cable is subjected to permanent loading during its operational life, the fibre should preferably not experience additional strain.

Note 2 — Aerial cable may be attached to a suspension wire. In this case, the strength member of the cable need only be designed to support the load during manufacture and installation.

2.1.5 *Crush and impact*

The cable may be subjected to crush and impact both during installation and operational life.

The crush and impact may increase the optical loss (permanently or for the time of application of the stress) and excessive stress may lead to fibre fracture.

In the case of self-supporting cylindrical aerial cables, the cable structure should be able to withstand the compression effects to prevent additional optical loss.

2.1.6 *Cable torsion*

Under dynamic conditions encountered during installation and operation, the cable may be subjected to torsion, resulting in residual strain of the fibres and/or damage of the sheath. If this is the case, the design of cable should allow a specified number of cable twists per unit length without an increase in fibre loss and/or damage to the sheath.

2.2 *Environmental conditions*

2.2.1 *Hydrogen gas*

In the presence of moisture and metallic elements, hydrogen gas may be generated. Hydrogen gas may diffuse into silica glass and increase optical loss. It is recommended that the hydrogen concentration in the cable, as a result of its component parts, should be low enough to ensure that the long-term effects on the increase of optical loss are acceptable.

By the use of dynamic gas pressurization , hydrogen absorbing materials, careful selection and construction (moisture barrier sheath) or elimination of metallic components, the increase in optical loss can be maintained within acceptable limits.

2.2.2 *Moisture permeation*

When moisture permeates the cable sheath and is present in the cable core, deterioration of the tensile strength of the fibre occurs and the time-to-static failure will be reduced. To ensure a satisfactory lifetime of the cable, the long term strain level of the fibre must be limited.

Various materials can be used as barriers to reduce the rate of moisture permeation. Alternatively, filled, metal-free cable constructions can be used.

Note — If required, minimum permeation is achieved by a longitudinal overlapped metallic foil. A continuous metallic barrier is effective to prevent moisture permeation.

2.2.3 *Water penetration*

In the event of damage to the cable sheath or to a splice closure, longitudinal penetration of water in a cable core or between sheaths can occur. The penetration of water causes an effect similar to that of moisture. The longitudinal penetration of water should be minimized or, if possible, prevented. Techniques such as filling the cable core with a compound, providing discrete water blocks or water swellable tapes, or providing unfilled cable with dry-air pressurization, may be applied to prevent water penetration.

Water in the cable may be freezed and, under some conditions, can cause fibre crushing with a resultant increase in optical loss and possible fibre breakage.

2.2.4 *Lightning*

Fibre cables containing metallic elements such as conventional copper pairs or a metal sheath are susceptible to lightning strikes.

To prevent or minimize lightning damage, consideration should be given to Recommendation K.21.

When a non-metallic cable is used, the cable should be filled and it should be protected against mechanical and thermal damage.

2.2.5 *Biotic damage*

The small size of an optical fibre cable makes it more vulnerable to rodent attack. Where rodents cannot be excluded, metallic protection should be provided. For further information reference should be made to Part IV-B, Chapter II of the manual *Outside plant technologies for public networks*

2.2.6 *Vibration*

When optical fibre cables are installed on bridges they will be subject to relatively high amplitude vibrations of various low frequencies, depending on bridge construction and on the type of traffic density. Cables should withstand these vibrations without failure or signal degradation. Care should be exercised, however, in the choice of installation method.

Underground optical fibre cable may be subject to vibrations from traffic, railways, pile-driving and blasting operations. Here again, cables should withstand vibrations generated by these activities without degration.

A well established surveillance routine will identify the activity in order to make a careful choice of route to minimize this type of problem.

2.2.7 *Temperature variations*

During their operational lifetime cables may be subjected to severe temperature variations. In these conditions the increase of attenuation of the fibres shall not exceed the specified limits.

2.2.8 *Wind*

For optical fibre aerial cable, fibre strain may be caused by tension, torsion and vibration occurring in connection with wind pressure. Induced dynamic and residual strain in the fibre may cause fibre breakage if the specified long-term strain limit of the fibre is exceeded.

To suppress any fibre strain induced by wind pressure, the strength member should be selected to limit this strain to safe levels, and the cable construction may mechanically decouple the fibre from the sheath to minimize the strain. Alternatively, to suppress fibre strain the cable may be lashed to a high strength support strand.

In aerial installations winds will cause vibrations and, in figure-of-eight and suspension wire installations, severe oscillations of the entire span of the cable may occur. Cables should be designed and/or installed to provide stability of the transmission characteristics in these situations.

2.2.9 *Snow and ice*

For optical fibre aerial cable, fibre strain may be caused by tension occurring in connection with snow loading and/or ice formation around the cable. Induced fibre strain may cause excess optical loss and may cause fibre breakage if the specified long-term strain limit of the fibre is exceeded.

Dynamic strain in the fibre may be induced by vibration caused by the action of snow and/or ice falling from the cable. This may cause fibre breakage.

Under the load of snow and/or ice, excessive fibre strain may easily be induced by wind pressure.

To suppress the fibre strain by snow loading and/or ice formation, the strength member should be selected to limit this strain to safe levels, and the cable profile may be selected to minimize snow loading. Alternatively, to suppress fibre strain the cable may be lashed to a high strength support strand.

2.2.10 *Strong electric fields*

Metal-free aerial cables installed on high voltage power lines are susceptible to the influence of the electric field of these power lines which may lead to phenomena such as corona, arcing and tracking of the cable sheath.

To prevent damage, special cable sheath materials may have to be used depending on the level of electric field.

3 Cable construction

3.1 *Fibre coatings*

3.1.1 *Primary coating*

Silica fibre itself has an intrinsically high strength, but its strength is reduced by surface flaws. A primary coating must therefore be applied immediately after drawing the fibre to size.

The optical fibre should be proof-tested. In order to guarantee long-term reliability under service conditions, the proof-test strain may be specified, taking into account the permissible strain and required lifetime.

In order to prepare for splicing, it should be possible to remove the primary coating without damage to the fibre, and without the use of materials or methods considered to be hazardous or dangerous.

The composition of the primary coating, coloured if required, should be considered in relation to any requirements of local light-injection and detection equipment used in conjunction with fibre jointing methods.

Note 1 — The coating should have a nominal diameter of 250 μm.

Note 2 — The primary coated fibres should be proof tested with a strain equivalent to at least 0.5% for a duration of one second. The test method should be in accordance with IEC publication 793-1 [1]. For aerial cable applications, taking into account large thermal changes and strong winds, a larger proof-test strain may be necessary.

Note 3 — Further study is required to advise on suitable testing methods for local light-injection and detection.

3.1.2 *Secondary protection*

Secondary protection of the fibre within the cable should be provided.

Note 1 — Methods of secondary protection are described in the manual on the construction, installation, jointing and protection of optical fibre cables [2].

Note 2 — When a tight secondary coating is used it may be difficult to use local light-injection and detection equipment associated with fibre jointing methods.

Note 3 — To limit axial fibre stress, the mechanical coupling between fibre and cable should be minimized.

3.1.3 *Fibre identification*

Fibre should be easily identifided by colour or position within the cable core. If a colouring method is used, the colours should be clearly distinguishable and have good colour-fast properties also in the presence of other materials, during the lifetime of the cable.

3.1.4 *Splicing properties*

Further study is required to advise on suitable testing methods for local light-injection and detection.

3.2 *Cable core*

The make-up of the cable core, in particular the number of fibres, their method of protection and identification, the location of strength members and metallic wires or pairs, if required, should be clearly defined.

3.3 *Strength member*

The cable should be designed with sufficient strength members to meet installation and service conditions so that the fibres are not subjected to excessive strain.

The strength member may be either metallic or non-metallic and may be located either in the cable core and/or in the sheath.

For example, in the metal-free self-supporting aerial cable the strength member may consist of a layer of aramid yarns located between the inner sheath and the outer sheath, or of a single glass-fibre reinforced strand in a figure-of-eight construction. A knowledge of span, sag, wind and ice-loading is necessary to design such a cable.

3.4 *Water-blocking materials*

Filling a cable with water-blocking material is one means of protecting the fibres from water ingress. Any materials used should not be harmful to personnel. The materials in the cable should be compatible, one with the other, and in particular should not adversely affect the fibre performance, or any identification colours of the fibres.

In addition, the material should be non-nutritive to fungus, and be electrically non-conductive, homogeneous and free from contamination.

3.5 *Pneumatic resistance*

If the cable requires dry air pressurization during operation, the pneumatic resistance should be specified.

Note — It is intended that a cable can be pressurized only if it allows a flux of air which is in accordance with the criteria defined in Part III of the manual *Outside plant technologies for public network* (see Recommendation L.1).

3.6 *Sheath*

The cable core should be covered with a sheath suitable for the relevant environmental and mechanical conditions associated with storage, installantion and operation. The sheath may be of a composite construction and may include strength members.

Sheath considerations for optical fibre cables are generally the same as for metallic conductor cables. Consideration should also be given to the amount of hydrogen generated from a metallic moisture barrier. The minimum acceptable thickness of the sheath should be stated, together with any maximum and minimum allowable overall diameter of the cable.

Note 1 — One of the most sheath materials is polyethylene. There may be however, some environmental conditions where it is necessary to minimize the flammability of a cable and limit the emission of fumes, smoke and corrosive products. Special materials should be used for the cable sheath in these situations.

Note 2 — For directly buried cables installed in areas with chemically contaminated soils (acids, hydrocarbons, etc.), specially designed cable sheath combinations may be used.

Note 3 — In the case of aerial cables, the outer sheath should be resistant to the degradation due to ultraviolet radiation.

3.7 *Armour*

Where additional tensile strength or protection from external damage is required, armouring should be provided over the cable sheath.

Armouring considerations for optical fibre cables are generally the same as for metallic conductor cables. However, hydrogen generation due to corrosion must be considered. It should be remembered that the advantages of optical fibre cables, such as lightness and flexibility, will be reduced when armour is provided.

Armouring for metal-free cables may consist of aramid yarns, glass fibre reinforced strands or strapping tape, etc.

3.8 *Identification of cable*

If a visual indentification is required to distinguish an optical fibre cable from a metallic cable, this can be done by visibly marking the sheath of the optical fibre cable.

4 Test methods

4.1 *Test methods for mechanical characteristics*

This section recommends appropriate tests and test methods for verifying the mechanical characteristics of optical fibre cables.

4.1.1 *Tensile strength*

This test method applies to optical fibre cables installed under all environmental conditions.

Measurements are made to examine the behaviour of the fibre attenuation as a function of the load on a cable during installation.

The test should be carried out in accordance with method IEC 794-1-E1 [3].

The amount of mechanical decoupling of the fibre and cable can be determined by measuring the fibre elongation, with optical phase shift test equipment, together with the cable elongation.

This method may be non-destructive if the tension applied is within the operational values.

4.1.2 *Bending*

This test method applies to optical fibre cables installed under all environmental conditions.

The purpose of this test is to determine the ability of optical fibre cables to withstand bending around a pulley, simulated by a test mandrel.

This test should be carried out in accordance with method IEC 794-1-E11 [3].

4.1.3 *Bending under tension (flexing)*

This test method applies to optical fibre cables installed under all environmental conditions.

This subject needs further study.

4.1.4 *Crush*

This test method applies to optical fibre cables installed under all environmental conditions.

This test should be carried out in accordance with method IEC 794-1-E3 [3].

4.1.5 *Squeezing (abrasion)*

This test method applies to optical fibre cables installed under all environmental conditions.

This subject needs further study, and is currently under consideration in the method IEC 794-1-E2 [3].

4.1.6 *Torsion*

This test method applies to optical fibre cables installed under all environmental conditions.

This test should be carried out in accordance with method IEC 794-1-E7 [3].

4.1.7 *Impact*

This test method applies to optical fibre cables installed under all environmental conditions.

This test should be carried out in accordance with method IEC 794-1-E4 [3].

4.2 *Test methods for environmental characteristics*

This section recommends the appropriate tests and test methods for verifying the environmental characteristics of optical fibre cables.

4.2.1 *Temperature cycling*

This test method applies to optical fibre cables installed under all environmental conditions.

Testing is by temperature cycling to determine the stability of the attenuation of a cable due to ambient temperature changes which may occur during storage, transportation and operation.

This test should be carried out in accordance with method IEC 794-1-F1 [3].

Note — For aerial self-supporting cables, the stability of the attenuation may be measured with a specified tension applied to the cable sample.

4.2.2 *Longitudinal water penetration*

This test method applies to completely filled outdoor cables installed under all environmental conditions. The intention is to check that all the interstices of a cable are continuously filled with a compound to prevent water penetration within the cable.

This test should be carried out in accordance with method IEC 794-1-F5 [3].

4.2.3 *Moisture barrier*

This test method applies to optical fibre cables installed under all environmental conditions.

This test applies to cables supplied with a longitudinal overlapped metallic foil. The moisture penetration can be tested according to the test method as described in Part I, Chapter III of the manual *Outside plant technologies in public networks* (see Recommendation L.1).

4.2.4 *Freezing*

This test method applies to optical fibre cables installed under all environmental conditions.

This subject needs further study and is currently under consideration in the method IEC 794-1-F6 [3].

4.2.5 *Hydrogen*

This test method applies to optical fibre cables installed under all environmental conditions.

A suitable short-duration test procedure needs to be determined for the factory complete cable, so that the results of factory tests enable the long-term increase in fibre loss to be predicted.

4.2.6 *Nuclear radiation*

This test method assesses the suitability of optical fibre cables to be exposed to nuclear radiation.

This subject needs further study and is currently under consideration in the method IEC 794-1-F7 [3].

4.2.7 *Vibration (bridge and underground cables)*

This test method assesses the suitability of optical fibre cables for bridge and underground application.

This subject needs further study.

4.2.8 *Vibration (aerial cables)*

This test method assesses the suitability of optical fibre cables for aerial application.

The subject needs further study.

4.2.9 *Ultraviolet resistance*

This test method applies to aerial optical fibre cable and assess the suitability of the cable sheath to withstand ultraviolet radiation.

This subject needs further study.

4.2.10 *Sheath tracking*

This test applies to aerial optical fibre cables used on high voltage power lines.

This subject needs further study.

References

[1] IEC publication 783-1 *Optical fibres, Part 1: Generic specifications* , Geneva, 1987.

[2] CCITT manual *Construction, installation, jointing and protection of optical fibre cables* , ITU, Geneva, 1985.

[3] IEC publication 794-1 *Optical fibre cables, Part 1: Generic specifications* , Geneva, 1987.

Recommendation L.11

JOINT USE OF TUNNELS BY PIPELINES AND TELECOMMUNICATION CABLES, AND THE STANDARDIZATION OF UNDERGROUND DUCT PLANS

(Melbourne, 1988)

The CCITT,

considering

(a) that many countries are interested in the joint use of tunnels and are aware of the advantages, disadvantages and specific dangers they hold;

(b) that the rules governing this type of ducting vary significantly from country to country;

(c) that the importance of the joint use of tunnels increases with increasing density of population and shrinking open spaces, i.e. in large towns;

recommends

that Administrations, who in the future will be interested in this type of installation, follow the rules described in this Recommendation.

1 General considerations

Duct tunnels and trenches are constructions containing one or generally more ducts belonging to different networks. Tunnels which can be inspected (inspectable tunnels) include one or more gangways for initial assembly work and for subsequent control, maintenance and repair operations. A tunnel without standing room, but designed for crawling should have a clear internal height of at least 0.8 m. Duct gangways may not be entered.

The above principles apply to inspectable tunnels, and apply by analogy to tunnels with crawling room only.

Tunnels may contain ducts belonging to the following types of networks:

— collective antennas;

— telecommunications;

— electricity;

— gas;

— water;

— district heating;

— ducted transport (e.g. pneumatic tubes);

— drainage water.

2 Establishment of a routing plan

2.1 *Structure*

Tunnel routing must take into account the structure of networks and their levels of priority.

The transport ducts of different networks do not generally follow the same itinerary, since neither the production units (e.g., power plants, pumping stations or telephone exchanges) nor the transit points from transport to primary distribution coincide. On the other hand, in densely populated areas, primary and secondary distribution ducts often do follow the same itineraries, so that it is advisable to run tunnels under arteries containing primary and secondary distribution ducts.

2.2 *Decision criteria*

The following factors should be taken into account when opting between trenches and tunnels:

2.2.1 *Distribution security*

A high level of distribution security will depen on the following factors:

— durability of material and joints;

— rapid location of damage when if occurs, easy access and minimum repair times;

— low exposure to outside effects (e.g. damage caused by third parties or by earthquakes).

Ducts laid in tunnels generally offer high durability and a low risk of deterioration. They may be repaired rapidly.

2.2.2 *Third party risk, disturbances due to installation and repair work*

Account should be taken of disturbances caused by installation and repair work (rerouting of traffic, noise) and of the possible consequences of damaged ducts (water and fire damage).

2.2.3 *Economic considerations*

Economic considerations should include not only the cost of constructing and maintaining tunnels, but also the savings which will arise in the future from avoiding the secondary effects of buried ducts. By secondary effects are meant the effects produced on local inhabitants, local activities, vehicle traffic and the environment in general by the installation, malfunction, repair and maintenance of ducts.

2.2.4 *Technical considerations*

Before either of the laying methods is chosen, the following factors should be considered:

— ducts, network, dimension (cross-section), power (capacity), material, protection against corrosion, number, distribution priority, duct routing, compatibility with other ducts, state of ducts, repairs, overhaul, replacement, reserves, extensions, emergency ducts, provisional installations, connections to buildings;

— roadway, road width, pavement width, greenery strip, traffic density, surface water drainage, superstructure;

— subsoil, type of ground, groudwater level, existing ducts, existing undergroung constructions;

— schedules, beginning of works, duration of works (stages), start-up.

When a tunnel is planned, special attention should be paid to branch connections with buildings, which may be derived directly from the tunnel if the necessary openings have been provided. An alternative method is to bury secondary distribution ducts alongside the tunnel.

3 Recommendations applicable to tunnels

3.1 *Phases*

The following sequence of phases should be considered:

— construction phase;

— operational phase.

3.2 *General recommendations*

In both the construction and the operational phases, the following requirements should be observed:

— *Introduction of duct components in the tunnel*

It should be possible to introduce any components either through normal access points or through special openings.

— *Cable pulling*

Cables in tunnels should be placed in appropriate technical containers, in order to facilitate their installation, repositioning or removal.

— *Construction aids*

For construction work, especially in the case of heavy tubing, securing devices should be provided at appropriate locations.

— *Movement of duct components in tunnel*

The necessary facilities should be provided for the transport of duct components inside a tunnel.

— *Reserve facility for network extension*

Since networks are likely to be extended in the future, appropriate reserve space should be set aside in the tunnel cross-section plan.

— *Clear space around ducts*

Enough clear space should be allowed between a tunnel wall and ducts, as well as beween ducts in proportion to their diameter (to facilite maintenance, repair and branching).

— *Ambient temeperature*

High temperatures may occur in tunnels containing heat-emitting ducts. Care should be taken to maintain physiologically acceptable environmental conditions in order to avoid any impairment to health during work or inspections. For telecommunication cables, see § 3.3.2.

— *Corrosion of ducts, fixtures and equipment accessories*

The working life of fixtures and equipment accessories should be as long as that of the ducts. High levels of humidity may produce condensation and cause non-rustproof metals to corrode. The appearance of corrosion should be considered in the light of Recommendation L.1. Metal components (pillars, racks or supports) should preferably be made of hot galvanized steel. In some cases, cathodic protection may be applied.

— *Vibrations*

Some ducts may be sensitive to vibrations. In some cases, vehicle traffic may produce vibrations which are propagated inside the tunnels.

3.3 *Comments on distribution networks*

3.3.1 *Collective antennas*

Extra space has to be provided in places to house amplifying equipment. Apart from that, collective antenna cables have no special requirements.

3.3.2 *Telecommunication cables*

The following requirements should be taken into account:

— *Distances from power lines*

Minimum distances from main ducts should be applied (see § 5).

— *Protection against thermal load*

Since telecommunications cables are vulnerable to thermal load, thermal conditions in tunnels must be taken into account. This applies especially for optical cables.

— *Protection against corrosion and lightning*

Telecommunication cables should generally be protected by metal sheaths or shields. This protection may be applied, but the use of joint earth electrodes is either not required or not permissible.

— *Protection against electrical interference*

Normally no special measures need be taken, although cable constructions with a high screening factor or overvoltage relays may be used in some cases.

— *Protection against mechanical forces*

Metal shields may be used to protect cables against mechanical effects such as vibrations or impacts. In the case of lead sheaths, vibration-resistent alloys should be used.

— *Protection against outside effects*

Plastic-covered cables may be protected against rodents with fibreglass or aramid-fibre shielding.

Contractable cable joints may provide protection against earthquakes.

— *Bends*

Since cable curvature is limited, layout plans must take account of permitted curvature radii.

— *Specialized work*

Since work has to be done relatively frequently on telecommunication installations, particularly on sleeves, sufficient working space should be provided (e.g. alcoves or chambers).

3.3.3 *Power cables*

The following requirements should be taken into account:

— *Bends*

The same rules apply, by analogy, as for telecommunication cables.

— *Ambient temperature*

The load capacity of electrical cables depends, among other parameters, on ambient temperature, which should be determined in each case to achieve the ideal balance between tunnel cooling and cable load capacity.

3.3.4 *Gas*

Tunnels containing gas ducts should be ventilated (naturally or artificially). Dilation sleeves should be leakproof and located in separate chambers.

3.3.5 *Water*

The choice of tunnel layout or cross-section should take account of the dimensions of special water duct components. Water ducts may require special precautions against climatic effects to avoid overheating or freezing. Ducts with a nominal diameter of 150 mm may give rise to special problems, in which case the following factors should be taken into account:

— *Temperature rise*

A rise of temperature in a tunnel will have only a negligible effect on the quality of drinking water.

— *Freezing in ducts*

The temperature in inspectable tunnels rarely falls below freezing. Should there be a risk of freezing, appropriate measures should be taken to protect the duct.

— *Bleeding and draining*

Bleeding and draining facilities should generally be located outside tunnels.

3.3.6 *District heating*

The following requirements should be taken into account:

— *Position of ducts*

For assembly purposes, the distance between district heating ducts (not including insulation) and the tunnel wall should not be less than 0.3 m.

— *Heatproofing*

Continuous thermal insulation will diminish heat losses and help prevent the occurrence of thermal shock in the event of a burst water duct.

— *Junctions and intersections*

Permitted radii of curvature for ducts should be observed at junctions and intersections.

— *Dilation devices*

Plans should allow sufficient space for dilation devices.

3.3.7 *Water drainage*

The following aspects should be considered:

— *General*

In most cases pipes will be naturally drained. The means that their level and slope can be adapted to tunnel layouts only within certain limits.

— *Link between drain and tunnel*

In view of the risk of backflow, there should be no open link between the drain and the tunnel.

4 Safety plan

4.1 *Safety objectives*

Various aspects of safety should be considered:

— safety of persons working in the tunnel;

— safety of persons and property outside the tunnel;

— security of distribution.

For the first two items, safety objectives concern the risk of personal injury.

Security of distribution is independent of personal safety. The importance of distribution ducts should not be overlooked, however, not only because of the convenience they provide to the public in general, but also because they may constitute in certain circumstances a vital factor of survival.

4.2 *Safety plan*

4.2.1 *Safety during the construction and installation phase*

The safety plan should comply with existing rules governing safety at work. Special attention should be paid to rules concerning construction work in enclosed spaces. In all cases, the maximum permissible levels of harmful substances or vapours, as defined by insurance companies, should not be exceeded.

4.2.2 *Safety during the operational phase*

The company owning an installation should be responsible for issuing instructions to be observed from the start of operations.

In the event of maintenance or extension work, the safety measures laid down for the construction phase should be observed.

Fire risk and fire-fighting facilities should be established in consultation with the fire brigade.

Tables A-1/L.11 and A-2/L.11 show a model of a safety plan in the operational phase, with an indication of possible preventive measures.

The rules applicable to the construction of a tunnel, as described in § 5, should be established in the light of the safety plan.

4.3 *Special problems to be considered*

A special study of safety aspects should be made, where necessary, with regard to the following points:

— interference between telecommunication lines and high voltage or d.c. railway lines;

— tunnel design;

— ventilation;

— thermal protection;

— water drainage;

— electrical installations;

— gas or fire detection systems.

5 Construction

5.1 *Transversal cross-section*

5.1.1 *General*

The transversal cross-section of a tunnel comprises the following elements:

— ducts and related facilities, including free spaces for repairs and maintenance;

— reserve spaces;

— duct intersections and junctions;

— service gangways.

5.1.2 *Positioning of ducts*

Over and above assembly requirements, the following rules should be applied:

— *Telecommunications and antenna cables*

The following spaces should be observed in relation to power lines:

— low voltage, up to 1000 V: 0.3 m

— high voltage with low induction: 0.3 m

— high voltage with high induction: to be determined

(rigid earthing systems)

— *Power line ducts*

Where cables are supported by brackets or racks, thermal and electromagnetic interaction should be taken into account.

— *Natural gas ducts*

These should be placed as high as possible in the tunnel. This will protect them against mechanical damage and in the event of a leak, gas will accumulate under the ceiling.

— *Water ducts*

These should be placed as low as possible in the cross-section, for which facilitates installation and anchoring. A further factor is that ambient temperature tends to be lower on the tunnel floor.

5.1.3 *Service gangway*

In order to facilitate free and safe transit through the tunnel, no steps should be placed across the service gangway.

Gangway dimensions should be subject to the following rules:

— minimum width: 0.7 m

— minimum height: 1.9 m

— dimension of the largest element to be introduced in the gangway, plus at least 0.2 m.

— dimensions to be increased according to circumstances, particularly at bends, intersections and working alcoves.

5.1.4 *Transversal slope*

A transveral slope should be provided for water drainage.

5.1.5 *Examples of tunnel profiles*

Figures B-1/L.11 and B-2/L.11 represent circular and rectangular tunnel cross-sections respectively. They show how the available space can be divided among the different networks.

5.2 *Openings, access and partitions*

5.2.1 *Openings for equipment*

Openings large enough should be provided to introduce the largest pieces of equipment during assembly and maintenance work in the tunnel. The openings should be located directly above the service gangway. Further openings may be provided during construction, but these should be sealed off before operations begin. Access should be provided for delivery vehicles.

5.2.2 *Access doors for staff*

Staff access points should be located in accordance with escapeways and alarms. Generally speaking, the distance between two access points should not exceed 500 m. The possibility of introducing emergency exits between access doors should be considered.

Access doors should be arranged so that they cannot be obstructed nor allow water or fumes to enter.

Equipment openings and staff access doors should be lockable and as leakproof as possible.

5.2.3 *Partitions*

Careful consideration should be given to the arrangement of transversal partitions. These should all be compatible with escapeways and exits.

5.2.4 *Facilities for the transport of equipment and assembly accessories*

The operational layout should make provision along the service gangway for transport facilities (e.g. ceiling-mounted rails), and for construction accessories (e.g. hooks for pullies and lifting gear or anchor ties for fixtures).

5.3 *Supports and fixtures*

5.3.1 *Loads to be considered*

The following requirements should be taken into account:

— *Permanent loads*

Permanent loads should be indicated in the operating plan.

— *Lifting*

All ducts should, generally speaking, be secured against lifting forces.

— *Seismic effects*

All ducts brackets, supports and cable racks should be able to resist the effects of seismic forces, in accordance with national standards.

— *Explosions*

The ducts and other contents of a tunnel may be strongly shaken by explosions. If the safety plan shows that essential ducts may be exposed to such overloading, it should be ensured that:

— the operation of such ducts is not affected by breakage or deformation;

— no movement may occur which might wrench essential supply ducts off their supports or allow them to collide against tunnel walls or other part of the construction.

Such risks may be avoided with the introduction of shockproof ties and an appropriate arrangement of ducts. Expert advice should be sought in such matters.

5.3.2 *Protection against corrosion*

It is important to protect supports and ties against corrosion in view of the long life of installations (see § 3.2).

5.4 *Transit points between tunnels and open ground*

At points where ducts transit between tunnels and open ground, due account should be taken to relative movements which may occur between the two types of environment.

Tunnel exit points should be as leakproof as possible, so as to avoid the penetration of gas or water in the tunnel.

5.5 *Shut-off devices*

Suitable care should be taken to position shut-off devices of gas, water, district heating and drainage water ducts, on either side of the tunnel wall. It should be possibe to operate all such devices from outside.

5.6 *Ventilation*

5.6.1 *Objectives and rules*

Ventilation should comply with the following objectives:

— *Environment*

Power lines and district heating ducts give off heat. Insofar as such heat is not transferred to the surrounding ground through tunnel walls, cooling must be provided by ventilation.

Controlled ventilation also provides a means of lowering air humidity and contributes to active protection against corrosion.

— *Safety*

As part of the safety plan, the aim of ventilation is to reduce the danger of explosion, to prevent the entry of vehicle exhaust gases and to maintain noxious fumes given off by welding or brazing at permitted working levels.

5.6.2 *Ventilation systems*

The systems of ventilation are:

— *Natural ventilation*

Natural ventilation causes a draft which arises as a result of differences of temperature and pressure. In many cases natural ventilation will produce sufficient movement of air.

— *Mechanical ventilation*

With pressured mechanical ventilation, air from the outside is blown down the tunnel with a fan. Apart from the movement of air, this leads to an increase in pressure, which prevents dangerous gases from entering the tunnel.

5.6.3 *Choice between natural and mechanical ventilation*

The criteria for the choice between ventilation systems are:

— *Technical and safety criteria*

Mechanical ventilation is generally needed in the following cases:

— when old gas ducts, which may not be leakproof, run alongside the tunnel;

— if there is risk that toxic or inflammable materials may enter the tunnel.

As far as operating safety is concerned, one advantage of natural ventilation is that since it relies on no mechanical or electrical component there is not risk of air circulation being stopped as a result of a breakdown.

— *Technical environmental criteria*

In shallow underground constructions, where the walls are in contact with the surrounding ground, internal temperature changes in the tunnel are offset by the thermal inertia of its surroundings. This is why natural ventilation is generally sufficient to provide the required environmetal conditions.

— *Protection against corrosion*

A high level of humidity and especially condensation will speed up the corrosion of ducts and fixtures. A high level of humidity in a tunnel may be caused by:

— the infiltration of water through the tunnel walls;

— bleeding or cleaning water;

— the cooling of warm humid air introduced from outside by ventilation.

High relative humidity should be avoided by the evacuation of any outside water by the shortest route. Mechanical ventilation should be switched off if the starts introducing warm humid outside air into a cool tunnel, as long as this does not lead to any undue increase in other risks.

5.6.4 *Dimensioning of mechanical ventilation*

The distribution of internal partitions should take account of ventilation sectors.

— *Dimensions according to temperature limits*

Temperature limits are generally determined according to physiological acceptable working conditions or according to the capacity of electricity ducts. Owing to the considerable effect of the surrounding terrain on heat transfer as well as thermal effects caused by the construction, relatively little cooling effect is produced by ventilation. Also, little effect is derived from the above-ground outside temperature.

— *Dimensioning allowing for the possibility of gas leaks*

The dimensioning of mechanical ventilation should allow in normal service for the possibility of slight leaks from the gas duct, provided that the concentration of gas is always maintained below the minimum explosive limit, with a sufficient margin of safety.

5.6.5 *Indications concerning the installation of a ventilation system*

In the case of natural ventilation, the cross-section of air inlets will be determined mainly by the quantity of air required.

Consideration should be given to providing suitable outlets on which mobile air extractors (such as those used by the fire brigade) may be attached to the event of a fault or special work.

5.7 *Water drainage*

5.7.1 *Objective and rules*

The objective is to extract the following types of water:

- groundwater and seepage water entering the tunnel owing to the permeability of the tunnel walls;
- tunnel cleaning water;
- water from the bleeding of water pipes;

— water from district heating ducts;

— water leaking from water pipes;

— condensation water.

The drainage of water from a burst duct should be provided under the safety plan.

The water drainage system should meet the following requirements:

— there should be no passage of gas from the tunnel to the drainage pipe;

— no odours should pass from the ducts to the tunnel (traps should be provided).

5.7.2 *Internal network in the case of small quantities of excess water*

The water drainage system will be similar to that of a building. If only small quantities of water are involved, a drainage channel may be provided if a tunnel is suitable inclined.

5.7.3 *Water drainage in the event of a burst duct*

In the case of a burst duct, the normal drainage channel will usually be insufficient to drain off excess water, possibly on account of insuffient capacity in the drainage pipe to which the tunnel is connected. The safety plan should determine what sort of quantity of escaping water needs to be taken into consideration for removal by the tunnel drainage system, in conjunction with appropriate damming and diversion facilities.

5.7.4 *Water drainage through piping situated below the tunnel*

This system allows water to be drained by the effect of gravity. Special care should be taken to prevent any backflow.

5.7.5 *Water drainage into piping situated above the invert level*

In this case, water has to be pumped from a drainage well. The safety plan should indicate whether one or more pumps are needed. The same considerations apply to the provision of separate emergency drainage. An electric pump should be supplemented with a second pump, driven by a different power source. Some sort of signalling system should generally be provided.

5.8 *Signalling systems*

5.8.1 *General*

Signalling and alarm systems should be installed only if all active safety measures have been considered and are deemed to be inadequate. Signalling and alarm systems should be covered by the special safety plan, but it should be borne in mind that the effectiveness of such equipment is only limited and that it is costly to maintain.

5.8.2 *Gas alarm systems*

These systems activate an alarm (signalled at access points) as soon as they detect a dangerous mixture of gas and air. In tunnels equipped with a ventilation system, the latter may be activated to dilute the mixture. Signalling systems, should be set so that the alarm is given at the latest when the gas concentration reaches 50 percent of the minimum detonation threshold. A system should be provided to ensure continuity of operation in the event of a power cut. All leaks should be detected. Detectors should be placed at regular intervals and if necessary above joints, valves, etc.

Gas detectors are indispensable in the case of tunnels connected directly to buildings. Service entraces in buildings should be leakproof. If fixed gas detection systems are not provided or should fail to operate, the absence of explosive or toxic gases should be ckecked with portable instruments before entry to a tunnel.

5.8.3 *Flood alarm systems*

Flood alarm systems should include floater switches placed at low points and in drainage wells, with additional floaters on different levels, thus setting off successive alarms.

5.8.4 *Fire alarm systems*

The need for a fire alarm system should be considered on a case-by-case basis.

5.9 *Other service installations*

5.9.1 *Telecommunication systems*

Internal service communications should be provided for inspections and repairs. The choice will depend on the length of the tunnel, the frequency of inspections and the maintenance plans of different users.

5.9.2 *Electrical power supply*

It may be necessary to use flameproof service equipment in the tunnel.

5.9.3 *Lighting*

Tunnels should generally be equipped with a permanent electrical lighting system. An independent emergency lighting system should also be provided.

5.9.4 *Tunnel cleaning*

The possibility of using clearing machinery should be considered at the outset (passage width, water taps).

5.9.5 *Marking and signalling*

All obstacles and safety devices should be clearly marked (steps, emergency exists, direction of exit). Ducts should be identified with specific, clearly visible and durable marking. In complex tunnel systems, route markings should be provided to help persons unfamiliar with the layout to find their way.

5.9.6 *Rules of usage*

Safety rules should be laid down for visits to the tunnel, drawing attention to communication, safety and evacuation facilities.

6 Standardization of plans for underground ducts in tunnels used jointly for pipelines and telecommunication cables

6.1 *Introduction*

This section describes the graphic representation of underground ducts in joint trenches or tunnels.

The graphic representation of underground ducts in joint tunnels is standardized in several countries, and this document therefore confines itself to a general presentation. The management of the network concerned is responsible for updating plans and documents.

Plans must contain all particulars required for the operation, maintenance and extension of underground ducts, as well as for their protection and continual operation during repairs.

6.2 *Terminology*

The term **underground duct** is defined in this Recommendation to mean a vector for the distribution of a fluid, connecting the place of production with the place of consumption or drainage. It covers pipelines for electricity as well as telecommunication cables.

6.3 *Field of application*

Underground duct plans form part of a general information system. These ducts, whether situated in public or in private areas, constitute public networks for distribution and drainage and for the protection of the environment.

6.4 *Rules applicable to underground duct plans*

6.4.1 *Scope of information*

Underground duct plans must contain, for the benefit of their users, complete and up-to-date information on:

- the characteristics of the various ducts;
- their location and level;
- their network connections.

6.4.2 *Characteristics*

Plans must contain all the particulars required for the operation, maintenance and extension of underground ducts, as well as for their protection and continual operation during repairs; they must correspond to the particular features of each network.

6.4.3 *Location and level*

It should be possible from the plans to determine the position of ducts and duct components accurately, to transpose it to other documents and to relate it unequivocally to official survey points. Measurements must be taken in conformity with current surveying rules.

6.4.4 *Network connections*

It should be possible to determine from the plans how ducts are connected to the network to which they belong. Overall plans or diagrams will often be required.

6.5 *Basic plan*

6.5.1 *Special rules*

The basic plan provides the basic reference for underground duct plans. Its purpose is to map the layout of areas where ducts are situated.

6.5.2 *Contents*

The basic plan essentially contains information on:

- fixed points (triangulation points, base points, levelling points);
- property limits, frontiers;
- buildings;
- types and boundaries of crops.

6.6 *Duct or network plans*

6.6.1 *Types of plan*

The network plan contains references to all the equipment and telecommand devices of a distribution or drainage network. Network plans are of the following types:

— drainage water;

— electricity;

— telecommunication installations;

— district heating;

— gas;

— collective antenna installations;

— water.

6.6.2 *Special rules*

Every duct or network plan must meet the operational requirements of the network concerned. The following rules shall apply:

— it must contain all legally required information;

— for ducts, it must give information on their development, construction, operation and maintenance;

— it must contain instructions for use in the event of breakdown or malfunction;

— it must supply operators and third parties with information on the location and level of ducts.

6.6.3 *Contents*

A duct plan generally comprises the following data:

Geometric data

— duct location;

— duct level.

Duct data

— fluid transported;

— managing enterprise;

— function;

— type and content;

— profile;

— dimensions;

— material;

— operational condition;

— construction or duct components;

— identification.

Auxiliary installation data

— Protective devices.

6.6.4 *Scale of plan*

The choice of scale depends on the density of ducts. The scale of the duct plan should correspond, if possible, to that of the basic plan drawn up in accordance with the survey.

The following scales are recommended: 1:100, 1:200, 1:250 or 1:500, according to the concentration of buildings in the area.

6.7 *Preparation of plans*

6.7.1 *Definition*

By **preparation of plans and data management** the capture, updating, processing and representation of all data relating to underground ducts is understood. Any information system for underground ducts can thus be run either manually or by computer.

6.7.2 *Surveys*

The principles of surveys are as follows:

Whenever ducts are laid or altered, their location and, if necessary, their level should be surveyed.

If excavations reveal ducts which were hitherto unknown or the location of which had been uncertain, these ducts must be surveyed. This rule also applies to ducts located by detection.

6.7.3 *Accuracy of location*

The accuracy of the points used to locate ducts must comply with land survey rules.

6.7.4 *Survey methods*

One of the following survey methods must be used:

- polar coordinates;
- orthogonal coordinates;
- distance resection;
- prolongations.

6.7.5 *Procedure for preparing plans*

— single-plan system. The basic plan and duct data should appear on the same medium. Ducts have to be copied onto the basic plan.

— system of separate superimposable plans. With this system, each level of data appears on a separate sheet. The basic plan, duct data and network data can appear as different data levels.

6.7.6 *Representation*

Ducts are represented graphically by means of conventional signs described in special standards.

6.7.7 *Writing*

Writing must be clearly legible and uniform and must be suitable for reduction and reproduction.

6.8 *Use of data processing systems — General analysis*

A very large volume of data on underground ducts needs to be captured, stored, updated, processed and reproduced, and they have to be extractable in different combinations. It is therefore advisable to use computer techniques, since this is the only way of establishing an integrated system of information on underground ducts. Such a system can meet various requirements, such as combining different data levels by the automatic process of separate superimposable plans; it can also produce extracts (plans, lists, etc.) with a diversified content.

An underground duct information system has to be designed as a continuous sequence of operations, including data capture in the field or in the office, storing and processing, and printing out of plans and lists.

6.9 *Maintaining plans up to date*

6.9.1 *Updating*

Duct plans cannot fulfil their purpose unless they are constantly updated. The following principles should be observed:

- data on new or modified ducts must be collected and processed as soon as work is completed;
- basic plans must be kept up to date.

6.9.2 *Access to localization data*

Localization documents should be available for consultation at any time between the completion of duct laying and the entry of data in the plan.

6.10 *Model plan*

6.10.1 *Content*

The model plan in Annex C shows distribution duct pipelines in addition to transport duct tunnels.

6.10.2 *Graphic representation*

The tunnels and pipelines should be drawn to scale, corresponding in width to the internal diameter of the tubes.

6.10.3 *Representation of ducts*

Since so many ducts and cables are either hung, laid or fixed inside tunnels, it is not possible to represent each duct individually. They are therefore represented in cross-sections of the tunnel, which are placed next to the pipeline or on separate sheets with an indication of their location.

Branches, splices, spurs and other details are entered either on the plans or in special files. The distribution ducts for the different fluids should be indicated by conventional signs.

ANNEX A
(to Recommendation L.11)

H.T. [1T1.11]
TABLE A-1/L.11
Safety plan against outside risks

Risk	Consequences	Level of risk	Security requirement	{		
				At source	During construction	In service

{
Incoming gas from parallel ducts or
intersections
}
Explosion, fire, asphyxia
or poisoning
}
Rare
Caused only by a burst duct
Damage will be extensive (to persons, ducts and tunnel)
}
Same as for load-bearing structure
}
Sealing or replacing gas ducts
}
Sealing duct exit between tunnel and ground
Natural ventilation
Forced ventilation (tunnel under pressure)
Tunnel to be divided into segments, with fireproof partitions
}
Measure gas concentration before entering tunnel
Check gas concentration regularly
}
	{
	{
	{
	{
	{
	{					

Incoming water from outside Possibility of drowning Damage to duct } Protection against flood water } Well-placed openings Leakproof doors, trap-doors and covers All pipes to be secured against upward thrust Efficient water drainage system }	{ Rare { Monitoring system	Distribution security	{			
Unstable ground foundation Duct bursts, particularly at transit point from tunnel to ground } Same as for load-bearing structure } Consolidation of foundation ground } Flexible fixtures Appropriate designs of duct transit points } Monitoring by measurement a) The above list of preventive measures is not exhaustive. }	{ Foreseeable effects { { {	{				

Table A-1/L.11 [1T1.11], p.

H.T. [2T1.11]

TABLE A-1/L.11 *(continued)*

Risk	Consequences	Level of risk	Security requirement	{ At source	During construction	In service
Seismic tremors Duct bursts, particularly at transit point from tunnel to ground } Variable probability according to regions Substantial effects } Continued operation of all ducts } Tremor-resistant fixtures Special design of duct exit points }	{ { {	{				

{
Effect of weapons, explosion impact
}
In time of war, effects are likely to lead to serious damage
}
Continued operation of all ducts
}
Shock-resistant fixtures
Appropriate design of duct exits
}
	Duct bursts
	
	{
		{
		
		{				

Sabotage Continued operation of all ducts }	Duct bursts Explosion Fire	Rare Lockable entry points	{ Entry control			

a) The above list of preventive measures is not exhaustive.

Table A-1/L.11 [2T1.11], p.

H.T. [1T2.11]

TABLE A-2/L.11

Safety plan for risks inherent in tunnel ducts

Description of risks {
Possible preventive measures | ua)
}
Network Risk Consequence Level of risk Security required

Electricity Fire, smoke {
Physical injury
Duct bursts
Cables on fire
Destruction of anticorrosion protective coatings and insulation
} {
Rare
Gives rise to personal risk and extensive material damage
} {
For persons, same for load-bearing structures
} Careful laying of ducts {
Segments to be separated with fire-resistant partitions
} Fire alarm system
Toxic and corrosive fumes {
Intoxication of persons
Damage to ducts and metal elements
} {
Restricted use of PVC-coated ducts
Exclusion of PVC cable fixtures
}
{
Oil leakage from oil-filled cables
} {
Pollution of groundwater and spring water
} {
Rare, gives rise to indirect personal risk
} {
For persons, same as for load-bearing structures
} {
Oil-filled cables to be placed as high as possible in tunnel
} Oil drainage device Monitoring of oil pressure

{

{

{

{

{

{

{

	{ Asphyxia and intoxication	Rare Physical injury						

Table A-2/L.11 [1T2.11], p.

Gas

H.T. [2T2.11]

TABLE A-2/L.11 *(continued)*

Description of risks							
Possible preventive measures | ua) } Network	Risk	Consequence	Level of risk	Security required		{	
Water Tunnel flooding due to duct burst } Possibility of drowing Damaged ducts } Rare Personal risk and little material damage } For persons, same as for load-bearing structures } Careful design and construction of installation } Strong fixtures Automatic valves Effective water drainage system All pipes to be secured against upward pressure } Regular checks for possible leaks Corrosion checks Alarm system (with floater switch) }	{ { { { { { {						
District heating Escaping steam or hot water due to duct burst or leak } Physical injury Duct bursts and other damage to ducts due to rapid rise of temperature } For persons, same as for load-bearing structures } Shut-off valves at tunnel ends controlled from outside Remotely controlled shut-off valves Partitions }	{ { Rare Extensive damage Careful installation of ducts Alarm system	{ {					
Drainage water Ducts to placed above the highest water level }	Partial flooding	Damage to ducts	Rare Little material damage	Limitation of material damage	{		
Physical injury and material damage } For persons, same as for load-bearing structures } Leakproof and lockable access points and inspection holes }	Complete flooding of tunnel Rare { T Ducts to be secured against upward pressure	{ {					

a) The above list of preventive measures is not exhaustive.

Table A-2/L.11 [2T2.11], p.

ANNEX B
(to Recommendation L.11)

Examples of tunnel profiles

Figure B-1/L.11, p.

Figure B-2/L.11, p.

ANNEX C
(to Recommendation L.11)

Model plan

Figure C-1/L.11, p.