भारतीय मानक

Indian Standards

IS 7098 (Part 3) Draft

अनुप्रस्थ जुड़े हुए पौलीइथाईलीन विद्युतरोधी ताप स्थायी ढके केबल की विशिष्टि

भाग 3 — 66 किलोवोल्ट से 220 किलोवोल्ट तक की कार्यकारी वोल्टता के लिए

(पहला पुनरीक्षण)

Cross Linked Polyethylene Insulated Thermoplastic Sheathed Cables Specification

Part 3 for working voltages above 33 kV up to and including 400 kV

(First Revision)

ICS 29.060.20

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Power Cables Sectional Committee, ETD 09	Last Date for Comments- 10/12/2023

FOREWORD

This draft Indian Standard Part 3 (First Revision) was adopted by the Bureau of Indian Standards after the draft finalized by the Power Cables Sectional Committee had been approved by the Electrotechnical Division Council.

Other two parts of this series of Indian Standards cover cross-linked polyethylene insulated thermoplastic sheathed cables of following grades:

Part 1 For working voltages up to and including 1 100V,

Part 2 For working voltages from 3.3 kV up to and including 33 kV

This standard was first published in 1993. This revision has been undertaken to align it with the international practices and to take into account the experience gained during this period in the manufacture of these types of cable in the country.

IS 16269:2018 “Recommended Short Circuit Rating of Electric Cables from 1.1 kV to 220 kV-Specification” may be referred for short circuit ratings of cables covered in this standard.

Special category of cables with improved fire performance has been included in this standard.

In the preparation of this standard, assistance has been derived from IEC 60840:2020 ‘Power cables with extruded insulation and their accessories for rated voltages above 30 kV (U_m=36 kV) up to 150 kV (U_m=170 kV)-Test methods and requirements and IEC 62067: 2022 ‘Power cables with extruded insulation and their accessories for rated voltages above 150 kV (U_m=170 kV) up to 500 kV (U_m=550 kV)-Test methods and requirements’ issued by the International Electrotechnical Commission.

The composition of the Committee responsible for the formulation of this standard is given in **Annex J**.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the results of a test, shall be rounded off in accordance with IS 2:2022 'Rules for rounding off numerical values (*Second Revision*)' . The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Attention is drawn to the fact that cables with low smoke & halogen free (LSHF) sheathes are mechanically not comparable with other categories of cables. Such cables should be handled and installed with sufficient protection against adverse environmental factors such as mechanical damage, exposure to excessive heat, exposure to corrosive substances or solvents, exposure to UV radiations and not intended for outdoor installation.

When cables or cable systems are installed in the ground, in locations with risks of water ingress or corrosion, a radial moisture barrier is recommended. Longitudinal moisture barriers are applied in order to avoid need to replace long sections of cable in case of damage in presence of water.

Draft Indian Standard

Cross linked polyethylene insulated thermoplastic sheathed cables specification—
Part 3 for working voltages above 33 kv and up to including 400 kv

(*First Revision)*

SECTION 1 GENERAL

1. SCOPE

1.1 This draft standard (Part 3) covers the requirements of single-core and three core cross-linked polyethylene insulated, screened and thermoplastic outer sheathed cables for 3 phase AC Earthed System for electric supply for the voltage grades given in **Table1**.

Table 1
(*Clause 1.1*)
Voltage Grades

System Voltage U	Rated Voltage Uo/U	Highest System Voltage Um
(kV)	(kV)	(kV)
45	26/45	52
66	38/66	72.5
110	64/110	123
132	76/132	145
220	127/220	245
400	220/400	420

NOTES -

i) Three core cables shall be with individual metallic screen and up to & including rated voltage 76/132 kV.
ii) For cables with radial moisture barrier such as Lead Alloy E sheath, Aluminium sheath and laminated tape, armouring is not required, unless specially agreed between purchaser & supplier.
iii) Cables in this standard are not for submarine application.

1.2 Cables covered under this standard are suitable for use where the combined ambient temperature and temperature rise due to load result in conductor temperature not exceeding 90°C under normal operation and 250°C under short-circuit operation.

NOTE—Under short duration emergency overload the conductor temperature shall not exceed 130^0C for rated voltage up to & including 76/132 kV and 105^0C for rated voltage 127/220 kV and 220/400kV. Operation up to the stated maximum overload temperature should not exceed 72 hours on average per year for the design life, without exceeding 216 hours in any 12months period and not exceeding 2880 hours during cable lifetime.

1.3 Construction and testing of cables or cable system(s) covered under this standard are suitable for testing as per IEC 60840 & IEC 62067 as relevant. Accordingly, cables or cable system(s) Type, PQ or EQ tested as per IEC 60840 or IEC 62067 are valid under this standard IS 7098 Part 3, subject to **3.2**.

Type tests, PQ or EQ Tests which have been successfully performed according to the previous edition of these standards are valid.

NOTE—Scope of testing of accessories in this standard is limited to those tested under the cable system Type, PQ or EQ test.

2. REFERENCES

2.1 Indian Standards listed in Annex A are necessary adjuncts to this standard. Latest revision with up-to-date amendments of the stated standards shall be applicable.

3. TERMINOLOGY

3.1.0 For the purpose of this standard, the following definitions in addition to those given in IS 1885 (Part 32) shall apply.

3.1.1 *Routine Test*—Tests carried out by the manufacturer on all finished cable lengths to demonstrate integrity of the cable.

3.1.2 *Type Tests*—Tests required to be made before supply on a type of cable (or cable system) on a general commercial basis in order to demonstrate satisfactory performance characteristics to meet the intended application.

NOTE—These tests are of such a nature that after they have been made, they need not be repeated unless changes are made in the materials, design or type of manufacturing process of cable or accessories which might change the performance characteristics.

3.1.3 *Acceptance Tests*—Tests carried out on samples taken from a lot for the purpose of acceptance of the lot.

3.1.4 *Optional Tests*—Special tests to be carried out, when required, by agreement between the purchaser and the supplier.

3.1.5 *Earthed System*—An electrical system in which the neutral-point or the mid-point connection is earthed in such a manner that even under fault conditions the maximum voltage that can occur between any conductor and the earth does not exceed 80 % of the nominal system voltage.

3.1.6 *Longitudinally Watertight cables*—Cables to meet the requirements to prevent the propagation of water along the length of the cable.

3.1.7 *Radially Watertight cables*—Cables to meet the requirements to prevent the radial propagation of water.

3.1.8 *Cable System*—Cable with installed accessories including components used for the mechanical restraint of systems limited to those used for terminations and joints only.

3.1.9 *Nominal Electrical Stress*—Electrical stress calculated at U_0 using nominal dimensions.

Calculated nominal electrical stress at conductor screen (E_i) and at insulation screen (E_o):

$$E_i = 2U_o / [d_{ii} (\ln(D_{io}/d_{ii})]$$
$$E_o = 2U_o/ [D_{io} (\ln(D_{io}/d_{ii})]$$

Where,

$D_{io} = d_{ii} + 2t_i$

U_0 is given in **Table 1**,

d_{ii} is the calculated nominal inner diameter of the insulation,

D_{io} is the calculated nominal outer diameter of the insulation and

t_i is the declared nominal insulation thickness.

3.1.10 *Prequalification test (PQ test)*—Tests made before supplying, on a general commercial basis, a type of cable system covered by this standard, in order to demonstrate satisfactory long-term performance of the complete cable system.

3.1.11 *Extension of Pre-qualification test (EQ Test)*—Tests made before supplying, on a general commercial basis, a type of cable system covered by this standard, in order to demonstrate satisfactory long-term performance of the complete cable system, taking into account an already pre-qualified cable system.

3.2 RANGE APPROVAL

3.2.1 *Range of Type Test Approval*—When type tests have been successfully performed on one or more cable or cable system (s) of specific cross-section (s), and of the same rated voltage and construction, the type approval shall be considered as valid for cable or cable systems within the scope of this standard with other cross-sections, rated voltages and constructions provided that all the conditions of **a** to **f** below are met:

a) The voltage group is not higher than that of the tested cable or cable system(s);

b) The nominal conductor cross-section is not larger than that of the tested cable;

c) The cable and accessories have the same or similar constructions as that of the tested cable or cable system(s);

NOTE—Cables and accessories of similar construction are those of the same type and manufacturing process of insulation and semi-conducting screens. Repetition of the electrical type tests is not necessary on account of the differences in the conductor or connector type or material or of the protective layers applied over the screened cores or over the main part of the accessory unless these are likely to have significant effect on the results of the test.

d) The calculated nominal electrical stress and the impulse voltage stress calculated using nominal dimensions at the cable conductor screen do not exceed the respective calculated stresses of the tested cable by more than 10 %;

e) The calculated nominal electrical stress and the impulse voltage stress, calculated using nominal dimensions at the cable insulation screen do not exceed the respective calculated stresses of the tested cable;

NOTE—Conditions **d** & **e** are not applicable when thickness of insulation conforms to **Table 7**.

f) The calculated nominal electrical stresses and the impulse voltage stresses calculated using nominal dimensions within the main insulation parts of the accessory and at the cable and accessory interfaces do not exceed the respective calculated stresses of the tested cable system(s).

NOTE—Condition **f** is applicable only for type test on cable system(s).

The type tests on cable components (*see* **20.1.1**) need not be carried out on samples from cables of different voltage ratings and/or conductor cross-sectional areas unless different materials and/or different manufacturing processes are used to produce them. However, repetition of the ageing tests on pieces of completed cable to check compatibility of materials may be mutually agreed with the purchaser if the combination of materials applied over the screened core is different from that of the cable on which type tests have been carried out previously.

NOTES

i) For rated voltages upto & including 76/132 kV, type test shall be performed on cable and not on the cable system(s), unless agreed between purchaser and supplier.
ii) For rated voltages up to & including 76/132 kV, type test performed on cable system are valid for the cables, subject to compliances required in this clause a to e).
iii) Type test performed on the cable system with voltage grades 127/220 kV and 220/400 kV shall not be valid for voltage grades 76/132 kV and below.
iv) Type test performed on a single core cable (or cable system) is not valid for a three core cable (or cable system).

3.2.2 *Range of Prequalification (PQ) Test Approval*—When a prequalification test has been successfully performed on a cable system, it qualifies the manufacturer as a supplier of cable systems of the same family with the same or lower voltage ratings as long as the calculated nominal electrical stresses at the cable insulation screen are equal to or lower than for tested cable system.

For rated voltages up to & including 76/132 kV, the PQ test shall be performed on cable systems where calculated nominal electrical stresses at conductor screen are higher than 8 kv/mm and/or electrical stresses at the insulation screen higher than 4 kv/mm.

The PQ test shall be performed except:

a) If cable systems with same construction and accessories of the same family have been pre-qualified for an equal or higher rated voltage, or

b) If the manufacture can demonstrate good service experience with cable systems with equal or higher calculated electrical stresses on the conductor and insulation screens, or

c) If the manufacturer has fulfilled the requirements of an equivalent long-term test, on a cable system at an equal or higher voltage rating with the same construction and accessories of the same family.

When a prequalified cable system is changed by exchanging a cable and/or accessory with another one that is already prequalified in another cable system with the same or higher calculated nominal electrical stresses at the insulation screen of the subjected system, the current prequalification shall be extended with this or other cable and/or accessory when requirements of **20.7** are met.

When a prequalified cable system is changed by using another cable and /or accessory that is not part of a prequalified cable system or is already prequalified in another cable system with lower calculated nominal electrical stresses at the insulation screen of the subjected system, the prequalification test on this new complete cable system shall be performed by meeting all the requirements of **20.6**.

The prequalification test need only be carried out once unless there is a substantial change in the cable system with respect to material, manufacturing process, design or design electrical stress levels. A substantial change is defined as that which might adversely affect the performance of the cable system. The manufacturer should provide a detailed case, including test evidence, if modifications are introduced which are claimed not to constitute substantial change.

It is recommended to carry out a prequalification test using a cable of a large conductor cross-section in order to cover thermo-mechanical aspects.

3.2.3 A test certificate of Type, PQ or EQ Test signed by the representative of a competent witnessing body, or a report by the manufacturer giving the test results and signed by the appropriate qualified officer, or a test certificate of Type, PQ or EQ test issued by an independent test laboratory, shall be acceptable as evidence of Type, PQ or EQ testing.

SECTION 2 MATERIALS

4. CONDUCTOR

4.1 The conductors shall be composed of plain copper or aluminium wires complying with IS 8130.

NOTE -Copper conductor can also be of enameled copper wires as agreed between manufacturer and purchaser.

5. INSULATION

5.1 The insulation shall be of cross-linked polyethylene (XLPE) conforming to the requirements given in **Table 2**.

6. SCREENING

6.1 The screening shall consist of one or more of the following:

a) Non-metallic semiconducting tape;
b) Non-metallic semiconducting compound;
c) Non-magnetic metallic tape, wire or sheath;
d) Semiconducting Copper woven fabric tape

NOTE—The semiconducting tape and the semiconducting compound shall be suitable for the operating temperature of the cable and compatible with the insulating material.

Table 2
(Clause 5.1)
Properties of XLPE Insulation

	Property	Requirement
a	Before aging -Tensile Strength -Elongation at break	 12.5 N /mm^2(Min) 200 % (Min)
b	Ageing in air oven : Treatment -Temperature -Duration	 135 $\pm$ 3ºC 168 h
c	Variation from corresponding values before ageing: -Tensile strength -Elongation at break	 $\pm$ 25 % (Max) $\pm$ 25 % (Max)
d	Hot set Treatment: -Temperature -Time under load -Mechanical Stress -Elongation under load -Permanent elongation after cooling	 200 $\pm$ 3ºC 15 Minutes 20 N/cm^2 175 % (Max) 15 % (Max)
e	Shrinkage [1)] Treatment: -Temperature -Duration -Shrinkage	 130 $\pm$ 3ºC 6 h 4.5 % (Max)

[1)] Applicable for cables up to and including 76/132 kV

7. MOISTURE BARRIER

7.1 Laminated Tape

This shall be a plastic coated non-ferrous metal tape.

7.2 Metallic Sheath

7.2.1 The metallic sheath shall be either lead alloy E sheath or aluminium sheath.

7.2.2 Lead Alloy E sheath shall be as per **Table 3**.

7.2.3 Aluminium for sheathing shall have minimum 99.6% by weight of aluminium.

NOTE—Other lead alloys may be used as agreed to between the purchaser and the supplier.

Table 3
(Clause 7.2)
Composition of Lead Alloy 'E' Sheath

	Elements	Min	Max
a	Antimony	0.15	0.25
b	Tin	0.35	0.45
c	Tellurium	-	0.005
d	Silver	-	0.005
e	Copper	-	0.06

f	Bismuth	-	0.05
g	Zinc	-	0.002
h	Total of other elements	-	0.01
i	Lead	Remainder	-

NOTES
i)Values are in percentage by weight
ii)Description of material: 0.4% Tin, 0.2% Antimony
iii) (-) denotes "not specified"

7.3 Water blocking materials (Tape/Powder/Yarn)

This shall be synthetic non-woven tape / powder / Yarn (or combination) with suitable water sellable absorbent. The tape can be either non-conducting or semi-conducting.

NOTE—Water blocking powder is not recommended since it is hazardous.

8. INNER SHEATH (OR SEPARATION SHEATH)

8.1 The inner sheath (or separation sheath) shall be of PVC compound or thermoplastic polyethylene (PE) compound, or LSHF (Low Smoke & Halogen Free) compound.

8.2 The PVC compound shall conform to Type ST2 of IS 5831.

8.3 The PE compound Type ST7 shall conform to **Table 4**.

8.4 The LSHF compound Type ST12 shall conform to **Table 5**.

9. ARMOUR

9.1 The armour shall be of non-magnetic metallic wires for single core cables and galvanized round steel wires / formed steel wires for 3 core cables.

9.2 Non-magnetic metallic material shall be hard drawn aluminium or as agreed between the purchaser and the supplier.

9.3 Material of galvanized round steel wires / formed steel wires shall conform to IS 3975.

10. OUTER SHEATH

10.1 The outer sheath shall be of PVC compound or thermoplastic polyethylene (PE) compound or LSHF (Low Smoke & Halogen Free) compound.

10.2 The PVC compound shall conform to Type ST2 of IS 5831.

NOTE–PVC outer sheathed cables with improved fire performance such as Flame Retardant (FR) or Flame Retardant Low Smoke and Halogen (FRLSH), shall meet additional requirements specified in this standard.

10.3 The PE compound Type ST7 shall conform to **Table 4**.

10.4 The LSHF compound Type ST12 shall conform to **Table 5**.

NOTE - For LSHF Cables, inner sheath (if applicable) shall be LSHF conforming to **Table 5**. Additionally, for three core LSHF cables, fillers shall be halogen free conforming to **Table 5(e)**.

Table 4
(Clause 8.3, 10.3)
Properties of PE sheathing compound Type ST7

	Properties	**Requirement**

a	Before aging -Tensile Strength -Elongation at break	 12.5 N /mm^2(Min) 300 % (Min)
b	After Ageing in Air Oven -Temperature -Duration -Elongation at break	 110 $\pm$ 2 ^{0}C 10 days 300 % (Min)
c	Hot-Deformation Test -Temperature -Duration - Depth of Indentation	 110 $\pm$ 2 ^{0}C 6 hours 50 % (Max)
d	Carbon black content (For Black sheath only)	2.5 $\pm$ 0.5%
e	Shrinkage test[1)] -Temperature -Duration -No. of cycles - Shrinkage	 80 $\pm$ 2^0 C 5 hours 5 3.0 % (Max)

[1)] Applicable for cables up to and including 76/132 kV

Table 5
(Clause 8.4, 10.4)
Properties of LSHF sheathing compound Type ST12

	Properties	**Requirement**
a	Before aging - Tensile Strength - Elongation at break	 12.5 N /mm^2(Min) 300 % (Min)
b	After ageing in Air Oven -Temperature -Duration - Tensile Strength - Variation of Tensile Strength - Elongation at break	 110 $\pm$ 2 ^{0}C 10 days 10.0 N /mm^2(Min) +/- 30% (Max) 300% (Min)
c	Hot-Deformation Test -Temperature -Duration - Depth of Indentation	 110 $\pm$ 2 ^{0} C 6 hours 50 % (Max)
d	Shrinkage test[1)] -Temperature -Duration -No. of cycles - Shrinkage	 80 $\pm$ 2^0 C 5 hours 5 3.0 % (Max)
e	- pH - Conductivity - HCl	4.3(Min) 10 µS/mm(Max) 0.5%(Max)
f	Cold elongation -Temperature -Duration Cold Impact test -Temperature -Duration	20% (Min) -15+/-2 ^{0}C 3 hours No cracks -15+/-2 ^{0}C 3 hours

[1)] Applicable for cables up to and including 76/132 kV

SECTION 3 CONSTRUCTIONS

11. CONDUCTOR

11.1 The conductor shall be of stranded circular compacted or segmented (Milliken) construction, complying with the requirements of Class 2 of IS 8130.

NOTES—As agreed between supplier & purchaser:

i) Conductor sizes 800 & 1000 sq.mm may be either compacted circular or segmented (Milliken).
ii) Conductors may be longitudinally watertight by using suitable water blocking materials.
iii) Copper conductors of large sizes eg.1600 sq. mm and above, may be composed of enameled wires.

12. CONDUCTOR SCREENING

12.1 The conductor screening shall consist of a layer of semi-conducting compound extruded over the conductor.

NOTE—Semi-conducting barrier tape (s) with suitable overlap may be applied between the conductor and extruded conductor screening.

12.2 The minimum thickness of extruded conductor screening shall be as per **Table 6**.

Table 6
(Clause 12.2 & 14.2.2)
Minimum Thickness of Extruded Semiconducting Screens

Rated Voltage	Conductor Screen	Insulation Screen
(kV)	(mm)	(mm)
26/45	0.5	0.5
38/66	0.8	0.8
64/110	0.8	0.8
76/132	0.8	0.8
127/220	1.0	0.8
220/400	1.5	1.0

13. INSULATION

13.1 The insulation shall be extruded cross-linked Polyethylene (XLPE) conforming to the requirements of **Table 2**.

13.2 The average thickness of insulation shall be not less than the nominal value (t_i) specified in **Table 7**.

13.3 The smallest of the measured values of thickness of insulation shall not fall below the nominal value (t_i) specified in **Table 7** by more than 0.1 ti.

Table 7
(Clause 13.2 and 13.3)
Nominal Thickness of XLPE Insulation

Size of Conductor	Rated Voltage U_o/U					
	26/45 kV	38/66 kV	64/110 kV	76/132 kV	127/220 kV	220/400 kV
mm^2	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
95	9.5	11	-	-	-	-
120	9.5	11	-	-	-	-
150	9.5	11	16	-	-	-
185	9.5	11	16	18	-	-
240	9.5	11	16	18	-	-

300	9.5	11	16	18	-	-
400	9.5	11	16	18	27	-
500	9.5	11	16	18	27	-
630	9.5	11	16	18	26	30
800	9.5	11	16	18	25	29
1 000	9.5	11	16	18	25	28
1 200	9.5	11	16	18	25	27
1 400	9.5	11	16	18	25	27
1 600	9.5	11	16	18	24	27
1 800	9.5	11	16	18	24	27
2 000	9.5	11	16	18	24	27
2 500	9.5	11	16	18	24	27

NOTE—In **Table 7** (-) denotes conductor sizes are not recommended for the respective rated voltages.

14. INSULATION SCREENING

14.1 The insulation screening shall consist of two parts, namely, non-metallic and metallic.

14.2 Non-metallic Part

14.2.1 The Non-metallic part shall consist of a layer of semi-conducting compound extruded directly over the insulation.

NOTE—Conductor screening, insulation and insulation screening shall be extruded in one operation.

14.2.2 The minimum thickness of extruded insulation screening shall be as per **Table 6**.

14.2.3 Semi-conducting barrier tape (s) with suitable overlap may be applied over the insulation screening.

14.3 Metallic Part

14.3.1 The metallic part of the screening shall consist of either copper wires / copper tape (s) helically applied over non-metallic screening, or metallic sheath of either aluminium or lead alloy E. The metallic sheath applied over the non-metallic part of the insulation screen shall form the metallic part of screening.

NOTE—For enhancing short circuit current carrying capacity of the screen / sheath, additional copper wires / tape (s) may be applied over/under metal sheath with suitable semiconducting separator tape or thickness of the metal sheath may be increased.

14.3.2 The diameter of copper wire in the screening shall not be less than 0.8 mm. The perpendicular gap between two adjacent wires shall not be more than 4.0 mm. The nominal thickness of copper tape shall not be less than 0.1 mm. The minimum thickness of shall not fall below the nominal value by more than 10%.

NOTE—The requirement of perpendicular gap between adjacent wires shall not be applicable for additional copper wire screen in combination with metallic sheath as per **14.3.1**.

14.3.3 A binder tape of copper shall be applied helically with open gaps over the copper wire screen. The nominal thickness of copper tape shall not be less than 0.1 mm. The minimum thickness of shall not fall below the nominal value by more than 10%.

15. MOISTURE BARRIER

15.1 The moisture barrier shall be provided as follows:

15.1.1 *Longitudinal moisture barrier*—Water blocking tape/powder/yarn or combination thereof applied suitably.

15.1.2 *Radial moisture barrier*—Laminated tape applied longitudinally with overlap and sealed or Metallic sheath of lead alloy ‘E’ or Aluminium sheath as per **15.2**.

NOTES

i) Moisture Barrier is optional for cables with rated voltage 26/45 kV.
ii) For 3 core cables, radial moisture barrier may be above the inner sheath or laid up cores.
iii) Radial moisture barrier with laminated tape or smooth aluminium sheath shall be firmly bonded to the thermoplastic sheath over it.

15.2 Metallic sheath

15.2.1 Metallic sheath shall consist of either lead alloy 'E' sheath as per **7.2.2** or Aluminium sheath as per **7.2.3**.

15.2.2 Thickness of metallic sheath shall not fall below the value specified in **Table 8**.

NOTES
i) Aluminium sheath can be either smooth or corrugated.
ii) Semiconducting Copper woven fabric tape shall be applied below the Corrugated Aluminium sheath for rated voltages 127/220 kV & above, for cables with rated voltages 38/66 kV to 76/132 kV as agreed between manufacturer & purchaser.
iii) Suitable anticorrosive coating e.g. bitumen shall be applied over the Corrugated Aluminium sheath.

Table 8
(Clause 15.2.2)
Minimum Thickness of metallic sheath

Calculated diameter under metallic sheath *[Ref Annex B]*		**Lead sheath**	**Aluminium Sheath (Corrugated or Smooth)**
Over	Up to and Including		
mm	mm	mm	mm
-	65	1.6	1.5
65	70	1.7	1.5
70	80	1.8	1.5
80	90	1.9	1.5
90	95	2.0	1.5
95	100	2.1	1.5
100	105	2.2	1.5
105	110	2.3	1.5
110	115	2.4	1.5
115	-	2.5	1.5

16. CORE IDENTIFICATION & LAYING UP OF CORES (for three core cables)

16.1 Cores shall be identified as follows:

a) By colored or numbered strips applied above the extruded insulation screen or above the metallic screen, or

b) By printing on the extruded insulation screen, or

c) Any other method as agreed between supplier & purchaser.

16.2 Cores shall be laid up together with a suitable right hand lay. The interstices shall be filled with non-hygroscopic material. Suitable binder tape (s) may be applied over the laid-up cores.

17. INNER SHEATH (SEPARATION SHEATH) (as applicable)

17.1 For three core cables, laid up cores shall be provided with inner sheath applied by extrusion. It shall be ensured that the shape is as circular as possible. The inner sheath shall be so applied that it fits closely on the laid up cores and it is possible to remove it without damage to the insulation.

17.2 For single core armoured cables with metallic screen or metallic sheath, there shall be extruded inner sheath between them.

17.3 Three core cables with unarmoured construction may have an extruded inner sheath.

17.4 The thickness of inner sheath at any point shall not be less than the value specified in **Table 9**.

17.5 In some cable constructions, it may be necessary to provide additional extruded separation sheath, in which case the thickness of such separation sheath at any point shall not be less than the value specified in **Table 9**.

Table 9
(Clause 17.4)
Minimum Thickness of Inner Sheath (or separation sheath)

Calculated diameter under Inner sheath (or separation sheath) *[Ref Annex B]*		**Thickness of Inner sheath (or separation sheath)**
Over	Up to and Including	
(mm)	(mm)	(mm)
-	40	0.9
40	45	1.0
45	55	1.1
55	60	1.2
60	65	1.3
65	70	1.4
70	-	1.5

18. ARMOUR (if applicable)

18.1 Armour, when specified, shall be applied over the non-metallic insulation screen in case of single core cables without metallic screen / sheath and over inner sheath (or separation sheath) in case of single core cables with metallic screen/sheath & three core cables.

NOTE - Suitable binder tape (s) may be provided under / over armour.

18.2 The nominal diameter of armour round wires and nominal thickness of formed wires shall not be less than the values given in **Table10** respectively.

18.3 The armour wires shall be applied helically with coverage not less than 90 %. The coverage of armour shall be calculated as per **Annexure- E**.

18.4 The direction of lay of armour shall be left hand.

18.5 The joints in armour wires shall be made by welding and the surface irregularities shall be removed. A joint in any wire shall be at least 300 mm from the nearest joint in any other armour wire in the completed cable.

18.6 Round aluminium wires taken from the cable shall meet the following requirements:

a) Minimum tensile strength shall not be less than 150 N/mm^2.

b) Shall meet wrapping test as per IS 8130.

c) Resistivity at 20^0C shall not exceed 28.264 $ohm.mm^2/km$.

Table 10
(Clause 18.2)
Nominal Dimension of armour round/formed wires

Calculated diameter under Armour *[Ref Annex B]*		**Diameter of round wires**	**Thickness of formed wires**	
Over	Up to andIncluding		Type A	Type B
(mm)	(mm)	(mm)	(mm)	(mm)
-	40	2.00	0.8	0.8
40	55	2.50	0.8	1.4
55	70	3.15	0.8	1.4
70	-	4.00	0.8	1.4

NOTE—Type A & Type B indicate two types of armouring with formed wires and unless specified, Type A is considered.

18.7 Requirements of non-magnetic armour wires, other than aluminium shall be as agreed between purchaser & supplier.

18.8 Galvanized round steel wires / formed steel wires taken from the cable shall meet the following requirements:

a) The Tensile strength of round steel wires / formed steel wires shall be not less than 250N/mm^2 and not more than 580 N/mm^2.

b) The elongation at break of round steel wires / formed steel wires shall not be less than 6%.

c) Round steel wires shall meet requirements of torsion test. The gauge length between vices and the minimum number of turns without break shall be as per IS: 3975.

d) The zinc coating shall not show any cracks and shall not flake off on rubbing by bare finger when the formed wire is subjected to winding test.

e) The uniformity of zinc coating of round steel wires / formed steel wires shall comply with the requirements of IS 3975 subject to the following:

i) Minimum number of dips shall be reduced by one-half minute dip.

ii) In case of formed wires, dip test is applicable only for the face.

f) The mass of zinc coating of round steel wires shall not be less than 95% of the mass specified in **Table 2** of IS 4826 and mass of zinc coating of formed steel wires shall not be less than 95% of the mass specified in IS 3975.

g) The resistivity of the round steel wires / formed steel wires shall meet the requirements of IS 3975.

19. OUTER SHEATH

19.1 The outer sheath shall be applied by extrusion. It shall be applied:

a) Over the moisture barrier or metallic screen for unarmoured cables, and

b) Over the armour for armoured cables

c) Over inner sheath for three core cables.

NOTE—Binder tape (s) may be applied under the outer sheath.

19.2 The colour of outer sheath shall be black or any other colour as agreed to between purchaser and supplier.

19.3 Thickness of outer sheath

19.3.1 *Unarmoured cables*—The thickness of outer sheath determined by taking average of a number of measurements shall not be less than the nominal value specified in col. 4 of **Table 11** and the smallest of the measured values shall not fall below minimum values specified in col. 5 of **Table 11**.

19.3.2 *Armoured cables* - The thickness of outer sheath shall not be less than the minimum value specified in col. 3 of **Table 11**.

19.4 The outer sheath shall be coated with a suitable conducting material, applied either by extrusion or as graphite coating. The thickness of such outer conducting layer shall not be a part of the outer sheath thickness.

NOTE -Coating is optional, for cables with rated voltage 26/45 kV and for three core cables.

Table 11
(Clause 19.3)
Thickness of Outer Sheath

Calculated diameter under outer sheath *[Ref Annex B]*		**Armoured Cables**	**Unarmoured Cables**	
Over	Up to and including	**Nominal thickness**	**Nominal thickness**	**Minimum thickness**
1	2	3	4	5
(mm)	(mm)	(mm)	(mm)	(mm)
-	40	2.4	2.4	1.72
40	45	2.6	2.6	1.88
45	50	2.8	2.8	2.04
50	55	3.0	3.0	2.20
55	60	3.2	3.2	2.36
60	65	3.4	3.4	2.52
65	70	3.6	3.6	2.68
70	75	3.8	3.8	2.84
75	85	4.0	4.0	3.00
85	95	4.2	4.2	3.16
95	105	4.5	4.5	3.40
105	115	4.8	4.8	3.64
115	125	5.2	5.2	3.96
125	135	5.6	5.6	4.28
135	-	6.0	6.0	4.60

SECTION 4 TESTS

20. Classification of Tests

20.1 **Type Tests:** The following shall constitute the Type tests:

20.1.1 Non-electrical tests:

	Test	**Ref of Requirements**	**Ref of Test Method (IS 10810)**
a)	Tests on conductor:		
	i) Conductor Construction	IS 8130	IS 8130
	ii) Resistance test	IS 8130	Part 5
b)	Physical test for insulation:		
	i) Test for dimensions of insulation and semiconducting screen	**21.15**	Part 6
	ii) Tensile strength & Elongation at break	**Table 2**	Part 7

	iii) Thermal Ageing in air oven	**Table 2**	Part 11
	iv) Hot set test	**Table 2**	Part 30
	v) Shrinkage test[1)]	**Table 2**	Part 12
c)	Resistivity of extruded semiconducting screen (without ageing)	**21.1**	Annex C
d)	DC resistance of metallic screen / sheath	**21.2**	**21.2**
e)	Test for thickness of metallic sheath	**21.4**	**21.4**
f)	Test for thickness of inner sheath	**17.4**	Part 6
g)	Tests for armouring material	**18, Table 10**, IS 3975	Part 3, 36 to 42
h)	Physical tests for outer sheath:		
	1) Measurement of thickness	**19.3**	Part 6
	2) **PVC Sheath**(also for FR & FRLSH sheath)		
	i) Tensile strength & Elongation at break	IS 5831	Part 7
	ii) Thermal ageing in air oven	IS 5831	Part 11
	iii) Loss of mass	IS 5831	Part 10
	iv) Heat shock test	IS 5831	Part 14
	v) Hot deformation test	IS 5831	Part 15
	vi) Shrinkage test[1)]	IS 5831	Part 12
	vii) Thermal stability	IS 5831	Part 60
	3) **PE Sheath**		
	i) Carbon black content	**Table 4**	Part 32
	ii) Tensile strength and elongation at break before and after ageing	**Table 4**	Part 7
	iii) Hot deformation	**Table 4**	Part 15
	iv) Shrinkage test[1)]	**Table 4**	Part 12
	4) **LSHF Sheath**		
	i) Tensile strength and elongation at break before and after ageing	**Table 5**	Part 7
	ii) Hot deformation	**Table 5**	Part 15
	iii) Shrinkage test[1)]	**Table 5**	Part 12
i)	Test for improved fire performance, as applicable		
	i) Oxygen Index Test	**21.18**	Part 58
	ii) Temperature Index Test	**21.19**	Part 64
	iii) Test for Halogen Acid Gas evolution	**21.20**	Part 59
	iv) Smoke Density Test	**21.21**	IS 13360-Part 6/Sec 9
	v) Light Transmission test	**21.25**	Part 63
	vi) Flame Retardance Test on single cable	**21.22**	Part 61
	vii) Flame Retardance Test on bunched cables	**21.23**	Part 62-Cat C
	viii) pH & conductivity tests	**Table 5**	**21.24**
j)	Tests for components of cables with longitudinally applied metal tape or foil, bonded to the outer sheath	**Annex H**	**Annex H**
k)	Flammability test, as applicable	**21.6**	Part 53
l)	Water penetration test	**21.7**	**Annex D& E**
m)	Thermal ageing on complete cable sample:		
	i) Tensile strength and elongation at break for insulation & outer sheath	**21.8**	Part 7
	ii) Resistivity test for semi conducting layers	**21.8**	**Annex C**

[1)] Shrinkage test of insulation or outer sheath is applicable for cables up to and including 76/132 kV.

20.1.2 Sequential Electrical Tests:

The tests a) to i) shall be made in the following sequence-

a)	Bending test followed by Partial Discharge test at	**21.10, 21.9**	Part 50 &Part 46

	ambient temperature		
b)	Tan δ and capacitance measurement[2)]	**21.12, 21.11**	Part 48 & **20.12**
c)	Heating cycle voltage test	**21.13**	Part 49
d)	Partial discharge tests		
	- at ambient temperature	**21.9**	Part 46
	- at high temperature		
	The tests shall be carried out after the final cycle of heating cycle voltage test or, alternatively, after the lightening impulse voltage test		
e)	Switching impulse voltage Test, as applicable	**21.14.2**	Part 47
f)	Lightening impulse voltage withstand test followed by high voltage test	**21.14.1**	Part 47 & Part 45
g)	Partial discharge tests, if not carried out after final cycle of heating cycle	**21.9**	Part 46
h)	Tests for outer protection for joints, as applicable[3)]	**Annex G**	**Annex G**
i)	Examination of the cable system with cable and accessories[4)]	**21.17**	**21.17**

[2)] Test may be carried out on different sample.

[3)] Test is applicable for type test on cable system. If the cable and joints are not to be subjected to wet conditions in service (i.e. not directly buried in earth or not intermittently or continuously immersed in water), the tests in **G-2** and **G-3.2** shall not be applicable.

For rated voltages up to & including 76/132 kV, test to be performed if agreed between purchaser & supplier.

[4)] In case of Type testing on the cables only, examination of cable shall be performed.

NOTE—Before commencement of the electrical type tests from 'a' to 'i' compliance of 20.5 shall be ensured.

20.1.2.1 The tests from (a) to (g) shall be performed successively on the same test sample of complete cable not less than 10 m in length between the cable accessories subject to provisions as per class. **20.1.2.2**. Also, the minimum length of free cable between adjacent accessories shall be 5 m.

20.1.2.2 During sequential electrical type testing on the cable system, if failure of accessories occurs, it may be repaired or replaced and the testing shall be continued from the point of break.

20.2 Acceptance Tests

20.2.1 The following tests shall constitute Acceptance tests—

	Test	**Ref. of Requirements**	**Ref. of Test Method (IS 10810)**
a)	Conductor construction	IS 8130	IS 8130
b)	DC resistance of Conductor	IS 8130	Part 5
c)	DC resistance of Metallic screen / sheath	**21.2**	**21.2**
d)	Test for dimensions of Insulation &extruded semiconducting screens	**21.15**	Part 6
e)	Hot set test for Insulation	**Table 2**	Part 30
f)	Test for thickness of Metallic sheath	**21.4**	**21.4**
g)	Test for thickness of Outer sheath	**19.3**	Part 6
h)	Test for thickness of Inner sheath (or separation sheath)	**17.4**	Part 6
i)	Diameter of Armour wires, armour coverage	**18.2, 18.3**	**21.5, Annex E**
j)	Partial discharge test (on full drum length)	**21.9**	Part 46
k)	High voltage test	**21.16**	Part 45
l)	Measurement of capacitance	**21.11**	**21.11**

m)	Measurement of diameters (if required)	**21.3**	**21.3**
n)	Lightening Impulse Test[1)]	**21.14.1**	21.14.1
o)	Water penetration Test	**21.7**	**Annex D & E**
p)	Tests for components of cables with longitudinally applied metal tape or foil, bonded to the outer sheath	**Annex H**	**Annex H**
q)	Tests for improved fire performance (as applicable):		
	i) Oxygen Index Test	**21.18**	Part 58
	ii) Temperature Index Test	**21.19**	Part 64
	iii) Test for Halogen Acid Gas evolution	**21.20**	Part 59
	iv) Smoke Density Test	**21.21**	IS 13360-Part 6/Sec 9
	v) Light Transmission test	**21.25**	Part 63
	vi) Flame Retardance Test on single cable	**21.22**	Part 61
	vii) Flame Retardance Test on bunched cables	**21.23**	Part 62-Cat C
	viii) pH & Conductivity test	**Table 5**	**21.24**

[1)] Lightening Impulse Test is not applicable for rated voltages up to & including 76/132 kV having calculated electrical stress at conductor screen $\leq$ 8 kV/mm.

20.2.2 *Sampling plan for Acceptance Tests*—Acceptance test shall be carried out on one length from each lot of same type and cross-section of cables, but shall be limited to not more than 10% of the number of lengths in any contract rounded off to the nearest whole number, with exception of the tests from n to q which shall be performed on one sample, for contracts with cable length greater than 20 km.

20.3 Routine Tests

20.3.1 The following tests shall constitute Routine test:

	Test	Ref. of Requirements	Ref. of Test Method (IS 10810)
a)	Conductor resistance test	IS 8130	Part 5
b)	High voltage test	**21.16**	Part 45
c)	Partial discharge test	**21.9**	Part 46
d)	dc Voltage Test on outer sheath	**21.25**	**21.25**

20.4 Optional Test (special)

Cold impact test as per IS 10810 (Part 21) &/or Cold Elongation test as per IS 10810 (Part 7) applicable for outer sheath with PVC type ST2 as per IS 5831& LSHF type ST12 as per **Table 5**.

20.5 Check on insulation thickness prior to electrical Type Test, PQ Test or EQ Test

The average value of the insulation thickness shall be measured on the cable test sample, as per Part 6 of IS 10810. If the average thickness of insulation is:

a) not more than 5% over the declared nominal value, the test voltages shall be as specified in **Table 12**;

b) more than 5% but not more than 15% over the declared nominal value, the test voltage as specified in **Table 12** shall be adjusted to give an electrical stress at the conductor screen equal to that in a) above;

c) More than 15% over the declared nominal value, another test sample shall be chosen.

NOTE—The declared nominal value of the insulation thickness in context with **20.5** shall mean the value declared by the manufacturer.

20.6 Prequalification (PQ) test on complete cable system

20.6.1 *Summary of the PQ Tests*—The prequalification test shall comprise the electrical tests on the complete cable system with approximately 100m of full sized cable (minimum 20 m in case of cables with voltage grade up to and including 76/132 kV),including at least one of each type of accessory. The minimum length of free cable between accessories shall be10m.The sequence of tests shall be as follows:

a) Heating cycle voltage test (*see* **20.13.2**);
b) Lightning impulse voltage test (*see* **20.14**);
c) Examination of the cable system after completion of the tests above (*see* **20.17**).

It could be the case that one or more of the accessories did not fulfill all the requirements of the prequalification tests in **20.6**. After repair of the test assembly, the prequalification tests may be continued on the remaining cable system (cable with the remaining accessories). In case all the requirements of the tests in **20.6** are met by this remaining cable system, this remaining system is prequalified. The accessory or accessories that did not fulfill the requirements are excluded from this prequalification.

However, the test may be continued for prequalification of the cable with the replaced accessory until all requirements of **20.6** are met. If the manufacturer decides to include the repaired accessory in the cable system prequalification, the beginning of the prequalification test of the complete system is considered starting after the repair.

20.6.2 *Test Arrangement for PQ test*—Cable and accessories shall be assembled in the manner specified by the manufacturer's instructions, with the grade and quantity of materials supplied, including lubricants, if any.

The test arrangement shall be representative of the installation design conditions, e.g. Flexible and transition arrangements, underground and in air. In particular, special attention shall be paid to thermo-mechanical aspects of accessories.

The test loop shall have U bend with diameter not greater than the test cylinder diameter as specified in **21.10**.

Ambient conditions may vary between installations and during the test and are not considered to have any major influence.

20.7 Tests for the extension of the prequalification (EQ) of a cable system

20.7.1 *Summary of the EQ Test*—The extension of prequalification tests shall comprise the electrical part of the tests on the complete cable system as specified in **20.7.2** and the non-electrical tests on the cable as specified in **20.1.1**.

20.7.2 *Electrical part of the EQ Test*—The tests listed in **20.7.3** shall be performed on one or more samples of complete cable of the already prequalified cable system, or having minor changes from an already prequalified design, depending on the number of accessories involved. The sample of the cable system shall contain at least one accessory of each type that needs the extension of the prequalification. The accessories, if any, shall already have been prequalified on a different cable system (with an insulation screen stress at least as high as the value for the EQ test) or had minor changes from the prequalified design.

The test may be performed in a laboratory and not necessarily in a situation simulating the real installation conditions.

The minimum length of cable between accessories shall be 5 m. The minimum total cable length shall be 20 m.

The test loop shall have U bend with diameter not greater than the test cylinder diameter as specified in **21.10**.

If the prequalification of a joint is to be extended for use both in flexible and in rigid installations, one joint shall be installed in a flexible configuration and the other one in a rigid configuration.

20.7.3 Sequence of the electrical part of the EQ tests

a) installation of the accessories shall be carried out by the manufacturer;
b) partial discharge test at ambient temperature (**21.9**) to check the quality of the installed accessories;

c) heating cycle test without voltage (**21.13.3**);
d) tan δ measurement (**21.12**);

NOTE - This test may be carried out on a different cable sample with special test terminations from that used for the remainder of the sequence of tests.

e) Heating cycle voltage test (**21.13**);
f) Partial discharge test (**21.9**) at ambient temperature and at high temperature. These tests shall be carried out after the final cycle of item e) above or, alternatively, after the lightning impulse voltage test in item h) below;
g) Switching impulse test (**21.14.2**) (applicable for rated voltage 220/400 kV only);
h) Lightning impulse voltage test followed by a power frequency voltage test (**21.14.1**);
i) Partial discharge tests, if not previously carried out in item f) above;
j) Tests of outer protection for joints (*see* **Annex F**);
k) Examination of the cable and/or accessories, shall be carried out after completion of the above tests (**21.17**).

21. METHOD OF TESTS

21.1 Resistivity test for semi-conducting screen (before ageing and after ageing as specified in **21.8**)

The resistivity for extruded semiconducting layers applied over the conductor and over the insulation shall be determined by measurement on test pieces taken from the core.

The procedure for measurement shall be in accordance with **Annex C**.

The resistivity shall not exceed the following:

i) Conductor Screen 1 000 Ohm-m
ii) Insulation Screen 500 Ohm-m

21.2 d.c. resistance of metallic sheath or screen

The d.c. resistance of metal sheath and / or screen shall be measured and corrected to a temperature of 20^0C and 1 km length as per IS 10810 Part 5. Correction factors for Aluminium, Copper shall be as per IS 8130.

NOTE -For temperature correction factors of other materials reference of IEC 60287-1-1 may be taken.

The corrected d.c. resistance at 20^0C shall not exceed the value declared by supplier.

21.3 Measurement of Cable diameters (where required)

Observed values shall be recorded. Test method under consideration. Reference may be taken from IEC 60811-203.

21.4 Measurement of thickness of Metallic Sheath

Thickness of lead sheath and Aluminium sheath shall be measured as per IS 10810 Part 34 and values shall not fall below the specified value in **Table 8**.

21.5 Dimension of armour wires / formed wires

a) *Non-magnetic armour wires:*

On a test piece with a length of around 1 m, all layers over the armour shall be removed. 10% of the armour wires subject to maximum 5 numbers shall be straightened and diameter shall be measured.

The average value of measured diameter shall not be less than nominal diameter specified in **Table 10** and minimum measured diameter shall not be less than the specified nominal values by more than 0.1 mm.

b) *Galvanised steel round wires or steel formed wires*:

The measured dimensions shall conform to **Table 10** & relevant tolerances as per IS 3975.

21.6 Flammability Test (for PVC sheathed cables)

Period of burning after removal of the flame shall not exceed 60 seconds and the unaffected (un-charred) portion from the lower edge of the top clamp shall be at least 50 mm.

21.7 Water Penetration Test

This test shall be carried out as specified in **Annex D** and **Annex E**. There shall be no water leakage from the ends of the sample.

Note: Water penetration test is applicable for cables with longitudinal water tightness features included in the cable. For three core cables, if conductor or metallic screens are longitudinally watertight, then the test shall be performed on one of the cores taken from the cable.

21.8 Thermal Ageing Tests on Complete Cable

This test shall be carried out to check that the insulation, non-metallic sheath and extruded semi-conducting layers over the conductor and insulation are not liable to deteriorate in operation due to contact with other components in the cable.

Three pieces of complete cable about 200 mm long shall be suspended vertically and substantially in the center of the oven at least 20 mm away from each other and shall not occupy more than 2% of the volume of the oven. The pieces of cable shall be kept in the oven at the temperature of $100 \pm 2^{o}C$ for duration of 168 hours.

a) The test pieces of insulation and sheath from the aged pieces of cable shall be prepared and subjected to tensile strength and elongation at break.

   The test results for tensile strength and elongation at break shall comply with the values of insulation and sheath after ageing as given in **Table 2** for insulation and IS 5831 for PVC outer sheath and **Table 4** for PE outer sheath and **Table 5** for LSHF sheath.

b) The resistivity of the extruded semi-conducting layers shall be as per **20.1**.

21.9 Partial Discharge Test

The partial discharge test shall be carried out in accordance with IS 10810 (Part 46), except for the test voltages and durations. The sensitivity shall be 10 pC or better for Routine & Acceptance Test and 5 pC or better for Type Test & EQ Test.

The test voltage shall be gradually increased to 1.75 times Uo maintained for 10 seconds and then slowly reduced to 1.5 times Uo and the partial discharge magnitude is measured.

When performed at high temperature, the test shall be carried out at a conductor temperature of 95 to $100^{0}C$ and the temperature shall be maintained for at least 2 hours.

There shall be no detectable discharge exceeding declared sensitivity from the test object at 1.5 U_0.

21.10 Bending Test

The bending test shall be carried out as per IS 10810 (Part 50).

The nominal diameter of the test cylinder shall be:

i) for cables with lead sheath, corrugated aluminium sheath and longitudinally applied laminated tape:
   - 25 (D+d) for single core cables;
   - 20 (D+d) for 3 core cables;

ii) for cables with smooth aluminium sheath bonded to the outer sheath: 20 (D+d);

iii) for other cables:
- 20 (D+d) for single core cables;
- 15 (D+d) for three core cables.

where,
D = Nominal overall diameter of the cable in mm,
d = Nominal diameter of the conductor in mm.

Tolerance for the diameter of the test cylinder is -0% to +5%. Smaller bending diameters may be used at the discretion of the manufacturer.

21.11 Capacitance measurement

Capacitance of the test sample shall be measured between conductor and metal screen / sheath, at ambient temperature. The measured value shall not exceed nominal value declared by the manufacturer by more than 8%.

21.12 Tan δ measurement (Dielectric Power factor Test)

The sample shall be heated by passing current through the conductor until the conductor reaches a steady temperature not less than 95ºC and not greater than 100ºC.

The tan δ (dielectric power factor) shall be measured as per IS 10810 (Part48) at U_o at the temperature specified above. The measured value of tan δ shall not exceed 0.001.

21.13 Heating Cycle Voltage Test

Heating cycle voltage test shall be carried out as per IS 10810 (Part 49), the test voltages shall be as specified here.

The sample shall be laid on the floor of the test room in a U bend having the diameter specified in **21.10**.

The sample shall be heated by passing current through the conductor so that the conductor reaches a steady temperature not less than 95 ºC and not more than 100 ºC.

The heating shall be applied for at least 8 hours. The conductor temperature shall be maintained for at least 2 hours of each heating period, followed by at least 16 hours of natural cooling.

NOTES
i) Heating cycles with a conductor temperature higher than 100^0C are also considered valid.
ii) Interruption of the heating cycles or the test voltage is allowed during the test, however required minimum number of cycles shall be carried out irrespective of interruptions.

21.13.1 *Heating Cycle Voltage Test (as Type Test & EQ Test)*—The cycle of heating and cooling shall be carried out 20 times. During the entire period of test a voltage of2Uo shall be applied to the assembly.

There shall be no breakdown during the test.

21.13.2 *Heating Cycle Voltage Test (as PQ Test)*—The cycle of heating and cooling shall be carried out at least 180 times. During the entire period of test 8760 h, a voltage of 1.7 U_o shall be applied to the assembly.

There shall be no breakdown during the test.

21.13.3 *Heating Cycle without Voltage Test (as EQ Test)*—The cycle of heating and cooling shall be carried out at least 60 times.

21.14 Impulse voltage withstand test:

21.14.1 *Lightening Impulse Voltage Test (followed by Power frequency Voltage Test)*—The cable (system) shall

withstand without failure 10 positive and 10 negative voltage impulses at conductor temperature not less than 95ºC and more than 100ºC, of the appropriate value specified **Table 12**.

The impulse wave form shall have a virtual Front time between 1µs and 5 µs and a nominal time to half the peak value between 40 µs and 60 µs. In other respects, the impulse pulse shall be in accordance with IS 10810 (Part 47).

After the impulse test, the cable sample shall be subjected to power frequency AC voltage test as per IS 10810 (Part 45) at 2.5 times the rated voltage U_o for 15 minutes for cables up to and including 76/132 kV and 2.0 times the rated voltage U_o for 15 minutes for voltage grade 127/220 kV and 220/400 kV, at room temperature and no breakdown of the insulation shall occur.

21.14.2 *Switching Impulse Voltage Test (applicable for rated voltage 220/400 kV)*—The cable shall withstand 1050 kV, without failure 10 positive and 10 negative voltage impulses at conductor temperature not less than 95ºC and more than 100ºC.

The impulse wave form shall have a virtual time to peak between 200 µs and 300 µs and a nominal time to half the peak value between 1000 µs and 4000 µs. In other respects, the impulse pulse shall be in accordance with IS 10810 (Part 47).

21.15 Test for Dimensions of Insulation& Extruded semiconducting screens

a) Test for thickness of extruded conductor & insulation screen

Thickness shall be measured as per IS 10810 (Part 6) and conform to **12.2** & **14.2.2**.

b) Test for Thickness of Insulation

Thickness shall be measured as per IS 10810 (Part 6) and shall conform to **13.2** & **13.3**.

c) Test for Eccentricity of Insulation

The eccentricity of the insulation shall be checked as follows:

Eccentricity (%) $=[t_{max} - t_{min}] / [t_{max}] \times 100$

where,*t* stands for the thickness of insulation (mm).

The eccentricity shall not be more than 15% for voltage grades up to and including 76/132 kV and not more than 10% for 127/220 kV and 220/400 kV.

NOTES -

i) t_{max} and t_{min} are the maximum & minimum thickness measured at the same cross-section of the insulation.

ii) The thickness of the semi-conducting screens on the conductor and over the insulation shall not be included in the thickness of the insulation.

d) Test for Ovality of core

The ovality of the core shall be checked as follows:

Ovality (%) $=[d_{core\ max} - d_{core\ min}]/ [d_{core\ max}] \times 100$

where, *d* stands for the diameter of the core (mm).

The ovality shall not be more than 5%.

21.16 High Voltage Test (As Routine and Acceptance Tests)

The cable shall withstand without any failure the power frequency AC voltage between conductor and metallic screen / sheath at room temperature as per **Table 12**.

21.17 Examination of cable and accessories

Examination of the cable by dissection of a sample and, whenever possible, of the accessories by dismantling, with normal or corrected vision, without magnification, shall reveal no signs of deterioration (e.g., electrical degradation, leakage, corrosion or harmful shrinkage) which could affect the system in service operation.

21.18 Oxygen Index Test (applicable for cables with FR or FRLSH or LSHF sheath)

Test performed as per IS 10810 (Part 58), on samples of outer sheath at ambient temperature, Oxygen Index shall not be less than 29.

21.19 Test for Temperature Index (applicable for cables with FR or FRLSH or LSHF sheath)

Test performed as per IS 10810 (Part 64) the extrapolated value of Temperature Index shall be Min. 250^0C at Oxygen Index of 21.

21.20 Test for Halogen Acid Gas Evolution (applicable for cables with FRLSH or LSHF sheath)

Test performed as per IS 10810 (Part 59), the level of HCL evolved shall not exceed 20 % by weight, for FRLSH and shall not exceed 0.5% for LSHF.

21.21 Test for Smoke Density (applicable for cables with FRLSH or LSHF sheath)

Test performed as per IS 13360 (Part 6/ Sec 9), Smoke Density Rating shall be maximum 60% for FRLSH and maximum 20% for LSHF.

21.22 Flame Retardance Test on single cable (applicable for FR or FRLSH or LSHF sheathed cables having overall diameter $\leq$ 35 mm)

After burning has ceased, there should be no visible damages on the test specimen within 300 mm from upper end. Mark of fixing devices, soot or changing of colour are not considered as damages.

21.23 Flame Retardance Test on Bunched Cables (applicable for FR or FRLSH or LSHF sheathed cables)

After burning has ceased, the cables shall be wiped clean and charred or affected portion should not have reached a height exceeding 2.5 m above the bottom edge of the burner, measured at the front and rear of the cable assembly.

NOTE—Requirements for this test are split in 3 categories that is A, B, C in IS 10810(Part 62). For the purpose of this standard, Category C test method shall be used.

21.24 pH & conductivity of LSHF sheath:

Test method is under consideration. IEC 60754-2 may be referred.

21.25 Light transmission for LSHF cables:

Completed cables shall be tested as per IS 10810 (Part 63). Light Transmittance shall be Min. 60%.

21.26 DC Voltage test on sheath:

A d.c. voltage of 8 kV per mm of the specified minimum thickness of the extruded outer sheath shall be applied for 1 min between the underlying metal layer at negative polarity and the outer conducting layer subject to maximum voltage of 25 kV.

No breakdown of outer sheath shall occur during the test.

NOTE- Test is applicable for Outer sheath having outer conductive layer.

21.27 Test Voltages: As per **Table 12**.

Table 12
(Clause 21.27)
Test Voltages

Rated Voltage Uo/U	Highest voltage Um	Uo	[1]High voltage test 21.16		PD Test 21.9	Tan Delta measurement 21.12	Heating cycle Voltage Test 21.13.1	Lightening Impulse Voltage test 21.14	Switching Impulse test voltage 21.14.2	Voltage Test after Impulse test 21.14.1
kV	kV	kV	kV	min	kV	kV	kV	kV	kV	kV
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
26/45	52	26	65	30	39	26	52	250	-	65
38/66	72.5	38	95	30	57	38	76	325	-	95
64/110	123	64	160	30	96	64	128	550	-	160
76/132	145	76	190	30	114	76	152	650	-	190
127/220	245	127	318	30	190	127	254	1050	-	254
220/400	420	220	440	60	330	220	440	1425	1050	440

SECTION 5 IDENTIFICATION, PACKINGAND MARKING

22. IDENTIFICATIONS

22.1 Manufacturer's Identification - The manufacturer shall be identified throughout the length of the cable by manufacturer's name or trade-mark and the voltage grade and year of manufacture indented, printed or embossed. The indentation, printing or embossing shall be done only on the outer sheath. Additionally, the cable outer sheath shall be marked with **FR** or **FR-LSH**, **LSHF** for such type of cables.

22.2 Cable Code – The following code shall be used for designating the cable:

Sl no.	Constituent	Code Letter
a)	Aluminium conductor	A
b)	XLPE insulation	2 X
c)	Copper screen	C
d)	Non-magnetic round wire armour	Wa
e)	Galvanised steel wire armour	W
f)	Galvanised steel formed wire armour	F
g)	Lead alloy sheath	Ly
h)	Aluminium sheath	A
i)	PVC outer sheath	Y
j)	PE outer sheath	2Y
k)	LSHF outer sheath	Z

NOTE—No code letter for conductor is required when the conductor material is copper.

23 PACKING AND MARKING

23.1 The cable shall be wound on a steel or wooden drum and packed. The ends of the cable shall be sealed by means of a non-hygroscopic sealing material.

NOTE—Guidelines for wooden drums maybe taken from IS 10418. Steel drums shall be as per drum supplier's standard. The recommended minimum barrel diameter of the drum for single core cables shall be 20 times nominal overall diameter of the cable and 15 times the nominal overall diameter of the cable for 3 core cables.

23.2 The cable shall carry the following information either stenciled on the drum or contained in a label attached to it:

a) Reference to this Indian Standard, IS 7098 (Part 3);
b) Manufacturer's name or trade-mark;
c) Type of cable and voltage grade
d) Number of cores;
e) Nominal cross-sectional area of conductor;
f) Cable code;
g) Length of cable on the drum
h) Number of lengths on the drum (if more than one);
i) Direction of rotation of drum (by means of an arrow);
j) Gross mass.
k) Country of manufacture;
l) Year of manufacture

23.3 The cable may also be marked with BIS Standards Mark as per BIS certification guidelines.

NOTE- The use of the Standards Mark is governed by the provisions of Bureau of Indian Standards Act, 1986 and rules and Regulations there under. The details of condition under which the license for use of the Standard Mark may be granted to manufacturers or producers may be obtained from Bureau of Indian Standards.

ANNEX A
(Clause 2.1)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
IS 1885 (Part 32) : 2019	Electrotechnical Vocabulary Part 32 Electric Cables (*Second Revision*)
IS 5831:1984	Specification for PVC insulation and sheath of electric cables (*First Revision*)
IS 8130:2013	Conductors for insulated electric cables and flexible cords - Specification (*Second Revision*)
IS 3975:1999	Low carbon galvanized steel wires, formed wires and tapes for armouring of cables - Specification (*Third Revision*)
IS 10810-	Methods of test for cables
(Part 1):1984	Methods of test for cables: Part 1 annealing test for wires used as conductors
(Part 2):1984	Methods of test for cables: Part 2 tensile test for aluminium wires
(Part 3):1984	Methods of test for cables: Part 3 wrapping test - For aluminium wires
(Part 5):1984	Methods of test for cables: Part 5 conductor resistance test
(Part 6):1984	Methods of test for cables: Part 6 thickness of thermoplastic and elastomeric insulation and sheath
(Part 7):1984	Methods of test for cables: Part 7 tensile strength and elongation at break of thermoplastic and elastomeric insulation and sheath
(Part 10):1984	Methods of test for cables: Part 10 loss of mass test
(Part 11):1984	Methods of test for cables: Part 11 thermal ageing in air
(Part 12):1984	Methods of test for cables: Part 12 shrinkage test
(Part 14):1984	Methods of test for cables: Part 14 heat shock test
(Part 15):1984	Methods of test for cables: Part 15 hot deformation test
(Part 21):1984	Methods of test for cables: Part 21 cold impact test
(Part 30):1984	Methods of test for cables: Part 30 hot set test
(Part 32):1984	Methods of test for cables: Part 32 carbon content test for polyethylene
(Part 34):1984	Methods of test for cables: Part 34 measurement of thickness of metallic sheath
(Part 36):1984	Methods of test for cables: Part 36 dimensions of armouring material
(Part 37):1984	Methods of test for cables: Part 37 tensile strength and elongation at break of armouring materials
(Part 38):1984	Methods of test for cables: Part 38 torsion test on galvanized steel wires for armouring
(Part 39):1984	Methods of test for cables: Part 39 winding test on galvanized steel strips for armouring

(Part 40):1984	Methods of test for cables: Part 40 uniformity of zinc coating on steel armour
(Part 41):1984	Methods of test for cables: Part 41 mass of zinc coating on steel armour
(Part 42):1984	Methods of test - For cables: Part 42 resistivity test of armour wires and strips and conductance test of armour (Wires strips)
(Part 45):1984	Methods of test for cables: Part 45 high voltage test
(Part 46):1984	Methods of test for cables: Part 48 partial dischar6e test
(Part 47):1984	Methods of test for cables: Part 47 impulse test
(Part 48):1984	Ethods of test for cables: Part 48 dielectric power factor test
(Part 49):1984	Methods of test for cables: Part 49 heating cycle test
(Part 50):1984	Methods of test for cables: Part 50 bending test
(Part 53):1984	Methods of test for cables: Part 53 flammability test
(Part 58):1998	Method of tests for cables: Part 58 oxygen index test
(Part 59):1988	Part 59 determination of the amount of halogen acid gas evolved during combustion of polymeric materials taken from cables
(Part 60):1988	Methods of test for cables: Part 60 thermal stability of PVC insulation and sheath
(Part 62):1993	Method of tests for cables: Part 62 flame retardance test for bunched cables
(Part 63):1993	Method of tests for cables: Part 63 measurement of smoke density of electric cables under fire conditions
(Part 64):2003	Methods of test for cables: Part 64 measurement of temperature index
IS 13360 (Part 6/Sec 9): 2001	Plastics - Methods of testing: Part 6 thermal properties section 9 determination of density of smoke from the burning or decomposition of plastics
IS 16269:2018	Recommended Short Circuit Ratings of Electric Cables with Rated Voltage from 1.1 kV to 220 kV — Specification
IS 3961 (Part 6):2016	Recommended Current Ratings for Cables Part 6 Cross linked Polyethylene Insulated PVC Sheathed Cables
IS 10462 (Part 1):1983	Fictitious calculation method for determination of dimensions of protective coverings of cables: Part 1 elastomeric and thermoplastic insulated cables

ANNEX B
(Tables 8, 9, 10, 11)
FICTITIOUS CALCULATION METHOD FOR DETERMINATION OF DIMENSIONS OF PROTECTIVE COVERINGS

B-1 GENERAL

B-1.1 The fictitious calculation is used only to determine dimensions of sheaths and cable coverings. It is not a replacement for the calculation of normal diameters required for practical purposes, which should be calculated separately.

B-1.2 The calculated value of fictitious diameter at each stage shall be rounded off to one significant place of decimal, i.e. 0.1 mm, before proceeding to next step. The rounding off shall be done in accordance with IS 2.

B-1.3 Thickness of insulation, metal sheath, inner sheath and armour in this **Annex B**, shall be as specified in this standard or declared by the manufacturer, whichever is higher.

B-2 CALCULATIONS

B-2.1 Conductor

The fictitious diameter of a conductor (d_L) for each cross sectional area shall be taken from **Table B.1**, irrespective of shape or compactness of conductor.

Table B.1
(Clause B-2.1)
Fictitious Diameter of Conductor (d_L)

Conductor Size	d_L	Conductor Size	d_L
mm^2	mm	mm^2	mm
95	11.0	800	31.9
120	12.4	1000	35.7
150	13.8	1200	39.1
185	15.3	1400	42.2
240	17.5	1600	45.1
300	19.5	1800	47.9
400	22.6	2000	50.5
500	25.2	2500	56.4
630	28.3		

B-2.2 Cores

The fictitious diameter of core (D_c) is given by:

$D_c = d_L + 2\ t_i + 3.0$ (mm) [for rated voltage upto and including 127/220 kV]

Dc =dL + 2 ti+ 5.0 (mm) [for rated voltage 220/400 kV]

where, t_i is the nominal thickness of insulation (mm).

NOTE—3.0 mm or 5.0 mm is allowed for extruded semiconducting layers.

B-2.3 Metal Sheath

B-2.3.1 *Lead Sheath*—The increase in fictitious diameter due to Lead sheath shall be twice the minimum thickness of lead sheath (t_m).

B-2.3.2 *Aluminium sheath*—The increase in fictitious diameter due to smooth aluminium sheath shall be twice the minimum thickness of aluminium sheath (t_m) and increase in fictitious diameter due to corrugated aluminium sheath shall be four times the minimum thickness of aluminium sheath (t_m).

B-2.4 Copper Screen

The increase in fictitious diameter due to copper screen (t_c)is given in **Table B.2**.

Table B.2 Increase in Diameter due to Copper Screen
(*Clause B-2.4*)

Area of Cu Screen	**t_c**	**Area of Cu Screen**	**t_c**
mm^2	mm	mm^2	mm
1.5	0.5	50	1.7
2.5	0.5	70	2.0
4	0.5	95	2.4
6	0.6	120	2.7
10	0.8	150	3.0
16	1.1	185	4.0
25	1.2	240	5.0
35	1.4	300 & above	6.0

If the cross sectional area of the copper screen lies between two of the values given in the **Table B.2**, then the increase in diameter is that for the higher of the two cross sections.

Area of copper screen shall be calculated as under:

i) Copper wires:

Copper Screen Area=$n \pi d^2 /4$ sq.mm

where,

n is the number of copper wires,

d is the nominal diameter of each wire in mm.

ii) Copper tapes: [only for overlapped tape (s)]

Copper Screen Area = n W Tsq.mm.

where,

n is the number of copper tape(s),

W is the nominal width of copper tape in mm,

T is the nominal thickness of each copper tape in mm.

An increase in fictitious diameter of core D_c shall be taken into account as per **B-2.3** and **B-2.4** or both, as the case may be, depending upon whether metallic part of insulation screen of cable has metal sheath /copper screen or both.

The fictitious diameter over the metal sheath / screen (D_{sc}) is given by-

D_{sc} = D_c + 2 t_m+ t_c (mm) – for lead sheath or smooth aluminium sheath

D_{sc} = D_c + 4 t_m + t_c (mm) – for corrugated aluminium sheath

t_m = declared thickness of metal sheath (mm),

t_c = increase in fictitious diameter due to copper screen (mm)

B-2.5 Diameter over laid up cores

The fictitious diameter over laid-up cores for 3 core cables (D_f) is given by-

D_f = 2.16 x D_{sc} (mm)[For single core cables, D_f = D_{sc}]

B-2.6 Inner sheath or Separation sheath

The fictitious diameter over the inner sheath (D_s) is given by-

D_s = D_f + 2 t_S(mm),

Where, t_S is the specified thickness of inner sheath in mm.

B-2.7 Armour

The fictitious diameter over the armour (D_A) is given by-

D_A =D_S + 2 d_A(mm),

where, d_A is the nominal diameter of armour round wire/ thickness of formed wires in mm.

Note—In case of 3 core cables with radial moisture barrier applied above the laid-up cores or over the inner sheath (or separation sheath), the diameters above the radial moisture barrier shall be calculated in line with **B-2.3** and D_s& D_a will be modified accordingly. No addition to diameter is necessary for radial moisture barrier by laminated tape applied longitudinally.

ANNEX C
(Clause 21.1)

METHOD OF MEASURING RESISTIVITY OF SEMI-CONDUCTING SCREEN

C-1 Test pieces shall be prepared from 150 mm lengths of completed cable.

C-2 The conductor screen test piece shall be prepared by cutting a sample of core in half longitudinally and removing the conductor and separator if any. (**Fig.1a**). The Insulation screen test pieces shall be prepared by removing all the coverings from a sample of core (**Fig.1b**).

C-3 The procedure for determining the resistivity of the screens shall be as follows:

C-3.1 Four silver plated electrodes A, B, C and D (**Fig.1a & 1b**) shall be applied to the semi-conducting surfaces. The two potential electrodes, B and C shall be each placed at least 25 mm beyond the potential electrodes.

C-3.2 Connections shall be made to the electrodes by means of suitable clips. In making connections to the conductor screen electrodes, it shall be ensured that the clips are insulated from the insulation screen on the outer surface of the test sample.

C-3.3 The assembly shall be placed in an oven preheated to 90℃ ± 2℃ and after an interval of 30 minutes, the resistance between the electrodes shall be measured by means of a circuit, the power of which shall not exceed 100 milli-watts.

C-3.4 After the electrical measurements, the diameter over the conductor screen and Insulation and the thickness of the conductor screen and insulation screen shall be measured optically each being the average of six measurements made on the sample.

C-3.5 The volume resistivity in ohm-m shall then be calculated as follows:

(i) Conductor Screen = $[R \pi (D - T) T] / [2L]$

where,

R = Resistance in ohms,
D= Diameter over the conductor screen (m),
T= Average thickness of conductor screen (m), and
L = Distance between potential electrodes (m).

(ii) Insulation Screen=$[R \pi (D + T) T] / L$

where,

R = Measured resistance in ohms,
D = Diameter over the insulation in meters,
T= Average thickness of insulation screen (m), and
L =Distance between potential electrodes (m).

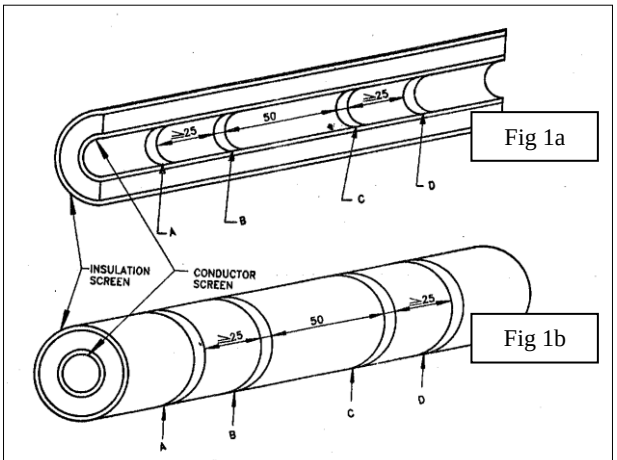

FIG. 1 PREPARATION OF SAMPLE FOR MEASUREMENT OF THE VOLUME RESISTIVITY OF THE CONDUCTOR AND INSULATION SCREENS

ANNEX D
(Clause 21.7)
METHOD FOR WATER PENETRATION TEST

D-1 GENERAL

D-1.1 This test is intended to be applicable to cables which are designed and constructed to meet the requirement of preventing the longitudinal propagation of water along the cable. For three core cables, this test shall be performed on one of the cores.

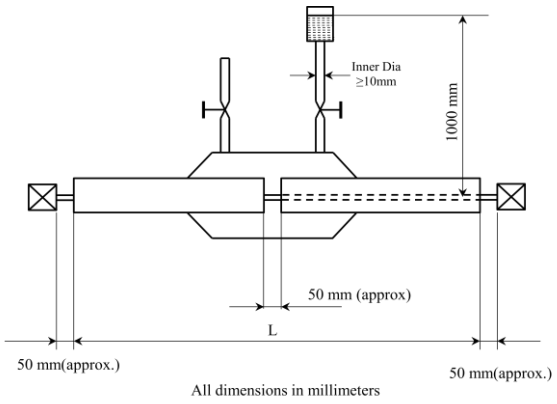

Fig. D.1 ARRANGEMENT FOR WATER-PENETRATION TEST

D-2 TEST SAMPLE

D-2.1 A sample of a complete cable is subjected to bending test as per **21.10**. Length of the sample L (Fig D.1) at least 6 m for rated voltages up to & including 76/132 kV and 8 m for rated voltages 127/220 kV and above, is cut for water penetration test. This test piece is straightened and placed horizontally. An annular ring of approximate 50 mm width is cut from the center of the sample. This ring shall comprise of all the layers external to the insulation screen; where the conductor is claimed to contain a longitudinal water barrier, the ring shall comprise of all the layers external to the conductor.

D-2.2 Suitable arrangements shall be made as in Fig. D.1 for allowing the relevant interstices to be exposed to water pressure of 1 m height. The minimum inner diameter of the water tube shall be 10 mm.

D-2.3 The assembly for maintaining the water pressure shall be suitably mounted on the outer sheath without causing any mechanical stress on it. Normal tap water at ambient temperature shall be used in the pressure head. The conductor ends shall be fitted with connections for circulation of suitable current through the conductor. Arrangements for the temperature measurements at the conductor shall be made.

D-3 TEST PROCEDURE

The test assembly as shown in Fig. D.1 shall be filled with normal tap water at ambient temperature and kept for a period of 24 h. The cable shall then be subjected to 10heating cycles. The heating period shall be 8 h followed by 16 h of natural cooling. During heating period suitable current shall be passed through the conductor, so that the conductor temperature is raised to a value between 95℃ and 100℃. However, it shall not reach the boiling point of water.

The specified conductor temperature shall be attained during last two hours of the heating period.

ANNEX E
(Clause 21.7)
METHOD FOR WATER PENETRATION TEST IN THE CONDUCTOR

E-1GENERAL

E-1.1 This test is intended to be applicable to conductors which are designed and constructed to meet the requirement of preventing the longitudinal propagation of water along the conductor. For three core cables, this test shall be performed on one of the cores.

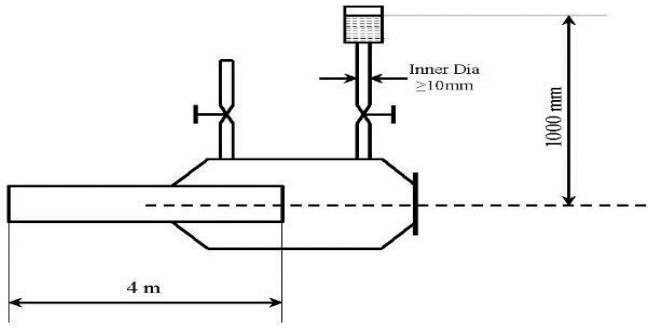

Fig. E.1 ARRANGEMENT FOR WATER-PENETRATION TEST IN CONDUCTOR

E-2 TEST SAMPLE

E-2.1 A sample of a complete cable is subjected to bending test as per **21.10**. Length of the sample 4 m is cut for water penetration test. This test piece is straightened and placed horizontally. All layers external to the insulation screen shall be removed from the sample and full cross section of the conductor shall be exposed at both ends of the test piece.

E-2.2 Suitable arrangements shall be made as in Fig. **E.1** for allowing the relevant interstices to be exposed to water pressure of 1 m height. The minimum inner diameter of the water tube shall be 10 mm.

E-2.3 The chamber shall be sealed to the surface of the insulation screen without causing any mechanical stress on it. Normal tap water at ambient temperature shall be used in the pressure head.

E-3 TEST PROCEDURE

The test assembly as shown in Fig. **E.1** shall be filled with normal tap water at ambient temperature. The sample shall be allowed to stand for 11 days at ambient temperature.

ANNEX F
(Clause 18.3)
CALCULATION OF ARMOUR COVERAGE PERCENTAGE

Armour coverage (%) = (N x d / W) x 100

where,

N=Number of armour wires
d= diameter wire/width of formed wires
W=π x D x Cos a
D=diameter under armour
a=angle between armouring wire/formed wires and axis of cable
tan a=π x D/C, and
C=lay length of armouring wires/formed wires

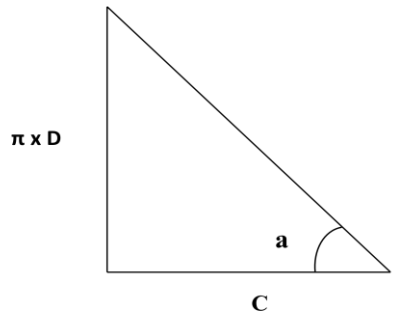

FIG E.1 Armour Coverage

ANNEX G
(Clause 20.1.2 h)
TEST OF OUTER PROTECTION FOR JOINTS

G-1 General

This test is applicable for type approval testing of joints outer protection of all types, used in buried joints or sheath interrupters employed on insulated sheath power cable systems and, where employed, the associated sheath sectionalizing insulation with screen interruption joints.

Tests in G-2 and G-3 shall be applied successfully to a joint which has passed the heating cycle voltage test (**21.13.1**) or to a separate joint which has undergone at least 20 thermal cycles (**21.13.1**) without voltage.

G-2 Water Immersion and heat cycle tests-

The test assembly shall be immersed in water at a depth of not less than 1 mtr at the highest point of the outer protection.

Total 20 thermal cycles (heating & cooling) shall be applied by raising the water temperature to within 70°C to 75°C. In each cycle the water shall be raised to the specified temperature, maintained for at least 5 hours and then permitted to cool to within 10°C above ambient temperature.

The minimum duration of each heating and cooling cycle shall be 12 hours and duration of raising water temperature to the specified temperature shall be as much as possible the same as duration for cooling the water to within 30°C or 10°C above ambient, whichever is higher.

G-3 Voltage tests-

G-3.1 General–

On completion of the heating cycles and with test assembly still immersed, voltage test shall be carried out as follows.

If it is not practicable to carry out the impulse test on the assembly whilst immersed in water, it may be removed from water and voltage tests carried out with a minimum of delay or it may be maintained wet by wrapping with a fabric or a conductive coating may be applied over the entire exterior surface of the test assembly.

No breakdown of the test object shall occur during any of the electrical withstand tests.

Failure or flashover of a termination of the cable shall not be considered a failure of the test object.

G-3.2 Assemblies embodying accessories without sheath sectionalizing insulation -

A test voltage of 25 kV d.c. shall be applied for 1 minute between the metal screen / sheath of the Power cable and the earthed exterior of the joint outer protection.

G-3.3 Assemblies embodying sheath sectionalizing insulation-

G-3.3.1 DC voltage tests-

A test voltage of 25 kV d.c. shall be applied for 1 minute between the metal screen / sheath of the Power cable at either end of the accessory, and also between the metal screens/sheath and the earthed exterior of the joint outer protection.

G-3.3.2 Impulse Voltage Test-

To test each part to earth, test voltage as per **Table G.1** shall be applied between metal screen / sheath and the exterior of assembly.

The test shall be performed with joint being at ambient temperature.

For the test between the metal screens/sheath, the assembly shall be removed from water. Test voltage as per **Table G.1** shall be applied.

No breakdown shall occur during any of the above tests. Failure or flashover of a termination of the cable shall not be considered failure of the test object.

Table G.1
(Clause G-3.3.2)
Test voltages for Impulse Test

Rated Voltage	Between parts	Each part to earth
kV	kV	kV
	A / B	A / B

26/45 &38 / 66	60 / 60	30 / 30
64 /110 & 76/132	60 / 75	30 / 37.5
127/220	60 / 95	30 / 47.5
220/400	75 /125	37.5 / 62.5

A - Bonding lead ≤3 mtrs or if sheath voltage limiters are placed adjacent to the joint,

B- Bonding lead > 3mtrs and ≤ 10 mtrs

G-4 Examination of the test assembly-

On completion of the tests as above, the test assembly shall be examined as follows:
-the accessory shall be examined with respect to the water protection barriers;

- Outer protection boxes filled with removable compounds shall be considered satisfactory if there is no visible evidence of either internal voids or internal displacements of compound by water ingress, or of compound loss via seals or box walls.

- Joint outer protections employing alternative designs & materials, there shall be no evidence of water ingress or internal corrosion behind the water protection barriers.

ANNEX H

TESTS ON COMPONENTS OF CABLES WITH A LONGITUDINALLY APPLIED METAL TAPE OR FOIL, BONDED TO THE OUTERSHEATH

H.1 Visual inspection

The cable shall be dissected and visually examined. Examination of the samples with normal or corrected vision without magnification shall reveal no de-lamination, folding, cracking or tearing of the metal tape or foil, or buckling or crossing of screen wires.

H.2 Adhesion strength of metal tape or foil

H.2.1 Procedure

The test specimen shall be taken from the cable covering where the metal tape/foil is adhered to the outer sheath.

The length and width of the test specimen shall be approximately 200 mm and 10 mm, respectively.

One end of the test specimen shall be peeled between 50 mm and 120 mm and inserted in at ensile testing machine by clamping the free end of the outer sheath in one grip. The free end of the metal tape or foil shall be turned back and clamped in the other grip (**Fig H-1**).

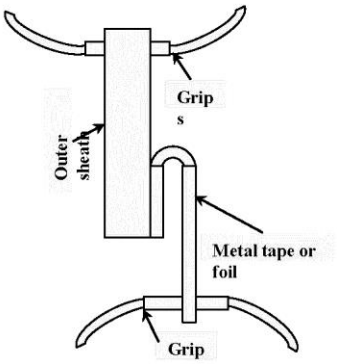

Fig H-1 Adhesion of metal tape or foil

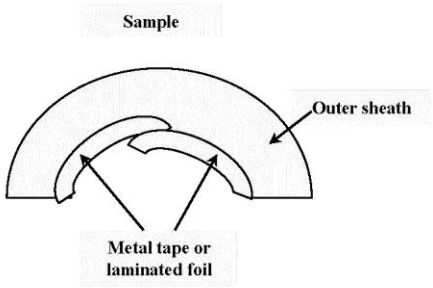

Fig H-2 Overlapped metal foil

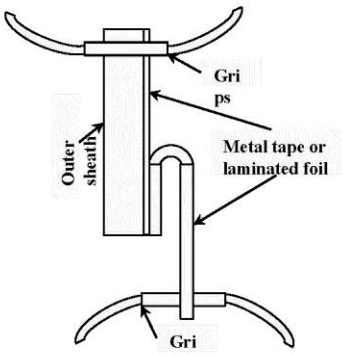

Fig H-3 Peel strength of overlapped metal foil

The specimen shall be held approximately vertical in the plane of the grips during the test.

After adjusting the continuous recording device, the metal tape/foil shall be stripped from the specimen at an angle of approximately 180° and the separation continued for a sufficient distance to indicate the adhesion strength value. At least one half of the remaining bonded area shall be peeled with a speed of approximately 50 mm/min.

H.2.2 Requirements

The adhesion strength shall then be calculated by dividing the peel force (F) in Newton, by the width of the specimen (w) in mm.

Total five test specimens shall be there, three on the overlap of metal foil or weld of the metal tape and two from the opposite side of the cable.

Minimum value of the adhesion strength shall be 1.0 N/mm.

NOTE—When the adhesion strength is greater than the tensile strength of the metal tape or foil so that the latter breaks before peeling, the test shall be terminated and the break point shall be recorded.

H.3 Peel strength of overlapped metal foil

H.3.1 Procedure

A sample specimen approximately 200 mm in length shall be taken from the cable including the overlapped portion of the metal foil. The test specimen shall be prepared by cutting only the overlapped portion from this sample (**Fig H-2**).

The test shall be conducted in the same manner as described in **H.2**. The arrangement of the testspecimen is shown in **Fig H-3**.

H.3.2 Requirements

The minimum value of the peel strength (F/w) shall be 1.0 N/mm.

NOTE–When the peel strength is greater than the tensile strength of the metal foil so that the latter breaks before peeling, the test shall be terminated and the breakpoint shall be recorded.

ANNEX I
(Informative)

I.1 Earth continuity conductors & Sheath Bonding cables:

a. Conductor size: Carry full screen earth fault rating of the Power cable.

b. Conductor material and flexibility: Copper, Class 2 or Class 5 as per IS 8130 (as specified by customer).

c. Insulation: XLPE/EPR/PVC, conforming to IS:7098 (Part1) or IS:7098 (Part 2), IS:9968 (Part 1) or IS:9968 (Part 2), IS:1554 (Part 1) or IS:1554 (Part 2).

d. Insulation thickness:

Earth continuity conductors: as per relevant standard such as IS 7098 (part 1), IS 1554 (Part 1), IS 9968 (Part 1)

Sheath bonding cables: Min. 3.3 mm.

Coaxial sheath bonding cables: Inner insulation Min. 4.4 mm and Outer insulation Min. 3.3 mm.

e. Outer conductor: concentric copper, area same as that of phase conductor

f. Outer sheath: PVC ST2 and thickness shall be as per relevant such as IS 7098 (Part 1), IS 1554 (Part 1), IS 9968 (Part 1).

g. Outer conductive coating such as graphite for sheath bonding cables and coaxial sheath bonding cables, is optional.

h. Test voltages for finished cables:

i. *Earth continuity conductors:* as per relevant standard such as IS 7098 (Part 1), IS 1554 (Part 1), IS 9968 (Part 1).

ii. *Sheath bonding cables:* 25 kV dc for 1 minute.

iii. *Coaxial sheath bonding cables:* Inner insulation 20 kV ac for 5 minutes and outer insulation 25 dc for 1 minute.

I.2 Handling &Installation of cables

I.2.1 Minimum Bending Radius (recommended)

Cables with Corrugated Al. sheath	20 x OD
Cables with Lead sheath	18 x OD
Cables with Laminated sheath	20 x OD
Cables with smooth Al. sheath bonded to Outer sheath	20 x OD
3 core cables	15 x OD

OD-Overall diameter of cable

I.2.2 Sheath Bonding methods& Sheath Voltage:
Reference may be taken from IEEE 575.

I.2.3 Electrical tests after installation:
Reference may be taken from IEC 60840 / IEC 62067.

I.4 Short circuit rating:

Reference may be taken from IS 16269 for adiabatic heating and IEC 60949 for non-adiabatic heating methods.

I.5 Continuous Current rating:
Reference may be taken from IEC 60287-1.

I.6 Emergency loading and cyclic loading:
Reference may be taken from IEC 60853.

ANNEX J
(*Foreword*)
COMMITTEE COMPOSITION
Power Cables Sectional Committee- ETD 09

Organization	Member Name
Central Power Research Institute, Bengaluru	SMT. MEENA K.P. ***(Chairperson)***
3 M Electro & Communication India Private Limited Bengaluru	SHRI SANJAY JHA SHRI PERMEET SINGH *(Alternate Member I)* SHRI ASHISH AGARWAL *(Alternate Member II)*
Apar Industries Limited, Mumbai	SHRI AMIT KUMAR SAMANTA SHRI BHARAT PATEL *(Alternate Member)*
Bharat Heavy Electrical Limited, New Delhi	SMT. TI SANTHA SHRI SAROJ KUMAR *(Alternate Member)*
Calcutta Electric Supply Corporation Limited, Kolkata	SHRI KIRIT RANA SHRI ARNAB GUHA *(Alternate Member)*
Central Board of Irrigation and Power, New Delhi	SHRI MANAS BANDYOPADHYAY SHRI JAIDEEP SINGH *(Alternate Member)*
Central Electricity Authority, New Delhi	SHRI YOGENDRA KR. SWARNKAR SHRI PAWAN KUMAR GUPTA *(Alternate Member)*
Central Power Research Institute, Bengaluru	SMT. R. ARUNJOTHI SHRI THIRUMURTHY *(Alternate Member I)* DR. NEHA ADHIKARI *(Alternate Member II)* SHRI P.V.SATHEESH KUMAR *(Alternate Member III)*
Central Public Works Department, New Delhi	SHRI SANDEEP MEHTA SHRI VIMAL KUMAR *(Alternate Member)*
Coal India Limited, Kolkata	SHRI RAI T. SHRI ROY S.K. *(Alternate Member)*
Delhi Metro Rail Corporation Limited, Delhi	SHRI DEVINDER SINGH PARMAR SHRI ASHISH ARORA *(Alternate Member)*
Electrical Research and Development Association, Vadodara	SHRI SHAILESH PATEL SHRI SHEETAL PANCHAL *(Alternate Member)*
Engineers India Limited, New Delhi	SHRI A. SAI SHRI MEHUL BASU *(Alternate Member I)* SHRI VIRENDRA TIWARI *(Alternate Member II)*
Ensto India Private Limited, Gurugram	SHRI SANJAY GUPTA
Finolex Cables Limited, Pune	SHRI P.N. KHAIRNAR SHRI BIPIN PATIL *(Alternate Member)*
Finolex J-Power Systems Limited, Pune	SHRI PRANAV VASANI SHRI AVIJIT CHAKRABORTY *(Alternate Member)*

Gujarat Energy Transmission Corporation Limited, Vadodara	SHRI A.A. JOSHI SMT. DHARA D. BHATT *(Alternate Member)*
Haryana Vidyut Prasaran Nigam Limited, Panchkula	ER. AMIT GAHLAWAT ER. VASU BAGGAN *(Alternate Member)*
Havells India Limited, Noida	SHRI HEM CHAND
Indian Electrical and Electronics Manufacturers Association, New Delhi	SHRI VIVEK ARORA SHRI RISHABH JOSHI *(Alternate Member*
International Copper Association India, Mumbai	SHRI AMOL KALSEKAR SHRI AVINASH KHEMKA *(Alternate Member I)* SHRI JYOTISH PANDE *(Alternate Member II)*
KEC International Limited, Mumbai	MS. RAJANI PANDE SHRI BHOOPENDRA SINGH *(Alternate Member I)* SHRI SUMIT SARDANA *(Alternate Member II)*
Lapp India Private Limited, Jigani	SHRI KUMAR KRISHNA S.
NTPC Limited, New Delhi	SHRI PRABHAT RANJAN SHRI RAJESH SHARMA *(Alternate Member)*
National Capital Region Transport Corporation, New Delhi	SHRI PAVAN KUMAR P. SHRI AFROZ ANSARI *(Alternate Member)*
National Hydroelectric Power Corporation, Faridabad	SHRI PANKAJ PRASOON MS. RASHMI SRASWAT *(Alternate Member)*
Nuclear Power Corporation of India Limited, Mumbai	SHRI ANANTHACHARI MANNEPALLI SHRI. SHASHANK SINGH *(Alternate Member)*
Paramount Communication Limited, Mumbai	SHRI ARUN SHARMA *(Alternate Member)*
Polycab Wires Private Limited, Mumbai	SHRI BHARAT SEHGAL SH. ANIL KUMAR *(Alternate Member)*
Power Grid Corporation of India, Gurugram	SHRI SUDHAKAR GUPTA SHRI BHASKAR DA *(Alternate Member)*
RR Kabel Limited, Silvassa	SHRI JOSE THOMAS SHRI RANADIP BHAUMIK *(Alternate Member I)* SHRI RONAK BHATT *(Alternate Member II)* SHRI BALACHANDRAN DHARMAN *(Alternate Member III)*
Raychem RPG Private Limited, Chennai	SHRI R.S. ANEKAR SHRI ABHIJIT DHAMALE *(Alternate Member I)*
Shakun Polymers Limited, Vadodara	SHRI PRITEN SHAH SHRI. PRATIK NAYAK *(Alternate Member)*
Shriram Institute for Industrial Research, Delhi	SHRI P.K. KAICHER SHRI JAIN PANKAJ *(Alternate Member)*
Steel Authority of India Limited (SAIL), New Delhi	SHRI SUBHASH RATHORE SHRI RAVI SHANKAR *(Alternate Member)*
Sterlite Power Transmission Limited, New Delhi	SHRI RAJESH GULATI SHRI KAMAL KHANNA *(Alternate Member)*
Tamil Nadu Electricity Board, Chennai	SUPERINTENDING ENGINEER EXECUTIVE ENGINEER/CDD *(Alternate Member)*
Tata Consulting Engineers Limited, Navi Mumbai	SHRI K.PRABHAKAR SHRI G.V. CHANDRA SHEKHAR *(Alternate Member)*
Tata Power Delhi Distribution Limited, New Delhi	SHRI SANJEEV ATRI SHRI KAPIL KUMAR *(Alternate Member)*
Tata Power Limited, Mumbai	SHRI VILAS V. PATIL SHRI MAYURESH V. DEODHAR *(Alternate Member)*
Universal Cables Limited, Gwalior	SHRI YOGENDRA SINGH TIWARI SHRI C.S. MOHANTY *(Alternate Member)*
EXPERT IN PERSONAL CAPACITY, Bengaluru	SHRI B. NAGESHWAR RAO
IN PERSONAL CAPACITY, Bengaluru	SHRI SITARAMAN RAMA PRASATH (Personal Capacity)

BIS Directorate General	SHRI A. R. UNNIKRISHNAN SCIENTIST 'F' AND HEAD (ETD) [REPRESENTING DIRECTOR GENERAL (Ex-officio)]

Member Secretary

MOHAMMAD ISRAFIL
SCIENTIST 'D' (ETD), BIS