IEC TR 62691

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TECHNICAL REPORT

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Optical fibre cables – Guidelines to the installation of optical fibre cables

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Optical fibre cables –
Guidelines to the installation of optical fibre cables

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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IEC TR 62691, which is a Technical Report, has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

This second edition cancels and replaces the first edition published in 2011. It constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) more details have been added on cables for lashed applications (transferred from IEC 60794-3-10);
b) more details have been added on cables for storm and sanitary sewer applications (transferred from IEC 60794-3-40);
c) more details have been added on cables for high pressure gas pipe applications (transferred from IEC 60794-3-50);

d) more details have been added on cables for drinking water pipe applications (transferred from IEC 60794-3-60);

e) a reference to IEC TR 62263 has been included, concerning optical cables installation on high voltage power lines;

f) a revision, and an update when applicable, has been done on the referred documents.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
86A/1721/DTR	86A/1730/RVC

Full information on the voting for the approval of this Technical Report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Optical fibre cabling provides a high performance communications pathway whose characteristics can be degraded by inadequate installation. This Technical Report provides guidance to assist the user and installer with regard to the general aspects of the installation of optical fibre cables covered by the IEC 60794 series, and the particular aspects of the "blowing" technique.

Optical fibre cables are designed so that normal installation practices and equipment can be used wherever possible. They do, however, generally have a strain limit rather lower than metallic conductor cables and, in some circumstances, special care and arrangements can be needed to ensure successful installation.

It is important to pay particular attention to the cable manufacturer's recommendations and stated physical limitations and not exceed the given cable tensile load rating for a particular cable. Damage caused by overloading during installation may not be immediately apparent but can lead to failure later in its service life.

This document does not supersede the additional relevant standards and requirements applicable to certain hazardous environments, for example electricity supply and railways.

OPTICAL FIBRE CABLES –

Guidelines to the installation of optical fibre cables

1 Scope

IEC TR 62691, which is a Technical Report, gives recommendations for handling and installing optical fibre cables on metropolitan communication networks. Installation methods covered by this document include underground ducts, trenchless technique, blowing in microducts, aerial installation on poles, lashed aerial in metropolitan networks, direct buried and use of trenches.

Special installation situations such as tunnelling and lead-in installations, on-bridges, underwater, use of sanitary sewers, high pressure gas pipes and drinking water pipes are commented and detailed.

Installation and maintenance of optical fibre cables on overhead power lines including the following are not covered by this document and are referred to in IEC TR 62263:

- optical ground wire (OPGW) fibre cable;
- optical phase conductor (OPPC) fibre cable;
- optical attached fibre cable (OPAC);
- all dielectric self-supporting (ADSS) optical fibre cable.

IEC TR 62263 includes an extensive coverage on recommendations to ensure the safety of personnel and equipment when installing or maintaining these types of optical fibre cables on overhead power lines.

2 Normative references

There are no normative references in this document.

3 Installation planning

3.1 Installation specification

The successful installation of an optical fibre cable can be influenced significantly by careful planning and assisted by the preparation of an installation specification by the user. The installation specification should address the cabling infrastructure, cable routes, potential hazards and installation environment and provide a bill of materials and technical requirements for cables, connectors and closures.

The installation specification should also detail any civil works, route preparation (including drawpits, ductwork, traywork and trunking) and surveying that are necessary, together with a clear indication of responsibilities and contractual interfaces, especially if there are any site or access limitations.

Post-installation requirements for reinstatement, spares, ancillary services and regulatory issues should also be addressed.

3.2 Route considerations

Whilst optical fibre cables are lighter and installed in longer lengths than conventional metallic cables, the same basic route considerations apply.

Route planning and cable handling methods shall carefully take into account the specified minimum bending radius and maximum tensile loading of the particular optical fibre cable being installed so that fibre damage, giving rise to latent faults, can be avoided.

Some of the most difficult situations for the installation of optical fibre cables are in underground ducts, and the condition and geometry of duct routes are of great importance. Where the infrastructure includes ducts in poor condition, excessive curvature, or ducts already containing cables or access points with abrupt changes of direction, the maximum pull distance will be reduced accordingly.

As provision of long cable lengths in underground duct or aerial situations may involve installation methods that require access to the cable at intermediate points for additional winching or blowing effort, or "figure-8" techniques, these sites should be chosen with care. Consideration should also be given to factors of time and disturbance. Installation equipment may be required to run for long periods of time, and the time of day, noise levels, and vehicular traffic disruption should be taken into account.

Because the condition of underground ducts intended for optical fibre cable is of particular importance, care should always be taken to ensure that ducts are in sound condition and as clean and clear as possible. Consideration can also be given to the provision of a subduct system, either in single or multiple form, to provide a good environment for installation, segregation of cables, extra mechanical protection and improved maintenance procedures. Subducts can be more difficult to rope and cable than normal size ducts, particularly over long lengths, and the diameter ratio between the cable and subduct should be considered. Note that in ducts or subducts, bundles of microducts can also be installed, for example by pulling or blowing.

For overhead route sections, a very important consideration is the need to minimise in-service cable movement. Movement of the cable produced by thermal changes, cable weight, ice loading, wind, etc. may have a detrimental effect. A stable pole route, with all poles set as rigidly as possible, is therefore an important element in reducing possible movement, and consideration should be given to purpose-designed, optical fibre-compatible, pole top fittings and attachments.

Although optical fibre cables are generally light in weight, their addition to an existing suspension member can take the optical fibre beyond its recommended strain limit, and the added dip and extension should be calculated before installation.

Where it is planned for long lengths of optical fibre cable to be directly buried or ploughed, those sections involving ploughing can, with advantage, be pre-prepared using specialised slitting or trenching equipment.

3.3 Cable installation – Tension considerations

The potential for providing very long lengths of optical fibre cable can lead to the need for confidence that a particular installation operation will be successfully achieved, particularly in underground ducts, and a good indication can be provided, in some cases, by calculating the maximum cable tension. This maximum tension can be compared with the stated mechanical performance of the cable and, where these values are close, consideration can be given to methods for providing a greater margin of safety such as an alternative cable design, shortening the route, changing the route or direction of cabling, provision of intermediate winches, or by taking special precautions at particular locations. Calculation considerations are indicated in 3.4 and 3.5.

Cable tensions in ploughing or trenching are generally minimal, much smaller than the rated tension of the cable. Momentary tensions and jerking due to cable reel inertia when paying off cables, which result in tensions in the immediate area being installed, should be considered. In ploughing, frictional tension through the plough chute shall be considered, but is generally small.

Cable compression and buckling in pushing and blowing should also be considered. Cable compression less than a critical maximum value generally has no effect on cable performance. Excessive pushing – either due to pushing or blowing – may cause the cable to corkscrew in the duct or fold over, which will damage the fibre. Considerations to be taken in account are:

- cable with smaller diameters will require a lower maximum push force;
- the maximum cable push force will also decrease with larger duct inside diameters.

In either case, a crash test per the cable and installation equipment manufacturers' procedures should be performed to determine the maximum push force.

See 3.5 and 3.6 for guidance on friction forces consideration during installation.

3.4 Duct installations – Cable tension predictions

It should be noted that the tension calculations for duct installations are of inexact necessity since the actual geometry and characteristics of the ducts are seldom well known. The calculations, therefore, should be utilized with regard to experience and empirical data from similar installations.

Two sets of equations are presented below. The first, presented in 3.5.2, is used to calculate cable tension in pulling applications. The second, presented in 3.5.3, is used to calculate cable tension in cable pushing and blowing applications; it may also be used for pulling. Note that the first set, for pulling only, is much simpler and neglects cable weight in Equation (3). The second set, for any of the duct installation methods, comprises very complex equations involving much more data, including amplitude and frequency of innerduct undulations. Much of this data is generally not known and shall be estimated from cable experiments and empirical data from similar installations.

3.5 Maximum tension or compression force exerted on cable

3.5.1 General

The following main contributory functions need to be considered when calculating cable forces-tensions or compression:

- the mass per unit length of cable;
- the diameter of the cable;
- the stiffness of the cable;
- the coefficient of friction between cable sheath and surfaces with which it will come in contact;
- the inner diameter of the duct;
- deviations (bends and undulations) and inclinations.

3.5.2 Total cable tension – pulling applications

The calculated cable tension or compression force should be evaluated with respect to the maximum rated cable tension (for pulling) or the maximum pushing force or crash force (for pushing or blowing) for the cable being installed according to the cable specification or the manufacturer's declared rating.

Figure 1 shows an example of routes and common tension formulae (see Equations (1) to (3)):

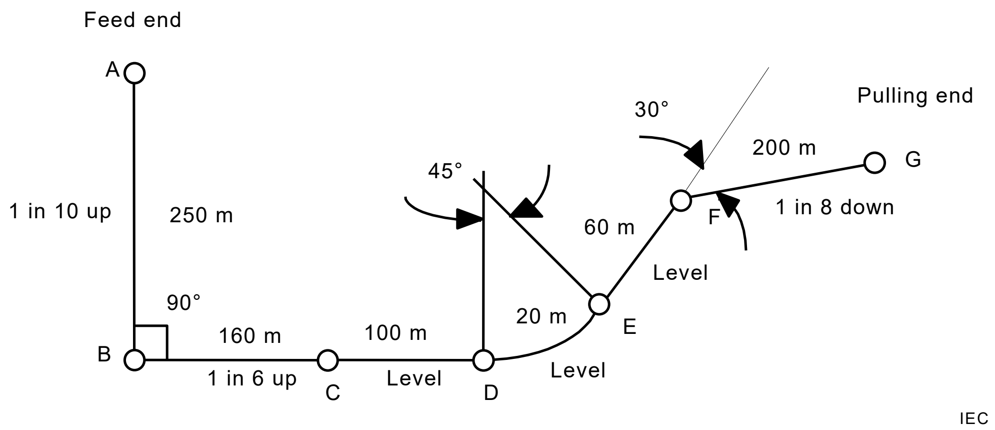

Figure 1 – Cable tension calculations (Equations (1) to (3))

Equation (1) is used for straight sections, Equation (2) for inclined sections and Equation (3) for deviated sections and bends.

$$T = T_i + \mu lwg \tag{1}$$

$$T = T_i + lwg\,(\mu \cos\theta + \sin\theta) \tag{2}$$

$$T = T_i \exp(\mu\theta) \tag{3}$$

where

T is the tension at end of section (N);

T_i is the tension at beginning of section (N);

μ is the coefficient of friction (between cable and duct or guide);

l is the length of section (m);

w is the cable specific mass (kg/m);

θ is the inclination (radians, + up, – down) or deviation (radians, horizontal plane);

g is the acceleration due to gravity (9,81 m/s^2);

The resulting total tensions calculations are shown in Table 1:

Table 1 – Calculation for total tension

Section	Length	Tension at beginning of section T_i	Inclination	Deviation	Equation	Tension at end of section (cumulative) T
	m	N	rad	rad		N
A	–	0	–	–	–	0
A – B	250	0	0,100	–	2	1 460
B	–	1 460	–	1,571	3	3 464
B – C	160	3 464	0,165	–	2	4 484
C	–	4 484	–	–	–	4 484
C – D	100	4 484	–	–	1	4 980
D	–	4 980	–	–	–	4 980
D – E	20	4 980		0,785	3	7 669
E	–	7 669	–	–	–	7 669
E – F	60	7 669	–	–	1	7 967
F	–	7 967		0,524	3	10 628
F – G	200	10 628	0,124	–	2	11 390

Where more than one cable per duct is installed, tension can be greatly raised, and it is necessary to take account of this by applying a factor before the deviation calculation. Factors vary with the number of cables, sheath/cable materials, cable/duct sizes, cable flexibility, etc. Values can be in the order of 1,5 to 2 for two cables, 2 to 4 for three cables and 4 to 9 for four cables.

3.5.3 Total cable tension – pushing, blowing, or pulling applications

3.5.3.1 General

Total tension can be calculated on a cumulative basis working through each section from one end of the route to the other. Calculation is done using the common tension and blowing formulae listed below:

$$F = \frac{WP^2}{8\pi A}\sinh\left[\frac{8\pi Afl}{P^2} + \sinh^{-1}\left(\frac{8\pi A}{WP^2}F_i + \frac{3AB}{2W(P/4)^4}\right)\right] - \frac{48B}{\pi P^2} \quad \text{(4) (horizontal pulling)}$$

$$F = \left(F_i \pm \frac{WP^2}{8\pi fA} + \frac{48B}{\pi P^2}\right)e^{\frac{8\pi fA}{P^2}l} \mp \frac{WP^2}{8\pi fA} - \frac{48B}{\pi P^2} \text{ (+ .. – for upwards)} \quad \text{(5) (vertical pulling)}$$

$$F = F_i e^{f\theta} + \frac{2Bf}{\sqrt{6\left(D_d - D_c\right)R_b^3}} \quad \text{(6) (deviations and bends)}$$

$$\frac{dF}{dx} = f\sqrt{(W\cos\alpha)^2 + \left[\frac{3AB}{2(P/4)^4} + \frac{8\pi A}{P^2}F\right]^2} + W\sin\alpha \quad \text{(7) (inclined pulling)}$$

$$\frac{dF}{dx} = f\sqrt{(W\cos\alpha)^2 + \left[\frac{3AB}{2(P/4)^4} + \frac{8\pi A}{P^2}F\right]^2 + \left(\frac{D_d - D_c}{\pi^2 B}F^2\right)^2} + W\sin\alpha \quad \text{(8) (inclined pushing)}$$

$$\frac{dF}{dx} = f\sqrt{(W\cos\alpha)^2 + \left[\frac{3AB}{2(P/4)^4} + \frac{8\pi A}{P^2}F\right]^2 + \left(\frac{D_d - D_c}{\pi^2 B}F^2\right)^2} + W\sin\alpha - \frac{\pi D_c D_d\left(p_i^2 - p^2\right)}{8l\sqrt{p_i^2 - \left(p_i^2 - p^2\right)\frac{x}{l}}}$$

(9) (blowing; inclined)

where

F is the force at end of section (N);

F_i is the force at beginning of section (N);

f is the coefficient of friction, COF (between cable and duct or guide);

m is the cable specific mass (kg/m);

l is the length of duct (m);

W is the cable specific weight = gm (N/m);

g is the acceleration of gravity (9,81 m/s^2);

B is the cable stiffness (Nm^2);

D_c is the cable diameter (m);

D_d is the duct inner diameter (m);

A is the amplitude of duct-undulations (m);

P is the period of duct-undulations (m);

R_b is the bending radius of bend (m);

θ is the deviation of bend (radians, horizontal plane);

α is the inclination (radians, + up, – down);

p_i is the air pressure (absolute) at beginning of section (N/m^2);

p is the air pressure (absolute) at end of section (N/m^2);

x is the position in the section (m).

Equations (4), (5) and (6) are analytical solutions; Equations (7), (8) and (9) have to be solved numerically.

Figure 2 shows an example of a cable with diameter of 18 mm, weight of 2 N/m and stiffness 5 Nm^2, which is installed in a 40/33 mm duct of 2 000 m total length laid in the trajectory below (the red sections are vertical):