IEC/TR 62470

Edition 1.0 2011-10

TECHNICAL REPORT

colour inside

Guidance on techniques for the measurement of the coefficient of friction (COF) between cables and ducts

IEC/TR 62470:2011(E)

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Guidance on techniques for the measurement of the coefficient of friction (COF) between cables and ducts

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE N

ICS 33.180.10 ISBN 978-2-88912-744-3

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

GUIDANCE ON TECHNIQUES FOR THE MEASUREMENT OF THE COEFFICIENT OF FRICTION (COF) BETWEEN CABLES AND DUCTS

FOREWORD

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IEC TR 62470, which is a technical report, has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
86A/1407/DTR	86A/1417/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 web site 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- withdrawn,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.

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GUIDANCE ON TECHNIQUES FOR THE MEASUREMENT OF THE COEFFICIENT OF FRICTION (COF) BETWEEN CABLES AND DUCTS

1 Scope and object

This technical report describes three techniques to measure the coefficient of friction (COF) between cables and ducts. For a given technique, cable construction, installation method (pulling, pushing, or blowing), and duct size, the relative values of the COF can give some indication as to the relative ease of installation. The techniques can be used for traditional cables and ducts (see IEC 60794-3-10) as well as for microduct cables and microducts (see IEC 60794-5). A fibre or fibre unit may be evaluated in place of a cable in all techniques.

Methods A, B, and C are distinguished by the equipment used for measurements:

- method A – using a wheel around which the duct is wound, a cable with attached weight being pulled through the latter, while measuring the force needed for this;
- method B – using a device to clamp a duct specimen, a cable specimen placed inside, tilting both while measuring the angle at which the cable specimen starts to slide, or the angle which sustains sliding; and
- method C – using a device to clamp and straighten a cable specimen, a duct specimen placed around it, tilting both while measuring the angle at which the duct specimen starts to slide, or the angle which sustains sliding.

The COF when the cable is not moving with respect to the duct is the static COF, and will increase until sliding suddenly starts. The COF while the cable is sliding within the duct is the kinetic or dynamic COF. It should be noted that the static COF will generally be a higher value than the kinetic COF.

The results from the three methods can be compared qualitatively, but are not represented as being equivalent. None of the methods are represented as being the Reference Test Method. Method A will yield the kinetic COF; methods B and C will yield both static and kinetic COF.

Both the static and kinetic COF may be dramatically affected by lubrication of the cable and/or duct. While not specifically addressed herein, the intent of these methods may be used with lubricated cable/duct samples.

These methods do not constitute a routine test used in the general evaluation of the installation performance of cables in ducts. This parameter is not generally specified within a detail specification.

2 Reference documents

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced documents (including any amendments) applies.

IEC 60794-1-1:2001, *Optical fibre cables – Part 1-1: Generic specification – General*

IEC 60794-3-10: *Optical fibre cables – Part 3-10: Outdoor cables – Family specification for duct, directly buried and lashed aerial optical telecommunication cables*

IEC 60794-5: *Optical fibre cables – Part 5: Sectional specification – Microduct cabling for installation by blowing*

3 Test procedures

3.1 Method A: wheel test

3.1.1 General

This subclause describes a technique for the measurement of the COF between a cable specimen and a duct specimen, an important parameter for the installation performance (pushing, pulling, blowing, etc.) of the cable in the duct; see IEC 60794-1-1:2001, Annex C (to be IEC/TR 62691). This method particularly evaluates the friction seen when a cable travels around a curve in a duct.

In this method, a cable specimen with attached weight is pulled through a duct specimen wound around the wheel and the pulling force is measured.

Several variants of wheel tests are used with different weights, diameters, and angles over which the duct is pulled over the wheel. Sometimes a pulley is also used to direct the cable in line with the pulling/force-measuring device. One variant is given here as an example.

3.1.2 Sample

The test sample comprises a duct specimen and a cable specimen of the type under consideration. A new, clean, grease-free specimen of each is required for each test to avoid the effects of wear and contamination. Sometimes a dummy cable, with the same weight but a lower stiffness than the cable to be tested, is used to minimise stiffness effects at the ends of the ducts.

The duct specimen is of sufficient length to wrap around the wheel or segment (see 3.1.3) the number of times required by the detail specification, with an additional length for an entrance and exit end (see Figure 1 and 3.1.4). Typically, 1 wrap around the wheel is used.

The cable specimen shall be long enough to fit within the duct specimen, with additional length to accommodate attachments at each end (see 3.1.3 and 3.1.4) and gauge length(s) for all test runs (see 3.1.4).

3.1.3 Apparatus

A wheel with radius R per the detail specification (50 $\pm$ 2 cm is the suggested standard value) is placed before a tensile test machine, see Figure 1. A mass, M, is attached to the tail end of the cable specimen to provide the specimen with a counter-weight, W (see Figure 1). The weight serves to simulate the upstream functional force, as friction from a long length of cable. The arrangement allows the pulling force to be measured where a cable specimen is pulled through a duct specimen wound around the wheel.

In the case of installation by blowing the attached weight in the wheel test must be small in order to simulate the friction in blowing practice as closely as possible. In this case its mass M should be approximately equal to the mass of a length of 2 m of the cable specimen. The low forces involved in said case do not allow the use of (relatively small diameter) pulleys, where bending the cable, thus dissipating energy, results in extra forces that cannot be ignored.

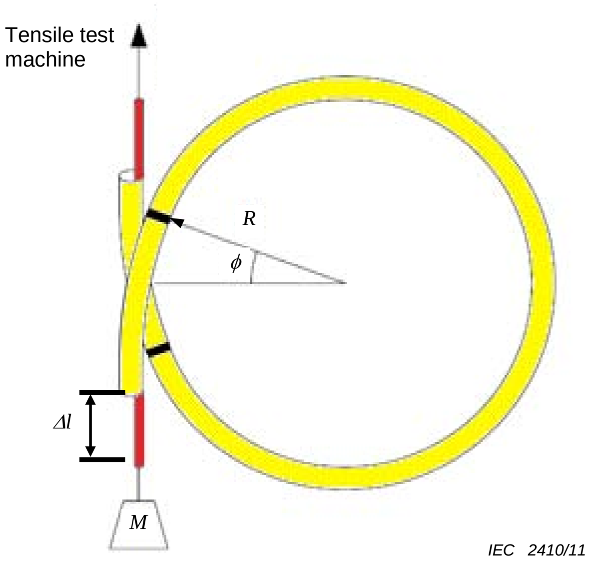


Figure 1 – Sketch of a wheel test

3.1.4 Procedure

The procedure follows the intent of the following steps, with variations as necessary for the specific test:

- Wind the duct specimen firmly around the wheel over the arc for the number of turns specified in the detail specification (360º, 1 wrap, is a common value). At each end of the duct specimen, a free angle, ϕ, of about 10º is provided (see Figure 1). This minimises the effect of bending a cable with stiffness from straight to curved.
- Insert the cable specimen into the duct by pushing or pulling, as appropriate. Take care to avoid damaging the inner surface of the duct.
- Attach a weight to the cable. The value of the mass is per the detail specification, mindful of the discussion in 3.1.3.
- Pull the cable through the duct at the specified speed for the specified length, continuously measuring the force. This sequence is the test run. A speed of 1,0 or 1,8 m/min is frequently used. A first length pulled is ignored in evaluating the force (typically 20 cm), thereafter, the force is measured for a gauge length (typically 50 cm).

  NOTE 1 The measured COF can be affected by the speed used in the test. The relationship of the measured COF to the effective COF in actual installations can therefore be affected. The actual installation speeds of interest could be used in the test, but this might lead to needing longer cable specimens in the test and modification of the test setup.

- Repeat the test run several times, as specified, and average the pulling force. Typically, about five test runs are performed. The data should be examined for outliers. Often, the first one or two test runs should be excluded from the averaging, best simulating the long length cable sliding found in a practical installation.

3.1.5 Calculations

The COF can be found from:

$$F = \left(M\mathrm{g} + W\Delta\right)\exp\left(2n\pi f\right) + \frac{2f}{1+f^2}WR\left[\exp\left(2n\pi f\right) - 1\right] \quad (1)$$

where

F force to pull the cable through the duct (N);

M is the mass of the weight (kg);

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

W is the weight of the cable specimen per unit length (N/m);

Δl is the length of cable outside the duct circle (m);

n is the number of wraps on the wheel;

f is the COF;

R is the radius of the wheel (m).

The force to pull the cable through the duct is the average of the values of the repeated test runs; see 3.1.4. The value of f can be calculated by iteration.

NOTE 2 See Bibliography for the equation.

NOTE 3 The equation is for coils oriented vertically (axis of helix horizontal). See Bibliography reference for other orientations.

NOTE 4 Different weights and wheel diameters may produce different results. They should be selected carefully to result in consistent results for a given cable construction.

3.1.6 Results

- The following information should be reported for each test:
- test apparatus arrangement;
- diameter of wheel;
- length of the cable outside the duct circle;
- cable specimen details
  - seath material
  - outer diameter
  - weight per unit of length;
- duct specimen details:
  - duct materials
  - inner diameter
  - details of the inner surface (smooth, ribbed, etc.);
- mass of the weight;
- speed at which the cable is pulled through the duct;
- force to pull the cable through the duct;
- calculated COF;
- relative humidity and ambient temperature during the test.

3.2 Method B: sloped duct test

3.2.1 General

This subclause describes a technique for the measurement of the COF between a cable specimen and a duct specimen, an important parameter for the installation performance (pushing, pulling, blowing, etc.) of the cable in the duct; see IEC 60794-1-1:2001, Annex C (to be IEC/TR 62691).

3.2.2 Sample

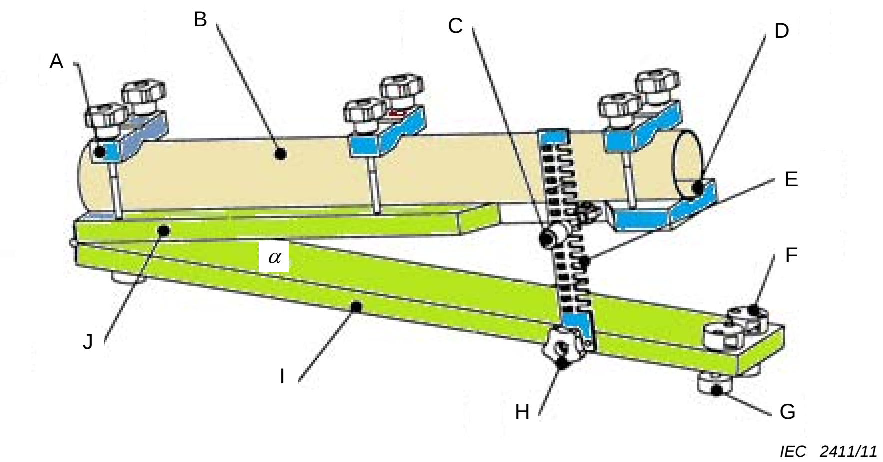
The test sample comprises a duct specimen and a cable specimen of the type under consideration. A new, clean, grease-free specimen of each is required for each test to avoid the effects of wear and contamination.

The duct specimen is of a length consistent with the apparatus of Figure 2. The duct specimen often must be straightened such that it will be straight when mounted in the apparatus.

The cable specimen is shorter than the duct specimen. Straightening of the cable specimen and a short length of this specimen is required to achieve a specimen that is substantially straight. Take care that the length of the cable specimen is short enough but not so short as to induce tumbling of the specimen. The (intrinsic) bend radius of the cable should not result in touching opposite walls of the duct, which would result in extra friction due to the spring action of the cable ends. Also care shall be taken that no filling compound drips out of the cable specimen and comes into contact with the cable specimen sheath. The ends of the cable specimen may be treated with a pencil sharpener or a similar tool, such that the duct is only in contact with the outer sheath of the cable. The combination of the straightness of the cable and its length can affect the results.

3.2.3 Apparatus

A duct specimen is mounted straight on a duct supporting plate, see Figure 2. In this duct specimen the cable specimen is placed. The duct supporting plate can be tilted with respect to the base plate. Care shall be taken to place the base plate as horizontally as possible.



KEY:

A:	duct fixing strap	F:	level indicator
B:	duct	G:	level setting screw
C:	setting wheel	H:	locking wheel
D:	cable	I:	base plate
E:	coefficient of friction indicator	J:	duct support

Figure 2 – Sketch of the sloped duct test

3.2.4 Procedure

The procedure follows the intent of the following steps:

- Attach the duct specimen, placing it straight on the duct support.
- Insert the cable specimen in the duct at the upper end, opposite the pivot of the supporting plate.
- Adjust the base plate horizontally using the level setting screw
- Static COF – Tilt the duct support with duct and cables specimens. Measure the angle with the base plate, α, at which the cable specimen starts sliding.
- Kinetic (sliding) COF – Tilt the duct supporting plate to the angle α to be evaluated. Start the cable specimen moving by hand, e.g. by tapping the specimen. If the cable does not continue sliding to the end of the duct, increase the angle α by a small increment and repeat the test until the cable slides. If the cable initially continues sliding, decrease the angle α by a small increment and repeat the test until the cable does not slide to the end of the duct. The smallest angle α at which continuous sliding occurs is the angle used to calculate kinetic COF.

For a valid measurement to be recorded the specimen must have travelled from the top to the bottom of the apparatus in one continuous motion.

NOTE Several test runs with each setup, with averaging of the calculated COF, may be advantageous.

This test is used mainly for traditional optical cables and ducts, since for microduct cable and microduct it is difficult to start the specimen sliding by hand.

3.2.5 Calculations

The COF can be found from:

$$f = \tan(\alpha) \tag{2}$$

where

α is the angle with the horizontal at which the cable specimen starts sliding (static COF) or continues sliding (kinetic COF);

f is the COF, static or kinetic, as applicable.

3.2.6 Results

The following information should be reported for each test:

- test apparatus arrangement;
- length of the duct specimen;
- length of the cable specimen;
- cable specimen details:
  - seath material
  - outer diameter
  - weight per unit of length;
- duct specimen details:
  - duct materials
  - inner diameter
  - details of the inner surface (smooth, ribbed, etc.);

- angle α with the base plate at which the cable specimen starts sliding (static COF) or continues sliding (kinetic COF);
- calculated COF (one or both types);
- relative humidity and ambient temperature during the test.

3.3 Method C: sloped cable test

3.3.1 General

This subclause describes a technique for the measurement of the COF between a cable specimen and a duct specimen, an important parameter for the installation performance (pushing, pulling, blowing, etc.) of the cable in the duct; see IEC 60794-1-1:2001, Annex C (to be IEC/TR 62691).

3.3.2 Sample

The test sample comprises a duct specimen and a cable specimen of the type under consideration. A new, clean, grease-free specimen of each is required for each test to avoid the effects of wear and contamination.

The cable specimen is of a length consistent with the apparatus of Figure 3. The cable specimen often must be straightened such that it will be straight when mounted in the apparatus. Note that most apparatus for this test hold the cable under tension, which will assist in straightening the cable specimen.

The duct specimen is shorter than the cable specimen. Straightening of the duct specimen and a short length of the specimen is required to achieve a specimen that is substantially straight. Take care that the length of the duct specimen is short enough but not so short as to fail to lay flat on the cable specimen during the test. The (intrinsic) bend radius of the duct shall not result in opposite walls touching the cable, which would result in extra friction due to the spring action of the duct ends. A mass, typically cylindrical and surrounding the duct, may be attached to the duct specimen to simulate the effects of upstream friction of a length of duct and cable. Longer duct lengths are possible when using a straight (metal) cylinder around the duct specimen, which at the same time serves as a weight. The total weight of duct specimen and cylinder per unit of length shall be between 1 and 10 times the weight of the cable specimen per unit of length.

The ends of the duct specimen may be treated with a conical drill or a similar tool, such that the cable is only in contact with the inner surface of the duct. The combination of the straightness of the duct and its length can affect the results.

3.3.3 Apparatus

The apparatus is a clamping device (see Figure 3), such that a cable specimen may be mounted straight. Before finishing clamping the cable specimen a short specimen of duct is sleeved around it, see 3.3.2. The tension of the cable specimen in the fixture must be large enough to straighten the cable specimen sufficiently such that the deviation of the cable from a straight line is minimised (see the discussion in 3.3.2). The deviation is typically less than 0.5° which can be estimated by visual examination; if in doubt it should be measured. The clamping device with specimens can be tilted with respect to the horizontal.

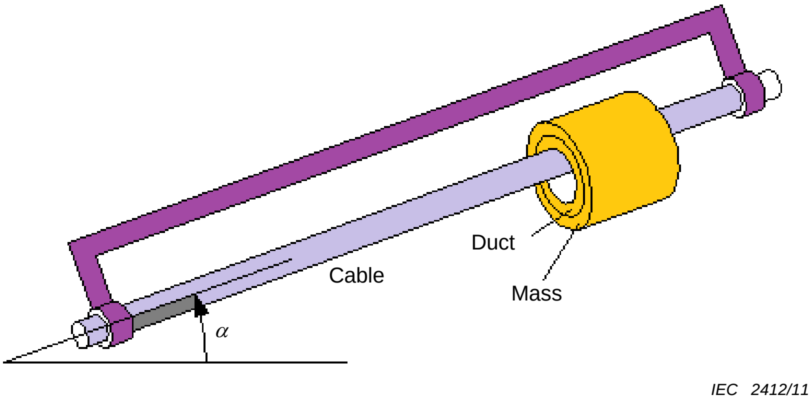


Figure 3 – Sketch of the sloped cable test.

3.3.4 Procedure

The procedure follows the intent of the following steps:

- Place the cable specimen in one side of the clamping device. Sleeve the duct specimen around the cable specimen. Mount the other end of the cable specimen in the other side of the clamping device, tensioning it such that the cable specimen is straight. Move the duct specimen to the end of the apparatus to be raised. See the discussion in 3.3.3.
- Static COF – Tilt the clamping device with duct and cable specimens. Measure the angle α at which the duct specimen starts sliding.
- Kinetic (sliding) COF – Tilt the clamping device to the angle α to be evaluated. Start the duct specimen moving by hand, e.g. by tapping the specimen. If the duct does not continue sliding to the end of the cable, increase the angle α by a small increment and repeat the test until the duct slides. If the duct does initially continue sliding, decrease the angle α by a small increment and repeat the test until the duct does not slide to the end of the cable. The smallest angle α at which continuous sliding occurs is the angle used to calculate kinetic COF.

For a valid measurement to be recorded the specimen must have travelled from the top to the bottom of the apparatus in one continuous motion.

NOTE Several test runs with each setup, with averaging of the calculated COF, may be advantageous.

3.3.5 Calculations

The COF can be found from:

$$f = \tan(\alpha) \tag{3}$$

where

α is the angle with the horizontal at which the duct specimen starts sliding;

f is the COF, static or kinetic, as applicable.

NOTE The use of increased duct-cylinder mass may affect the resulting COF. Caution in using these results in comparison to results from other methods is advised.

3.3.6 Results

The following information should be reported for each test:

- test apparatus arrangement;
- length of the duct specimen;

- length of the cable specimen;
- cable specimen details:
  - seath material
  - outer diameter
  - weight per unit of length;
- duct specimen details:
  - duct materials
  - inner diameter
  - details of the inner surface (smooth, ribbed, etc.)
  - weight of the cylinder around the duct specimen (optionally);
- angle α which is the angle with the horizontal at which the duct specimen starts sliding (static COF) or continues sliding (kinetic COF);
- calculated COF (one or both types);
- relative humidity and ambient temperature during the test.

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Griffioen, W., et al, "*Installation of optical cables in ducts*", Plumettaz, PTT Research 1993 (ISBN 90-72125-37-1), Chapter 2.

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