MV impregnated paper insulated distribution cables of rated voltages of 3.8/6.6 kV to 19/33 kV

ICS 29.060.20

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee, GEL/20 Electric Cables, to Subcommittee GEL/20/16, Medium/high voltage cables, upon which the following bodies were represented:

British Approvals Service for Cables

British Cables Association

British Plastics Association

Electricity Association

ERA Technology

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Contents

Foreword

BS 7894 was prepared by Subcommittee GEL/20/16 in order to complete the implementation of nationally applicable parts and sections of HD 621 S1:1996 published by the European Committee for Electrotechnical Standardization (CENELEC), in accordance with the decision of the CENELEC Technical Board. Sections 3-J1, 3-J2, 4-J1 and 4-J2 of HD 621 are already implemented by BS 6480. BS 7894 therefore implements the remaining nationally applicable parts and sections, which are as follows:

Part 1: General requirements;
Part 2: Additional test methods;
Section 4-J3: Three core cables with aluminium sheath.

NOTE 1 Only the texts of these two parts and one section are reproduced here, together with the CENELEC foreword and contents page.

NOTE 2 The CENELEC foreword includes the statement that "By decision of the Technical Board (D68/047) National Committees need at present only implement in their national language those sections having national applicability".

BS 7894, together with BS 6480, specifies a range of medium voltage impregnated paper insulated cables for power distribution having rated voltages up to and including 19/33 kV.

In the implementation of this HD the following change has been made:

in Section 4-J3, A.8 3) (marking clause) the standard number has been changed from "HD 621 4J-3" to "BS 7894".

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

WARNING This British Standard calls for the use of substances and/or procedures that may be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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

Summary of pages
This document comprises a front cover, inside front cover, pages i and ii, the HD title page, pages 2 to 78, an inside back cover and a back cover.

HARMONIZATION DOCUMENT
DOCUMENT D'HARMONISATION
HARMONISIERUNGSDOKUMENT

HD 621 S1

October 1996

ICS 29.040.20; 29.060.20

Descriptors: Electric cable, insulated cable, composition, dimension, construction characteristics, mechanical characteristics, test, marking, impregnated paper

English version

Medium voltage impregnated paper insulated distribution cables

Câbles de distribution moyenne tension isolés au papier imprégné

Energieverteilungskabel mit getränkter Papierisolierung für Mittelspannung

This Harmonization Document was approved by CENELEC on 1996-03-05. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for implementation of this Harmonization Document on a national level.

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

This Harmonization Document exists in three official versions (English, French, German).

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

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

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. HD 621 S1:1996 E

FOREWORD

This Harmonisation Document was prepared by WG9 of CENELEC Technical Committee TC20, Electric Cables. It was agreed by TC20 at its Helsinki meeting (May 1994) to be submitted for formal vote by National Committees.

The document contains the following Parts, arranged according to the main constructional features of the cables covered:

Part 1 - General requirements
Part 2 - Additional test methods
Part 3 - Impregnated paper insulated cables-single core, also pre-assembled
Part 4 - Impregnated paper insulated cables - three core

Each of Parts 3 and 4 are further divided into particular sections and, by decision of the Technical Board (D68/047) National Committees need at present only implement in their national language those sections having national applicability. The obligation remains however to announce the full HD in public by titles and numbers, and also to withdraw any conflicting national standards.

Page numbering reflects the arrangement into Parts and particular sections, e.g. Page 4-C-3 is page 3 of particular section C of Part 4.

References to other HDs, ENs and international standards are given in the particular parts or sections.

The draft was submitted to the CENELEC members for formal vote in August 1995 and was approved by CENELEC as HD 621 S1 on 1996-03-05 .

The following dates were fixed:

-	latest date by which the existence of the HD has to be announced at national level	(doa)	1996-09-01
-	latest date by which the HD has to be implemented at national level by publication of a harmonised national standard or by endorsement	(dop)	1997-03-01
-	latest date by which the national standards conflicting with the HD have to be withdrawn	(dow)	1997-03-01

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HD 621 S1:1996

MEDIUM VOLTAGE IMPREGNATED PAPER INSULATED DISTRIBUTION CABLES

PART 1 - GENERAL REQUIREMENTS

CONTENTS

REFERENCES

Part 1 of HD 621 incorporates by dated or undated reference, provisions from other publications. These 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 Part 1 of HD 621 only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 60811 Common test methods for insulating and sheathing materials of electric cables
HD 383 Conductors of insulated cables (Endorsing IEC 228 and 228A)
HD 405 Tests on electric cables under fire conditions
HD 605 Electric cables: Additional test methods

IEC 55-1 Paper-insulated metal-sheathed cables for rated voltages up to 18/30kV (with copper or aluminium conductors and excluding gas-pressure and oil-filled cables). Part 1: Tests.
IEC 229 Tests on cable oversheaths which have a special protective function and are applied by extrusion
IEC 287 Calculation of the continuous current rating of cables (100% load factor)

1. General

1.1 Scope

HD 621 applies to impregnated paper insulated cables for rated voltages Uo/U(Um) from 3,6/6(7,2)kV up to 20,8/36(42)kV used in power distribution systems.

This part (Part 1) specifies the general requirements applicable to these cables, unless otherwise specified in the particular sections of this HD.

Test methods specified are given in HD 605, EN 60811, HD 383 and HD 405 and in IEC 55-1 and IEC 229.

Part 2 covers all those test methods which are specific to paper insulated cables, and not included in HD 605.

The particular types of cables are specified in Parts 3 and 4.

1.2 Object

The objects of this Harmonisation Document are:

- to standardise cables that are safe and reliable when properly used, in relation to the technical requirements of the system of which they form a part;
- to state the characteristics and manufacturing requirements which have a direct or indirect bearing on safety;
- and to specify methods for checking conformity with those requirements.

2. Definitions

2.1 Definitions relating to insulating and sheathing materials

The insulation covered by this HD is paper, made from tapes, impregnated with suitable draining or non-draining compound. A suitable metallic sheath (lead or aluminium) is applied over the individual cores (single or separately lead sheathed cores) or over the assembly of the insulated cores (3-core belted or screened cables). The cable may be protected by an armouring and relevant serving and/or an outer sheath.

2.2 Definitions relating to the tests

Note: Tests classified as sample (S) or routine (R) maybe required as part of any type approval schemes.

2.2.1 Type tests (Symbol T)

Tests required to be made before supplying a type of cable covered by this HD on a general commercial basis in order to demonstrate satisfactory performance characteristics to meet the intended application. These tests are of such a nature that, after they have been made, they need not be repeated unless changes are made in the cable material, design or type of manufacturing process which might change the performance characteristics.

2.2.2 **Sample tests (Symbol S)**

Tests made on samples of completed cable, or components taken from a completed cable adequate to verify that the finished product meets the design specifications.

2.2.3 **Routine tests (Symbol R)**

Tests made on all production cable lengths to demonstrate their integrity.

2.2.4 **Tests after installation**

Installation tests are made to demonstrate the integrity of the cable and its accessories as installed.

2.3 **Rated voltage**

The rated voltage of a cable is the reference voltage for which the cable is designed, and which serves to define the electrical tests.

The rated voltage is expressed by the combination of the following values Uo/U (Um) expressed in kV.

Uo is the rms value between any insulated conductor and earth (metal covering of the cable).

U is the rms value between any two phase-conductors of a multicore cable or of a system of single core cable.

Um is the maximum rms value of the highest system voltage for which the equipment may be used.

The standard rated voltages Uo/U (Um) of the cables in this HD are as follows:

Uo/U (Um) = 3,6/6 (7,2) - 3,8/6,6 (7,2) - 6/10 (12) - 6,6/11 (12) - 7/12 (14,5) - 8,7/15 (17,5) - 12/20 (24) - 12,7/22 (24) - 15/20 (24) - 15/26 (30,5) - 18/30 (36) - 19/33(36) - 20,8/36 (42) - kV rms

In an alternating current system, the rated voltage of a cable shall be at least equal to the nominal voltage of the system for which it is intended. If used in DC systems, the maximum voltage has to be specified in the particular sections.

3. **Marking**

3.1 **Indication of origin**

Cables shall be provided with an identification of origin consisting of the marking of the manufacturer's name or trademark, or (if legally protected) identified number by one of the three following alternative methods:

(a) printed tape within the cable;
(b) printing on the insulation of at least one core;
(c) printing, indenting or embossing on the sheath.

3.1.1 **Continuity of marks**

The distance between the end of one complete set of marks and the beginning of the next is specified in the particular sections.

3.2 **Additional marking**

Additional marking requirements may be specified in the particular sections.

3.3 **Durability**

Printed markings shall be durable.

3.4 **Legibility**

All markings shall be legible. Printed markings shall be in contrasting colours.

3.5 **Common marking**

Under consideration.

3.6 **Use of the name CENELEC**

The name CENELEC, in full or abbreviated, shall not be directly marked on, or in, the cables.

4. **Core identification**

If required, the cores shall be identified by numbers, or by other schemes detailed in the particular sections of this HD.

5. **Construction of cables**

Compliance with the requirements specified in sub-clauses 5.1 to 5.11 and in the particular sections of this HD shall be checked by inspection and by measurement according to the test methods listed in the particular sections.

5.1 **Conductors**

5.1.1 **Material**

Conductors shall be either plain annealed copper or plain aluminium in accordance with HD 383 and with the requirements specified in the particular sections of this HD.

Conductors shall be stranded either circular or shaped, or (for aluminium only) solid.

5.1.2 **Electrical resistance**

The resistance of each conductor shall be in accordance with the requirements in HD 383 for the given class of conductor.

5.2 **Insulation**

5.2.1 **Material**

Insulation shall be made of paper tapes, helically applied around the conductor and impregnated with suitable draining or non draining compound.

Test requirements for the insulation are specified in the particular sections.

5.2.2 **Thickness**

Insulation thickness values for the core and the belt insulation are specified in the particular sections for each cable type, size and voltage.

The mean value of the insulation thickness shall be not less than the nominal value specified in the particular sections of this HD.

The minimum measured value shall not be less than the minimum value specified in the particular sections of this HD.

Compliance shall be checked by the test method given in part 2.

5.2.3 **Additional characteristics, if any**

These are specified in the particular sections.

5.2.4 **Belted cables**

In a belted cable a further thickness of insulating paper shall be applied around the assembled unscreened cores.

5.3 **Screening of cores**

Screening of cores, when required, shall consist of an insulation screening with or without a conductor screening, as specified in the particular sections of this HD. The screening shall consist of a semi-conducting and/or a metallised paper tape, as given in the particular sections of this HD.

5.4 **Assembly of cores**

In multicore cables, the cores shall be laid up helically or with another suitable method.

5.5 **Fillers and binder tape**

For each type of cable, the particular sections detail whether that cable includes fillers or not.

A centre filler may be used in multicore cables, and the assembly of cores and fillers may be held together by a binder tape.

5.5.1 Materials

The fillers and binder tapes, if any, shall be composed of a suitable material. When fillers or binder tapes are applied, there shall be no harmful interactions between their constituents and the insulation and/or the sheath.

5.5.2 Application

Fillers in multicore cables shall be laid up together with the cores to form a round and compact cable.

5.6 Metallic sheath

The metallic sheath shall be applied as a common sheath over the laid up cores including the belt insulation (if any) or separately over individual cores.

It is commonly made of lead, lead alloy or aluminium; requirements are given in the particular sections.

5.7 Inner covering (bedding)

The inner covering may be extruded or lapped (e.g. bitumen impregnated paper tapes) over the metallic sheaths.

5.7.1 Material

The material used for inner coverings shall be compatible with the cable components with which it is in contact, and shall be selected by reference to the maximum conductor temperature of the cable in normal operation.

5.7.2 Thickness

Unless otherwise specified for the particular type, the thickness of lapped beddings need not be checked by measurement.

The thickness of extruded inner covering for each type of cable shall be specified in the particular sections.

Compliance shall be checked by the test specified in the particular sections.

5.8 Inner sheath (if any)

An inner sheath may be specified in the particular sections.

5.8.1 Material

The material used for the extruded inner sheath shall be compatible with the cable components with which it is in contact, and shall be selected by reference to the maximum conductor temperature of the cable in normal operation.

The test requirements are specified in tables 4A and 4B unless stated otherwise in the particular sections.

5.8.2 Application

The inner sheath shall be extruded in a single layer as specified in the particular sections.

5.8.3 **Thickness**

The thickness of the extruded inner sheath shall be as detailed in the particular sections.

5.9 **Armouring (if any)**

The following types of armourings may be applied as specified in particular sections:

(a) steel round wire or flat wire armouring;
(b) steel tape armouring;
(c) non magnetic armouring.

Detailed constructions of armourings are given in the particular sections.

5.10 **Serving (if any)**

Over the armouring a suitable serving made of fibrous material is applied; requirements for the applications as well as for the materials are given in the particular sections.

5.11 **Outer sheath (if any)**

5.11.1 **Material**

The outer sheath shall be applied as specified in the particular sections and shall be of an extruded synthetic material suitable for the maximum conductor temperature in normal operation and of the type detailed in the particular sections.

The test requirements for these compounds are specified in Tables 4A and 4B unless stated otherwise in the particular sections.

5.11.2 **Thickness**

5.11.2.1 **Sheath applied over a smooth surface**

For a sheath applied on a smooth cylindrical surface, such as a metallic sheath, unless otherwise specified. the mean value of the thickness of the outer sheath shall be not less than the specified value for each type and size of cable in the particular sections.

However, the thickness at any place may be less than the specified value provided that the difference does not exceed 0,1mm + 15% of the specified value.

Compliance shall be checked by the test methods given in HD 605, sub-clause 2.1.2.

5.11.2.2 **Sheath applied over an uneven surface**

For a sheath applied on an irregular cylindrical surface, such as a corrugated metallic sheath or a sheath applied directly over an armour, unless otherwise specified the minimum thickness measured at any point of the outer sheath shall not fall below the specified value given in the particular sections by more than 0,2mm + 20% of the specified value.

Compliance shall be checked by the test methods given in HD 605.

5.11.3 **Mechanical properties before and after ageing**

The sheath shall have appropriate mechanical characteristics.

Compliance shall be checked according to the requirements specified in Tables 4A and 4B unless otherwise stated in the particular sections.

5.11.4 **Additional properties**

These are specified in the particular sections.

6. **Completed cables**

All cables shall comply with the requirements specified in sub-clauses 5.1 to 5.11 and in the particular sections of this HD and shall be checked by inspection and by measurements according to the test methods in documents listed in the particular sections.

7. **Sealing and packing**

Prior to storage or shipment, cable ends shall be sealed by appropriate caps so that water ingress is efficiently prevented, as well as to prevent leakage of the impregnating compound.

Cables shall be packed on drums. Refer to the particular sections.

8. **Current carrying capacity**

The current intensity that cables to this document can carry is determined by different conditions, either electrical (voltage drop) or thermal, whichever is most demanding.

The current-carrying capacity resulting from thermal limitations are calculated according to IEC Publication 287 or equivalent existing methods.

These calculations shall take into account the operation and installation conditions.

Tabulated values of current-carrying capacities according to the cable for typical installation conditions may be found in the particular sections.

9. **Guide to use and selection of cables**

For guidance on the use of cables see particular sections of this HD.

When selecting the cables, attention is drawn to the fact that national conditions or regulations, covering, e.g. climatic conditions or installation requiements, may exist. These should therefore be followed in conjunction of this HD.

Table 4A - Requirements of sheathing compounds : PVC

1	2	3	4	7	8	9	10	11
COMPOUND NO. ***TYPE*** MAXIMUM OPERATING TEMPERATURE OF THE CONDUCTOR	**TEST METHOD**	**UNIT** °C	**DMV 1** ***PVC sheath*** 70	**DMV 10** ***PVC sheath*** 90	**DMV 13** ***PVC sheath*** 90	**DMV 18** ***PVC sheath*** 90	**DMV 23** ***PVC sheath*** 90	**DMV 25** ***PVC sheath*** 90
Mechanical properties								
- before ageing on sample								
minimum tensile strength		MPa	12,5	12,5	12,5	12,5	12,5	12,5
minimum elongation at break		%	125	150	125	150	150	150
- after ageing on sample								
temperature		°C	80	100	100	100	100	100
duration T1		h	168	168	168	168	168	168
minimum tensile strength		MPa	12,5	12,5	12,5	12,5	12,5	12,5
maximum variation T1/TO		%	±20	±25	±20	±25	±25	±25
minimum elongation at break		%	125	150	125	150	150	150
maximum variation T1/TO		%	±20	±25	±20	±25	±25	±25
- after ageing on complete cable (non contamination test)								
temperature		°C	80	100	100	100	100	100
duration T1		h						
duration T2		h	168	168	168	168	168	168
minimum tensile strength		MPa		12,5	12,5			12,5
maximum variation T2/TO		%	±25	±25	±20	±25	±25	±25
maximum variation T2/TO		%						
minimum elongation at break		%		150	125			
maximum variation T2/TO		%	±25	±25	±20	±25	±25	±25
maximum variation T2/T1		%						
Physical and chemical properties								
shrinkage test								
duration		h						
temperature		°C						
maximum of shrinkage		%						

Note: 1MPa = 1N/mm²

Remark: The tolerance on temperature values is given in HD 605 sub-clause 1.5.2 but may be varied if specified in the particular sections

Table 4A - Requirements of sheathing compounds : PVC (continued)

1	2	3	4	7	8	9	10	11
COMPOUND NO. ***TYPE*** MAXIMUM OPERATING TEMPERATURE OF THE CONDUCTOR	**TEST METHOD**	**UNIT** °C	**DMV 1** ***PVC sheath*** 70	**DMV 10** ***PVC sheath*** 90	**DMV 13** ***PVC sheath*** 90	**DMV 18** ***PVC sheath*** 90	**DMV 23** ***PVC sheath*** 90	**DMV 25** ***PVC sheath*** 90
Physical and chemical properties (continued)								
loss of mass duration temperature maximum loss of mass		 h °C mg/cm²	 168 100 2	 168 100 1,5		 168 100 1,5	 168 100 1,5	 168 100 1,5
pressure test at high temperature duration temperature coefficient k maximum depth of indentation		 h °C %	 4/6 80 0,8 50	 6 90 0,8 50	 4/6 90 0,6/0,7 50	 4/6 80 0,8 50	 4/6 90 0,6/0,8 50	 6 90 50
heat shock test duration temperature		 h °C	 1 150	 1 150	 1 150	 1 150	 1 150	 1 150
tests at low temperature *elongation test at low temperature* temperature minimum elongation *impact test at low temperature* temperature *bending test at low temperature* temperature		 °C % °C °C	 -15 20 -15 -15	 -25 20 -20 -25	 -15 20 -15 -15	 -15 20 -15 -15	 -15 20 -15 -15	 -15 20 -15
thermal stability temperature duration		 °C min	 200 30					 200 80

Note: 1MPa = 1N/mm²

Remark: The tolerance on temperature values is given in HD 605 sub-clause 1.5.2 but may be varied if specified in the particular sections

Table 4A - Requirements of sheathing compounds : PVC (continued)

1		2	3	12	13	14	15	16
COMPOUND NO.		**TEST METHOD**	**UNIT**	**DMV 26**	**DMV 27**	**DMV 28**	**DMV 29**	**DMV 41**
TYPE				*PVC sheath*	*PVC sheath*	*PVC sheath*	*PVC sheath*	*PVC sheath*
MAXIMUM OPERATING TEMPERATURE OF THE CONDUCTOR			°C	90	90	90	90	70
Mechanical properties								
- before ageing on sample								
minimum tensile strength			MPa	12,5	12,5	12,5	12,5	12,5
minimum elongation at break			%	150	200	150	150	125
- after ageing on sample								
	temperature		°C	100	100	100	100	80
	duration T1		h	168	168	168	168	168
minimum tensile strength			MPa	12,5	17,5	12,5	12,5	12,5
	maximum variation T1/T0		%	±25	±25	±25	±25	±20
minimum elongation at break			%	150	200	150	150	125
	maximum variation T1/T0		%	±25	±25	±25	±25	±20
- after ageing on complete cable (non contamination test)								
	temperature		°C	100	100	100	100	
	duration T1		h		336			
	duration T2		h	168	1008	168	168	
minimum tensile strength			MPa	12,5		12,5	12,5	
	maximum variation T2/T0		%	±25	±30	±25	±25	
	maximum variation T2/T0		%		±20			
minimum elongation at break			%	150		150	150	
	maximum variation T2/T0		%	±25	±30	±25	±25	
	maximum variation T2/T1		%		±20			
Physical and chemical properties								
shrinkage test								
	duration		h		6			
	temperature		°C		120			
	maximum of shrinkage		%		4			

Note: 1MPa = 1N/mm²

Remark: The tolerance on temperature values is given in HD 605 sub-clause 1.5.2 but may be varied if specified in the particular sections

Table 4A - Requirements of sheathing compounds : PVC (continued)

1	2	3	12	13	14	15	16
COMPOUND NO.	**TEST METHOD**	**UNIT**	**DMV 26**	**DMV 27**	**DMV 28**	**DMV 29**	**DMV 41**
TYPE			***PVC sheath***	***PVC sheath***	***PVC sheath***	***PVC sheath***	***PVC sheath***
MAXIMUM OPERATING TEMPERATURE OF THE CONDUCTOR		°C	90	90	90	90	70
Physical and chemical properties (continued)							
loss of mass							
duration		h	168	168	168	168	
temperature		°C	100	100	100	100	
maximum loss of mass		mg/cm²	1,5	1,5	2	1,5	
pressure test at high temperature							
duration		h	6	6	6	6	4/6
temperature		°C	80	80	90	90	80
coeffiecient k				0,8	0,7	0,7	
maximum depth of indentation		%	50	50	50	50	60
heat shock test							
duration		h	1		1	1	
temperature		°C	150		150	150	
tests at low temperature							
elongation test at low temperature							
temperature		°C	-15	-15	-20	-15	
minimum elongation		%	20	20	20	20	
impact test at low temperature							
temperature		°C	-15	-15	-20	-15	-15
bending test at low temperature							
temperature		°C			-20	-15/-25	
thermal stability							
temperature		°C	200				
duration		min	80				

Note: 1MPa = 1N/mm²

Remark: The tolerance on temperature values is given in HD 605 sub-clause 1.5.2 but may be varied if specified in the particular sections

Table 4A - Requirements of sheathing compounds : PVC (continued)

1		2	3	20	21	22
COMPOUND NO.		**TEST METHOD**	**UNIT**	**DMV 44**	**DMV 45**	**DMV 46**
TYPE				***PVC sheath***	***PVC sheath***	***PVC sheath***
MAXIMUM OPERATING TEMPERATURE OF THE CONDUCTOR			°C	90	70	70
Mechanical properties						
- before ageing on sample						
minimum tensile strength			MPa	12,5	12,5	12,5
minimum elongation at break			%	125	125	125
- after ageing on sample						
	temperature		°C	80	80	80
	duration T1		h	168	168	168
minimum tensile strength			MPa	12,5	12,5	12,5
	maximum variation T1/T0		%	±20	±20	±20
minimum elongation at break			%	125	125	125
	maximum variation T1/T0		%	±20	±20	±20
- after ageing on complete cable (non contamination test)						
	temperature		°C	80	80	80
	duration T1		h			
	duration T2		h	168	168	168
minimum tensile strength			MPa	12,5	12,5	
	maximum variation T2/T0		%	±20	±20	±25
	maximum variation T2/T0		%			
minimum elongation at break			%	125	125	
	maximum variation T2/T0		%	±20	±20	±25
	maximum variation T2/T1		%			
Physical and chemical properties						
shrinkage test						
	duration		h			
	temperature		°C			
	maximum of shrinkage		%			

Note: 1MPa = 1N/mm²

Remark: The tolerance on temperature values is given in HD 605 sub-clause 1.5.2 but may be varied if specified in the particular sections

Table 4A - Requirements of sheathing compounds : PVC (concluded)

1	2	3	20	21	22
COMPOUND NO. *TYPE* MAXIMUM OPERATING TEMPERATURE OF THE CONDUCTOR	**TEST METHOD**	**UNIT** °C	**DMV 44** ***PVC sheath*** 90	**DMV 45** ***PVC sheath*** 70	**DMV 46** ***PVC sheath*** 70
Physical and chemical properties (continued)					
loss of mass					
duration		h	168	168	168
temperature		°C	80	80	80
maximum loss of mass		mg/cm^2	2	2	2
pressure test at high temperature					
duration		h	4/6	4	4
temperature		°C	80	70	80
coefficient k			0,6/0,8		0,8
maximum depth of indentation		%	50	50	50
heat shock test					
duration		h		1	1
temperature		°C		150	150
tests at low temperature					
elongation test at low temperature					
temperature		°C	-15	-20	-15
minimum elongation		%	20	20	20
impact test at low temperature					
temperature		°C	-15	-20	-15
bending test at low temperature					
temperature		°C	-15	-15/-25	-15/-25
thermal stability					
temperature		°C			
duration		min			

Note: 1MPa = $1N/mm^2$

Remark: The tolerance on temperature values is given in HD 605 sub-clause 1.5.2 but may be varied if specified in the particular sections

Table 4B - Requirements of sheathing compounds : PE

1	2	3	5	6	7	8	9
COMPOUND NO.	TEST METHOD	UNIT	DMP 5	DMP 8	DMP 9	DMP 10	DMP 11
TYPE			*PE sheath*	*PE sheath*	*PE sheath*	*PE sheath*	*PE sheath*
MAXIMUM OPERATING TEMPERATURE OF THE CONDUCTOR		°C	90	90	90	90	90
Mechanical properties							
- before ageing on sample							
minimum tensile strength		MPa	12,5	18	15	10	10
minimum elongation at break		%	300	300	350	300	300
- after ageing on sample							
temperature		°C	110	110	110	100	100
duration T1		h	336	336	336	240	240
minimum tensile strength		MPa			15		
maximum variation T1/T0		%			±25		±25
minimum elongation at break		%	300	300	350	300	300
maximum variation T1/T0		%			±25		
- after ageing on complete cable (non contamination test)							
temperature		°C	100	100	100	100	100
duration T1		h					
duration T2		h	168	168	168	168	168
minimum tensile strength		MPa			15		
maximum variation T2/T0		%	±25		±25		
maximum variation T2/T0		%					
minimum elongation at break		%		300	350	300	300
maximum variation T2/T0		%	±25		±25		
maximum variation T2/T1		%					

Note: 1MPa = 1N/mm²

Remark: The tolerance on temperature values is given in HD 605 sub-clause 1.5.2 but may be varied if specified in the particular sections

Table 4B - Requirements of sheathing compounds : PE (continued)

1	2	3	5	6	7	8	9
COMPOUND NO. ***TYPE*** MAXIMUM OPERATING TEMPERATURE OF THE CONDUCTOR	**TEST METHOD**	**UNIT** °C	**DMP 5** ***PE sheath*** 90	**DMP 8** ***PE sheath*** 90	**DMP 9** ***PE sheath*** 90	**DMP 10** ***PE sheath*** 90	**DMP 11** ***PE sheath*** 90
Physical and chemical properties							
pressure test at high temperature duration temperature coefficient k maximum depth of indentation		h °C %	6 115 50	6 115 30	6 115 30	6 90 0,7 50	6 90 0,7 50
shrinkage test duration temperature maximum shrinkage		h °C %	5 80 4	5 x 6 80 7	5 x 5 80 7		
tests at low temperature *elongation test at low temperature* temperature minimum elongation *impact test at low temperature* temperature *bending test at low temperature* temperature		 °C % °C °C				 -20 20 -20 -20	
carbon black content minimum		%	2,5 ± 0,5	2,5 ± 0,5	2,3	2	2,0
shore-D hardness minimum				55			55
melt index maximum					**		0,4
stress cracking resistance maximum				48	*		
UV resistance							

Note: 1 MPa = 1 N/mm²
* under consideration
** No value required but a variation of ± 20% with respect to granulates
Remark: The tolerance on temperature values is given in HD 605 sub-clause 1.5.2 but may be varied if specified in the particular sections

Table 4B - Requirements of sheathing compounds : PE (continued)

1	2	3	10	11	12	13
COMPOUND NO. ***TYPE*** MAXIMUM OPERATING TEMPERATURE OF THE CONDUCTOR	**TEST METHOD**	**UNIT** °C	**DMP 12** ***PE sheath*** 90	**DMP 21** ***PE sheath*** 90	**DMP 22** ***PE sheath*** 90	**DMP 23** ***PE sheath*** 90
Mechanical properties						
- before ageing on sample						
minimum tensile strength		MPa	10	10		12,5
minimum elongation at break		%	300	300	350	300
- after ageing on sample						
temperature		°C	100	100	100	110
duration T1		h	240	240	48	336
minimum tensile strength		MPa		10		
maximum variation T1/T0		%				
minimum elongation at break		%	300	300		300
maximum variation T1/T0		%			± 25	
- after ageing on complete cable (non contamination test)						
temperature		°C	100			100
duration T1		h				
duration T2		h	168			168
minimum tensile strength		MPa				
maximum variation T2/T0		%				
maximum variation T2/T0		%				
minimum elongation at break		%	300			300
maximum variation T2/T0		%				
maximum variation T2/T1		%				

Note: 1MPa = 1N/mm²

Remark: The tolerance on temperature values is given in HD 605 sub-clause 1.5.2 but may be varied if specified in the particular sections

Table 4B - Requirements of sheathing compounds : PE (concluded)

1	2	3	10	11	12	13
COMPOUND NO. *TYPE* MAXIMUM OPERATING TEMPERATURE OF THE CONDUCTOR	**TEST METHOD**	**UNIT** °C	**DMP 12** ***PE sheath*** 90	**DMP 21** ***PE sheath*** 90	**DMP 22** ***PE sheath*** 90	**DMP 23** ***PE sheath*** 90
Physical and chemical properties						
pressure test at high temperature						
duration		h			1 + 1[2]	4/6
temperature		°C			90	115
coefficient k					[3]	
maximum depth of indentation		%			40	50
shrinkage test						
duration		h				
temperature		°C				
maximum of shrinkage		%				
tests at low temperature						
elongation test at low temperature						
temperature		°C	-15			
minimum elongation		%	20			
impact test at low temperature						
temperature		°C	-15		-35	
bending test at low temperature						
temperature		°C	-15/-25			
carbon black content						
minimum			2			
shore-D hardness						
minimum						
melt index						
maximum				0,4	0,5	
stress cracking resistance						
maximum						
UV resistance			[1]			

Note: 1MPa = 1N/mm²

Remark: The tolerance on temperature values is given in HD 605 sub-clause 1.5.2 but may be varied if specified in the particular sections

[1] under consideration

[2] 1 hour preheating and 1 hour under load

[3] A force of 3.0N is applied via a 3.18mm diameter punch

HD 621 S1:1996

MEDIUM VOLTAGE IMPREGNATED PAPER INSULATED CABLES

PART 2: ADDITIONAL TEST METHODS

CONTENTS

REFERENCES

Part 2 of HD 621 incorporates by dated or undated reference, provisions from other publications. These 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 Part 2 of HD 621 only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 60811: Common test methods for insulating and sheathing materials of electric cables
HD 48: Impulse tests on cables and their accessories (Endorsing IEC 230)
HD 405: Tests on electric cables under fire conditions
HD 605: Electric cables: Additional test methods

MEDIUM VOLTAGE IMPREGNATED PAPER INSULATED DISTRIBUTION CABLES

PART 2: ADDITIONAL TEST METHODS

1. GENERAL

1.1 Scope

This part collates and specifies the test methods to be used for testing impregnated paper insulated electric cables for medium voltage public distribution systems.

Test methods in this part are additional to those already harmonised , eg EN 60811, HD 405 and HD 605, and are used for testing cable types specified in HD 621. In each case this HD gives complementary information needed for the practical application to each specific type. Therefore the present part as such is not sufficient for carrying out and evaluating the tests on electric cables.

Full test conditions (e.g. temperatures, durations) and/or test requirements are not always specified in this part. Such data needed to carry out the tests is given in the particular sections.

1.2 Applicable tests

Tests applicable to each type of cable are specified in the particular sections which state also the sequence, the frequency of test, and the possibility of repeating failed tests.

1.3 Classification of tests

The classification of tests is given in Part 1 of HD 621.

1.4 Sampling

The size and number of samples are specified in the particular section of HD 621.

If a marking is indented in the sheath surface, the samples used for the tests shall be taken so as to include such markings.

1.5 Test conditions

1.5.1 Ambient temperature

Tests shall be made at an ambient temperature within the range 5°C to 35°C unless otherwise specified in the details for the particular test.

1.5.2 Tolerance on temperature values

Unless otherwise specified in the particular section, the tolerance on temperature values quoted in the test methods are the following:

Specified temperature. t(°C)	Tolerance (K)
$-40 \leq t \leq 0$	± 2
$0 < t \leq 50$	according to relevant clause
$50 < t \leq 150$	± 2
$t > 150$	± 3

1.5.3 Frequency and waveform of power-frequency test voltages

Unless otherwise specified the test voltage shall be in the range 49 to 61 Hz of approximately sine-wave form, the peak value/r.m.s. value being equal to $\sqrt{2}$ with a tolerance of ± 7%. The values given are r.m.s.

2. NON-ELECTRICAL TESTS

2.1 Dimensions and constructional regularity of cable components

2.1.1 Measurement of insulation thickness

2.1.1.1 Method 1

(i) Cables of voltage rating up to 12 700/22 000 V

a) Micrometer

The micrometer shall be capable of measuring the thickness with an error not greater than ± 0,006mm. The pressure foot shall have a diameter of not less than 6mm and not greater than 8mm. The pressure applied shall be 350 kN/m² ± 5%. The faces shall be concentric and parallel to within 0,003mm over the range of travel.

The faces of the micrometer shall be cleaned before each measurement.

b) Procedure

Make the measurement of the insulation thickness on a sample not more than 150mm long, taken not less than 200mm from the end of each factory length of cable selected for the test. Bunch together the individual paper tapes removed from the finished cable without removing surplus compound, and measure the total thickness by a deadweight (dial) micrometer having the characteristics given in (a) . Include all the tapes which make up the insulation in the measurement.

If necessary, separate the insulation into a few group to obtain a satisfactory measurement and add the thickness of all the groups to obtain the total thickness.

(ii) Cables of voltage rating 19 000/33 000 V

Make the measurement of the insulation thickness on a sample not more than 150mm long, taken not less than 200mm from the end of each factory length of cable selected for the test.

Dismantle the sample until the dielectric screening tapes are removed. Measure the diameter of the core in this condition by means of a diameter measuring tape, having scale divisions not exceeding 0,5mm. Take the measurements at 50mm and 100mm from one end of the sample.

Then remove the insulation until the conductor screen is exposed and measure the diameter over the conductor screen at the same points with the diameter measuring tape.

Calculate the insulation thickness at each point of measurement by halving the difference between the two diameters at each position.

2.1.1.2 Method 2

The thickness of the paper-insulation shall be determined on test pieces removed about 500mm from both ends. All constructional components over the paper-insulation, including semi conducting layers, shall be cut off.

The diameters over the insulation and the conductor shall be determined with a measuring tape. The scale division of the measuring tape shall be 0.5mm. For small cables the diameter over the insulation and conductor shall be measured with a slide gauge (vernier calliper) on 3 places around the circumference. For cables with sector shaped conductors the height and width over the insulation and the conductor shall be determined on the great and small axis of the conductor with a slide gauge.

The insulation thickness measured in mm at any place is the difference of the two measured values at this place divided by two. The average value is the average of all measured values on the test pieces. The lowest value shall be quoted to two decimal places.

The measured values shall be in accordance with the requirements specified in the particular section.

2.1.1.3 Method 3

(i) Measurement of the thickness of the belt-insulation and the insulation of round (stranded) cores with a cross sectional area $\geq$ 120mm².

Use a diameter measuring tape (steel tape, width $\leq$ 6mm). The accuracy and the sale division of the measuring tape shall be such that it will be possible to measure a diameter difference of 0,5mm.

Measure the diameter over the insulation, remove the belt-insulation or core-insulation over a distance of about 30mm and measure the diameter at this place.

The insulation thickness at each point of measurement shall be calculated by halving the difference of the two diameters measured at that position.

(ii) Measurement of the thickness of the insulation of sector shaped cores and round cores with a cross sectional area < 120mm².

Use a micrometer with plane faces of 6 to 8mm diameter and an accuracy of ± 0,01mm.

Measure the diameter, in case of round cores, or the sector height, in case of sector shaped cores, of the core-insulation. Remove the core-insulation over a distance of about 30mm and measure the diameter or height at this place.

The insulation thickness at each point of measurement shall be calculated by halving the difference of the two diameters measured at that position.

2.1.2 Measurement of sheath thickness

2.1.2.1 Measurement of lead or lead alloy sheath thickness

Take the measurement either on a ring or, for cables less than 12mm diameter over the sheath, on a flattened circumferential strip carefully cut from a sample taken not less than 200mm from the end of each factory length of cable selected for the test.

Determine the thickness of the sheath at a sufficient number of points around the circumference of the ring sample or along the surface of the strip sample, to ensure that the minimum thickness is measured.

Make the measurement with a micrometer having one flat nose and one ball nose or one flat nose and a flat rectangular nose 0,8mm wide and 2,4mm long. When the measurements are made on the ring sample, apply the ball nose or the flat rectangular nose to the inside of the ring.

2.1.2.2 Measurement of thickness of metallic sheath (method 1)

The thickness of lead sheath shall be determined by the strip method. The measurement shall be made on a test piece of sheath about 50mm in length removed from the finished cable about 500mm from the end. A test piece shall be taken from both cable-ends.

The piece shall be slit longitudinal and carefully flattened. After cleaning the test piece, 5 measurements shall be taken along the circumference of the sheath and not less than 10mm away from the edge of the flattened piece. The measurement shall be made with a micrometer having either a spherical nose or a ball nose (0,20 to 0,25mm radius) and an accuracy of ± 0,01mm.

The measured values must be in accordance with the requirements specified in the particular sections.

2.1.2.3 Measurement of sheath thickness

A sheathing ring having an approximate length equal to the cable diameter, with a minimum of 20mm, shall be taken from the cable length.

The ring can be opened and flattened by hand in a shape of a rectangular strip.

By means of a friction micrometer, both with spherical noses if the sample has been left in the ring shape or with at least one flat nose if it has been flattened, 5 measurement shall be performed in well distributed locations at least 10mm far from the edges.

2.1.2.4 Measurement of thickness of metallic sheath (method 2)

The thickness of lead sheaths shall be determined by the following method:

Strip method

The measurement shall be made on a test piece of sheath about 50mm in length removed from the finished cable length. The test piece shall be taken a sufficient distance from the cable end to allow a proper measurement to be made.

The piece shall be slit longitudinally and carefully flattened. After cleaning the test piece, a number of measurements shall be taken along the circumference of the sheath and at least 5mm away from the edge of the flattened piece to ensure that the minimum thickness is measured. The measurement shall be made with a micrometer with plane faces of 2mm diameter and an accuracy of ± 0,01mm.

2.1.2.5 Measurement of thickness (excluding insulation and metallic sheath)

(i) Sampling

For the measurement of thickness of oversheath, take a sample of not less than 200mm from one end of each drum length of cable selected for the test.

If any of the thicknesses measured does not comply with the requirements check two further samples for the non-compliant items. If both of the further pieces meet the specified requirements, the cable is deemed to comply, but if either does not meet the requirements the cable is deemed not to comply.

(ii) Test procedure

Make measurements for thickness of oversheath by the method described in EN 60811-1-1.

When determining an average thickness from several measurements, round the resultant value to the nearest 0,1mm (0,05mm rounded upwards).

For the sample tests, the measurements may be made generally in accordance with EN 60811-1-1, but using a micrometer or optical device.

In case of dispute, the equipment specified in EN 60811-1-1 shall be used.

2.1.2.6 Measurement of undersheath clearance

To check for compliance with the requirements for sheath clearance, the internal diameter of the sheath shall be measured at a trough position using internal callipers. Two such diameters shall be measured at right-angles to each other and the average taken. The diameter over the cable assembly, including any optional tapes, shall be measured at the same position by means of a diameter tape. The difference between the internal diameter of the sheath and the diameter over the cable assembly is the diametral clearance.

2.1.3 Measurement of armouring and related dimensions

2.1.3.1 Measurement of diameter of round wire armour

Ten percent of the total number of wires shall be taken at random from one sample of completed cable and the diameter of each wire determined with a micrometer by taking two measurements at right angles to each other.

The average of all the measurements shall be taken as the wire diameter.

2.1.3.2 Measurement of the dimensions of steel wire

(i) Round wire

Use a micrometer with plane faces of 6 to 8mm diameter and an accuracy of ± 0,01mm.

(ii) Flat wire

Use a micrometer with plane faces of 2mm diameter and an accuracy of ± 0,01mm.

2.1.3.3 Measurement of the thickness of steel tape

Use a micrometer with plane faces of 2mm diameter and an accuracy of ± 0,01mm.

2.1.3.4 Measurement of thickness of bedding and serving

Use a diameter measuring tape (steel tape, width ≤ 6mm). The accuracy and the scale division of the measuring tape shall be such that it will be possible to measure a diameter difference of 0,5mm.

The thickness concerned at each point of measurement shall be calculated by halving the difference of the two diameters "under" and "over" the layer measured at that position.

2.1.4 Verification of constructional regularity

2.1.4.1 Insulation - evaluation of registrations

A cable sample 300mm long shall be dismantled by removing the insulation, at not more than 5 tapes per time, and evaluating the number of registrations.

A registration shall be considered to have occurred when one or both edges of tape lie for a maximum of 0,5mm and for at least one complete turn or convolution, directly over or under:

a) the corresponding edge or edges on an adjacent tape, or

b) any part of the gap between 2 adjacent turns of the adjacent layers

Note: when there are 3 consecutive tapes under a) or b) conditions, 2 registrations shall be considered.

2.2 Tests on paper insulation

2.2.1 Test for water soluble impurities in insulating paper

The paper shall be free from chemical impurities, acids, alkalis and salts to such an extent that not more than 1% by mass is soluble in water when tested in accordance with this method.

Dry approximately 10g of the paper in an air oven at a temperature between 103°C and 105°C for 1h and weigh to an accuracy of 1mg. Then cut it into squares of side approximately 15mm and subject it to extraction in a porcelain dish or glass beaker on a boiling water bath with 200ml of distilled water for 15min. Decant off the extract through a filter paper and repeat the process until four extractions have been made, the same filter paper being used in each case.

Evaporate the total extracts to dryness on a water bath and finally dry to constant mass at a temperature between 103°C and 105°C.

Then carry out a blank determination and subtract any mass obtained from the mass obtained in the test.

Calculate the value obtained as a percentage of the dry paper mass.

The conductivity of the aqueous extract shall not exceed 6 mS/m.

The pH value of the aqueous extract shall be not less than 6,0 and not more than 8,0.

The ash content of the paper shall not exceed 1,5% on a moisture free (oven-dry) basis.

2.2.2 Drainage test

2.2.2.1 Method 1

Requirement. The sheathed cable shall be tested and the maximum drainage of compound into the space provided shall be documented.

Method. Carry out the test on a sample not less than 900mm long, cut from a selected length of cable in its sheathed state. Seal the test sample at both ends, and leave a space at one end for the collection of any compound which may drain out of the cable during the test. Suspend the sample vertically, with the drainage space at the lower end, in a heated chamber for 7 days, at not less than the appropriate temperature given in the table. Measure the amount of compound which has drained into the space provided at the end of this period.

Table 2.2.2.1 - Maximum drainage

1	2	3	4
Voltage designation	Type	Test temperature	Maximum drainage*
		°C	%
Up to and including 6 600/6 600V	All types	80	3,0
6 350/11 000	Screened single-core and three-core	70	2,5
6 350/11 000 and 8 700/11 000	Belted three-core	65	2,5
8 700/15 000	All types	70	2,5
12 700/22 000	All types	65	2,5
19 000/33 000	All types	65	2,5

*Percentage drainage based on volume of interior of sheath of sample

2.2.2.2 Method 2

(i) Cable sample

The cable sample, of length (300 ± 10)mm and with both ends opened, shall be vertically suspended in an air over heated to the maximum cable working temperature ± 2K.

(ii) Test method

At the end of the heating period, the volume of drained compound, measured at room temperature and related to the volume comprised inside the metallic sheath inner surface, shall not exceed the values specified in the particular sections.

2.2.3 Measurement of breaking load and elongation at break of impregnated paper

Carry the test out on samples of crease free impregnated paper tapes, taken from the completed cable. Cut the tapes into strips 15mm wide and not less than 220mm long. Condition the strips for 24h at a relative humidity of 65% and a temperature between 17°C and 21°C. Remove the surplus compound and measure the thickness of the conditioned strips to the nearest 0,002mm. Test the strips in a tensile testing machine having a distance of approximately 180mm between grips.

Test six samples from each cable. Discard the highest and lowest measurements. The final recorded value for elongation at break is the mean of the results of the remaining four samples.

When tested in accordance with 2.3.3 the paper, after removal from an impregnated core, shall comply with the following:

(a) the breaking load of the test strip shall be not less than 650 N/mm of thickness;

(b) the elongation at break of the test strip shall be not less than 1,5%.

2.3 Tests on other cable components

2.3.1 Mass of zinc coating of galvanised steel wire or tape

A sample of ten wires, or a sample of tape, shall be taken at random from one sample of completed cable and the mass of zinc coating determined by either a gravimetric or gas volumetric method.

The average of all the measurements shall be taken as the mass of the zinc coating.

2.3.2 Corrosion test

2.3.2.1 Test on corrosion protection of aluminium sheath

(a) Method A : Trough method

(i) Test pieces

The test piece shall be taken from a cable sample which has been bent according to HD 605. After the bending-test the corrosion protection shall be broken through with a cork-drill of 10mm diameter up to the aluminium sheath at 4 places in the middle part of the bent sample. At these places the corrosion protection shall be removed and the metal-sheath cleaned carefully without using any solvent. The 4 places shall be staggered by 90° and a distance of 100mm each.

(ii) Preparation of the test

The test piece is then bent roughly according to the minimum bending diameter in a U-form and put into a non metallic trough. The trough is filled with a solution of $Na_2\ SO_4$ (10g dry $Na_2\ SO_4$ or 22,7g $Na_2\ SO_4.10H_2O$ dissolved in 1 litre of water) so that the level of the solution is at minimum 500mm above the hollows. The ends of the test piece shall be raised above the solution. If due to a higher cable diameter the test piece could not be bent into a U-form, the test piece has to be sealed with a insulating tape at both ends. This test piece is then laid down into the solution, so that the level of the solution is at minimum 500mm above the hollows.

(iii) Test procedure

The metal sheath shall be connected to the negative pole of a DC source of (100 ± 5) V. Metal plates of a stainless steel (i.e. X 10 Cr NiS 189) shall be used as the anode. The minimum cross section of the anode has to be 100mm² per test piece. With a resistor of (10 ± 0,5)k Ω the current shall be limited to about 10 mA. For each test piece one resistor shall be used.

The DC voltage shall be applied for (100 ± 2) h. After that the corrosion protection of the test piece shall be removed and the aluminium sheath shall be cleaned.

(iv) Evaluation of test results

None of the corrosion places, when viewed with the naked eye, shall be have diameter of more than 30mm.

If the results are not within these requirements the test may be repeated once with a double number of test pieces.

(b) Method B : Beaker Method

(i) Test pieces

The test pieces shall be taken from a cable sample which has been bent according to HD 605. Four test pieces, each 200mm in length shall be cut out of the middle of the bent sample. With a cork-drill of 10mm diameter the corrosion protection shall be broken through up to the aluminium sheath at 4 places in each test piece. At these places the corrosion protection shall be removed and the metal-sheath cleaned carefully without using any solvent. Two of the hollows shall be on opposite sides of the circumference and the second pair at 90° thereto. The longitudinal distance between the pairs shall be about 50mm.

(ii) Preparation of the test

The test pieces shall be sealed at the ends with an insulating tape. Then they are put in a beaker (1000ml), filled with a solution of $Na_2\ SO_4$ (10 g dry $Na_2\ SO_4$ or 22,7 g $Na_2\ SO_4.10H_2O$ dissolved in 1 litre of water). The level of the solution shall be at least 20mm above the upper hollow. Afterwards a cylindrical bent metal plate made of stainless steel (i.e. X10 Cr Ni S 189) shall be placed in the beaker, one per test piece. The metal plates shall be at the inner side of the beaker and equidistant from to the hollows.

(iii) Test procedure

The metal sheaths shall be connected to the negative pole of a DC source of (100 ± 5)V, the metal plates to the positive pole. With a resistor of (10 ± 0,5)k Ω per test piece the current shall be limited to about 10 mA.

The DC voltage shall be applied for (288 ± 12) h. After that the corrosion protection of the test pieces shall be removed and the aluminium sheath shall be cleaned.

(iv) Evaluation of results

None of the corrosion-places, when viewed with the naked eye, shall be more than 40mm diameter, and further the arithmetical average of the diameters of the biggest corrosion areas from all 16 hollows shall be less than 30mm.

If the results are not within these requirements the test may be repeated once with the double number of test pieces.

2.3.2.2 Corrosion Test (for cables under aluminium sheath)

(i) General

This test is carried out to ascertain that, in the case of local damage to the protective covering of the aluminium sheath, the possible corrosion of the external surface of the aluminium sheath shall remain essentially close to the damaged surface.

The cable sample shall be previously submitted to the bending test (see 2.4.2).

(ii) Test method

At the centre of the sample, and using a circular punch having a diameter of 10mm, the protective covering shall be pierced in 4 places, 100mm longitudinally spaced and 90° circumferentially.

Care must be used to clean the aluminium surface and to remove bituminous or similar compound, from the holes.

The cable sample shall be then U-bent over a bending radius not lower than that shown in 2.4.2, and then immersed in water containing 1% of sodium sulphate, in such a way that the holes are immersed at least 500mm in water. The cable ends shall be left outside the water.

The aluminium sheath shall be then connected to the negative pole of a DC generator of about 100V output voltage.

A zinc coating plate sufficiently large shall be used as anode.

The output current shall be maintained at a constant value of 10mA by means of a variable resistor of about 10 kΩ (one resistor for each cable sample).

After (100 ± 2) h of test the cable sample shall be taken out from the water, and the protective covering removed, taking care to clean bituminous and similar compounds from the aluminium surface. The aluminium sheath shall be then examined visually.

2.3.2.3 Test for bitumen coating of aluminium sheath

A layer of bitumen shall be deemed to be present where, as a minimum, there is a brown coloration of the sheath or, if the sheath presents a bright appearance, the missing bitumen can be shown to be adhering to the underside of the PVC sheath removed for the purpose of the test.

A 200mm length of cable shall be subjected to visual examination. When the PVC oversheath is stripped off, it shall be evident and agreed that the aluminium sheath was covered with bitumen before the removal of PVC. If it is evident that the aluminium sheath was not covered with bitumen the sample is deemed to have failed. If, as a result of this examination, there is a disagreement as to the completeness of the bitumen coating, the following procedure shall apply.

A further sample of cable from the same factory length, approximately 600mm long, shall be divided into two equal pieces. Both pieces shall be immersed in boiling water for not more than 1 minute. The samples shall then be removed from the water and the oversheath cut longitudinally and peeled off. If both pieces are completely covered with bitumen then the cable is deemed to have passed the test. If either of these two pieces is not completely covered then the length of the cable is deemed to have failed.

2.3.2.4 Test for restriction of corrosion of aluminium sheath

After a sample of the cable has been subjected to the bending operations specified the PVC oversheath shall be punctured down to the aluminium sheath in four places in the mid-portion of the specimen, by, for example, a cork drill, to produce holes of 10mm diameter. The four holes shall be spaced about 100mm apart along the sample and around the circumference at about 90° from each other. The aluminium surfaces exposed in the holes shall be carefully cleaned of all adhering PVC and bitumen. The sample shall then be bent into a U-shape with a radius not less than that specified for the bending test and placed in a bath containing 1% sodium sulphate solution at room temperature, so that the four holes are covered by at least 500mm of solution, whilst the cable ends are protruding. The aluminium sheath shall be connected to the negative pole of a supply of about 100 V d.c. The positive pole of the supply shall be connected to a metal electrode immersed in the solution. The current shall be kept at approximately 10 mA by means of a variable resistor of about 10 kΩ included in the circuit. After electrification for (100 ± 2) hours the sample shall be taken out of the bath, the PVC oversheath removed, and the aluminium sheath cleaned of bitumen. No signs of corrosion extending for more than 10mm beyond the boundaries of any of the initial holes at any point, shall be visible on the aluminium sheath to the unaided eye.

2.3.3 Undersheath pressure test

A 15m length of cable shall have the ends sealed by encapsulation in resin, the PVC sheath having been removed for a short distance at each end sufficient to allow the resin to bond effectively to the aluminium sheath and to allow room the for the connection of current loading leads to the aluminium sheath.

The leads for the purpose of sheath heating shall be plumbed to the aluminium sheath at each end of the aluminium sample after the ends have been sealed. A short length of metal pipe of small bore, suitable for the connection of a pressure gauge, shall be plumbed to the aluminium sheath at the crest of a corrugation at about middle of the length, after removal of only as much PVC oversheath as necessary to permit the operation. When the sample has cooled, a hole shall be drilled in the aluminium sheath by way of the bore of the connected piece of pipe. The piece of pipe shall be filled with hydraulic oil and a pressure gauge connected, the stem of the pressure gauge being filled so far as possible with hydraulic oil. In all plumbing to the sheath of the sealed cable, care should be taken to avoid excessive or too rapid heating which could cause a dangerous local pressure. The cable shall then be heated in a horizontal position by passing current through the sheath so that the sheath temperature is raised to 60°C. The temperature shall be measured by a thermocouple inserted under the PVC oversheath about half-way between the gauge and the end of the sample. Ensuring the gauge reading is steady, the undersheath pressure shall be not less than 20 kN/m² nor greater than 120 kN/m² after maintenance of the sheath temperature for at least 4 hours.

2.3.4 Water penetration test

This test shall be carried out on a 5m length of cable with open ends; this cable must be a length adjacent to the sample used in the undersheath pressure test. A saw cut round the circumference shall be made in the centre of the 5m length through the PVC and aluminium sheaths at the crest of a corrugation.

The exposed belt shall be subjected to a 800mm head of water for 7 days at ambient temperature.

At the end of this period, about 150mm of the outer insulating paper of the belt, taken approximately 100mm in from each end, shall be immersed in a compound bath at (130 ± 5)°C, and no frothing shall be observed.

2.3.5 Non-staining test

A small area in the centre of a test piece of PVC oversheath material, approximately 50mm², shall be cleaned and degreased using a clean rag wetted with a suitable solvent.

After allowing sufficient time for the solvent to evaporate, three or four drops of glacial acetic acid shall be applied to the test area by means of a dropping bottle. The reaction shall be allowed to proceed for 15 minutes with further additions of drops of acetic acid, as necessary, to prevent drying of the test area.

At the end of the 15 minute period a further two drops of acetic acid shall be added to the test area followed by three or four drops of a saturated solution of sodium sulphide. (Since hydrogen sulphide will be released, this part of the test should be carried out in a fume cupboard.)

The wetted portion shall then be agitated with a glass rod and the test piece allowed to stand for 1 minute. At the end of this period the reactants shall be washed from the test area and the surface examined.

For the test to be successful, the original colour of the PVC sheath shall be identifiable with the unaided eye.

2.3.6 Corrugated aluminium sheath removal test

A 600mm length of PVC shall be removed from the end of a length of cable and the exposed bitumen cleaned off. A circumferential cut shall then be made through the aluminium sheath on the crest of a corrugation at approximately 100mm from the end. The 100mm of aluminium sheath shall then be drawn off the cable.

In the manner described above, three further sections of aluminium sheath, approximately 150mm in length, shall be drawn off the cable, each being rotated in the direction of lay of the papers.

For the cable to pass this test it shall be possible to remove the 150mm lengths of aluminium sheath without excessive force being necessary and without disturbing the semiconducting carbon papers.

2.4 Bend test on the complete cable

2.4.1 Method 1

(i) Sampling

The bending test shall be carried out on a sample of completed cable with open ends, of sufficient length to give at least one complete turn round the test cylinder specified in table 2.4.1(A). Alternatively, for SL cables, the test may be made on one of the lead sheathed cores, treating the cores as a single core cable.

(ii) Procedure

The sample shall be bent at room temperature between 15°C and 25°C, around a test cylinder to make one complete turn. The sample shall then be unwound and the process repeated in the opposite direction. This cycle of operations shall be performed three times. The sample shall be bent at a reasonably uniform speed, each half cycle of the test taking between 0,5s and 1,0s per millimetre diameter of the lead or lead alloy sheath, but in no case shall the time be less than 10 s.

The diameter of the test cylinder shall be as given in table 2.4.1(A).

Table 2.4.1 (A) - Diameter of test cylinder		
1	2	3
Cable	Multicore	Single-core
Cables of voltage rating up to and including 8 700/11 000V	12(D + d)	15(D + d)
Cables of voltage rating 8 700/15 000V up to and including 12 700/22 000V	15(D + d)	18(D + d)
19 000/33 000V cables	18(D + d)	21(D + d)
NOTE: D is the diameter over the lead or lead alloy sheath or for three-core SL cables the diameter over the laid up cores given in the appropriate table and d is the diameter of a main conductor, or of the equivalent circular stranded conductor, if the conductors are shaped, but in no case should the diameter of the test cylinder be less than 250mm.		

Following the bend test subject to the sample to a voltage test and examine it.

(iii) Requirements

The sample shall comply with the following requirements:

(a) The sample shall withstand a voltage test in accordance with sub-clause 3.1.1, but with the routine test voltage increased by 50%.

(b) After the voltage test, a 300mm length cut from the middle of the sample shall be stripped and examined. The serving or oversheath shall be free from splits, the armour shall not be noticeably displaced and the lead or lead alloy sheath shall be free from splits and cracks.

(c) The number of papers in the 300mm length that contain longitudinal or edge tears exceeding in length 6mm or 50% of the paper width, whichever is the smaller, shall not exceed the amount given in table 2.4.1(B).

At no point throughout the insulation of cables having voltage ratings of 6 350/11 000V and above shall there be more than three coincidental tears of any length in adjacent papers.

Table 2.4.1(B) - Papers containing tears

1	2	3
Cable	Belt papers of multicore belted cables	Core papers of single-core cables and each core of multicore cables
	%	%
1 900/3 300V, and 3 300/3 800V,	No limit	50
3 800/6 600V, and 6 600/6 600V,	50	25
6 350/11 000V and 8 700/11 000V	20	10
8 700/15 000V	-	10
12 700/22 000V and 19 000/33 000V	-	5

For the purpose of this clause conductor screening papers shall be considered together with the insulating papers. Belt screening papers shall not contain any tear which extends across their complete width.

The conductor shall be examined visually. Impregnating compound shall be seen to have penetrated through the interstices of stranded conductors.

2.4.2 Method 2

(i) Cable sample

A cable sample having a length not lower than 3.5D, (D_t being the test cylinder diameter) shall be prepared, leaving the sample ends unsealed.

The sample shall be conditioned at a temperature between 10 °C and 15°C, but, for particular laying conditions, a different temperature can be agreed between manufacturer and purchaser.

(ii) Test Method

The sample of complete cable shall be bent around a test cylinder for one complete turn, at a reasonably uniform speed, for a total time of about 2 or 3 min. Care shall be taken to leave the sample ends straight.

The diameter of the test cylinder D_1 shall not be higher than:

- Single core cables and multicore cables with non radial electric field — $D_1 = 20\ (D+d)$
- Multicore cables with radial electric field (except for the cables with 3 metallic sheaths) — $D_1 = 20\ (D+d)$
- Cables with 3 metallic sheaths — $D_1 = 15\ (D+d)$

For cables with smooth (non corrugated) aluminium sheath, the test cylinder diameter shall be the higher between D_1 as above calculated and $D_2 = 30\ D$.

In the formula D is the external diameter of the metallic sheath, or the diameter of the circle circumscribed to the assembled metallic sheathed cores in the case on 3 sheath cables, and in the case of corrugated sheath it is measured over the undulations;

d is the conductor diameter, or the diameter of the biggest cable conductor, if they are different; when it is not possible to measure it, it shall be calculated as $d = 1.3\sqrt{A}$; A (mm^2) being the conductor cross section.

After bending, the sample shall be unwound, straightened and the process repeated, except that the sample shall be bent in the reverse direction, but always in the same axial plane.

The cycle of double operations shall be carried out three times.

2.4.3 Method 3

(i) Cable sample

A cable sample with a length of at least 3 times the circumference of the test cylinder shall be prepared.

The sample shall be conditioned at a temperature between 10°C and 15°C.

(ii) Test Method

The sample shall be bent around the test cylinder for three complete turns. The sample shall then be unwound and the process repeated, except that the bending of the sample shall be in the reverse direction.

This cycle of operations shall be carried out three times.

The diameter of the test cylinder shall be:

- Single core armoured cables	:	20 x D
- Single core unarmoured cables	:	25 x D
- Three core armoured cables	:	12 x D
- Three core unarmoured cables	:	15 x D

Where D = outer diameter of the cable.

3. ELECTRICAL TESTS

3.1 Insulation voltage test

3.1.1 Voltage test on complete cable

(i) Requirement

When tested as described in either method A (3.1.1(ii)) or method B (3.1.1(iii)) there shall be no breakdown of insulation.

NOTE: Cables will be tested in accordance with method A unless the manufacturer requests permission to carry out the test in accordance with method B.

(ii) Method A

Make the test with a power-frequency voltage using either three-phase or single-phase or a combination of both at the discretion of the manufacturer. When using three-phase on a belted cable, connect the neutral point of the transformer to the lead or lead alloy sheath, thus applying a voltage between the conductor and the lead or lead alloy sheath equal to the value in column 2 of table 3.1.1 divided by $\sqrt{3}$. This is equivalent to the value in column 3 except for cables rated 3 300/3 300V, 6 600/6 600V and 8 700/11 000 V for which an additional test is required. Make this additional test by applying a single-phase voltage between the conductors connected together and the lead or lead alloy sheath.

In all cases the test voltage shall be increased gradually to the appropriate values specified in table 3.1.1 and maintained constant for 5 min.

(iii) Method B

Carry out the test as described in Method A except that the voltage test shall be made with direct current, the applied voltage being equal to 2,4 times the appropriate alternating test voltage and the duration of each application being 5min.

Table 3.1.1 - Test voltage on completed cable at works			
1	2	3	4
Voltage designation	Alternating test voltage (r.m.s)		
	Belted cables		Single-core and screened cables
	Between conductors	Between any conductor and lead or lead alloy sheath	Between any conductor and lead or lead alloy sheath
V	V	V	V
1 900/3 300	10 000	5 800	6 000
3 300/3 300	10 000	10 000	-
3 800/6 600	17 000	9 800	10 000
6 600/6 600	17 000	17 000	-
6 350/11 000	25 000	14 000	15 000
8 700/11 000	25 000	22 000	-
8 700/15 000	-	-	22 000
12 700/22 000	-	-	30 000
19 000/33 000	-	-	45 000

3.2 Power factor, tan δ

3.2.1 Method 1

(i) Requirement

When cables rated at 19 000/33 000V are tested as described below the value of tan δ determined by the test at 0,5 U_0 shall not exceed the appropriate value specified in column 1 of table 3.2.1. The difference in tan δ between 0,5 U_0 and 1,25 U_0, and between 1,25 U_0 and 2,0 U_0 shall not exceed the appropriate value specified respectively in columns 2 and 3 of table 3.2.1

The tan δ of the insulation shall be measured at ambient temperature and the test shall be made before the voltage test described in 3.1.1.

(ii) Method

The sequence of testing shall be at 0,5 U_0 1,25 U_0 and 2,0 U_0 i.e. 9,5kV, 24kV and 38kV. Apply the test voltage between each conductor and the lead or lead alloy sheath, the other conductors connected to the lead or lead alloy sheath when three-core cable is tests. Make the measurements with a dissipation factor bridge, using a loss free capacitor as standard. Correct any measurements made at temperatures below 20°C either by subtracting from the measured value 2% of this value per degree Celsius of the difference between the test temperature and 20°C, or by the use of a correction curve appropriate to the insulant if agreement on such a curve has been reached between the purchaser and the manufacturer. Make no correction for a test temperature of 20°C or greater.

Table 3.2.1 - Power factor, tan δ, of 19 000/33 000 V cables		
1	2	3
Maximum tan δ at 0,5 times U_o at 20°C	Maximum difference in tan δ between	
	0,5 and 1,25 times U_o	1,25 and 2,0 times U_o
30×10^{-4}	20×10^{-4}	40×10^{-4}

3.2.2 Method 2

The measurement of dielectric power factor is made on all cores of the complete cable.

The accuracy of the measuring device at 50Hz must be at least + (1% of measured value + 0.1×10^{-3}).

The test voltages are applied between the conductor and the metallic sheath or the screen.

The measured values shall be in accordance with the requirements given in the particular sections.

3.2.3 Method 3 - Tan δ on cables for rated voltage $U_o \geq 4.8$kV

Measurement of tan δ shall be made with a dissipation factor bridge. In case of single core cables the test voltage is applied between the conductor and lead sheath; in case of three core cables between one of the conductors and the lead sheath, the other conductors connected to the lead sheath.

Determination of tan δ

Make the measurement in 8 voltage steps of 0,25 U_o in the range from 0,5 up to 2,5 U_o.

The requirements for the maximum increase of tan δ and the maximum value of tan δ at U_o are given in the particular specification.

Determination of tan δ at elevated temperature and after cooling

Heat the complete cable length by passing an alternating current through the conductor(s), until the conductor reaches a temperature between 40 and 45°C (controlled by measurement of the conductor resistance).

The cable length is held at this temperature for 0,5 h before tan δ is measured.

Make the measurement in 8 voltage steps of 0,25 U_o in the range from 0,5 up to 2,5 U_o.

The requirements for the maximum increase of tan δ and the maximum value of tan δ at U_o are given in the particular specification.

Then the cable on the drum is cooled rapidly in a water bath or under a shower till a temperature of at least 25K lower than the temperature during heating is reached.

The time between the measurement of tan δ at elevated temperature and after cooling shall be at least 12 h.

Make the measurement in 8 voltage steps of 0,25 U_o in the range from 0,5 up to 2,5 U_o.

The requirements for the maximum increase of tan δ and the maximum value of tan δ at U_o are given in the particular section.

3.3 Sheath voltage test

3.3.1 D.C. voltage test on oversheath

NOTE: This is an optional routine test requirement, and needs to be specified by the purchaser in the enquiry or order.

(i) Requirement

The oversheath shall not break down on the application of a test voltage as described below.

(ii) Method

The d.c. test voltage shall be applied between the underlying metal layer at negative polarity and the outer conducting layer for a period of 1 min.

The voltage applied shall be equal to 8kV per millimetre of specified thickness of oversheath subject to a maximum of 25kV.

3.4 Impulse voltage test

3.4.1 Method 1

3.4.1.1 Thicknesses

As a preliminary to the type testing procedure the insulation thickness of the cable submitted for test shall be checked by the relevant method in 2.1.1.1, to confirm that it is in accordance with the specified thickness within a tolerance of + 0,4mm.

3.4.1.2 Test installation

Only a test installation that has satisfactorily completed the load cycle test shall be submitted to this test.

No arcing horns shall be fitted to the sealing ends.

3.4.1.3 Principle

A loading current is applied to the test assembly until, for constant current, the cable sheath temperatures have been steady (i.e. variations not greater than 2°C, after due allowance has been made for ambient temperature variations), for 2 h with the maximum conductor temperature not less than 65°C and not greater than 70°C. With this loading current maintained, the test core of the test assembly is submitted to 10 successive negative followed by 10 successive positive impulses at 194kV (peak) and of waveshape as follows:

Front time	(T_1) between 0,5 μs & 5,0 μs
Tail time of half value	$(T_2)_{50}$ = (50 ± 20) μs

3.4.1.4 Detailed test method

(i) General

The test installation shall be connected to the impulse generator and its associated voltage divider system. The circuit values of the system shall be adjusted to produce impulse voltage wave-shapes complying with 3.4.1.3 Oscillograms on suitable time sweeps shall be made to record both the wave front and wave tail duration of the wave.

The circuit values of the impulse generator shall not be altered for the remainder of the test period. In the case of three-core power cable systems, all three-cores shall be tested in sequence at each voltage level. A loading current shall be applied to the test assembly to raise the maximum conductor temperature to its required value. This current shall be maintained constant until the cable sheath temperatures have been steady (i.e. variations not greater than 2°C after due allowance has been made for ambient temperature variations) for at least 2 h. During the period when the temperature of the cable is maintained at a constant value, before commencement of the withstand test, the impulse generator system shall be calibrated with the test installation connected, using either a sphere gap (see 3.4.1.4(ii)) or an impulse voltage divider system of known ratio (see 3.4.1.4(iii)).

NOTE: The choice of method is at the option of the manufacturer.

(ii) Calibration using a sphere gap

For every given setting of the sphere gap, the charging voltage of the generator shall be adjusted so as to give 50% sparkover of the gap, and an oscillogram of the impulse voltage shall then be taken.

This procedure shall be carried out for at least three different settings of the sphere gap using negative impulses. The gap settings shall be selected so that their 50% sparkover voltages are approximately 50%, 70% and 90% of the specified test level.

A curve shall be drawn showing the charging voltages as a function of the sphere gap sparkover voltage. This curve shall then be extrapolated to establish the necessary charging voltage to obtain the specified test level.

The ratio of the voltage divider shall be determined from consideration of the oscillograms and the calibration curve determined as described above.

(iii) Calibration using a impulse voltage divider system of know ratio

A series of measurements shall be made using a calibrated impulse voltage divider with either a cathode ray oscillograph or an impulse crest voltmeter, to establish the relationship between generator charging voltage and the generator output voltage. These measurements shall be made using negative polarity impulses at output voltage levels corresponding to approximately 50%, 70% and 90% of the specified withstand level.

A curve shall be drawn showing the charging voltage as a function of output voltage. This curve shall then be extrapolated to establish the necessary charging voltage to obtain the specified test level. If so required the impulse voltage divider system may be calibrated in the presence of an independent witness.

(iv) Application of impulses at withstand voltage specified

With the cable maintained at the required temperature and the sphere gap setting increased, the samples shall be subjected to a series of 10 negative impulses at the withstand voltage specified.

The time interval between successive impulses shall be the minimum possible, but should be adequate to ensure that the impulse generator is charged at the correct voltage.

Immediately after the applications of the first 10 negative impulses, the generator shall be recalibrated for positive polarity using the conditions described in 3.4.1.4(i) and the methods in tests described in 3.4.1.4(ii) and 3.4.1.4(iii) and a series of 10 positive impulses of the same voltage to the cable applied. The time interval between successive impulses shall be the minimum possible, but should be adequate to ensure that the impulse generator is charged at the correct voltage.

(v) Oscillograms and readings

Oscillograms of at least the first and the tenth impulses of each sequence of 10 impulses shall be taken, each including base and voltage calibration lines and a timing oscillation.

Readings shall be taken at least once an hour, of cable sheath and ambient temperature, throughout the test period.

3.4.2 Method 2 (Hot impulse test)

(i) General

The waveform in accordance with HD 48, shall have a front duration between 1 and 5 μs, and a duration to half the peak value of (50 ± 10) μs. Before each test the test device shall be suitably calibrated.

Each cable sample shall be at least 5m long, not including the terminations, and it must undergo the bending test in 2.4.2. The cable sample, suitably terminated, shall be slowly heated by current circulation in the conductors, up to a maximum temperature between the working temperature and a temperature 5°C higher and maintained for 2 hours.

(ii) Test method

After this period, the sample shall undergo to 10 negative pulses and then 10 positive ones, whose peak value is given in the table. For radial electric field cables the test voltage shall be applied between one conductor only and the relevant screen, for non radial electric field cables between one conductor only and the other connected to the metallic sheath.

An oscillogram of the first and last wave of each polarity, to the prescribed peak value, shall be registered.

Uo (kV)	6	8,7	12	15	18	26
Up (kVp) peak value	75	95	125	150	170	250

To check the withstanding of the impulse test, the sample shall undergo, after cooling to room temperature, an A.C. voltage test for 15 min up to 2,5 U_0 + 2,5 (kV) for radial electric field cables, and up to 1,25(U_0 + U) + 2,5(kV) for non-radial electric field cables.

3.5 Special voltage test

3.5.1 4 U_o test on 3-core 185mm² conductor

As a preliminary to the type testing procedure the insulation thickness of the cable submitted for test shall be checked by the relevant method in 2.1.1.1 , to confirm that it is in accordance with the specified thickness within a tolerance of + 0,4mm.

(a) At the commencement of the test the cable sample shall be at least 15m in length excluding terminations. A termination shall be deemed to include 200mm of cable below any seal on the lead sheath and should be designed to accommodate the selected voltage for at least 100 hours. Should a termination fail, the end may be reterminated, the test continued and the test time accumulated provided the cable sample is never less than 10m in length excluding the termination. All termination failures shall be recorded.

(b) The power factor shall first be measured in accordance with sub-clause 3.2.1 and then an a.c. voltage of 4 U_o (76kV) shall be applied either simultaneously or consecutively to each phase of the cable at ambient temperature.

(c) The test shall continue until each core has withstood 100 hours without failure (excluding terminations failure).

3.6 Dielectric security test

3.6.1 The dielectric security tests are applicable for cables having a rated voltage U_o of 3,5 kV and above.

3.6.2 Sample of cable length: not less than 3m

3.6.3 A.C. voltage test

voltage:	3 U_o
duration:	4h
test result:	no breakdown.

4. LONG TERM TESTS

4.1 Loading cycle test

4.1.1 Preliminary procedure

As a preliminary to the type testing procedure the insulation thickness of the cable submitted for test shall be checked by the relevant method in 2.1.1.1, to confirm that it is in accordance with the specified thickness within a tolerance of +0,4mm.

4.1.2 Loading cycle test

(i) Test installation

The installation shall include at least 30m of cable and, if any accessories are included, there shall be at least 4m of cable between adjacent accessories.

All cables used in the test installation shall have been bent in accordance with the procedure described in sub clause 2.4.1. The installation shall contain a vertical rise to the gland wipe of the terminations to give a head of not less than 2m; it shall be situated indoors in reasonably still air, and away from direct sunlight. The cable installation shall include a vertical loop at least 6m in height.

(ii) Procedure

The test installation shall undergo at least 100 cycles at 25,4kV (1,33 times normal working voltage) with not more than five loading cycles in any 7 successive days.

Each cycle shall consist of 6 h with conductor current loading followed by 18 h without current loading.

During the last 3h of each current loading period maintain the maximum conductor temperature at not less than 70°C nor more than 75°C.

The test voltage shall be at normal power frequency and shall have an r.m.s value of 25,4 kV, continuously between the conductor(s) and the sheath. Measure one cold and one hot tan δ value at this voltage on each of the three cores in turn.

NOTE: If the available conductor loading current supplies are inadequate to produce the above temperature it is permissible to apply a uniform thickness of thermal insulation throughout the length of the test assembly, excluding the sealing ends.

The test shall be carried out for a maximum of 250 heat cycles, but if the tan δ is shown to be stable after 100 heat cycles the test may be discontinued.

4.2 Accelerated ageing test

4.2.1 Cable sample preparation

The test shall be carried out on a 3-core cable sample 25m long, not including the terminations.

The sample shall undergo the bending test according to 2.4.2 but applying 1 bending cycle only instead of 3.

The sample shall then be laid in free air in vertical position, with a relief of at least 20m, and terminated with suitable "stop" terminations, under agreement between cable manufacturer and customer.

4.2.2 Test method

The sample shall undergo to 180 thermal cycles, with an A.C. voltage permanently applied between conductors and grounded sheaths of 1,6 U_o ± 3%.

During the heating period the conductors, heated by current circulation, shall get a temperature of 80°C to 85°C, and this temperature shall be maintained for at least 4h. The heating plus the temperature regimen period shall last about 8h.

The cooling period, under voltage but without current, shall last about 16h.

In case of power breakdowns during the test, the test time shall be suitably prolonged for an equivalent period.

The total amount of power breakdown time shall not be higher than 240h; when higher, the test shall be repeated on a new cable sample.

No insulation breakdowns shall occur during the test.

At the end of the cycle, from the upper part of each core samples of cable 4m long, not including the terminations, shall be cut immediately under the termination used for the test.

All the samples shall undergo the "A.C breakdown voltage test" applying a step rise of 5 kV/24 h for each step, starting for a voltage of 50kV (for 12/20 kV cable).

SECTION J-3

THREE-CORE CABLES WITH ALUMINIUM SHEATH

NOTE: Section J of Part 4 is divided into:

Section J-1: Three core cables with lead sheath (19/33kV)

Section J-2: Three core cables with lead sheath, up to and including 12.7/22kV

Section J-3: Three core cables with aluminium sheath.

CONTENTS

REFERENCES

Section J-3 of Part 4 of HD 621 incorporates by dated or undated reference, provisions from other publications. These 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 Section J-3 of Part 4 of HD 621 only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

HD 383 Conductors of insulated cables (Endorsing IEC 228 and 228A)
HD 605 Electric cables : Additional test methods

1. General

This section specifies the construction, dimensions and test requirements of 3 core paper insulated power cables with aluminium sheath. (Operating voltage 6.35/11(12)kV).

(a) Insulating material

Paper

(b) Rated voltage Uo/U (V)

6,350/11,000 (12,000)V

(c) Highest rated conductor temperature for the insulating compound

(i) Continuous operation: 70°C (screened cables)
65°C (belted cable)

(ii) Short circuit: 160°C

(d) Sheathing material

Corrugated aluminium.

(e) Type approval

Type approval for the whole range of cables in Part 4, Section J-3, or part of the range, is obtained by following the procedure given in Appendix D of this section.