BRITISH STANDARD

BS EN 50117-1 : 1997

Incorporating Amendment No.1

Coaxial cables used in cabled distribution networks

Part 1. Generic specification

The European Standard EN 50117-1 : 1995 together with its amendments A1 : 1995 and A2 : 1997 has the status of a British Standard

ICS 33.120.10

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee EPL/46, Cables, wires and waveguides, RF connectors and accessories for communication and signalling, to Subcommittee EPL/46/1, Communication cables, on which the following bodies were represented:

AEA Technology
British Approvals Service for Cables
British Broadcasting Corporation
British Cable Makers Confederation
British Railways Board
British Telecommunications plc
Cable Communications Association
Confederation of Aerial Industries
ERA Technology Ltd
Federation of the Electronics Industry
London Underground Ltd
Ministry of Defence
Society of Cable Television Engineers

This British Standard, having been prepared under the direction of the Electrotechnical Sector Board, was published under the authority of the Standards Board and comes into effect on
15 February 1997

Amendments issued since publication

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Contents

National foreword

This British Standard has been prepared under the direction of Technical Committee EPL/46/1 and is the English language version of EN 50117-1 : 1995, *Coaxial cables used in cabled distribution networks*, incorporating Amendments A1 : 1995 and A2 : 1997 published by the European Committee for Electrotechnical Standardization (CENELEC).

Cross-references

Publication referred to	Corresponding British Standard
EN 60068-1 : 1994	BS EN 60068 *Environmental testing*
	Part 1 : 1995 *General and guidance*
EN 60068-2-1 : 1993	Part 2 *Test methods*
	Section 1 : 1993 *Tests A. Cold*
HD 323.2.3 S2 : 1987	BS 2011 *Environmental testing*
	Part 2.1 *Tests*
	Part 2.1 Ca : 1977 *Test Ca. Damp heat, steady state*
HD 323.2.38 S1 : 1988	Part 2.1 Z/AD : 1977 *Tests Z/AD. Composite temperature/ humidity cyclic test*
HD 134	BS 3041 *Radio-frequency connectors*
HD 402 S2	BS 6746C : 1993 *Colour chart for insulation and sheath of electric cables*
HD 405.3 S1	BS 4066 *Tests on electric cables under fire conditions*
	Part 3 : 1994 *Tests on bunched wires or cables*
HD 602 S1	BS 6425 *Test on gases evolved during the combustion of materials from cables*
	Part 2 : 1993 *Determination of degree of acidity (corrosivity) of gases by measuring PH and conductivity*

Compliance with a British Standard does not of itself confer immunity from legal obligations.

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 50117-1

June 1995

+ A1

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+ A2

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ICS 33.120.10

Descriptors: Coaxial cables, cabled distribution networks

English version

Coaxial cables used in cabled distribution networks
Part 1: Generic specification

(includes amendment A1 : 1995 and A2 : 1997)

Câbles coaxiaux pour réseaux câblés de distribution
Partie 1: Spécification générique
(inclut l'amendement A1 : 1995 et A2 : 1997)

Koaxialkabel für Kabelverteilanlagen
Teil 1: Fachgrundspezifikation
(enthält Änderung A1 : 1995 und A2 : 1997)

This European Standard was approved by CENELEC on 1994-12-06; amendment A1 was approved by CENELEC on 1995-11-28; amendment A2 was approved by CENELEC on 1996-12-09. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. EN 50117-1 : 1995 + A1 : 1995 + A2 : 1997 E

Foreword

This European Standard was prepared by SC 46XA, Coaxial cables, of Technical Committee TC 46X, Communication cables.

The text of the draft was submitted to the formal vote and was approved by CENELEC as EN 50117-1 on 1994-12-06

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	1995-12-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	1995-12-01

Foreword of amendment A1

This amendment A1 to the European Standard EN 50117-1 : 1995 was prepared by SC 46XA, Coaxial cables, of Technical Committee TC 46X, Communication cables.

The text of the draft was submitted to the formal vote and was approved by CENELEC on 1995-11-28.

The following dates were fixed:

– latest date by which the existence of the amendment has to be announced at national level	(doa)	1996-06-01
– latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	1996-12-01
– latest date by which the national standards conflicting with the amendment have to be withdrawn	(dow)	1996-12-01

Foreword of amendment A2

This amendment was prepared by SC 46XA, Coaxial cables, of Technical Committee CENELEC TC 46X, Communication cables.

The text of the draft was submitted to the Unique Acceptance Procedure and was approved by CENELEC as amendment A2 to EN 50117-1 : 1995 on 1996-12-09.

The following dates were fixed:

– latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	1997-12-01
– latest date by which the national standards conflicting with the amendment have to be withdrawn	(dow)	1997-12-01

Contents

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1 Scope

This standard establishes the requirements and applicable tests for coaxial cables with characteristic impedance of 75 Ω used in CATV networks.

This standard takes into account the IEC 96 requirements. The relating cables are recommended for use with connectors according to IEC 169.

2 Normative references

This European Standard incorporates by dated or undated references, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments)

NOTE. When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 28	1925	*International standard of resistance for copper*	—	—
IEC 50	Series	*International Electrotechnical Vocabulary*	—	—
IEC 68-1	1988	*Environmental testing* Part 1: *General and guidance*	EN 60068-1[1]	1994
IEC 68-2-1	1990	Part 2: *Tests — Test A: Cold*	EN 60068-2-1	1993
IEC 68-2-3	1969	*Test Ca: Damp heat*	HD 323.2.3 S2[2]	1987
IEC 68-2-38	1974	*Test Z/AD: Composite temperature/humidity cyclic test*	HD 323.2.38 S1	1988
IEC 96	series	*Radio frequency cables*	—	—
IEC 169	series	*Radio frequency connectors*	HD 134 EN 60169	series series
IEC 304	1982	*Standard colours for insulation for low frequency cables and wires*	HD 402 S2	1984
IEC 332-1	1993[3]	*Test on electric cables under fire conditions —* Part 1: *Tests on a single vertical insulated wire or cable*	—	—
IEC 332-3	1992	Part 3: *Test on bunched wires or cables*	HD 405.3 S1	1993
IEC 754-1	1994	*Test on gases evolved during combustion of electric cables* Part 1: *Determination of the amount of halogen acid gas evolved during the combustion of polymeric materials taken from cables*	—	—
IEC 754-2 (mod)	1991	Part 2: *Determination of degree of acidity of gases evolved during the combustion of materials taken from electric cables by measuring pH and conductivity*	HD 602 S1	1992
IEC 811-1-1	1993	*Common test methods for insulating and sheathing materials of electric cables* Part 1: *Methods for general application* Section 1: *Measurement of thickness and overall dimensions — Tests for determining the mechanical properties*	EN 60811-1-1	1995
IEC 811-1-2	1985	Section 2: *Thermal ageing methods*	EN 60811-1-2[4]	1995
IEC 811-1-4	1985	Section 4: *Tests at low temperature*	EN 60811-1-4[5]	1995
IEC 811-3-1	1985	Part 3: *Methods specific to PVC compounds* Section 1: *Pressure test at high temperature — Tests for resistance to cracking*	EN 60811-3-1[6]	1995
IEC 811-3-2	1985	Section 2: *Loss of mass test — Thermal stability test*	EN 60811-3-2[7]	1995
IEC 811-4-1	1985	Part 4: *Methods specific to polyethylene and polypropylene compounds* Section 1: *Resistance to environmental stress cracking — Wrapping test after thermal ageing in air — Measurement of the melt flow index — Carbon black and/or mineral content measurement in PE*	EN 60811-4-1[8]	1995
ISO/R 402		*Tensile testing of copper and copper alloy wire*		
CISPR 8B		*Reports and study questions of the CISPR 2 Supplement, Amendment No. 1*		

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[1] EN 60068-1 includes A1 : 1992 to IEC 68-1.
[2] HD 323.2.3 S3 includes A1: 1984 to IEC 68-2-2.
[3] IEC 332-1: 1979 is harmonized as HD 405.1 S1 : 1983.
[4] EN 811-1-2 includes corrigendum May 1986 and A1 : 1989 to IEC 811-1-2.
[5] EN 811-1-4 includes corrigendum May 1986 and A1 : 1993 to IEC 811-1-4.
[6] EN 811-3-1 includes corrigendum May 1986 to IEC 811-1-2.
[7] EN 811-3-2 includes corrigendum May 1986 and A1 : 1993 to IEC 811-3-2.
[8] EN 811-4-1 includes corrigendum May 1986 and A2 : 1993 to IEC 811-4-1.

3 Definitions

3.1 IEV definitions

Terms used in the Publication which are defined in the International Electrotechnical Vocabulary IEC Publication 50 are given in the table below:

Term	IEV definition	Term	IEV definition
absorption	726-06-05	matched termination	726-22-09
absolute error	301-08-06	megohmeter	20-15-160
analogue signal	37-15-050	measurement	301-10-04
armour of cable	25-30-110		
attenuation	303-01-04	noise	303-0-09
attenuation coefficient	55-05-255	normalized impedance	726-07-03
attenuation distortion	55-10-010		
attenuator	303-03-17	pad attenuator	726-12-03
		phase delay	55-05-230
bonded screen	461-03-06	phase distortion	55-10-015
braiding	25-30-090	phase velocity	726-05-13
brazing soldering	40-15-005	plug-in unit	303-03-16
		port	726-11-05
cable	55-30-010	probe	303-03-15
cable core	25-30-045	propagation coefficient	726-0-0
cable drum	461-20-01		
capacitance	05-15-175	radio frequency	55-05-060
capacitance meter	20-15-2	reflection coefficient	726-07-08
coaxial cable	55-30-050	reflected wave	726-02-05
coaxial pair	55-30-045	relative error	301-08-07
composite loss	55-05-175	repeatability of measurement	301-10-04
conductor	461-01-01	reproducibility of measurement	301-10-05
conductor resistance	05-20-140	resolution	301-10-03
		resonance method of measurement	301-01-09
delay distortion	55-10-020	return loss	55-05-195
delay time	726-15-24	rise time	351-04-02
dielectric	05-15-095		
dielectric constant/permittivity	05-15-120	screen	55-25-355
dielectric strength	05-15-205	sensitivity	66-10-385
digital signal	37-15-055	sheath (of a cable)	25-30-105
direction of propagation	726-02-01	short circuit	
directional coupler	726-14-02	signal generator	303-03-12
directivity	726-14-03	slotted line	726-19-06
drain wire	461-03-07	spark test	461-22-01
		spectrum analyser	303-03-09
earth	05-40-155	stabilized supply apparatus	303-03-11
electrification	05-15-015	standing wave minimum (maximum)	726-02-09
frequency	05-02-055	strand	461-01-19
frequency range	303-06-10	surface wave	726-02-13
gain	303-01-05	termination	726-11-07
group delay	726-05-16	thermoplastic insulation	461-02-10
group velocity	726-05-17	transformer bridge	302-05-03
guided wave	726-02-10	transmission line	726-01-01
		transmitted wave	726-02-06
impedance to earth	303-02-15	travelling wave	726-02-02
incident wave	25-50-055		
input (output) impedance	303-02-13	VSWR	726-07-09
insertion loss	726-06-17		
insulation resistance	05-40-200	wheatstone bridge	302-05-01
instrinsic error	301-01-09		
Kelvin/Thomson double bridge	302-05-02		

3.2 Additional definitions

In addition to the definitions given in IEC Publication 50 the following will apply.

3.2.1 air spaced cables

Cables in which the dielectric is air, except for the portion occupied by insulating spacers assembled on the inner conductor at regular intervals or helically applied tapes and/or threads. It is characteristic of this type of insulation that outside the spacers it is possible to pass from the inner conductor to the outer conductor without passing through a layer of solid plastic dielectric.

3.2.2 braiding formulae

The variables used in the formulae are given in the following table:

Variable	Description
d	Diameter of braid wire or thickness of braid tape
D	Mean diameter of braid i.e. diameter over dielectric plus 2.25 d
L	Lay length of braid
n	Number of ends of wire per spindle
m	Total number of spindles

3.2.2.1 braid angle θ

The braid angle θ is defined as:

$$\theta = \arctan (\pi D / L) \quad (1)$$

3.2.2.2 lay factor K_l

The lay factor is defined as:

$$K_l = \sqrt{(1 + \pi^2 D^2 / L^2)} \quad (2)$$

3.2.2.3 filling factor K_f

The filling factor is defined as:

$$K_f = \left(\frac{mnd}{2 \pi D}\right) \sqrt{(1 + \pi^2 D^2 / L^2)} \quad (3)$$

which may also be expressed as

$$K_f = \left(\frac{mnd}{2 L \sin \theta}\right) \quad (4)$$

3.2.2.4 coverage factor K_c

The coverage factor is related to the filling factor such that:

$$K_c = 2 K_f - K_f^2 \quad (5)$$

3.2.3 void

3.2.4 ovality

The ovality of the cross section of a dielectric or cable is defined as the ratio of the maximum difference between two orthogonal diameters divided by the mean of these diameters and expressed as a percentage.

3.2.5 screening attenuation

The screening attenuation is defined as the logarithmic ratio of power in a matched primary (*inner*) circuit to the maximum of total power in the secondary (*outer*) circuit.

3.2.6 screening effectiveness

Aptitude of the outer conductor and/or screen(s) to increase immunity of the cable against electromagnetic disturbances or radiation.

3.2.7 semi-air spaced cables

Cables in which the dielectric is a plastics/air construction comprising either cellular polymer or an insulating tube at the centre of which the inner conductor is supported by discs, or another construction.

It is characteristic of this type of cable that it is not possible to pass from the inner conductor to the outer conductor without passing through a layer of plastic dielectric.

3.2.8 solid dielectric cables

Cables in which all the space between the inner conductor and the outer conductor is substantially filled by solid plastic dielectric. The dielectric may be either homogeneous or composite, the latter comprising two or more concentric layers which may have different properties.

3.2.9 transfer impedance Z_T

The transfer impedance is defined as the ratio of the voltage measured along the inside of the screen of the cable to the current flowing along the outside of the screen or vice versa.

3.2.10 minimum static bending radius

Minimum static bending radius is the minimum permissible bending radius for a single bend in a fixed installation with no performance degradation.

3.2.11 minimum dynamic bending radius

Minimum dynamic bending radius is the minimum permissible bending radius for multiple bending during handling with no performance degradation.

4 Materials and cable construction

4.1 Cable construction

The cable construction shall be in accordance with the details and dimensions given in the relevant cable specification.

4.2 Inner conductor

4.2.1 *Conductor material*

The conductor shall consist of annealed copper uniform in quality and free from defects. The properties of the copper shall be in accordance with IEC Publication 28.

Alternatively the conductor shall consist of copper clad steel. The layer of copper coating shall be continuous and shall adhere to the steel conductor circular in cross section such that the maximum resistance of the coated conductor shall not exceed that given for a copper conductor in accordance with IEC Publication 28 by more than a factor of 2.8 for 40 % nominal conductivity grade copper clad steel. The percentage of the elongation at break when tested in accordance with sub-clause **9.7** of this Standard shall be not less than 1 %. The minimum tensile strength shall be 760 N/mm[2)].

Alternatively the conductor shall consist of copper clad aluminium. The layer of copper coating shall be continuous and shall adhere to an aluminium conductor circular in cross section such that the maximum resistance of the coated conductor shall not exceed that given for copper conductor in accordance with IEC Publication 28 by more than a factor of 1.8. The percentage of the elongation when tensile tested in accordance with sub-clause **9.6** of this Standard shall not be less than 10 %.

4.2.2 ***Conductor construction***

The construction and material of the inner conductor shall be as specified in the relevant cable specification.

Where the inner conductor consists of a single wire or tube there shall be no joint in the wire or tube made subsequent to the last drawing operation.

Joints in individual strands of a stranded copper inner conductor shall be cold pressure welded, brazed or silver soldered using a non acid flux such that the strand diameter shall not be increased.

No joint in an individual strand shall be within 0.3 m of a joint in any other individual strand.

4.3 Dielectric

The type of dielectric required for each cable shall be specified in the relevant cable specification. The diameter over dielectric and ovality shall be given in the relevant cable specification.

4.4 Outer conductor or screen

The construction and material of the outer conductor and/or screen shall be specified in the detail specification.

The outer conductor or screen may be:

a) A double braid of plain or tinned annealed copper wire. Joints in the braiding wires shall be soldered, twisted or woven-in and there shall be no joint in the complete braid. The braid shall be evenly applied. The braid angle and the filling factor shall be specified in the detail specification;

b) A copper or aluminium tape formed round the core as a continuous and closed screen with a sufficient overlap bonded or not bonded as specified in the detail specification;

c) A gas-tight tube of copper or aluminium material (i.e. extruded, welded smooth or corrugated);

d) A layer of metal or metallized film applied with a sufficient overlap, bonded or not bonded, covered with a copper braid where the foil is copper, and an aluminium or tinned copper braid where the foil is aluminium, as in item a) above, applied over the film;

e) A layer of metal or metallized film applied with a sufficient overlap bonded or not bonded, covered with two layers bi-directional helically wound wires of copper where the foil is copper, and an aluminium or tinned copper braid where the foil is in aluminium, as in item a) above, applied over the film.

4.5 Sheath

The outer sheath of the cable shall be of plastic material and specified in the relevant cable specification.

Black polyethylene shall have a carbon black content of (2,5 ± 0,5) %. Green and blue polyethylene may be allowed and shall be specified in the relevant cable specification.

PVC shall be coloured in accordance with IEC Publication 304.

Low smoke halogen free materials can be used. Their characteristics and the related test methods are under consideration.

5 Standard ratings and characteristics

The ratings and characteristics applicable to a cable shall be stated in the relevant cable specifications.

6 Identification marking and labelling

6.1 Cable identification

Cable identification shall be defined by sheath marking.

6.2 Sheath marking

Sheath marking shall be in accordance with the relevant cable specification.

6.3 Labelling

Unless otherwise specified in the sectional or detail specification drums or coils shall be provided with a label with a nondegradable print containing the following minimum information:

- designation of cable;
- length of cable;
- name of supplier.

7 Delivery and storage

Delivery shall be made on drums or as coils with suitable protection.

The ends of the finished cable shall be adequately sealed to prevent the ingress of moisture. Sealing shall be carried out immediately after inspection and acceptance tests.

Temperature ranges for storage, installation and operation shall be stated in the relevant specification.

8 List of test methods

Characteristic	This standard	IEC/ISO Standards	
	Clause	Publ.	Clause
Material and cable construction tests	**9**		
General	**9.1**		
Visual examination	**9.2**	–	–
Measurement of dimensions	**9.3**	811-1-1	**8**
Ovality	**9.4**	–	–
Carbon black content	**9.5**	811-4-1	**11**
Tensile strength and elongation after break for metals	**9.6**	ISO/R402	–
Tensile strength and elongation at break for metals	**9.7**	–	
Torsion test for copper clad metals	**9.8**	–	–
Tensile strength and elongation for plastics	**9.9**	811-1-1	**9**
Flammability	**9.10**	332-1 332-3	
Mechanical and thermal characteristics	**10**		
Adhesion of dielectric	**10.1**	–	–
Bending	**10.2**	–	–
Tensile strength of cable	**10.3**	–	–
Crush resistance of cable	**10.4**	–	–
Vibration test for aerial figure eight cables	**10.5**	–	–
Climatic tests	**10.6**	68-2-38 68-2-3	
Electrical characteristics - Measurement and test methods	**11**		
Conductor resistance	**11.1**	–	–
Insulation resistance	**11.2**	–	–
Voltage test of dielectric	**11.3**	–	–
Voltage test of sheath	**11.4**	96 – xxx	**6.6**
Characteristic impedance	**11.5**	–	–
Return loss	**11.6**	–	–
Relative propagation velocity (velocity ratio)	**11.7**	–	–
Longitudinal loss	**11.8**	–	–
Regularity of impedance	**11.9**	–	–
Screening attenuation	**11.10**	–	–
Transfer impedance	**11.11**	–	–

9 Material and cable construction tests

9.1 General

Unless otherwise specified all measurements shall be carried out under standard atmospheric conditions for testing in accordance with clause **5** of IEC Publication 68-1.

9.2 Visual examination

Visual inspection shall be carried out to ensure that there are no observable defects in the cable. The examination shall be carried out with normal or corrected vision without magnification.

9.3 Measurement of dimensions

The measurement of thickness and diameters shall be carried out in accordance with clause **8** of IEC Publication 811-1-1.

9.4 Ovality

9.4.1 *Principle*

The ovality of the cable is determined from the measurement of two orthogonal overall diameters of the cross section of a cable sample.

9.4.2 *Test equipment*

A measuring microscope allowing a resolution of 0.01 mm shall be used.

Alternatively a measuring projector with a magnification power of at least 10 may be used. In case of doubt the microscope method shall be applied.

9.4.3 *Preparation of test specimens*

Three samples shall be cut, at least 100 mm apart, from the finished cable. The ends of each specimen shall be cut squarely and carefully deburred.

9.4.4 *Procedure*

For each cross section make two measurements of the overall diameter of the cable such that the diameters are perpendicular to each other.

In each case select the position where the two diameters, while remaining perpendicular to each other, give the maximum difference between them.

9.4.5 *Expression of results*

The ovality shall be calculated using the following formula:

$$\text{ovality} = \left(\frac{2[D_1 - D_2]}{[D_1 + D_2]}\right) \times 100 \quad \text{in \%} \qquad (6)$$

where

D_1 is the larger measured value of diameter;

D_2 is the smaller measured value of diameter.

The ovality is the mean of the three measurement results.

9.4.6 *Requirements*

The ovality shall be not more than the value stated in the relevant cable specification.

9.5 Carbon black content

Carbon black content shall be verified in accordance with IEC publication 811-4-1.

9.6 Tensile strength and elongation after break for metals

9.6.1 ***Principle***

The test determines the maximum load and the plastic extension of the solid conductor.

9.6.2 ***Procedure***

A test specimen shall be tested in accordance with the method specified in ISO Recommendation R402 with a rate of separation of the jaws of 100 ± 20 mm/min.

9.6.3 ***Requirements***

The tensile strength and elongation after break shall meet the values stated in **4.2.1**.

9.7 Tensile strength and elongation at break for metals

9.7.1 ***Principle***

The test determines the percentage elongation at the time of break of a solid conductor with low elongation of about 1 %.

9.7.2 ***Test equipment***

An extensometer or other device suitable for measuring elongation of a gauge length of 250 mm shall be used. The equipment shall have a vernier resolution not worse than 0.25 mm.

9.7.3 ***Procedure***

A test specimen shall be fitted in the jaws of the testing machine and loaded to 10 % of the minimum specified breaking load. An extensometer or other suitable device shall be attached to the test specimen to measure the extension.

The elongation shall be observed while applying a tensile load to the specimen and the reading at which fracture occurs shall be recorded as the elongation of the specimen.

The rate of separation of the jaws shall not be greater than 100 ± 20 mm/min.

9.7.4 ***Expression of results***

The elongation under tension due to breaking the conductor shall be expressed as a percentage of the original sample length.

Tests in which the fracture occurs within 25 mm apart from the jaws or extensometer clamps shall be disregarded.

9.7.5 ***Requirements***

The tensile strength and percentage elongation values shall be in accordance with sub-clause **4.2.1** of this publication.

9.8 Torsion test for copper clad metals

9.8.1 ***Principle***

The test examines the surface of the conductor after it has been twisted to destruction to indicate the presence of inherent defects.

9.8.2 ***Procedure***

A length of wire shall be clamped between two jaws with light tension, the jaws being separated by a distance equivalent to 100 times the nominal diameter of the test specimen. One jaw is fixed and the other is rotated to apply twists at the rate of 15 turns per minute. All twists shall be made in the same direction to destruction.

The end of the conductor at the break shall be examined with normal or corrected vision without magnification.

9.8.3 ***Requirements***

The wire shall withstand without fracture not less than the number of twists given in the relevant cable specification.

The surface shall not reveal any seams, pits or slivers of sufficient magnitude to indicate inherent defects. There shall be no separation of copper from the parent metal.

9.9 Tensile strength and elongation for plastics

9.9.1 ***Principle***

The test determines the tensile strength and elongation before and after ageing.

9.9.2 ***Procedure***

Tensile strength and elongation for plastics shall be performed in accordance with IEC Publication 811-1-1. Thermal ageing shall be carried out in accordance with IEC Publication 811-1-2.

9.9.3 ***Requirements***

The values of the elongation and tensile strength and elongation shall be as stated in the relevant cable specification.

9.10 Flammability

NOTE. This test method is designed for indoor drop cables, where it is required to test lower cable densities than presently included in HD 405.3 or where it is required to test cables in a bundle formation.

9.10.1 ***Fire propagation***

9.10.1.1 *Principle*

This test is designed to determine fire propagation characteristics in a simulated installation environment.

9.10.1.2 *Apparatus*

These proposals use the apparatus and general methodology of HD 405.3.

9.10.1.3 *Procedure*

For cables with overall diameter above 8 mm, procedure a) shall be applied. Cables with overall diameter ≤ 8 mm shall be subject to procedure b).

a) Category NMV 0,5

This test shall be carried out as for HD 405.3 category C except that the nominal total volume of non-metallic material shall be 0.5 l/m.

Cable mounting one (or more) layer(s) on 500 mm ladder.

b) Category NMV 0,5 (bundles)

This test shall be carried out as for HD 405.3 category C except that the ladder loading will be:

– bundles of cable of approximate diameter 20 mm spaced by half the bundle diameter;
– a minimum of two bundles shall be tested;
– the number of bundles shall be determined as that necessary to give a nominal total volume of non-metallic material of 0,5 l/m;
– the bundle formation shall be as shown hereafter;
– the number of bundles tested and NMV of each bundle shall be recorded;
– thecable to be tested shall be selected such that the total volume of non-metallic material in the bundles to be tested exceeds 0,4 l/m but does not exceed 0,6 l/m.

Formation of bundles

The number of cables in each bundle shall be as follows.

Cable diameter (mm)	**No. of cables in a bundle**
Up to and including 3,3	37
Above 3,3 up to and including 4,3	19
Above 4,3 up to and including 6,0	12
Above 6,0 up to and including 8,0	7

The cables in the bundle shall be laid straight in the formation given and then subjected to a unidirectional twist to give a lay length of approximately 15 *D* (where *D* is the cable diameter).

The bundle shall be tightly twisted.

9.10.1.4 *Requirement*

The maximum extent of the charred portion measured on the test sample shall be in accordance with HD 405.3.

10 Tests for mechanical and thermal characteristics

10.1 Adhesion of dielectric

10.1.1 ***Principle***

The test determines the value of adhesion of the dielectric to the inner conductor and/or between the dielectric and the outer conductor.

10.1.2 ***Preparation for test specimens***

Two test specimens separated by at least 300 mm shall be cut from the finished cable, unless otherwise specified in the relevant cable specification. Each test specimen shall be prepared as shown in figure 1. Stripping shall be done carefully so as not to effect the adhesion of the test sample.

The inner conductor shall be sufficiently long to be gripped by the jaw of a tensile testing device.

10.1.3 ***Procedure***

The test piece shall be loaded into the tensile testing machine and test fixture as shown in figure 2. The diameter of the hole in the test plate shall be larger than the diameter of the centre conductor or the dielectric by 0,10 ± 0,03 mm.

The inner conductor shall be pulled steadily at a rate not exceeding 100 mm/min until the dielectric or the outer conductor and sheath is/are completely removed. Sudden pulls and jerking shall be avoided. The physical handling of the test specimens shall be kept to a minimum to avoid specimen deterioration.

10.1.4 ***Expression of results***

Dielectric adhesion shall be defined as the highest tensile reading obtained when the conductor to dielectric bond is broken.

10.1.5 ***Requirements***

The value of the adhesion and the lengths l of the dielectric shall be in accordance with the values stated in the relevant cable specification.

The conductor surface must be exempt from any remaining insulating material.

10.2 Bending

10.2.1 ***Multiple bending***

10.2.1.1 *Principle*

This test determines the suitability of the cable to meet the handling and installation requirements by subjecting a length of cable to a bend test.

The length of cable is also subjected to bending on a mandrel to determine its suitability to be packaged.

10.2.1.2 *Preparation of test specimen*

Select a portion of cable about 10 m from the running end of a length of finished cable without cutting it.

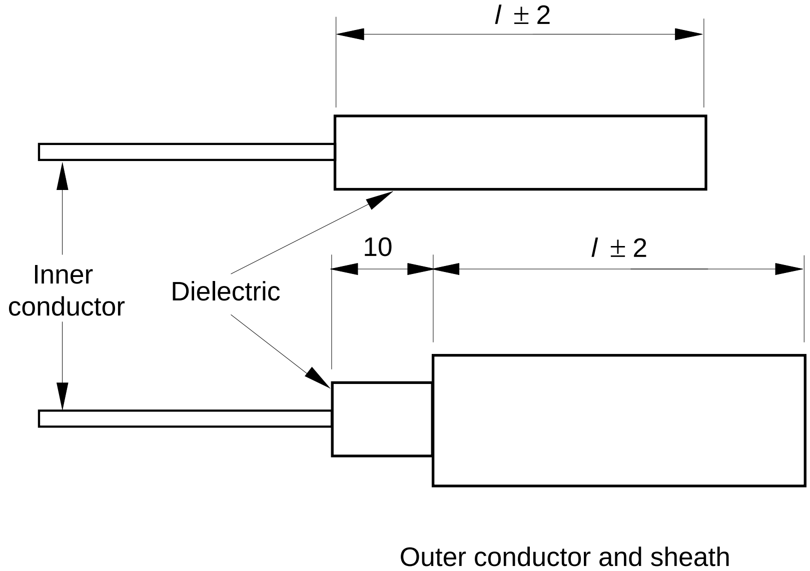
10.2.1.3 *Procedure*

The cable shall be bent at the selected position not less than 90° around a mandrel of diameter given in the relevant cable specification and then straightened.

Repeat the bends for three such complete cycles ensuring that the same portion of the cable is bent on each occasion.

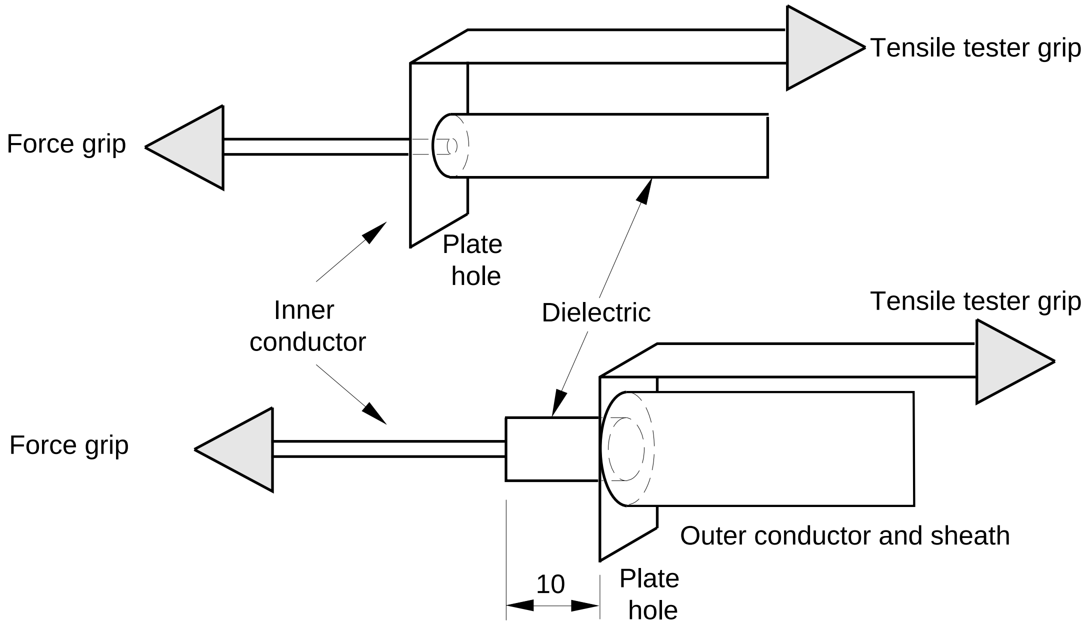
Using the same end of the cable wind three complete turns around a mandrel with the same diameter ensuring that a sufficient tension is applied such that the turns remain in contact with the mandrel and the portion previously bent is within the three turns.

The sample which has been subjected to both tests shall be straightened, electrically tested in accordance with clause **11.9** of this standard and then examined using normal or corrected vision without magnification (if it is impossible to check the outer conductor, if it is bonded to sheath, a screening effectiveness test shall be achieved).



Dimensions in millimetres

Figure 1. Stripping dimensions



Dimensions in millimetres
Figure 2. Test set up

10.2.1.4 *Requirements*

The electrical characteristics shall be in accordance with the values stated in the relevant cable specification.

There shall be no cracks or breaks neither in dielectric, metallic elements nor sheath.

10.2.2 *Flexing*

10.2.2.1 *Principle*

The test determines the ability of the cable to withstand a number of alternate bendings under tension.

10.2.2.2 *Procedure*

According to figure 3 the cable is pulled back and forth over the two pulleys through a 10 m length. The radius of the pulleys, the number of test cycles and the restraining force F_r are as given in the relevant cable specification.

The bending angle of the cable on each pulley shall be 120° or more.

The speed of pulling shall be not less than 1 m/min.

After execution of the test, measurement of impedance regularity and screening attenuation shall be carried out in accordance with clause **11.9** and **11.10** of this standard respectively.

The sample shall be stripped down and examined using normal or corrected vision without magnification.

10.2.2.3 *Requirements*

The electrical characteristics shall not exceed the values stated in the relevant cable specification.

There shall be no cracks or breaks either in dielectric, metallic elements or sheath.

10.2.3 *Cold bend performance*

10.2.3.1 *Principle*

This test determines the suitability of the cable to be bent at low temperatures.

10.2.3.2 *Preparation of test specimen*

The sample shall be cut from a finished cable and shall have a length of approximately 120 times the overall diameter of the cable. The sample shall be coiled to a diameter not less than 30 times the nominal overall diameter of the cable.

10.2.3.3 *Procedure*

The sample and the test apparatus shall be cooled in accordance with test Aa of IEC Publication 68-2-1 for a period not less than 20 h at −10 °C unless otherwise specified.

The cold bend test apparatus used shall be in accordance with IEC 811-1-4.

After this period and while still in the cold chamber, the sample shall be wrapped three times around a mandrel with a diameter specified in the relevant specification.

The velocity of wrapping shall be approximately one turn per 4 s.

The sample shall be stripped down and examined with normal or corrected vision without magnification.

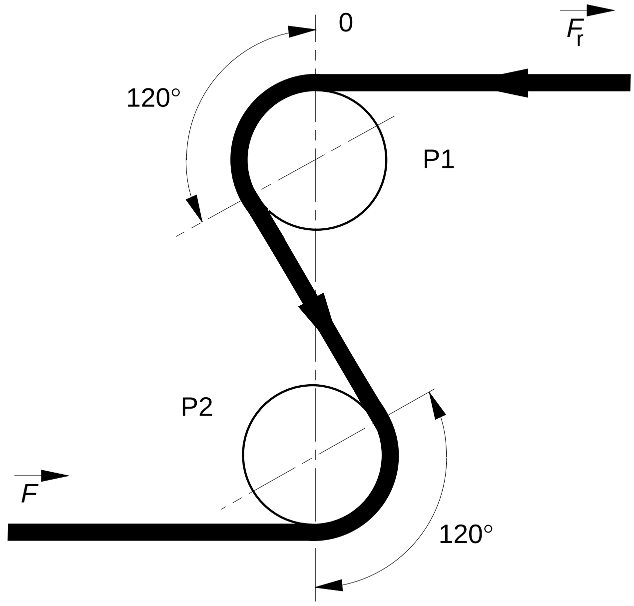


Figure 3. Principle of the flexing procedure

10.2.3.4 *Requirements*

There shall be no cracks or breaks either in dielectric, metallic elements or sheath.

10.2.4 *Static bend test*

10.2.4.1 *Principle*

This test determines the suitability of the cable for installation in severe conditions simulated by subjecting the cable to a single bend test.

10.2.4.2 *Preparation of the test specimen*

Select a portion of a least 20 m from the running end of finished cable to be subjected to test.

10.2.4.3 *Procedure*

10.2.4.3.1 A few metres from the free end, the cable shall be bent 180° around a mandrel of diameter stated in the relevant cable specification.

10.2.4.3.2 The cable shall be tested in accordance with **11.9** of this standard.

10.2.4.4 *Requirements*

The electrical characteristics shall be in accordance with the value stated in the relevant cable specification. There shall be no cracks or breaks in the dielectric, metallic elements, or sheath.

10.3 Tensile strength test

10.3.1 *Principle*

This test determines the suitability of the cable to withstand, during installation in duct, the maximum permissible load stated in the relevant cable specification.

This test applies only to distribution and trunk cables without messenger.

10.3.2 *Preparation of the test specimen*

Select a portion of at least 20 m from the running end of the finished cable to be subjected to test.

10.3.3 *Procedure*

10.3.3.1 At the free end, the cable shall be fitted with a suitable fitting which allows an even distribution of the load between the inner and outer conductors.

10.3.3.2 A few metres from the free end, the cable shall be bent 90° around a mandrel of diameter stated in the relevant cable specification for multiple bending.

10.3.3.3 The load shall be applied and increased until the value stated in the relevant cable specification is reached. This value shall be held for 15 min.

10.3.3.4 At the free end, a cable portion of 30 cm shall be cut and the cable shall be tested in accordance with **11.9** of this standard

10.3.3.5 The cable shall be straightened and the part subjected to bend shall be examined using normal or corrected vision.

10.3.4 *Requirements*

The electrical characteristics shall be in accordance with the value stated in the relevant cable specification. There shall be no cracks or breaks in the dielectric, metallic elements, or sheath.

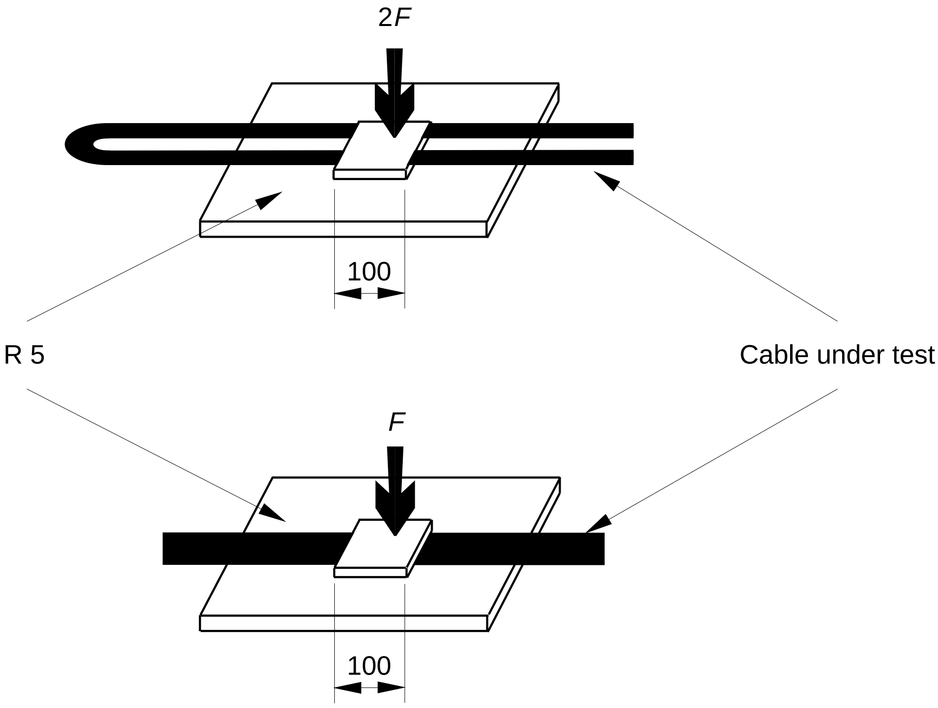
10.4 Crush resistance of cable

10.4.1 *Principle*

The test determines the ability of the cable to withstand crushing.

10.4.2 *Procedure*

A 10 m length cable specimen shall be mounted on the base plate of the test apparatus so that lateral movement is prevented. The cable specimen is compressed by a parallel flat movable steel plate with rounded edges applying a load (see figure 4). The load (*F*) as indicated in the relevant cable specification shall be applied gradually without any abrupt change for a duration of 2 min. If incremental loading is used the steps shall not exceed a ratio of 1,5.



Dimensions in millimetres

Figure 4. Crushing test

The movable plate shall apply the crushing force uniformly over a 100 mm length of the specimen. Its rounded edges shall have a 5 mm radius. After the load has been removed the magnitude of the impedance irregularity introduced by the test shall be measured by a pulse of TDR method in accordance with clause **11.9** of this specification.

10.4.3 ***Requirement***

The magnitude of the impedance irregularities shall be in accordance with the values stated in the relevant cable specification.

10.5 Vibration test for aerial figure eight cables

Under consideration.

10.6 Climatic tests

10.6.1 ***Climatic sequence***

10.6.1.1 *Principle*

The test determines the ability of the cable to withstand climatic changes and the effect of them on its electrical characteristics as well as on the integrity of the jacket.

10.6.1.2 *Procedure*

A finished length of cable (about 100 m length, unless otherwise specified in the relevant cable specification), after conditioning for 16 h at + 20 ˚C and attenuation measurement in the specified frequency range is subjected to test Z/AD of IEC Publication 68-2-38. Temperature values and the number of cycles shall be in accordance with the relevant cable specification.

The sample shall be examined with normal or corrected vision without magnification. After conditioning for 16 h at + 20 ˚C the attenuation shall be remeasured.

10.6.1.3 Requirements

The attenuation shall neither exceed the values stated in the relevant cable specification nor increase more than 5 % from the initial values.

There shall be no cracks or breaks in the outer conductor or sheath.

10.6.2 ***Damp heat (steady state)***

10.6.2.1 *Principle*

The test determines the ability of the cable to withstand a long exposure in humidity and the effect of it on its electrical characteristics as well as on the integrity of the jacket.

10.6.2.2 *Procedure*

A finished length of cable (about 100 m length, unless otherwise stated in the relevant cable specification) – after conditioning for 16 h at 20 ˚C and attenuation measurement in the specified frequency range shall be subjected to test Ca of IEC Publication 68-2-3. The duration of the test shall be 21 days.

The sample shall be examined with normal or corrected vision without magnification. After conditioning for 16 h at 20 ˚C the attenuation shall be measured.

10.6.2.3 *Requirements*

Attenuation shall neither exceed the values stated in the relevant cable specification nor increase more than 5 % from the initial values.

There shall be no cracks or breaks in the outer conductor or sheath.

11 Electrical characteristics — Measurement and test methods

11.1 Conductor resistance

11.1.1 ***Principle***

The test determines the d.c. resistance of the inner and outer conductors in a cable.

11.1.2 ***Test equipment***

The equipment shall be capable of measuring within a degree of uncertainty of 0,5 % of the value to be measured.

11.1.3 ***Preparation of test specimen***

Both ends of the cable sample shall be stripped. The ends of the outer conductor shall be prepared to ensure that the current shall flow in all the elements of the outer conductor.

The cable sample shall be pre-conditioned at a constant temperature between 15 and 35 °C for a sufficient time to allow it to equalize in temperature.

11.1.4 ***Procedure***

The current density shall not exceed 1 A/mm^2 in order to avoid any significant increase of temperature during the test. The length of the cable sample shall be measured to a degree of uncertainty not exceeding 1 %.

11.1.5 ***Expression of results***

The measured value of resistance shall be corrected for length and expressed in ohm/km. This value shall be referred to the standard temperature of 20 °C which involves multiplying the measured value, by the factor k where:

$$k = 1 / (1 + 0{,}004(t - 20)) \quad (7)$$

In this formula t is the temperature in degrees Celsius at which the measurement is made.

11.1.6 ***Requirements***

The values of conductor resistance shall not exceed the values specified in the relevant cable specification.

11.2 Insulation resistance

11.2.1 *Principle*

The test determines the d.c. insulation resistance between the conductors of a cable.

11.2.2 *Test equipment*

D.C. power supply, maximum 500 V.

Megohmmeter with range $\geq 2 \times 10^5$ MΩ

11.2.3 *Preparation of test specimen*

The test shall be carried out on a length of finished cable after preconditioning between 15 °C and 35 °C and checking the continuity of the conductors. The conductor ends shall be stripped of insulation.

11.2.4 *Procedure*

The insulation resistance shall be measured between inner and outer conductor. Unless otherwise specified in the relevant cable specification the test voltage shall be between 80 V and 500 V and the minimum duration of electrification shall be 1 min.

11.2.5 *Expression of results*

The insulation resistance shall be expressed in MΩ for 1000 m. When the test length differs from 1000 m the measured value shall be corrected as follows:

$$R = R_m l \quad \text{in G}\Omega\ \text{km} \qquad (8)$$

where

R_m is the insulation resistance, measured in GΩ;

l is the cable length in km.

11.2.6 *Requirements*

The corrected value shall not be less than the value specified in the relevant cable specification.

11.3 Voltage test of dielectric

11.3.1 *Principle*

The test verifies the specified withstand voltage of dielectric under a.c. or d.c. conditions.

11.3.2 *Test equipment*

– A.C. or d.c. power supply;

– Kilovoltmeter.

11.3.3 *Preparation of the test specimen*

The test shall be carried out on a cable after the continuity or the conductor resistance test. The conductors shall be stripped over a sufficient length to avoid breakdown or partial discharge. The insulation at these points shall be properly cleaned.

11.3.4 *Procedure*

The dielectric between outer and inner conductor of the cable shall be subjected to an a.c. or d.c. voltage for 1 min. The type and value of the voltage shall be specified in the relevant cable specification. The frequency of the a.c. voltage shall be between 40 Hz and 60 Hz and the wave form shall be sinusoidal. The rate of increase of the test voltage shall not exceed 2 kV/s.

11.3.5 *Requirements*

There shall be no breakdown.

11.4 Voltage test of sheath

11.4.1 *Principle*

The test verifies the specified withstand voltage of the sheath under a.c. or d.c. conditions. The spark test shall be in accordance with IEC Publication 96-1 clause **10.2.**

Nominal thickness of the sheath (mm)	**Test a.c.** (kV rms)	**Voltage d.c.** (kV)
Over 0,4 up to and including 0,5	2,5	3,75
Over 0,5 up to and including 0,8	3	4,5
Over 0,8 up to and including 1,0	5	7,5
Over 1,0	8	12

11.4.2 *Requirements*

There shall be no breakdown.

11.5 Characteristic impedance

11.5.1 *Mean characteristic impedance*

11.5.1.1 *Principle*

The test determines the mean characteristic impedance Z_Φ.

11.5.1.2 *Definition*

Z_Φ is defined as the value which the mean characteristic impedance approaches at high frequencies.

$$Z_\Phi = \frac{l_e}{3{,}10^8\ C} = \frac{l}{\Delta f C} \quad \text{in Ohm} \qquad (9)$$

where

l_e is the electrical length of the test specimen at approximately 200 MHz in metres;

C is the capacitance of the test specimen in Farad;

Δf is the change of frequency corresponding to 360° phase variation of the test specimen at approximately 200 MHz in Hertz;

l is the physical length of the cable.

11.5.1.3 *Procedure*

a) Electrical length

The test circuit to determine the electrical length shall be in accordance with clause **11.7.3** of this specification.

b) Capacitance

The capacitance C of the test specimen shall be measured in accordance with IEC 46A (CO) 159, clause **6.3**

1) Test equipment

Capacitance meter or capacitance bridge with an accuracy equal or better than one part in a thousand. The frequency shall be between 800 Hz and 1 KHz.

2) Preparation of test specimen

Both ends shall be prepared in order to avoid stray capacitance.

3) Procedure

The capacitance shall be measured between the inner and outer conductor.

c) Change in frequency

The change in frequency, f for the test specimen shall be measured in accordance with IEC 46A (CO) 159 clause **6.10.5** or **6.10.6**.

11.5.1.4 *Expression of results*

The mean characteristic impedance shall be calculated using equation 9.

11.5.2 ***Void.***

11.6 Return loss

11.6.1 ***Principle***

The test determines the electrical homogeneity of the cable. The return loss shall be determined using either directional couplers to separate the incident and reflected waves or by measurement of the input reflection coefficient by bridge circuit.

11.6.2 ***Definition***

The return loss characterizes the regularity of impedance in the frequency domain. It is defined as:

$$a_r = 20 \log(u_i / u_r) \quad \text{in dB} \qquad (10)$$

where

- u_i is the magnitude of the incident wave with reference to the impedance Z_Φ (75 Ω);
- u_r is the magnitude of the reflected wave with the test specimen terminated in the impedance Z_Φ (75 Ω);
- Z_Φ is the nominal characteristic impedance.

The return loss is related to the reflection coefficient r, by:

$$r = \frac{u_r}{u_i} = 10 \; \frac{-(a/20)}{r} \qquad (11)$$

It is indirectly related to the standing wave ratio, by:

$$S = \frac{(|1 + r|)}{(|1 - r|)} \qquad (12)$$

11.6.3 ***Test equipment***

The test equipment shall be assembled in accordance with the circuit arrangement shown in figure 5.

11.6.4 ***Preparation of test specimen***

Test connectors shall be fitted on both ends of the test specimen to allow direct connection to the bridge of reflectometer as well as to the 75 Ω termination. Unless otherwise specified the length of test specimen shall be such that the insertion loss at 10 MHz is at least 3 dB.

11.6.5 ***Procedure***

11.6.5.1 *Calibration with total reflection*

During calibration the test port of the bridge or reflectometer shall be set in open circuit and then short circuit with reference standards. The reflected signal corresponds to a reflection coefficient of 1 or 0 dB return loss signal. If the signal levels obtained with open and short circuited test port differ, the average of both shall be taken as the reference level.

Calibration lines shall be established for different signal levels which are plotted against frequency over the specified test frequency range. The respective signal levels shall be achieved either by the attenuator set (4) or by the signal processing unit (10) if it contains a step attenuator.

11.6.5.2 *Calibration with standard mismatch*

Calibration may be performed using a standard mismatch having a known reflection coefficient or return loss over the specified frequency range.

Calibration lines shall be established as described in **11.6.5.1**.

11.6.5.3 *Measurement*

When using analogue signal processing and recording, the frequency sweep rate shall be suitable for the transient response of the signal processing unit display and recorder. The sweep rate shall be reduced until there is no further change in the amplitude of any peak.

When using digital signal processing and/or recording, the frequency range and the number of sampling points must be selected to suit the length, velocity ratio, and attenuation of the cable under test. In case of doubt, the number of sampling points shall be increased or measured bandwidth reduced until there is no further change in the magnitude of any peak.

In theory, the following condition should be satisfied:

$$n \leq 3\,(f_2 - f_1)\; 1 / (150 v_r) \qquad (13)$$

where

n is the number of sampling points in the frequency range f_1 to f_2 forming the response curve;

f_1 is the lowest frequency in the range in MHz;

f_2 is the highest frequency in the range in MHz;

l is the physical length of the test specimen in m;

v_r is the nominal velocity ratio of the specimen.

Failure to satisfy this condition may result in loss of resolution of peaks, and therefore to measurement inaccuracy.

11.6.6 ***Requirements***

The value of return loss shall meet the requirements stated in the relevant cable specification.

11.7 Relative propagation velocity (velocity ratio)

11.7.1 ***Principle***

The test is to determine the relative propagation velocity v_r (velocity ratio) of cables.

11.7.2 ***Definition***

The relative propagation velocity v_r is that value the relative propagation velocity approaches at high frequencies. It is defined as:

$$v_r = v / c = l / l_e \quad (14)$$

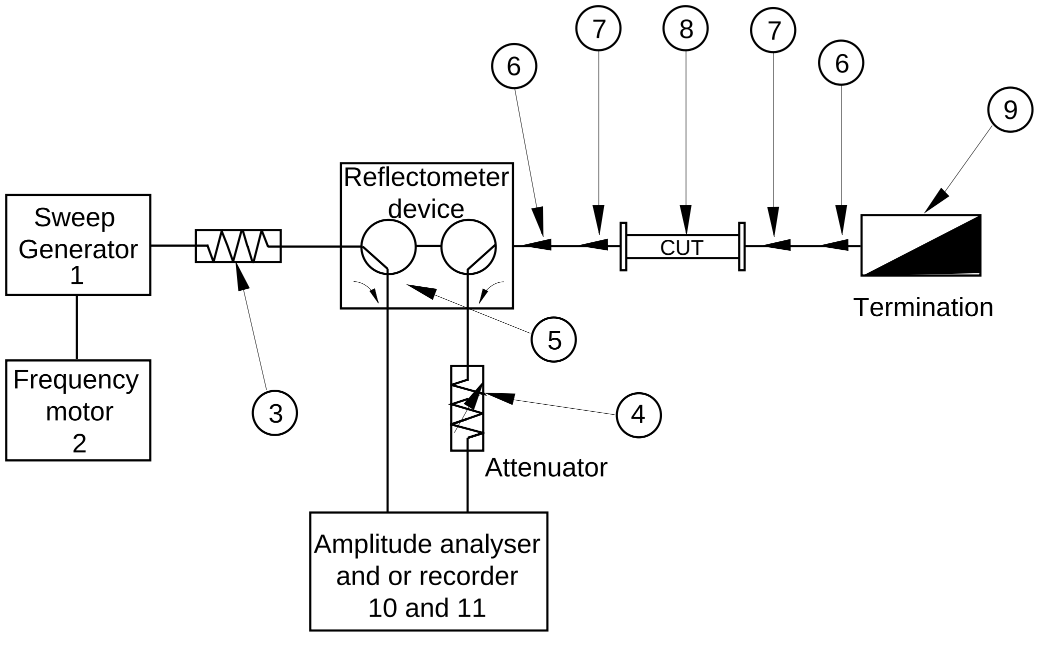
where

v is the propagation velocity of the cable sample at approximately 200 MHz;

l is the physical length of the cable sample;

l_e is the electrical length of the cable sample at approximately 200 MHz;

c is the propagation velocity in free space.



1	sweep generator	level ≥ 10 dBm
2	frequency counter	
3	attenuator set	10 dB
4	attenuator	0 to 50 dB in 1 dB steps with an uncertainty ≤ 0,1 dB
5	bridge/reflectometer	directivity ≥ 36 dB (Note. the reflectometer or bridge must be of the same nominal impedance as the test specimen)
6	test adapters (in case the matching surfaces of the test port and the connector differ)	inherent return loss ≥ 40 dB
7	test connector	//
8	cable	
9	termination	//
10	signal processing unit	
11	signal recorder	

Figure 5. General lay-out of test circuit for return loss measurement

11.7.3 ***Test Equipment***

The test circuit to determine the electrical length shall be in accordance with figure 6.

A measuring instrument to determine the physical length of the cable sample shall be within an uncertainty of 1 %.

11.7.4 ***Procedure***

The electrical length of the cable sample shall be measured as described below. The physical length of the cable sample shall be measured.

At a frequency > 100 MHz (usually ~ 200 MHz) the exact frequency f_i of a voltage minimum at the near end of a short-circuited cable (or of a voltage maximum at the near end of an open-circuited cable) is measured.

Then the generator is tuned to higher frequencies to the $(i + m)$th minimum (or maximum), where $1 \leq m \leq 10$.

The propagation time is:

$$T_{p'fi} = m / (f_{(i+m)} - f_i) \quad \text{in } \mu s \qquad (15)$$

with frequencies in MHz

The electrical length of the cable sample is with this:

$$l_e = 300\ T_p \quad \text{in m} \qquad (16)$$

or

$$l_e = (300\ m) / (f_{(i+m)} - f_i) \quad \text{in m} \qquad (17)$$

NOTE. For frequency $f_i \geq 200$ MHz the electrical length l_e becomes $l_{e\Phi}$.

11.7.5 ***Expression of results***

The relative propagation velocity shall be expressed as a percentage by:

$$v_r = 100(l / l_{e\Phi}) \quad \text{in \%} \qquad (18)$$

where l and $l_{e\Phi}$ are in metres.

11.7.6 ***Requirements***

The relative propagation velocity shall be in accordance with the value specified in the relevant cable specification.

11.8 Longitudinal loss

11.8.1 ***Principle***

The test determines the longitudinal loss of coaxial cables preferably at frequencies above than 10 MHz but also at lower frequencies if the magnitude of the complex characteristic impedance $|Z|$ is approximately equal to the nominal impedance Z of the test specimen.

11.8.2 ***Definition***

The attenuation constant is defined as

$$a = 10 \log (P_1 / P_2)\ (100 / l) \quad \text{in dB/100 m} \qquad (19)$$

where

P_1 is the output power of a source where the load impedance and the source impedance are equal and of the same value as the nominal value of the test specimen;

P_2 is the output power measured at the end of the test specimen inserted into the test system as defined above;

l is the physical length of the cable sample in metres.

If at very low frequencies the deviation of $|Z|$ and Z cannot be neglected the length of the test specimen shall be so long that:

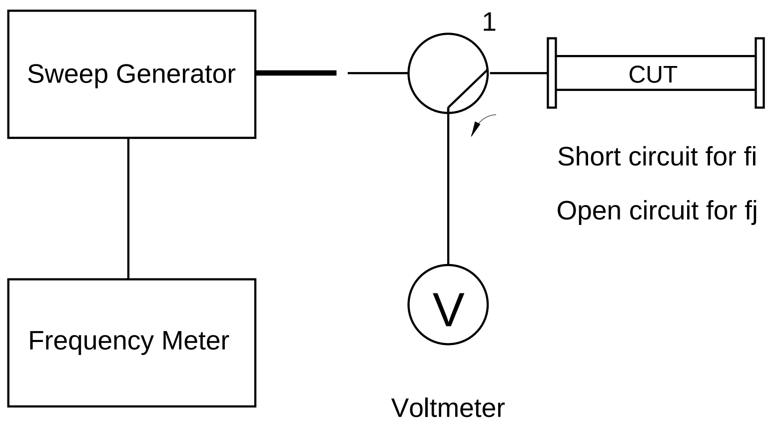
$$al / 100 >> 8{,}7r^2 \qquad (20)$$

where

$$r = (|Z| - Z) / (|Z| + Z) \qquad (21)$$

l is the physical length in m;

a is the nominal longitudinal loss in dB/100 m.



NOTE. Item 1 is a loose coupling device (e.g. a capacative coupler) or a bridge with an open circuit in its reference path.

Figure 6. General layout for electrical length measurement

11.8.3 ***Preparation of test specimen***

The length of the test specimen shall be such that the uncertainty of the measurement of the longitudinal loss will not exceed 2 %. The length of the test specimen shall be determined with a degree of uncertainty not exceeding 1 %. Thus the accumulated degree of uncertainty of the longitudinal loss should not exceed 3 %.

Connectors shall be fitted on each end of the test specimen. The connectors shall match directly the ports of the test equipment or test adapters shall be used.

11.8.4 ***Test method***

The test equipment shall be arranged generally in accordance with the circuit shown in figure 7.

11.8.5 ***Procedure***

The test circuit shall be calibrated in the test frequency range with the test ports connected together. The test specimen shall then be inserted into the circuit and the ratio of the input and output voltage or power shall be recorded reading 'a' in dB.

With systems where the longitudinal loss of the cable under test is measured using digital signal processing and/or recording, it may happen that not all details of the actual attenuation distortions are detected completely. This effect, caused by a too small number of sampling points, normally may be neglected if the return loss requirement, stated in the relevant cable specification, is met.

In case of doubt see **11.6.5.3**.

11.8.6 ***Expression of results***

The longitudinal loss, corrected to ambient temperature of 20 °C, shall be determined as follows:

$$a_{(20)} = a_{(t)}(1 / (1 + 2{,}10^{-3}\ [t - 20]))\ (100 / l) \quad \text{in dB/100 m} \qquad (22)$$

where

$a_{(t)}$ is the reading in dB at the test temperature;

l is the length of test specimen in m;

t is the temperature of the test sample in °C.

11.8.7 ***Requirements***

The longitudinal loss shall not exceed the value stated in the relevant cable specification.

11.9 Regularity of impedance

11.9.1 ***Method A: Pulse return loss***

11.9.1.1 *Principle*

The test determines in the time domain the return loss of coaxial cables using a pulse signal.

NOTE. The pulse return loss is displayed against time to show the local irregularities of the characteristic impedance. The procedure also allows the characteristic impedance at the ends of the cable to be determined. The procedure normally is used with long cable lengths relative to the pulse width.

11.9.1.2 *Definitions*

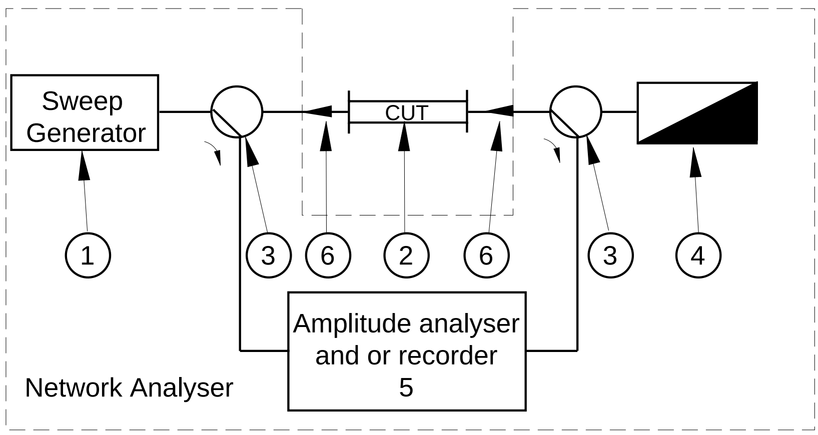
Pulse return loss, a_p is defined as

$$a_p = 20 \log (u_s / u_{r.x}) \quad \text{in dB} \qquad (23)$$

where

u_s is the voltage of the sending pulse at the input end;

$u_{r.x}$ is the voltage of the pulse reflected by an irregularity at a distance x from the cable input end and measured at the input end of the cable.



1 Sweep generator
2 Cable under test
3 Insertion unit
4 Termination load
5 Analyser
6 Adapters (if needed)

Figure 7. General layout of the test circuit for longitudinal loss measurement

The corrected pulse return loss, $a_{p.c}$ is the return loss measured at the input end minus the pulse attenuation by travelling $2x$. It is defined by

$$a_{p.c} = a_p - (2\alpha x / 100) \quad \text{in dB} \qquad (24)$$

where

α is the attenuation constant in dB/100 m at the frequency f_e around which the main part of the pulse energy is concentrated and x is the measured distance in m. For a sensitive determination of $a_{p.c}$ it should be noted that the pulse attenuation may not vary linearly with length due to the pulse distortion.

The resolution, δl, is the minimum distance between two faults which can be distinguished on a return loss curve.

The pulse width, t_p, is characterised by the value of the pulse width at half height.

11.9.1.3 *Test equipment*

The test equipment shall be assembled generally in accordance with the figure below.

11.9.1.4 *Procedure*

The pulse is an approximately sine squared pulse.

Unless otherwise specified in the relevant cable specification, the width of the pulse shall be $\leq$ 10 ns.

The resolution δl is determined by

$$\delta l = 0{,}15\, t_p v_r \quad \text{in m} \qquad (25)$$

where

t_p is the pulse width in ns;

v_r is the velocity ratio of the test specimen.

The frequency f_e is determined by

$$f_e = 250 / t_p \quad \text{in Mhz} \qquad (26)$$

Items 5 and 6 in figure 8 shall be adjusted for minimum reflection.

The return loss shall be displayed and recorded.

11.9.1.5 *Requirements*

The regularity of impedance shall not exceed the value stated in the relevant cable specification.

11.9.2 ***Method B : Step function return loss***

11.9.2.1 *Principle*

The test determines in the time domain the return loss of cables using a step function signal.

NOTE. The step function return loss is displayed against time to show the local distribution of magnitude and phase of irregularities of the characteristic impedance near the input end of the test specimen.

11.9.2.2 *Definitions*

The step reflection coefficient is defined as

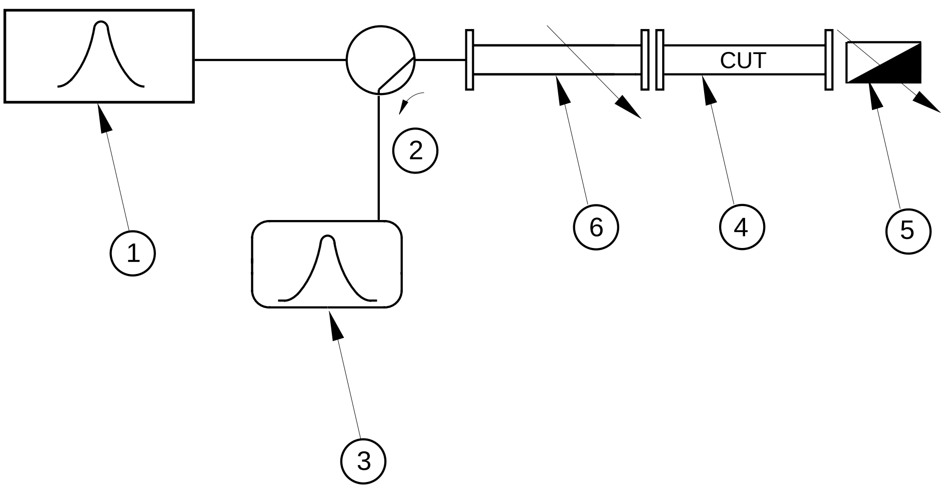
$$r_s = u_{r.x} / u_s \times 100 \quad \text{in \%} \qquad (27)$$

where

$u_{r.x}$ is the step voltage reflected by an irregularity at a distance x from the input end of the cable;

u_s is the step voltage applied to the test specimen.

For a step function the rise time, t_r, is defined as the difference in time between the 10 % and 90 % value of step amplitude. The rise time affects the resolution.



1 Pulse generator
2 Hybrid, directional coupler
3 Signal processing/display unit
4 Test specimen
5 Adjustable terminating load
6 Adjustable reference standard

Figure 8. General layout of pulse return loss equipment

The resolution δ1 can be determined by:

$$\delta l = 150 \times 10^{-6} \times t_r \times v_r \quad \text{in m} \qquad (28)$$

where

t_r is the rise time in ps;

v_r is the velocity ratio of the test specimen.

11.9.2.3 *Test equipment*

The test equipment shall be assembled generally in accordance with figure 9.

11.9.2.4 *Procedure*

The step function used to test the test specimen shall have a rise time ≤ 5 ns.

The regularity of the step reflection coefficient shall be recorded.

11.9.2.5 *Requirements*

The step reflection coefficient shall comply with the value indicated in the relevant cable specification.

11.10 Screening attenuation (absorbing clamp method)

11.10.1 ***Principle***

The test determines the screening efficiency of a coaxial cable using absorbing clamps.

11.10.2 ***Definitions***

The cable screen, which is usually the outer conductor of the coaxial cable, acts as a radiating or receiving antenna. The radiated power is coupled in or out continuously along the entire length of the cable. The mutual coupling of cable and environment can be assumed to be reciprocal.

The cable, as the primary system, is fed with the power P_1. Due to the electro-magnetic coupling between the cable and the environment surface waves are excited and propagated in both directions along the cable surface. The surface currents are measured with an arrangement containing a current transformer for picking up the power of the surface waves, and an absorber (usually a ferrite tube), forming the load of the secondary circuit.

Combinations of this kind are known as absorbing clamps. On the basis of the peak values of the measured surface currents it is possible to calculate the maximum power, $P_{2,\,max}$ in the secondary system formed by the outer conductor of the cable and the environment.

The logarithmic ratio of the powers P_1 and $P_{2,max}$ is termed screening attenuation expressed in dB.

The line attenuation of the test item, which is usually short, is disregarded.

The surface current can be measured:

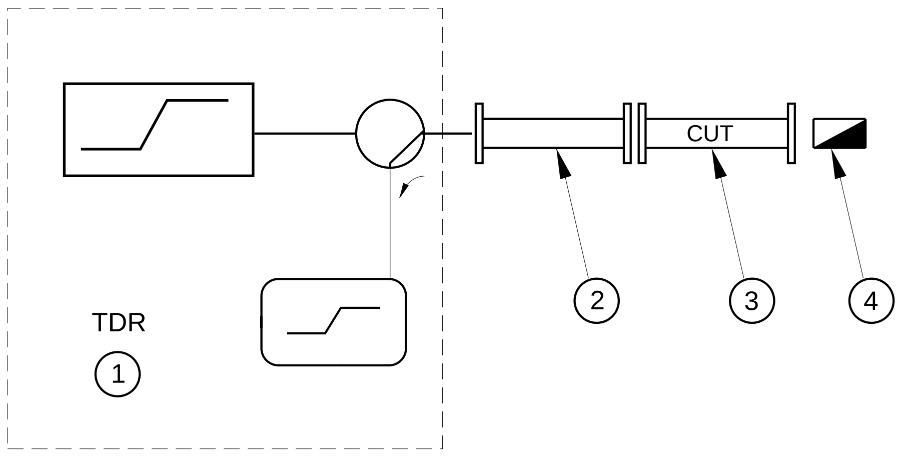
– at fixed frequencies with a moving absorbing clamp;

– on a swept-frequency basis with a stationary clamp;

– on a swept-frequency basis with a moving clamp.

11.10.3 ***Test equipment***

The figures 10 and 11 are schematic diagrams of the arrangements for measuring the surface waves arriving at the far and the near end of the sample, respectively, as viewed from the generator.



1 TDR
2 Standard line (option)
3 Test specimen
4 Terminating load

NOTE. A standard line is preferred with the nominal characteristic impedance of the test specimen to determine the characteristic impedance at the ends of the test specimen.

Figure 9. Layout of step function test equipment

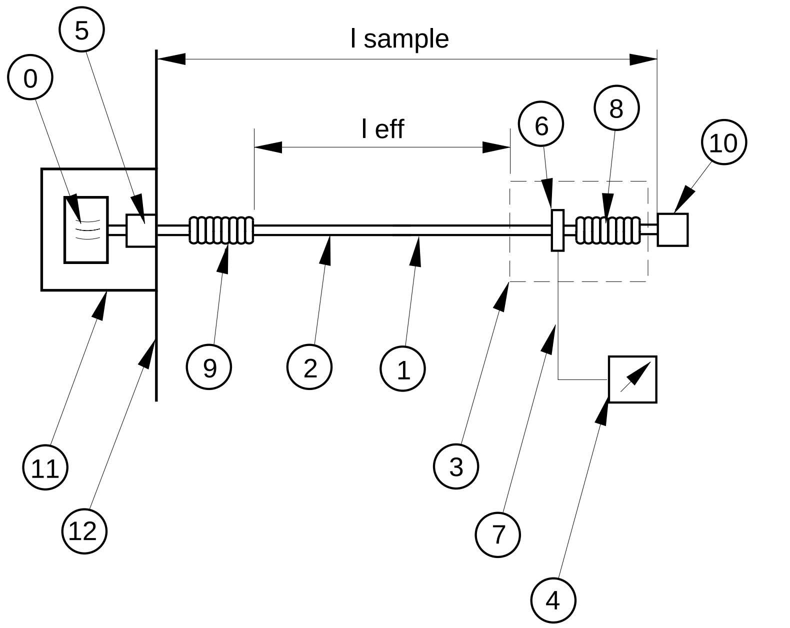


Figure 10. Measurement of the surface wave at the far end of the sample

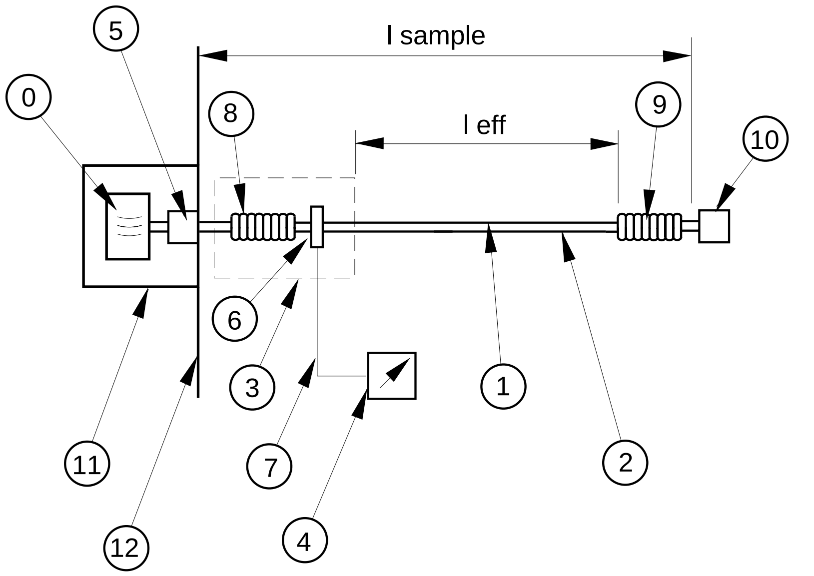


Figure 11. Measurement of the surface wave at the near end of the sample

Reference	Item
0	Signal generator, output impedance Z_0.
1	Cable sample, characteristic impedance Z_1 .
2	Outer circuit of outer conductor, characteristic impedance Z_2 .
3	Absorbing clamp, impedance Z_3.
4	Measuring receiver.
5	Matching network, if Z_0 is different to Z_1 (use the same in both measurement and calibration).
6	Current transformer.
7	Measuring receiver line (use the same in both measurement and calibration).
8	Absorber (ferrite tube) of the clamp, attenuation 10 dB.
9	Second absorber (or second clamp), attenuation 10 dB.
10	Termination Z_1 of cable sample.
11	Shield of signal generator.
12	Reflector plate.
l_{sample}	Total length of cable sample.
l_{eff}	Effective length of cable sample.

11.10.4 ***Preparation of test specimen***

The effective length of the test specimen is limited by the absorbing clamp and the ferrite tube, as shown in figure 11. In order to determine the maximum power in the secondary system the test specimen shall have an effective length given by:

$$l_{eff} \geq (150[v_{r,2}\ v_{r,1}]) / (f_{min}\ [v_{r,2} - v_{r,1}]) \qquad (29)$$

for $v_{r,1} = v_{r,2}$

where

l_{eff} is the effective length of the test specimen in metres;

f_{min} is the lowest measuring frequency in MHz;

$v_{r,1}$ is the relative propagation velocity of the primary circuit;

$v_{r,2}$ is the relative propagation velocity of the secondary circuit.

If the required minimum effective length cannot be realized, it is permissible to use a shorter test specimen with length l_{actual} . In this case the measured far-end cross-talk must be modified by dividing the value by:

$$\sin^2[(\pi / 2)\ \ (l_{actual} / l_{eff})] \qquad (30)$$

11.10.5 ***Indications and general precautions***

The signal generator shall be carefully shielded, if necessary by means of a shielding case. Where a shielding case is used the generator and the matching network shall be housed in the shielding case. Directly in front of the generator a vertical metallic reflector plate shall be erected, whose height and width shall each be at least 800 mm. The plate is connected to the generator housing and has a central hole to accommodate the cable under test.

The cable sample is laid on a non-metallic table. No metallic objects or any person shall be closer than 800 mm to the cable sample in any direction that is perpendicular to the axis of the cable, see figure 12.

All connectors, connecting pieces and connecting cables shall be carefully mounted to minimize r.f. leakage. In case of doubt, the screening attenuation of the measuring arrangement shall be tested by replacing the test specimen by a cable with a tubular outer conductor. The screening attenuation measured in this case shall be at least 10 dB above that of the test specimen.

If a measurement sensitivity of 100 dB or more is required, shielding precautions shown in figure 5 of amendment no. 1 to the second supplement to CISPR Publication 8B shall be applied.

The cable sample shall be positioned centrally in the current transformer.

NOTE 1. If the generator and receiver sections are adequately decoupled other instruments can be used, for example a combined level oscillator and measuring receiver.

NOTE 2. It is advisable to have a metal floor covering, about 1m wide, under the cable sample (in the required distance)

11.10.6 ***Expression of results***

The screening attenuation a_s is given by:

$$a_s = 10 \log (P_1 / (P_{2,n} + P_{2,f})) \qquad (31)$$

where

P_1 input power of the inner circuit of the sample in mW;

$P_{2,n}$ maximum near end crosstalk power of the matched outer circuit in mW;

$P_{2,f}$ maximum far end crosstalk power of the matched outer circuit in mW.

NOTE. $P_{2,max} = P_{2,n} + P_{2,f}$

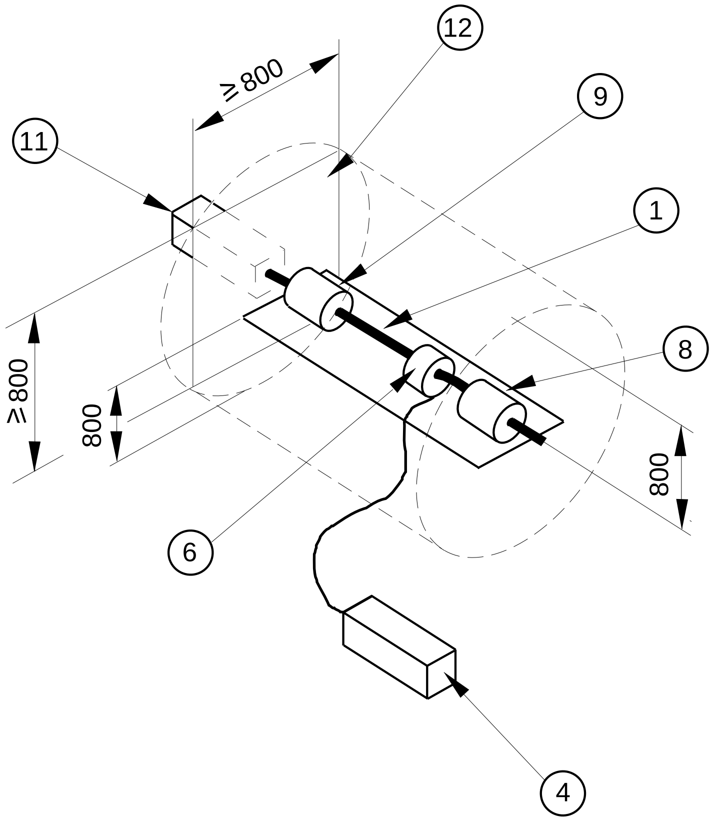
The measured powers (indicated by the measuring receiver, equipment no. 4 of figure 12) are $P_{4,n}$ and $P_{4,f}$ respectively. Hence we have:

$$a_s = 10 \log (P_0 / (P_{4,n} + P_{4,f})) - a_M \qquad (32)$$

where

P_0 power of the signal generator in mW;

a_M insertion loss of the measuring set up, according to **11.10.7.1**.



All items as specified in figures 10 and 11, the dimensions are given in mm.

Figure 12. Shielding arrangements

11.10.7 *Calibration of the measuring set up*

11.10.7.1 *Insertion loss of the measuring set up*

In the measuring arrangement shown in figure 13 the electrically insulated outer conductor of the test item is connected to the inner conductor of the generator output.

The maximum and minimum readings of the level meter 4 are to be observed when the clamp is moved along the cable. The insertion loss a_M of the measuring set up is given by:

$$a_M = 1/2[10 \log (P_0 / P_{4max}) + 10 \log (P_0 / P_{4min})] - a_R - a_c \quad \text{in dB} \qquad (33)$$

where

- P_0 power of the signal generator in mW;
- P_{4max} maximum power at the level meter 4 in mW;
- P_{4min} minimum power at the level meter 4 in mW;
- a_R radiation loss in dB;
- a_c calibration loss, due to the mismatch between generator output impedance Z_1 and the impedance Z_2 of the outer circuit of the outer conductor, in dB.

The losses a_R and a_c respectively and Z_2 are to be calculated from:

$$a_R = 8{,}686 [\log (221_A / \lambda) / \log (0{,}271_A \ \lambda / d^2)] \quad \text{in dB} \qquad (34)$$

$$a_c = 10 \log ((Z_0 + Z_2)^2 / (4Z_0Z_2)) \quad \text{in dB} \qquad (35)$$

$$Z_2 = (\ln(\lambda / \pi d) - 0{,}6)60 \quad \text{in Ohm} \qquad (36)$$

where

- 1_A mean value of 1_A according to figure 13;
- λ free space wavelength;
- d outer diameter of outer conductor of cable 1.

11.10.7.2 *Attenuation of the absorbers*

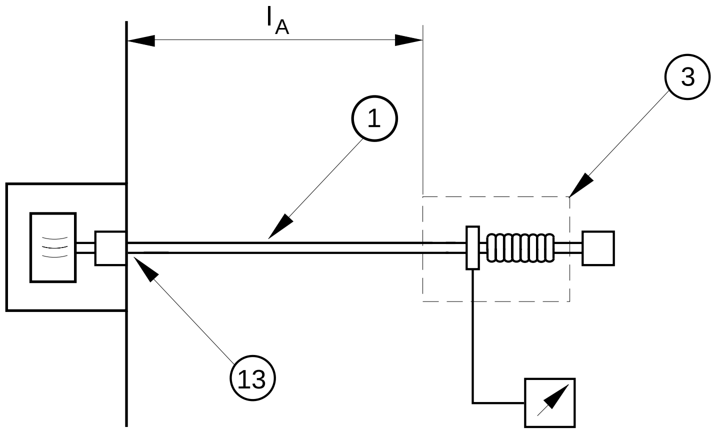
The attenuation of the absorbers shall be such that waves reflected by the cable section behind the absorber are suppressed. A value ≥ 10 dB is necessary.

The measuring arrangement is shown in figure 14.

The absorber to be tested is to be positioned as close as possible to connection point 13. The gap shall be much smaller than 1/4 of the wavelength in the secondary system.

Directly behind the absorber under test, as viewed from the generator, the current in the outer conductor is measured with an absorbing clamp.

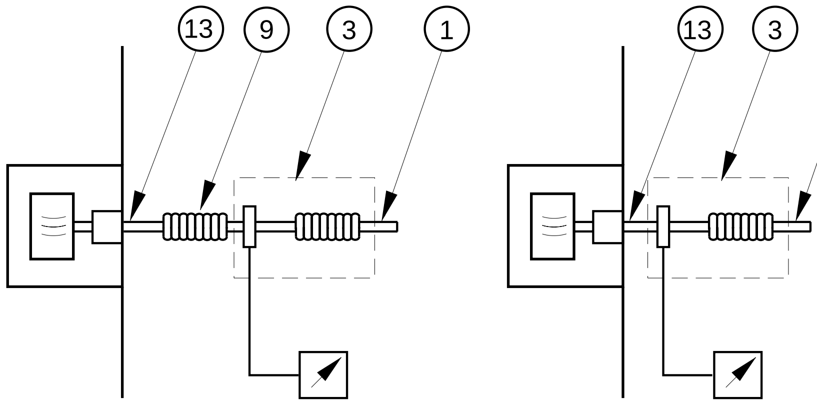
The absorber under test is then removed and the absorbing clamp is moved forward to the connection point 13. The clamp current is measured again. The level difference is the attenuation of the absorber.



Reference	Item
1	Cable sample
3	Absorbing clamp
13	Connection of the outer conductor of cable sample 1 to the inner conductor of the generator
l_A	Distance between the absorbing clamp and the connection point 13.
l_A =	1.0 .... 5.0 m, if $f < 500$ MHz
	1.0 .... 2.0 m, if $f > 500$ MHz

All other items as in figures 10 and 11.

Figure 13. Test arrangement for insertion loss measurement



Reference	Item
1	Cable sample
3	Absorbing clamp
9	Absorber under test
13	Connection of the outer conductor of the cable sample 1 to the inner conductor of the generator

Figure 14. Measurement of the attenuation of the absorbers

11.10.8 ***Requirements***

The screening attenuation shall be in accordance with the values stated in the relevant cable specification.

11.11 Transfer impedance

Under consideration.

12 Quality assessment procedures

12.1 Purpose

The purpose of quality assessment is to provide assurance that the product conforms to the requirements of the relevant specifications. This assurance is achieved by implementing relevant systems and procedures during the design, development, production, inspection and test of the product supplied. Although the systems and procedures may vary with different quality assessment schemes, the purpose of assuring product conformance is common to each scheme.

The choice of quality assessment scheme is a matter for agreement between customer and supplier. Qualification Approval and Capability Approval schemes are available for selection where appropriate, and all recognised approved schemes invoke the requirements of EN 29000.

An outline of two principle schemes which remain under consideration for this generic specification is given below in sections **12.3** (Qualifications Approval) and **12.4** (Capability Approval).

12.2 General

12.2.1 ***Related documents***

EN 29000

EN 29001

EN 29002

EN 29003

CECC 00114 : RP14

CECC 00107

12.2.2 ***Standard and preferred values***

Whenever possible, standard and preferred values according to the generic specification and the relevant sectional specifications shall be used.

12.2.3 ***Terminology***

12.2.3.1 *The Capability Manual*

The Capability Manual (CM) of a manufacturer is a complete description of design rules, manufacturing processes, and test procedures, including their limits and verification procedures. The Capability Manual is the basic document required in support of Capability Approval.

12.2.3.2 *The Quality Manual*

The Quality Manual describes either directly, or by reference to the manufacturer's internal documents, the procedures used by the manufacturer to ensure conformity of his products with the applicable specifications. The Quality Manual is required for both Qualification and Capability Approval.

12.2.3.3 *Capability Qualifying Component (CQC)*

CQC's are test specimens specially designed or taken from production and used for verifying capability limits in accordance with the Capability Manual.

12.2.3.4 *Primary Stage of Manufacture*

The Primary Stage of Manufacture is the first activity under the control of the manufacturer according to the Capability Manual, and shall be in accordance with the generic specification.

12.3 Qualification Approval

12.3.1 ***Introduction***

Qualification Approval is appropriate when products are made to standard patterns and (usually) in continuous production.

Qualification Approval can only be achieved for existing detail specifications.

The relevant specifications state the requirements for the Qualification Approval of the cable assembly (test schedule, number of specimens, number of defectives permitted, etc.).

12.3.2 ***How to obtain Qualification Approval***

To obtain Qualification Approval the following steps shall be performed:

a) Approval of the manufacturer on the basis of his ability to produce and inspect products in conformance with the specification and the agreed rules of procedure, limited to specified organization and facilities, and verified by audits on the manufacturer's quality system as described in the Quality Manual by the NSI in accordance with, for instance, EN 29001 or EN 29002;

b) Successful completion of qualification tests, usually made on production items, according to the relevant specification.

12.3.3 ***How to maintain Qualification Approval***

To maintain Qualification Approval the manufacturer shall comply with the following conditions to the satisfaction of the NSI:

a) Results of periodic audits by the NSI on the Quality Manual shall be satisfactory;

b) Delivered products shall fulfil the specified Quality Assurance requirements;

c) An inspection of current production is carried out in accordance with the relevant specifications. Products from lots which do not fulfil the specifications shall not be permitted to be delivered;

d) Successful completion of periodic tests according to the detail specification.

12.3.4 ***Modifications likely to affect Qualification Approval***

Modifications likely to affect Qualification Approval shall be carried out in accordance with the requirements of rules of procedures CECC 00107/1.

The manufacturer shall report to the NSI any technical modifications, including changes of place of manufacture, which could affect the results obtained if Qualification Approval procedures were to be repeated.

The NSI shall then decide whether it is necessary to repeat all or some of the Qualification Approval tests before any components subject to the modifications are delivered under the system.

The NSI shall, as part of its surveillance, ensure that the reporting of modifications has taken place.

12.4 Capability Approval

12.4.1 ***Introduction***

As Capability Approval is process orientated, it is appropriate when the cable manufacturing process technologies are fully controlled and the requirements of the customer and the product application are not affected by design changes.

Capability Approval is valid for all existing and future detail specifications within the Capability limits.

The Capability Manual stated the requirements for the Capability Approval of all products within the Capability limits.

12.4.2 ***How to obtain Capability Approval***

To obtain Capability Approval the following steps shall be performed:

a) Approval of the manufacturer on the basis of his ability to produce and inspect components according to the specifications and the agreed rules of procedure limited to specified organization and facilities checked by audit on the Quality Manual by the NSI according to EN 29001 or EN 29002;

b) Approval of the manufacturer on the basis of his Capability Manual by the NSI;

c) Successful completion of qualification test on CQC's specified by the Chief Inspector according to the Capability Manual and the relevant specifications.

12.4.3 ***How to maintain Capability Approval***

To maintain Capability Approval the manufacturer shall comply with the following conditions to the satisfaction of the NSI:

a) Evidence that the Capability limits stay valid by periodic testing of the CQC's according to the Capability Manual;

b) Results of periodic audits on the Quality Manual led by the NSI shall be satisfactory;

c) The delivered products shall fulfil their Quality Assurance requirements;

d) The Capability Manual shall be regularly updated;

e) The register of the associated products shall regularly updated.

12.4.4 ***Procedure for Reduction, Extension or Change of Capability***

Where an approved manufacturer wishes to reduce, extend or change the scope of his Capability Approval, it is the responsibility of the Chief Inspector to decide whether the reduction, extension or change is significant or not.

Where the reduction, extension or change is not significant, it shall be recorded by the manufacturer who may proceed without the approval of the NSI.

Where the reduction, extension or change is significant the manufacturer shall notify the NSI in advance.

The results of the tests carried out to demonstrate the effect of the change on the products shall be made available to the NSI.

12.4.5 ***Contents of the Capability Manual***

12.4.5.1 *Object*

This section shall give in general terms, details of the products covered by the Capability Approval, and shall make reference to the relevant generic and/or sectional specifications.

12.4.5.2 *List of revision*

The validation of Capability Manual updates is part of the audit procedure.

Revisions shall be identified by an index and the date of the revision.

When a revision takes place, a complete list of all changes shall be made which occurred during the preceding period.

12.4.5.3 *Related Documents*

The Capability Manual shall make reference to all relevant documents.

12.4.5.4 *Capability, Domain, Capability Limits and their related CQC's*

This section shall define the Capability domain in terms of relevant design parameters (materials, dimensions, construction, testing, etc...)

The section shall also give a reference list of the Capability limits and the CQC's chosen to assess these limits from the primary stage of manufacture through to the final product.

12.4.5.5 *Flow chart, including process parameters*

This section shall include:

a) General flow charts giving the full sequence of manufacturing and inspection processes, from the primary stage of manufacture to delivery, making reference to the corresponding CQC's;

b) Work instructions and inspection procedures for all processes contained on the flow chart, generally by reference to in-house documentation;

c) Flow Charts for CQC's.

12.4.5.6 *Purchased raw materials*

This section shall identify purchasing specifications for the raw materials used in the manufacturing processes.

12.4.5.7 *Design rules*

Unless covered by Quality Manual, the manufacturer's design rules shall be stated either directly or by reference to the manufacturer's internal documents.

12.4.5.8 *Register of associated products*

This section shall give the list of products which are or can be delivered under Capability Approval generally by reference to an Appendix.

12.4.6 ***Criteria for capability limits***

The sectional specifications shall preferably give guidance for capability limits, technology, process, performance and their related CQC's. The Capability Manual may include one or several sub-families from one or several sectional specifications.

12.5 Quality conformance inspection

After Qualification Approval or Capability Approval has been obtained, the manufacturer is responsible for ensuring that no technical changes likely to affect the approval are introduced for the products without reapproval being undertaken and that the Quality conformance inspection required by the specifications is carried out and is satisfactory.

The Quality conformance inspection is divided into two parts:

a) a first group of tests which is carried out lot-by-lot and serves to accept the individual production lot on which the tests are carried out;

b) a second group of tests, containing the time consuming and more expensive tests, which are carried out on a periodic basis.

Under Qualification Approval, the full test programme is given in the detail specification.

Under Capability Approval, periodic tests shall be performed on CQC's as prescribed in the Capability Manual.

12.5.1 ***Formation of inspection lots***

An inspection lot will be formed by samples taken from a single production lot.

Any inspection lot may be formed by the aggregation of several production lots, provided that:

a) The production lots are manufactured under essentially the same conditions without significant interruption;

b) All the production lots are manufactured from the same raw materials.

12.5.2 ***Lot by lot tests***

Lot by lot tests are carried out on each production lot.

Generally lot by lot tests cover the visual and dimensional inspections and the principal characteristics of products.

12.5.3 ***Periodic tests***

Periodic tests are carried out at fixed intervals on samples taken from lots which have already satisfied the lot by lot tests, or on CQC's in the case of Capability Approval. The periodicity and the number or samples are given in the detailed specification.

12.5.4 ***Release or rejection of lots***

Release criteria shall be in accordance with the requirements of Paragraph **3** of CECC 00114 : RP14 Part III.

Unless otherwise stated in the relevant specification, the lots shall be released or rejected on the basis of the lot by lot tests. The failure of any sample submitted to one of the periodic tests shall result in the rejection of the lot from which the sample came.

12.5.5 ***Procedure in the event of failure in a periodic test***

This shall be in accordance with the requirements of Paragraph **2.10** of CECC 00114 : RP14 Part III.

List of references

See national foreword.

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