Appendixes :

General Introduction to Cable

History of Copper

The word copper comes from the Latin word cuprum, which in turn comes from Cyprium (in English Cyprus) place from which the Romans and the Greeks obtained their copper supplies.
Copper is a metallic element that over millions of years was pushed to the surface by geological rocesses, originating varied deposits of this mineral throughout the planet.
The use of copper dates back to the earliest civilizations, when about 10,000 years ago, mankind slowly began to use this metal to manufacture tools and utensils, setting aside the use of stone as the main material (event that gave rise to a period of pre-history known as "The Copper Age").
The earliest known copper object is an earring found in Northern Iraq, which was made in the year 8,700 B.C.
Over the years, copper was mixed with tin giving rise to Bronze, a metal whose importance gave rise to the Bronze Age. The expansion in the use of this metal began mainly with the Egyptians, who were followed by the Greeks and the Romans.
The latter began to make large scale use of the material, with supplies coming mainly from the island of Cyprus (from where the metal's name originates).

Due to its ductility and resistance to corrosion, copper and its alloys continued to be used in various utensils throughout the middle ages and the centuries that followed; but it was in 1831 when there was a twist in the history of this metal because as a result of his experiments, Michael Faraday discovered electromagnetic induction and the magnificent electrical conductivity properties of copper.

At present, due to the numerous properties of copper, such as: excellent conductivity, maintains its properties in recycling and a good ductility, it is essential to our lives. Today, this noble metal contributes, among other benefits, the fact that we have efficient energy and telecommunications transmissions, the development of information technologies, an excellent urban beautification material in buildings and an efficient bactericide in piping systems, properties that will undoubtedly consolidate and promoted the use of this metal in the future.

Advantages of Copper :

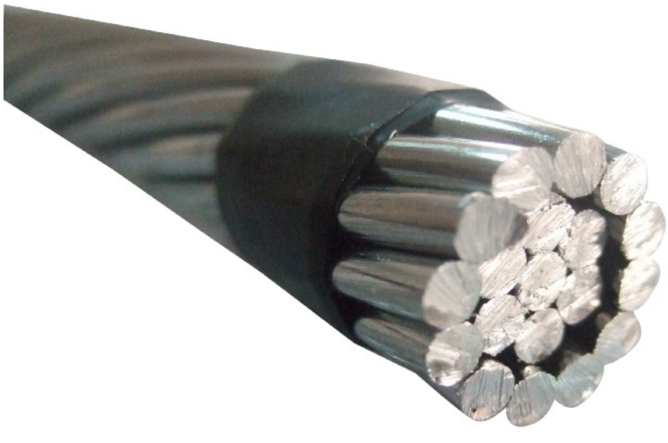
* High degree of thermal and electrical conductivity.
* It maintains its properties indefinitely in recycling processes.
* Great resistance to corrosion.
* High capacity for metallic alloy processing.
* Good capacity for cold and hot deformation.
* Bactericide properties (inhibits microbiological multiplication).
* Basic element for vegetable and animal life (present in our internal functions).
* Ductile and malleable material which permits the creation of fine cables and thin sheets.
* Metallic existence in its natural state.

History of Aluminum

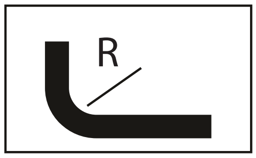
The name of this metal comes from the Latin "alumen" (in English "alum" = any double sulphate of aluminum and another metal), word with which the Romans described substances with astringent properties (constipation). Both in Greece and in Rome, alum was used for two basic functions; the first use had to do with the dyeing industry, where alum was used to fix the colors on textiles and the second use, already mentioned as an astringent in medicine.
Many centuries went by until this metal could be isolated. The first steps were taken by the Danish scientist Hans Christian Oersted, who obtained an impure form of aluminum in the early XIX century (it contained levels of lead). Years later, the German chemist Friedrich Wöhler was able to obtain pure aluminum, an achievement recorded in 1827.
In 1886, the American Charles Martin Hall and the Frenchman Héroult simultaneously discovered a simpler method to the costs of manufacturing this metal and its subsequent massive use. Two years later, Hall founded the company.
From the early days of its production until today, aluminum evolved from a costly metal to a versatile and widely-used product, which has countless properties, such as light weight, good conductivity, recyclable and very abundant in the ground.

Advantages of Aluminum :

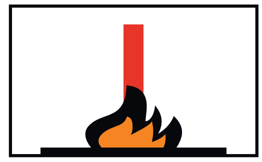
* Light metal.
* High degree of thermal and electrical conductivity.
* Cheap metal and easily recyclable.
* High resistance to corrosion.
* Ductile and malleable material, which permits creating fine cable and thin sheets.
* Permits alloys with other metals to improve its properties.
* Abundant in nature.
* Low melting point.

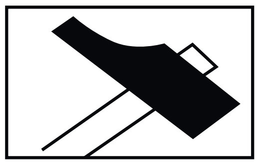


Used Symbols (In cable's datasheets)

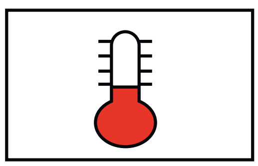


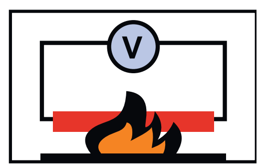
Minumum Bending Radius


Flame Retardant

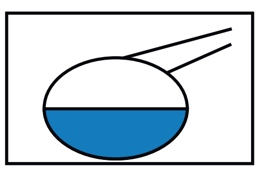

Mechanical Protection


Improved Flame Retardant

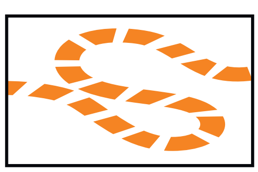

Maximum Conductor Temperature



Fire Resistant

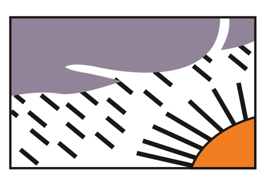

Protection against Chemicals


Low Smoke


Flexibility

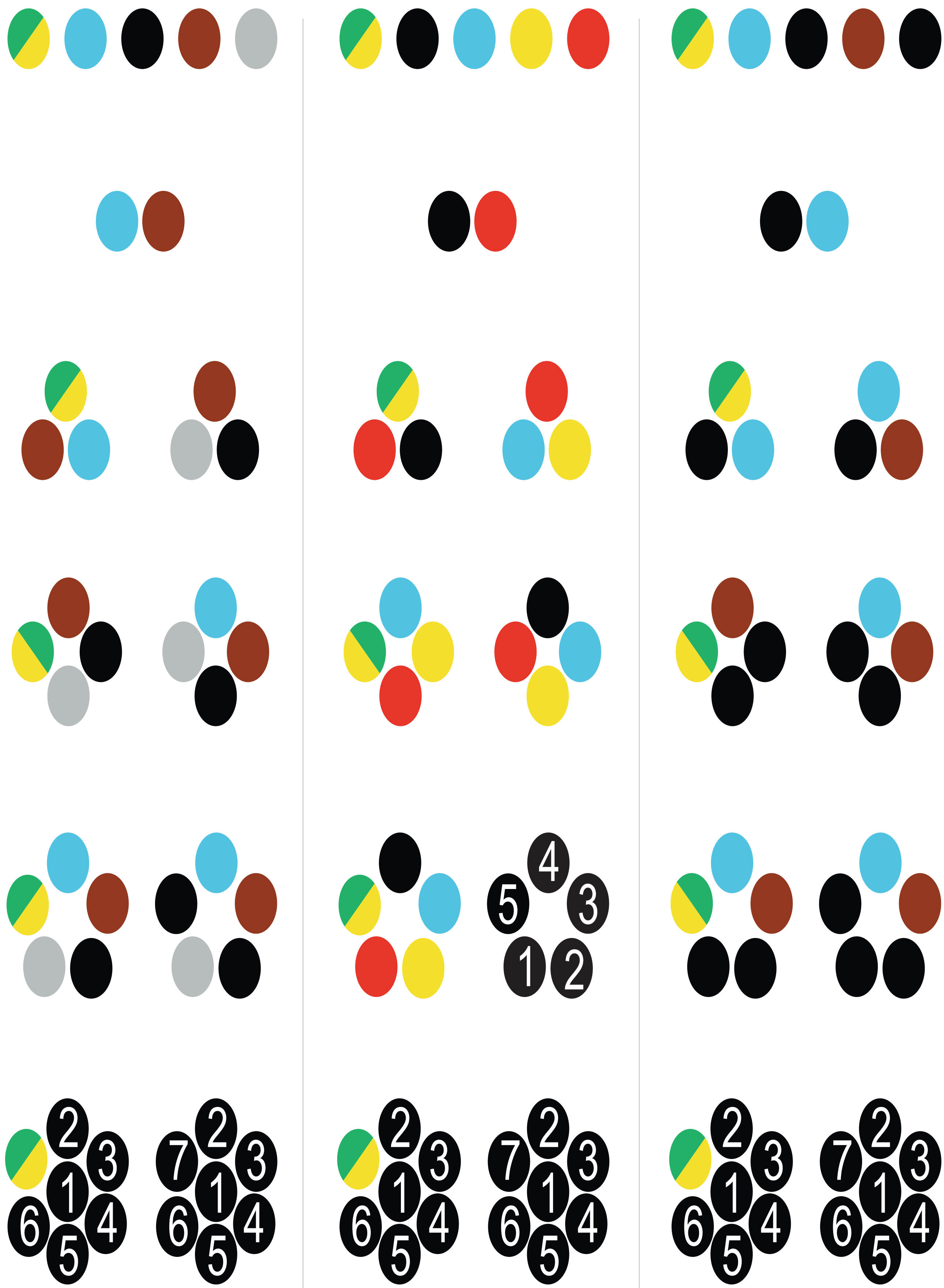
Low Halogen Acid/Gas


Protection against
Electromagnetic Fields


UV / Weather Resistant

Color Codes for Power Cables

acc to IEC/BS/EN 60446 | acc to Old BSI Standards | acc to Old IEC/VDE Standards



Cable Capacitance / Inductance FORMULAS

Essential Electrical Parameters
Formula for capacitance

$$C=\frac{\varepsilon}{18\ ln\left(\frac{d_0}{d_i}\right)} \qquad [\mu F / km]$$

Where ε = relative permittivity of the insulation
d0 = external diameter of the insulation (mm)
d_i = diameter of conductor, including screen (mm)
ε XLPE = 2.5 (Value from IEC 60287)

Formula for inductance

$$L= 0.05+0.2ln\left(\frac{K.s}{r_c}\right) \qquad [mH / km]$$

Where trefoil formation: K = 1
flat formation: K = 1.26
s = distance between conductor axes (mm)
rc = conductor radius (mm)

Formula for inductive reactance

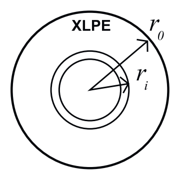
$$X= 2\pi f \cdot \frac{L}{1000} \qquad [? / km]$$

where f = frequency (Hz)
L = inductance (mH/km)

Formula for electric stress

Conductor

Insulation screen



r_i = radius of conductor screen
r0 = radius of XLPE insulation
U = voltage across insulation

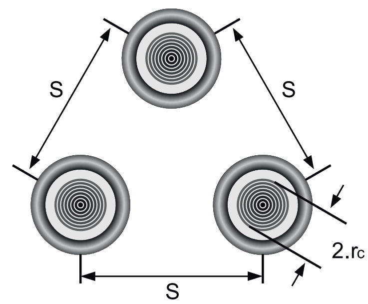
$$E_i=\frac{U}{r_i\, ln\left(\frac{r_0}{r_i}\right)} \qquad [kV / mm]$$

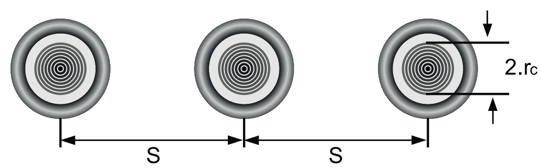
$$E_0=\frac{U}{r_0\, ln\left(\frac{r_0}{r_i}\right)} \qquad [kV / mm]$$

Formula for dielectric losses

$$W_d=\frac{U^2}{3}.2\pi fC.tan(\delta) \qquad [W / km]$$

Where U = rated voltage (kV)
f = frequency (Hz)
C = capacitance (μF/km)
tan δ = loss angle





Formula for inductance

$$I_{sh}=\frac{I_1}{\sqrt{t_{sh}}} \qquad [kA]$$

Ish = short-circuit current during time tsh
I1 = short-circuit current rating during 1 second.
see the 1 second value in tables 14 for the conductor and in Table 15 for the metallic screen .
tsh = short-circuit duration (sec)

For XLPE insulated conductors the maximum allowable short circuit temperature is 250°C.

Formula for calculation of dynamic forces between two conductors

$$F=\frac{0.2}{s}.I^2_{peak} \qquad [N/m]$$

Where; Ipeak = 2.5 Ish [kA]
Ish = short current [kA] RMS
S = centre to centre spacing between conductors [m]
F = maximum force [N/m]

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Insulation thickness of power cables acc to IEC 60502-1

Nominal Cross Section of Conductor	PVC Insulated		XLPE Insulated	
mm²	0.6/1 kV	1.8/3 kV	0.6/1 kV	1.8/3 kV
1.5 & 2.5	0.8		0.7	
4 & 6	1.0		0.7	
10 & 16	1.0	2.2	0.7	2.0
25 & 35	1.2	2.2	0.9	2.0
50	1.4	2.2	1.0	2.0
70	1.4	2.2	1.1	2.0
95	1.6	2.2	1.1	2.0
120	1.6	2.2	1.2	2.0
150	1.8	2.2	1.4	2.0
185	2.0	2.2	1.6	2.0
240	2.2	2.2	1.7	2.0
300	2.4	2.4	1.8	2.0
400	2.6	2.6	2.0	2.0
500	2.8	2.8	2.2	2.2
630	2.8	2.8	2.4	2.4
800	2.8	2.8	2.6	2.6
1000	3.0	3.0	2.8	2.8

MV power cables acc to IEC 60502-2

Nominal Cross Section of Conductor	XLPE Insulated				
mm²	3.6/6 kV	6/10 kV	8.7/15 kV	12/20 kV	18/30 kV
10	2.5	----	-----	-----	-----
16	2.5	3.4	-----	-----	-----
25	2.5	3.4	4.5	-----	-----
35	2.5	3.4	4.5	5.5	-----
50 to 185	2.5	3.4	4.5	5.5	8.0
240	2.6	3.4	4.5	5.5	8.0
300	2.8	3.4	4.5	5.5	8.0
400	3.0	3.4	4.5	5.5	8.0
500 to 1000	3.2	3.4	4.5	5.5	8.0

Note : Any smaller conductor cross-section than those given in this table is not recommended. However, if a smaller cross-section is needed, either the diameter of the conductor may be increased by a conductor screen , or the insulation thickness may be increased in order to limit, at the values calculated with the smallest conductor size given in this table, the maximum electrical stresses applied to the insulation under test voltage.

Conversion Factors & Tables

Cross sectional conductor areas to Metric and US standards

Metric Cross sectional areas acc to IEC: Cross sectional conductor area (mm²)
0.75
1.50
2.50
4.00
6.00
10.00
16.00
25.00
35.00
50.00
70.00
95.00
120.00
150.00
185.00
240.00
300.00
400.00
500.00
625.00

American Wire gauge: Equivalent Metric CSA (mm²)	AWG or MCM
0.653	19 AWG
0.832	18
1.040	17
1.310	16
1.650	15
2.080	14
2.620	13
3.310	12
4.170	11
5.260	10
6.630	9
8.370	8
10.550	7
13.300	6
16.770	5
21.150	4
26.670	3
33.630	2
42.410	1
53.480	1/0
67.430	2/0
85.030	3/0
107.200	4/0
126.640	250 AWG
152.000	300
202.710	400
253.350	500
304.000	600
354.710	700
405.350	800
506.710	1000

Temperature

°F	°C
320°	160°
305°	150°
290°	140°
275°	130°
260°	120°
245°	110°
230°	100°
212°	90°
200°	80°
185°	70°
170°	60°
155°	50°
140°	40°
125°	30°
110°	20°
95°	10°
80°	0°
65°	-10°
50°	-20°
32°	-30°
20°	-40°
5°	
-10°	
-25°	

Length

Non-metric system →	SI system
1 mil	0.0254 mm
1 in	2.54 cm = 254 mm
1 ft	30.48 cm = 0.305 m
1 yd	0.914 m
1 mile	1.609 km = 1609 m
SI system →	**Non-metric system**
1 mm	39.37 mil
1 cm	0.394 in
1 m	3.281 ft = 39.370 in
	= 1..094 yd
1 km	0.621 mile = 1.094 yd

Area

Non-metric system →	SI system
1 in²	6.452 cm² = 654.16 mm²
1 ft²	0.093 m² = 929 cm²
1 yd²	0.836 m²
1 acre	4046.9 m²
1 mile²	2.59 km²
SI system →	**Non-metric system**
1 mm²	0.00155 in²
1 cm²	0.155 in²
1 m²	10.76 ft² = 1550 in²
	= 1.196 yd²
1 km²	0.366 mile²

Volume

Non-metric system	SI system
1 in^3	16.387 cm^3
1 ft^3	28.317 dm^3 = 0.028 m^3
1 yd^3	0.765 m^3
1 fl. oz.	29.574 cm^3
1 quart	0.946 dm^3 = 0.946 l
1 pint	0.473 dm^3 = 0.473 l
1 gallon	0.785 dm^3 = 3.785 l
1 barrel	158.987 dm^3 = 1.589 m^3 = 159 l
SI system	**Non-metric system**
1 cm^3	0.061 in^3 = 0.034 fl. oz.
1 dm^3 = 1 l	61.024 in^3 = 0.035 ft^3 = 1.057 quart = 2.114 pint = 0.264 gallon
1 m^3	0.629 barrel

Force

Non-metric system	SI system
1 lbf	4.448 N
1 kgf	9.807 N
1 tonf	9.964 kN
SI system	**Non-metric system**
1 N	0.225 lbf = 0.102 kgf
1 kN	0.100 tonf

Torque , moment of force

Non-metric system	SI system
1 lbf	0.113 Nm = 0.012 kgf m
1 kgf	1.356 Nm = 0.138 kgf m
SI system	**Non-metric system**
1 Nm	8.851 lbf in = 0.738 lbf ft (= 0.102 kgf m)

Volume rate of flow

Non-metric system	SI system
1 gallon/s	28.35 g
1 gallon/min	0.454 kg = 453.6 g
1 ft^c	101.941 m^3/h
1 ft^3/min	1.699 m^3/h
SI system	**Non-metric system**
1 l/s	0.264 gallon/s
1 l/h	0.0044 gallon/min
1 m^3/h	4.405 gallon/min = 0.589 ft^3/min = 0.0098 ft^3/s

Energy , work , heat

Non-metric system	SI system
1 hp h	0.746 kWh = 2.684 x 10^6 J = 2.737 x 10^5 kgf m
1 ft lbf	0.138 kgf m
1 Btu	1.055 kJ = 1055.06 J (= 0.252 kcal)
SI system	**Non-metric system**
1 kWh	1.341 hp h = 2.655 kgf m = 3.6 x 10^5 kgf m
1 J	3.725 x 10^{-7} hp h = 0.738 ft lbf = 9.478 x 10^{-4} Btu (= 2.388 x 10^{-4} kcal)
1 kgf m	3.653 x 10^{-6} hp h = 7.233 ft lbf

Power

Non-metric system	SI system
1 hp	0.746 kW = 745.70 W = 76.040 kgf m/s (= 1.014 PS)
1 ft lbf/s	1.356 W (= 0.138 kgf in/s)
1 kcal/h	1.163 W
1 Btu/h	0.293 W
SI system	**Non-metric system**
1 kW	1.341 hp = 101.972 kgf m/s (= 1.36 PS)
1 W	0.738 ft lbf/s = 0.86 kcal/h = 3.412 Btu (= 0.102 kgf m/s)

Pressure

Non-metric system	SI system
1 in HG	0.034 bar
1 psi	0.069 bar
1 lbf/ft^2	4.788 x 10^{-4} bar = 4.882 x 10^{-4} kgf/cm^2
1 lbf/in^2	0.069 bar = 0.070 kgf/cm^2
1 tonf/ft^2	1.072 bar = 1.093 kgf/cm^2
1 tonf/in^2	154.443 bar = 157.488 kgf/cm^2
SI system	**Non-metric system**
1 bar = 10^5 pa = 10^2 kpa	29.53 in Hg = 14.504 psi = 2088.54 lbf/ft^2 = 14.504 lbf/in^2 = 0.932 tonf/ft^2 = 6.457 x 10^{-3} tonf/in^2 (= 1.02 kgf/cm^2)

Mass , weight

Non-metric system	SI system
1 oz	28.35 g
1 lb	0.454 kg = 453.6 g
1 sh ton	0.907 t = 907.2 kg
SI system	**Non-metric system**
1 g	0.035 oz
1 kg	2.205 lb = 35.27 oz
1 t	1.102 sh ton = 2205 lb

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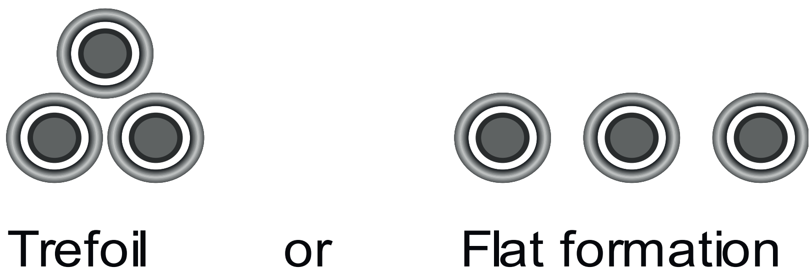
Underground Cable System Configurations

Cable system configurations

Trefoil and flat formation

The three cables in a 3-phase circuit can be placed in different formation. Typical formations include trefoil (triangular) and flat formations. The choice depends on several factors like screen bonding method, conductor area and available space for installation.



Bonding of the metallic screens

The electric power losses in cable in cable circuit are dependent on the currents flowing in the metallic sheaths of the cables. Therefore, by reducing or eliminating the metallic sheath currents through different methods of bonding, it is possible to increase the load current carrying capacity (ampacity) of the cable circuit. The usual bonding methods are described below:

Earthing methods, induced voltage

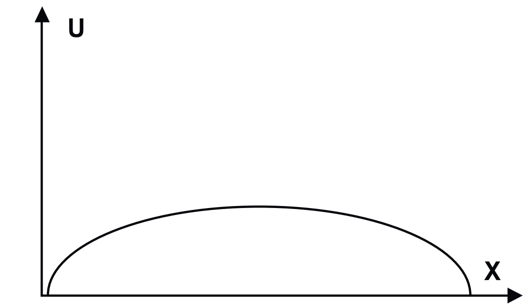
High voltage cables have a metallic sheath, along which a voltage is induced as a function of the operating current. In order to handle this induced voltage, both cable ends have to be bonded sufficiently to the earthing system. The following table gives an overview of the possible methods and their characteristics:

Earthing method	Standing voltage at cable ends	Sheath voltage limiters required	Typical application
Both-end bonding	No	No	Substations , short connections , hardly applied for HV cables rather than for LV and MV Cables
Single-end bonding	Yes	Yes	Usually for circuit lengths up to 1 kM
Cross-bonding	Only at cross bonding points	Yes	Long distance connections where joints are required

Overview of earthing methods and their characteristics

Both-ends bonding

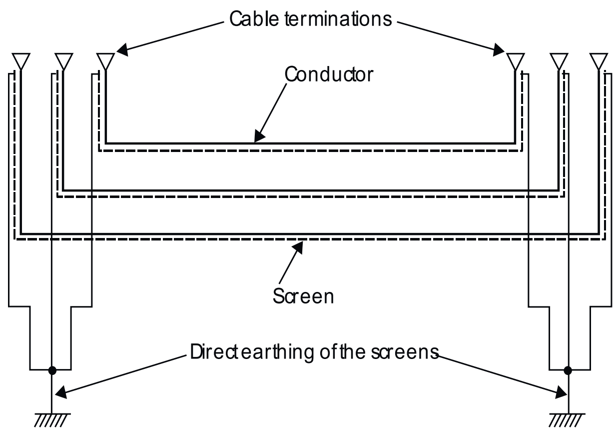
A system is both ends bonded if the arrangements are such that the cable sheaths provide path for circulating currents at normal conditions. This will cause losses in the screen, which reduce the cable current carrying capacity.
These losses are smaller for cables in trefoil formation than in flat formation with separation.



Induced voltage distribution at both-end bonding

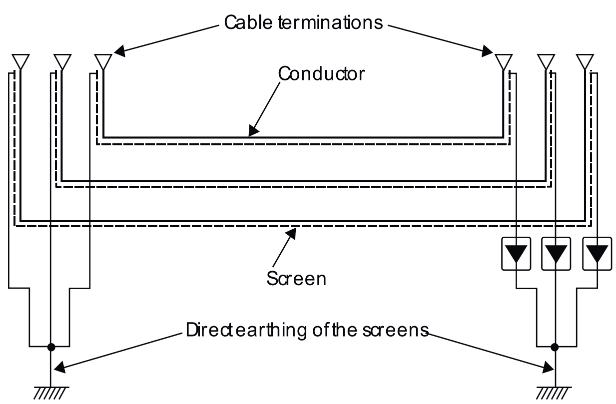
Single-point bonding

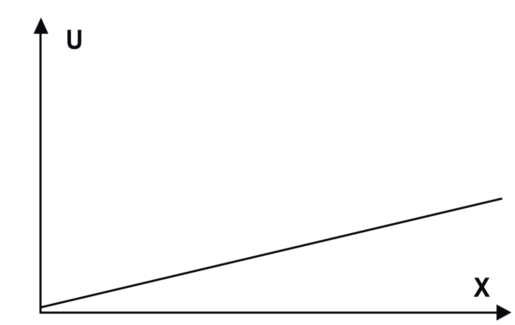
A system is single point bonded if the arrangements are such that the cable sheaths provide no path for the flow of circulating currents or external fault currents. In such case, a voltage will be induced between screen of adjacent phases of the cable circuit and between screen and earth, but no current will flow. This induced voltage is proportional to cable length and current. Single-point bonding can only be used for limited route lengths, but in general the accepted screen voltage potential limits the length.



Cross-bonding

A system is cross-bonded if the arrangements are such that the circuit provides electrically continuous sheath runs from earthed termination to earthed termination but with the sheaths so sectionalized and cross-connected in order to eliminate the sheath circulating currents.
In such case, a voltage will be induced between screen and earth, but no significant current will flow. The maximum induced voltage will appear at the link boxes for cross-bonding.
This method permits a cable current-carrying capacity as high as with single-point bonding but longer route lengths than the latter.
It requires screen separation and additional link boxes.





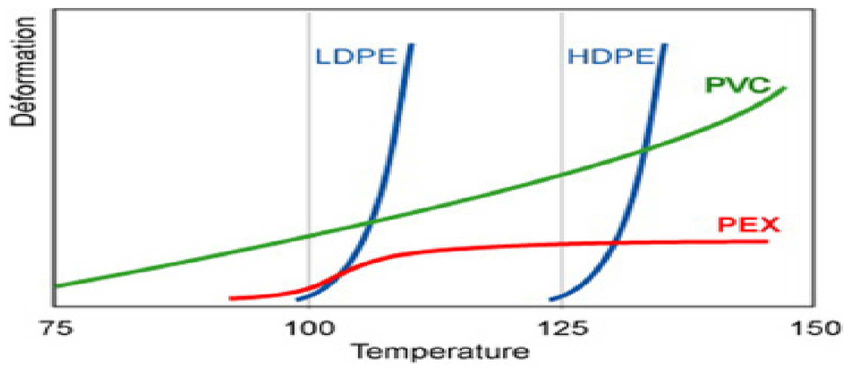
Induced voltage distribution at single-end bonding

XLPE (Cross-liked Polyethylene)

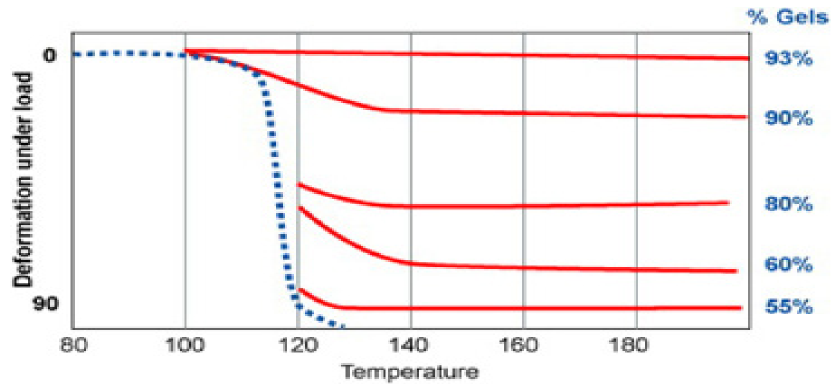
PE Crosslinking Advantages

1) Increased Maximum Operating Temperatures

One key reason to Crosslink PE in applications such as Pipes or cables is to raise the thermal stability of the material under load. PEX continuous service temperature is around 100-120°C. Following figure compares thermo-mechanical deformation resistance versus temperature of various polymers.



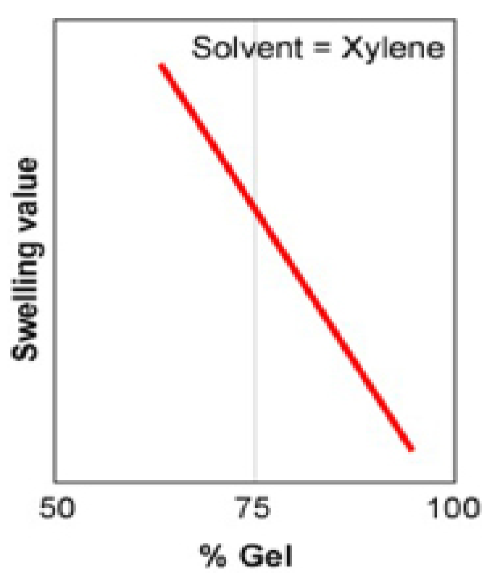
The thermal-mechanical stability of PEX depends strongly on its degree of crosslinking (%gels). This figure shows how % gel influences thermo-mechanical performances of PEX



2) Increased Chemical and Environmental Crack Resistance

In general, as the molecular weight of polyethylene increases, the environmental stress cracking resistance (ESCR) is improved. In some extend, PEX can be considered as an infinite molecular weight PE. PEX exhibits superior ESCR and better slow crack growth resistance than standard HDPE .

It is also well recognized that chemical resistance of polymers increases with the degree of crosslinking.
This Figure shows how the degree of crosslinking influences the swelling value of PEX in a solvent such as Xylene.

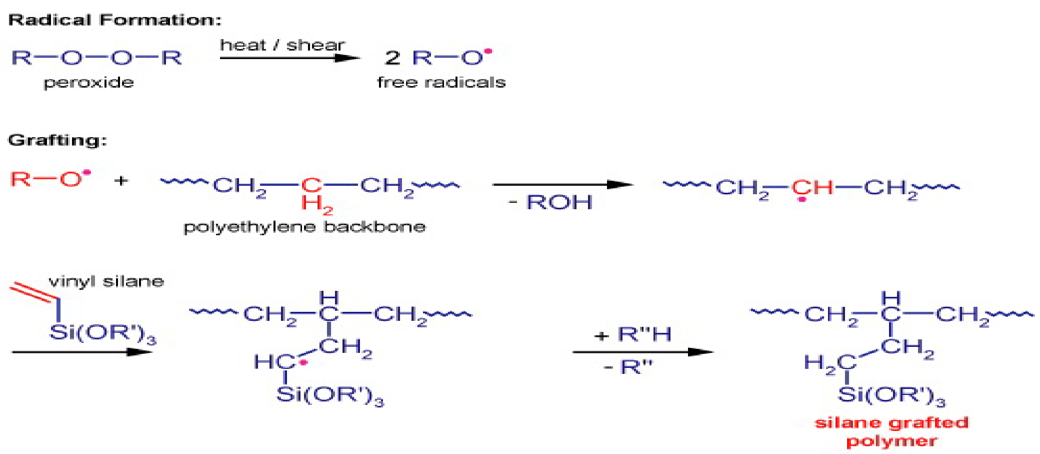


Silaine Crosslinking Mechanism

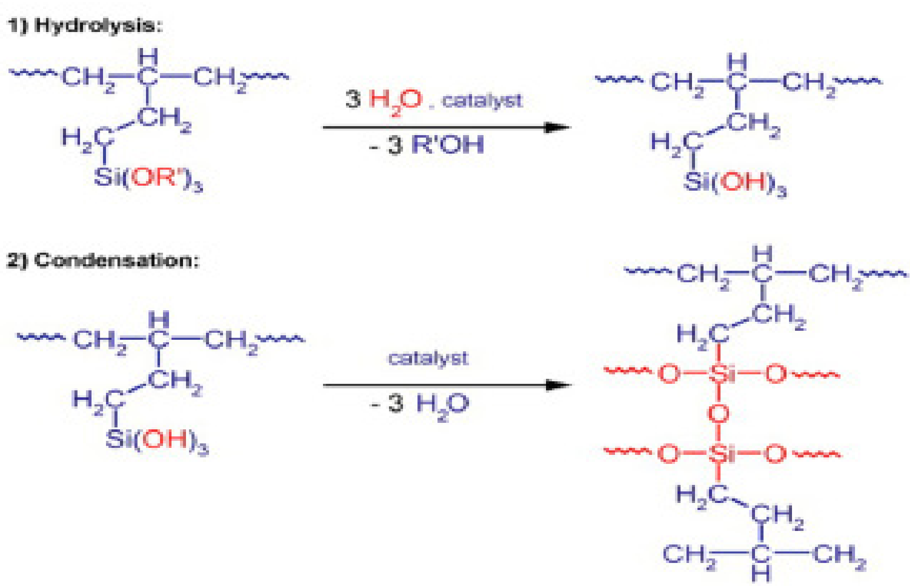
Why Use Silaine Crosslinking Technology?
For high performance polyethylene applications, requiring higher temperature, creep, abrasion and chemical resistances, crosslinking is a must. Of all the crosslinking technologies, Silaine is the one which exhibits the greatest process flexibility (by providing the possibility to trigger the crosslinking after extrusion) and superior mechanical performance. As opposed to other processes, Silaine Crosslinking technology is easy to implement and does not require special processing equipment.
Silaine Crosslinked PE is called PEX or XLPE .

Silaine technology consists of two steps:

• **Step 1**: incorporation of the Silaine into the polymer, either by grafting of vinylsilane onto the polymer backbone or by copolymerization of vinylsilane with ethylene in the polymerization reactor, and



• **Step 2:** crosslinking in the presence of water, generally catalyzed by tin compounds or other suitable catalysts. This second step can be controlled and made during or after the extrusion process. This is the difference between a One-Step and a Two-Step Process.



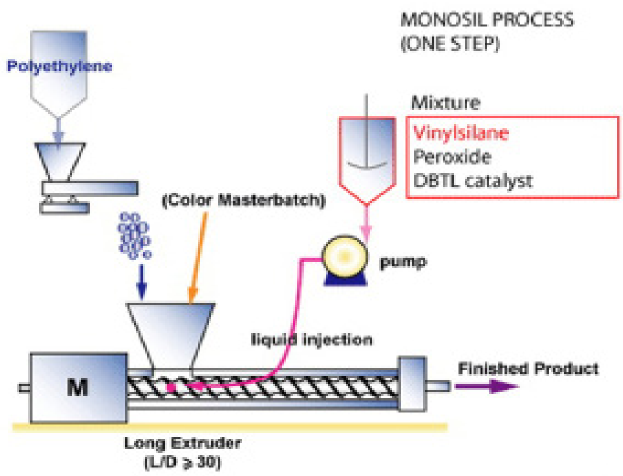
Silaine XLPE processing Types

One unique benefit offered by Silaine crosslinking technology is its ability to trigger the crosslinking at the desired time and particularly after the extrusion of the product.
With Silaine technology, crosslinking can be triggered at the desired time.
Crosslinking of polyethylene is done by grafting a trialkoxysilyl group onto the PE polymer chain. Once this is done, the combination of a tin catalyst and moisture will cause the alkoxylsilyl groups to react together to form a crosslink between the polymer chains.

There are 2 main processes used to make PEX:

- one step process, called **Monosil**
- two step process called **Sioplas**

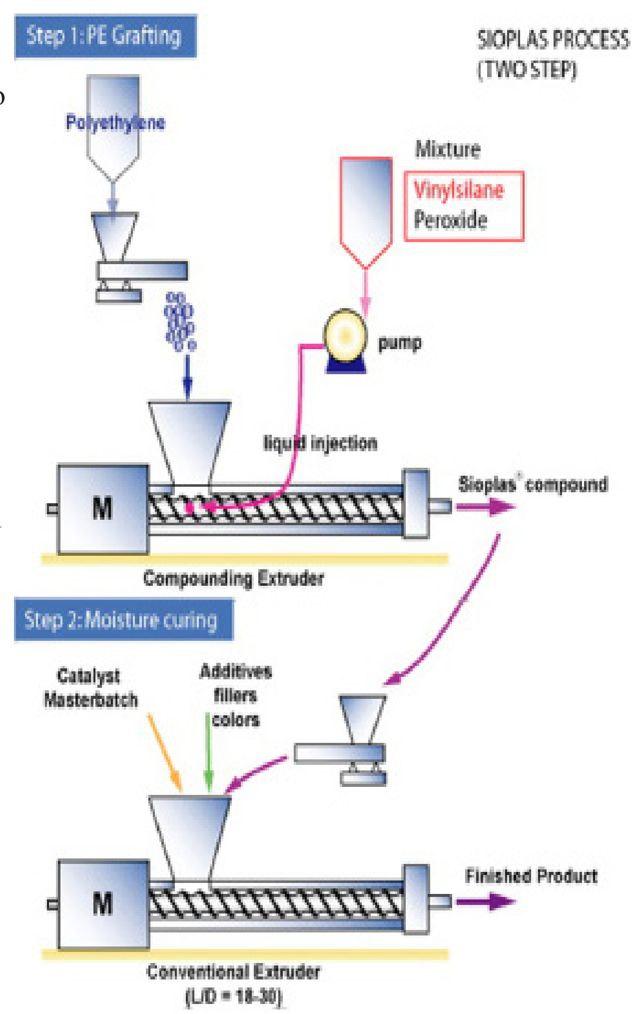
Monosil process (One step process)
The monosil technique introduces in a single step a mixture of Vinylsilane-peroxide-crosslinking catalyst antioxidant into polyethylene during a conventional extrusion process (such as pipe or cable).
The finished product is moisture-cured (water bath or steam sauna).



Advantages of Monosil process :

• Cost effective on a larger scale
• Single step- high speed
• Lowest variable cost
• Wide formulation latitude and wide customization
• No additional heat history to the PE

Sioplas process (Two steps process)
In the Sioplas process, Polyethylene is first grafted in the presence of a mixture of Vinylsilane and peroxide to make a crosslinkable polyethylene. The material can be either processed directly or stored in dry conditions for up to several months.
In a Separate step, the crosslinking catalyst, typically a tin derivative such as dibultinlaurate (DBTDL), and an anti-oxidabt are mixed with polyethylene in a single or twin-screw extruder. This is the catalyst masterbatch, part B, to be used with the Silaine polyethylene, part A.



In a second step, grafted polyethylene is dry blended with a catalyst masterbatch (a concentrate of Tin derivative in PE), in a traditional single screw extrusion process.
The extrudate is most of the time cooled down into a water bath which provides the moisture necessary for crosslinking. The reaction is fast but diffusion of moisture in the material is a limiting factor. For this reason, hot water bath or low pressure steam autoclave are often used to speed up crosslinking.

Advantages of Sioplas process :

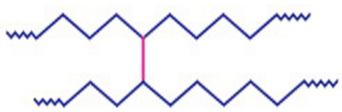
• Wide range of applications
• Multiple suppliers/sourcing options
• Cost effective significant
• Can use reinforcements

Silaine Crosslinking Advantages

1) More Flexible crosslinked polymer

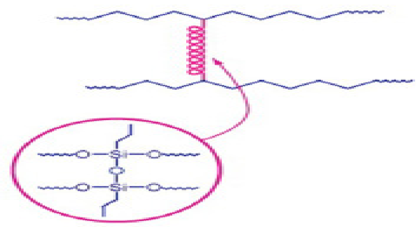
The use of silanes results in a more flexible and more economical process for crosslinking. Silaine crosslinked polyolefins are linked through an Si-O-Si moiety instead of the C-to-C bond created via peroxide or radiation cure. Siloxane bridges are less rigid than C-to-C bonds and give flexibility to the crosslinked polymer, as shown in the figure below.

C-to-C bond: rigid



Structure of PE crosslinked
by **Peroxide** or **Radiation**

Si-O-Si bond: flexible



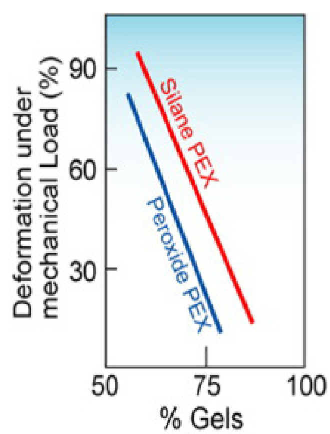
Structure of PE crosslinked
by **Silaine** Technology

2) Better Tensile and Impact Performance

In general, Crosslinking of a polymer reduce slightly its impact performance.
Silaine crosslinked polyolefins are linked through a Si-O-Si moiety instead of the C-to-C bond created via peroxide or radiation cure. Siloxane bridges are less rigid than C-to-C bonds and give flexibility to the crosslinked polymer .

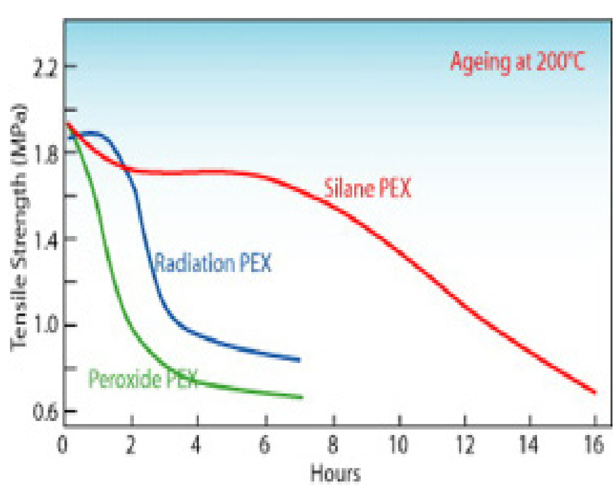
3) Reduced Creep

In Materials Science, creep is the tendency of a solid material to slowly move or deform permanently under the influence of stresses. It occurs as a result of long term exposure to high levels of stress that are below the yield strength of the material. Creep is more severe in materials that are subjected to heat for long periods, and near melting point. Creep always increases with temperature.
The rate of this deformation is a function of the material properties, exposure time, exposure temperature and the applied structural load. It is well known that Creep Resistance increases with the crosslinking density of a polymer.
This can be easily explained by the fact that in a crosslinking system polymer chains are linked together and can't slide against each other.
PE crosslinking increases its Creep Resistance
Figure 1 below shows how the croslinking density (%gel) influences the deformation under mechanical load of crosslinked PE.



4) Better Weatherability

Studies have demonstrated that the use of Silaine crosslinking provide material with better heat ageing. This figure compares the mechanical properties retention of PEX crosslinked using different technologies at 200°C .
It shows clearly that Silaine PEX exhibits better retention in tensile strength than irradiation and peroxide PEX .



Kerman & Kavian Cable Industries (KCI)

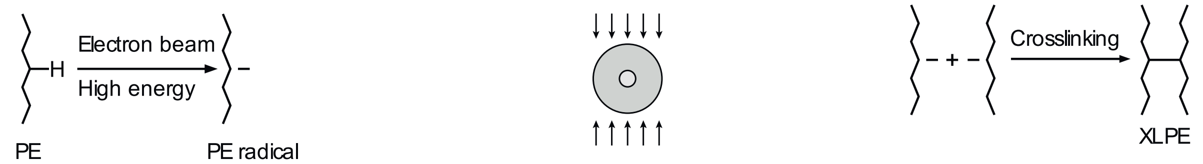
Power Cables

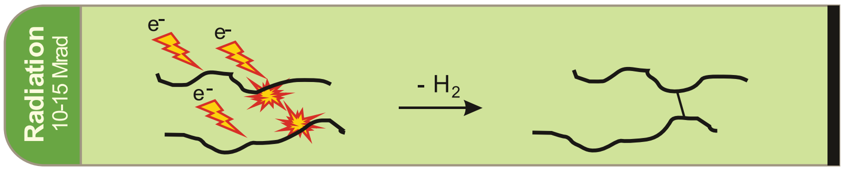
Summary of Cross Linking Methods

Radiation cross linking

1.Formation of PE radical by high energy electron beam

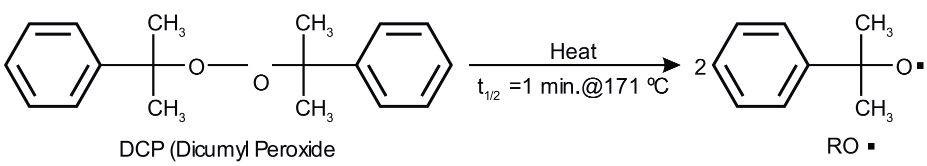
Cosslinking



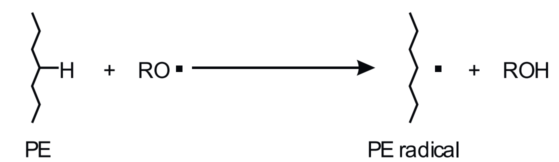


Peroxide cross linking

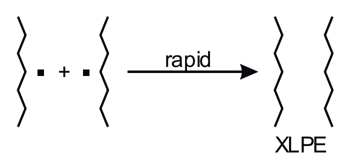
1.Peroxide decomposition

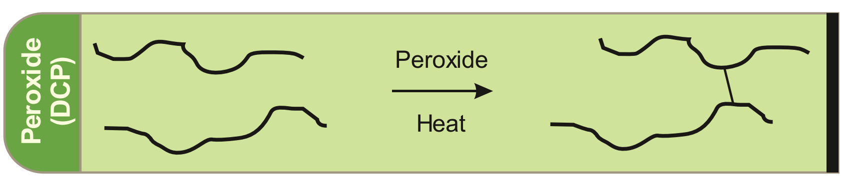


2. PE chain radical formation



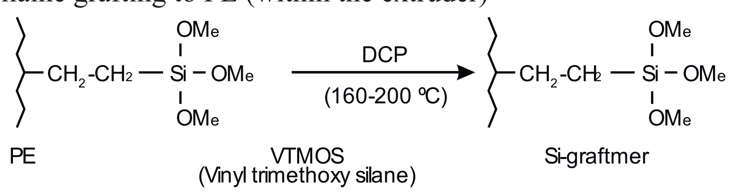
3. Cross linking



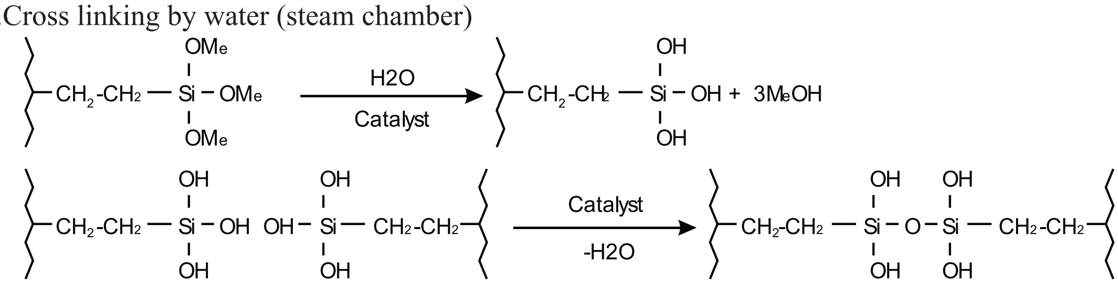


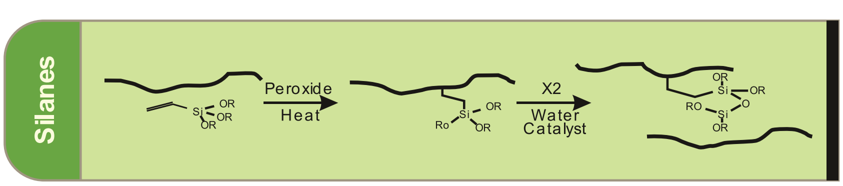
Silaine cross linking

1.Silaine grafting to PE (within the extruder)



2.Cross linking by water (steam chamber)





Comparison Table of Cross Linking Methods

	Peroxide	Silaine	Irradiation
Curing Media	Organic Peroxide	Silane Compound	High Frequency Radiation
Curing Equipment	High Pressure & High Temperature Curing Duct	Saturated Steam Bath	Electron Beam Generator
Strong Point	Most Common No Thickness Limit	Cheap Equipment Low Energy Cost High Speed Line	High Speed Extrusion Low Running Cost
Weak Point	Expensive Equipment Limited Line speed High Energy Cost	Wall Thickness Limit	Expensive Equipment Limited Beam Cap. Wall Thickness Limit
Application Voltage	6000 v – 500 Kv	150 V – 33 kv	Max 600v

WATER TREEING CAUSES

Water treeing is the major defect of insulation of medium and high voltage cables.
It is independent of the Peroxide , Silaine or Irradiation methods of cross-linking and It can be categorized as following matters :

1- Impurities
related to the purity of the raw materials for the insulation and very important the semiconducting screens

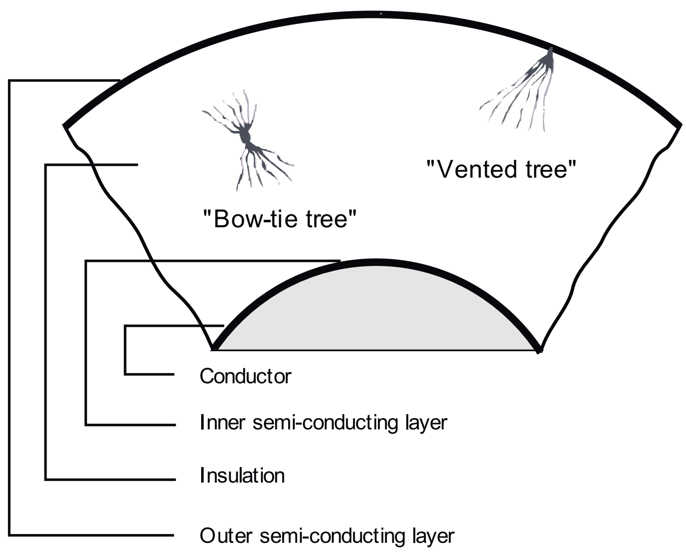
2- Moisture in cable screens and insulation
2a. after production (is low both cables i.e. Silaine cured or dry cured ; was high in steam cured cables)
2b. during service operation (can be kept low in both cables i.e. Silaine cured or dry cured by water tight constructions)

3- Electrical Fields
Only Depends on fabrication of conductor (to be round) and tightness of layers and totally no sharp edges!

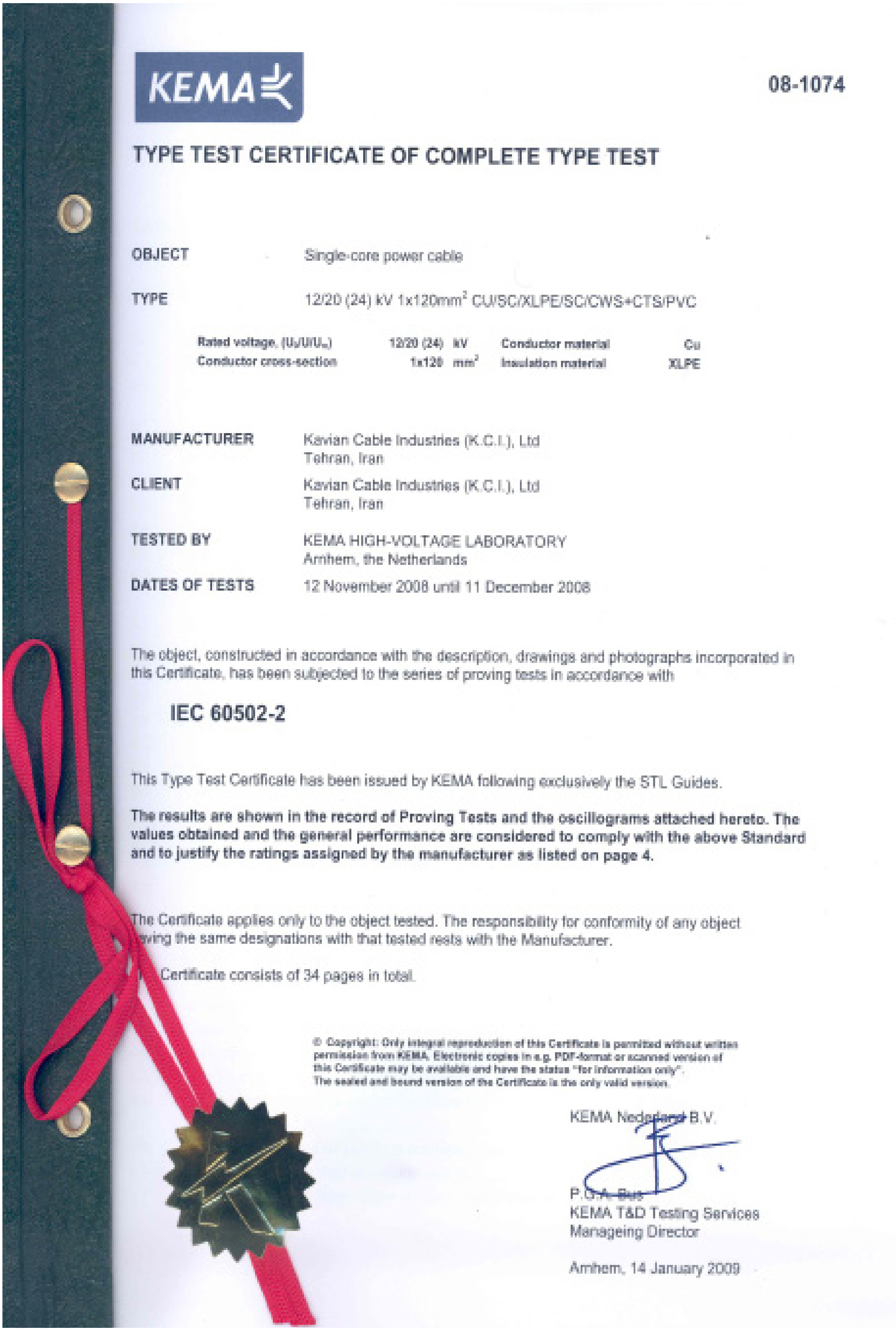
There are two most common Treeing type in Insulation :

*** Bow-tie tree**

*** Vented tree**



Type Test Certificate of KEMA for Kavian Cable



KEMA

08-1074

TYPE TEST CERTIFICATE OF COMPLETE TYPE TEST

OBJECT	Single-core power cable
TYPE	12/20 (24) kV 1x120mm² CU/SC/XLPE/SC/CWS+CTS/PVC

Rated voltage, ($U_0/U/U_m$)	12/20 (24) kV	Conductor material	Cu
Conductor cross-section	1x120 mm²	Insulation material	XLPE

MANUFACTURER	Kavian Cable Industries (K.C.I.), Ltd Tehran, Iran
CLIENT	Kavian Cable Industries (K.C.I.), Ltd Tehran, Iran
TESTED BY	KEMA HIGH-VOLTAGE LABORATORY Arnhem, the Netherlands
DATES OF TESTS	12 November 2008 until 11 December 2008

The object, constructed in accordance with the description, drawings and photographs incorporated in this Certificate, has been subjected to the series of proving tests in accordance with

IEC 60502-2

This Type Test Certificate has been issued by KEMA following exclusively the STL Guides.

The results are shown in the record of Proving Tests and the oscillograms attached hereto. The values obtained and the general performance are considered to comply with the above Standard and to justify the ratings assigned by the manufacturer as listed on page 4.

The Certificate applies only to the object tested. The responsibility for conformity of any object ving the same designations with that tested rests with the Manufacturer.

Certificate consists of 34 pages in total.

KEMA Nederland B.V.

P.G.A. Bus
KEMA T&D Testing Services
Manageing Director

Arnhem, 14 January 2009

KEMA

Type test Certificate of Complete Type Test

Kavian Cable Industries (K.C.I.), Ltd

Tehran, Iran

has successfully passed the type test sequence on a

Three/Single-core power cable

Type: 12/20 (24) kV 1x120 mm^2 CU/SC/XLPE/SC/CWS+CTS/PVC

The test requirements are stated in clauses 18 and 19 of

IEC 60502-2

The test results are recorded in Certificate No.

08-1074

This Certificate is issued on 14 January 2009

KEMA Nederland B.V.

P.G.A. Bus
KEMA T&D Testing Services
Managing Director

General Electrical Data of Cables

Cable's Rated Voltage and Range of use

Cable Conductor's Electrical Data DC Resistance/AC Resistance

Inductive Reactance at 50Hz of Low-Voltage (0.6/1 kV) Power cables

Voltage drop (50 Hz , mV/A/m) Low Voltage (0.6/1 kV)

Electrical (AC Resistance , Reactance , Capacitance) of MV Cables

PVC Insulated , 1.8/3 kV

XLPE Insulated , 1.8/3 kV

XLPE Insulated , 6/10 kV , 8.7/15 kV

XLPE Insulated , 12/20 kV , 18/30 kV

Current Rating of Power cables

PVC Insulated LV (0.6/1 kV) Power cables (Armoured)

XLPE Insulated LV (0.6/1 kV) Power cables (Armoured)

MV Power cables with Rated Voltage 1.8/3kV (Armoured)

XLPE Insulated MV Rated Voltages : 3.6/6 kV - 6/10 kV - 8.7/15 kV

XLPE Insulated MV Rated Voltages : 12/20 kV - 18/30 kV

Short-Circuit Calculation for Power Cables

Screen Short-circuit current capacity of XLPE insulated MV cables

PVC Insulated Power Cables Copper / Aluminium Conductor

XLPE Insulated Power Cables Copper / Aluminium Conductor

Cable’s Rated Voltage and Range of use

Cables in accordance with IEC 60502-1 are intended for fixed installation :

- indoors
- outdoors
- underground
- in water

(Note: The relevant national installation regulations must be observed)

Nominal and highest cable voltages

	Nominal rated voltage U_0/U	Highest system voltage U_0		
	kV	Three phase system (kV)	Single phase system (kV)	Single phase system (kV)
Low voltage (LV) acc to IEC 60502-1	0.6 / 1	1.2	1.4	0.7
	1.8 / 3	3.6	4.2	2.1
Medium voltage (MV) acc to IEC 60502-2	3.6 / 6	7.2	8.3	4.2
	6 / 10	12.0	14.0	7.0
	8.7 / 15	17.5	20.0	10.0
	12 / 20	24.0	28.0	14.0
	18 / 30	36.0	42.0	21.0

1) both phases insulated
2) one phase grounded
3) max.voltage in d.c. systems 1.8 kv

U : Rated power-frequency voltage between phase conductors for which the cable is suitable.
U_0 : Rated power-frequency voltage between conductor and earth or armour, metal sheath or screen for which the cable is suitable.
Um : Maximum value of the “highest system voltage” between phase conductors for which the cable is suitable.

	IEC Ratings	BSI Equivalent
U0 /U (Um) kV	1.8 / 3 (3.6) *	1.9 / 3.3 (3.6) *
	3.3 / 6 (7.2)	3.8 / 6.6 (7.2)
	6 / 10 (12)	6.35 / 11 (12)
	8.7 / 15 (17.5)	8.7 / 15 (17.5)
	12 / 20 (24)	12.7 / 22 (24)
	18 / 30 (36)	19 / 33 (36)

* 1.8 kV cable is referred to IEC 60502-1 and BSI 5467

Cable Conductor’s Electrical Data DC Resistance/AC Resistance

Nominal Cross Section of Conductor (mm^2)	DC Resistance of Plain Copper at 20°C Maximum (Ohm/kM)			DC Resistance of Aluminium at 20°C (Ohm/km)	Maximum AC Resistance of (Ohm/kM)			
					Plain Copper		Aluminium	
	Solid (class 1)	Strand (class 2)	Bunch (class 5)	Strand (class 2)	For PVC at 70°C	For XLPE at 90°C	For PVC at 70°C	For XLPE at 90°C
1.5	12.1	12.1	13.3		14.5	15.4		
2.5	7.41	7.41	7.98		8.87	9.45		
4	4.61	4.61	4.95	7.41	5.52	5.88		
6	3.08	3.08	3.30	4.61	3.69	3.93		
10	1.83	1.83	1.91	3.08	2.19	2.33		
16		1.15	1.21	1.91	1.38	1.47		2.45
25		0.727	0.780	1.20	0.872	0.927		1.54
35		0.524	0.554	0.868	0.628	0.668		1.11
50		0.387	0.386	0.641	0.464	0.494	0.771	0.822
70		0.268	0.272	0.443	0.321	0.342	0.533	0.568
95		0.193	0.206	0.320	0.232	0.247	0.385	0.411
120		0.153	0.161	0.253	0.184	0.197	0.305	0.325
150		0.124	0.129	0.206	0.150	0.160	0.248	0.265
185		0.0991	0.106	0.164	0.121	0.128	0.198	0.211
240		0.0754	0.0801	0.125	0.0929	0.0989	0.152	0.162
300		0.0601	0.0641	0.100	0.0752	0.0802	0.122	0.130
400		0.0470	0.0486	0.0778	0.0604	0.0640		
500		0.0366	0.0384	0.0605	0.0484	0.0515		
630		0.0283	0.0287	0.0469	0.0398	0.0420		
800		0.0221		0.0367	0.0334	0.0363		
1000		0.0176		0.0291	0.0290	0.0316		

KCI

Inductive Reactance at 50Hz of Low-Voltage (0.6/1 kV) Power cables

Nominal Cross Section of Conductor (mm^2)	Reactance of PVC Insulated cables (Ohm/kM)			Reactance of XLPE Insulated cables (Ohm/kM)		
	Single (1) Core		Multi Core	Single (1) Core		Multi Core
	Trefoil	Flat		Trefoil	Flat	
1.5			0.119			0.114
2.5			0.114			0.105
4			0.110			0.098
6			0.103			0.094
10			0.097			0.088
16	0.117		0.087	0.118		0.081
25	0.110		0.084	0.112		0.079
35	0.105		0.081	0.107		0.077
50	0.112	0.198	0.081	0.106	0.164	0.076
70	0.107	0.193	0.079	0.103	0.161	0.075
95	0.103	0.189	0.077	0.098	0.156	0.073
120	0.103	0.188	0.076	0.096	0.154	0.073
150	0.101	0.186	0.076	0.097	0.155	0.073
185	0.099	0.184	0.076	0.096	0.154	0.073
240	0.096	0.182	0.075	0.092	0.150	0.073
300	0.094	0.181	0.074	0.090	0.148	0.072
400	0.091	0.178	0.074	0.090	0.148	
500	0.089	0.176		0.089	0.146	
630	0.086	0.173		0.086	0.144	
800	0.086			0.086	0.144	
1000	0.084	0.181		0.084	0.142	

Note (1) : Values are given for aluminium wire armouring and in touching trefoil arrangement.
Note (2) : Values are given for armoured cables (for non-armoured values can be reduced approx by 10%)

Voltage drop (50 Hz , mV/A/m) Low Voltage (0.6/1 kV) Armoured Cables PVC Insulated

Conductor size (mm^2)	Copper Conductor				Aluminium Conductor			
	Single-core [1]		2-core	3- or 4-core	Single-core [1]		2-core	3- or 4-core
	Trefoil	Flat [2]			Trefoil	Flat [2]		
16			2.8	2.4			4.5	3.9
25			1.75	1.5			2.9	2.5
35			1.25	1.1			2.1	1.8
50	0.82	0.86	0.94	0.81	1.35	1.35	1.55	1.35
70	0.58	0.68	0.65	0.57	0.93	1.00	1.05	0.92
95	0.45	0.57	0.50	0.43	0.70	0.80	0.79	0.68
120	0.37	0.50	0.41	0.35	0.57	0.68		0.55
150	0.32	0.45	0.34	0.29	0.47	0.58		0.44
185	0.27	0.41	0.29	0.25	0.39	0.51		0.37
240	0.23	0.37	0.24	0.21	0.32	0.44		0.30
300	0.21	0.34	0.21	0.185	0.27	0.40		0.25
400	0.195	0.32	0.185	0.16				
500	0.18	0.30						
630	0.17	0.28						
800	0.16							
1000	0.155							

XLPE Insulated

Conductor size (mm^2)	Copper Conductor				Aluminium Conductor			
	Single-core [1]		2-core	3- or 4-core	Single-core [1]		2-core	3- or 4-core
	Trefoil	Flat [2]			Trefoil	Flat [2]		
16			2.9	2.5			4.8	4.2
25			1.9	1.65			3.1	2.7
35			1.35	1.15			2.2	1.95
50	0.87	0.90	1.00	0.87	1.4	1.4	1.65	1.45
70	0.62	0.70	0.69	0.60	0.98	1.05	1.15	0.97
95	0.47	0.58	0.52	0.45	0.74	0.83	0.84	0.72
120	0.39	0.51	0.42	0.37	0.60	0.70		0.58
150	0.33	0.45	0.35	0.30	0.49	0.60		0.47
185	0.28	0.41	0.29	0.26	0.41	0.53		0.39
240	0.24	0.37	0.24	0.21	0.34	0.46		0.31
300	0.21	0.34	0.21	0.185	0.29	0.41		0.26
400	0.195	0.33	0.19	0.165				
500	0.18	0.31						
630	0.17	0.29						
800	0.165	0.26						
1000	0.155	0.24						

Note (1) : Data for aluminium wire armoured cables

Note (2) : Twice cable diameter spacing between cores

Electrical (AC Resistance , Reactance , Capacitance) of MV Cables PVC Insulated , 1.8/3 kV

Conductor size (mm^2)	Single-core cables [1)]					
	AC resistance @ 90°C		Reactance (50 Hz)		Capacitance [1)]	
	Copper	Aluminium	Trefoil	Flat [2)]	Copper	Aluminium
	(Ohm/km)	(Ohm/km)	(Ohm/km)	(Ohm/km)	(microF/km)	(microF/km)
50	0.464	0.771	0.115	0.173	0.86	0.77
70	0.321	0.533	0.109	0.167	1.00	0.89
95	0.232	0.385	0.107	0.165	1.08	0.96
120	0.185	0.305	0.102	0.160	1.20	1.05
150	0.149	0.248	0.099	0.157	1.30	1.15
185	0.120	0.198	0.096	0.154	1.44	1.26
240	0.0929	0.152	0.093	0.151	1.62	1.41
300	0.0752	0.122	0.091	0.149	1.69	1.48
400	0.0600		0.091	0.149	1.71	
500	0.0484		0.089	0.147	1.81	
630	0.0398		0.086	0.144	2.03	
800	0.0334		0.086	0.137	2.17	
1000	0.0290		0.084	0.142	2.32	

Note (1) : Not applicable to non armoured cables
Note (2) : Twice cable diameter spacing between cores

Conductor size (mm^2)	3-core cables				
	AC resistance @ 90°C		Reactance	Capacitance	
	Copper	Aluminium	(50 Hz)	Copper	Aluminium
	(Ohm/km)	(Ohm/km)	(Ohm/km)	(microF/km)	(microF/km)
16	1.380	2.29	0.107	0.54	0.50
25	0.870	1.44	0.097	0.65	0.57
35	0.627	1.04	0.094	0.71	0.64
50	0.464	0.770	0.090	0.78	0.70
70	0.321	0.533	0.086	0.90	0.80
95	0.232	0.385	0.082	1.01	0.91
120	0.184	0.305	0.080	1.10	0.97
150	0.150	0.248	0.079	1.20	1.06
185	0.121	0.198	0.077	1.32	1.16
240	0.0929	0.152	0.075	1.45	1.27
300	0.0752	0.122	0.075	1.50	1.32
400	0.0604		0.074	1.58	

Electrical (AC Resistance , Reactance , Capacitance) of MV Cables
XLPE Insulated , 1.8/3 kV

Conductor size (mm^2)	Single-core cables 1)					3-core cables			
	AC resistance @ 90°C		Reactance (50 Hz)		Capacitance	AC resistance @ 90°C		Reac-tance	Capacitance
	Copper	Aluminium	Trefoil	Flat 2)	(microF/km)	Copper	Aluminium	(50 Hz)	(microF/km)
	(Ohm/km)	(Ohm/km)	(Ohm/km)	(Ohm/km)		(Ohm/km)	(Ohm/km)	(Ohm/km)	
16						1.470	2.45	0.104	0.18
25						0.927	1.54	0.094	0.22
35						0.668	1.11	0.091	0.25
50	0.493	0.822	0.116	0.172	0.31	0.494	0.822	0.088	0.27
70	0.342	0.568	0.110	0.165	0.36	0.342	0.568	0.084	0.31
95	0.246	0.410	0.104	0.160	0.42	0.247	0.411	0.081	0.35
120	0.195	0.325	0.104	0.159	0.45	0.197	0.325	0.079	0.38
150	0.160	0.265	0.100	0.156	0.49	0.160	0.265	0.077	0.42
185	0.128	0.211	0.098	0.154	0.54	0.128	0.211	0.076	0.46
240	0.098	0.162	0.094	0.150	0.63	0.098	0.162	0.074	0.51
300	0.080	0.130	0.091	0.147	0.70	0.080	0.130	0.073	0.57
400	0.064		0.090	0.147	0.77				
500	0.051		0.089	0.145	0.80				
630	0.042		0.086	0.143	0.84				

XLPE Insulated , 3.6/6 kV

Conductor size (mm^2)	Single-core cables 1)					3-core cables			
	AC resistance @ 90°C		Reactance (50 Hz)		Capacitance	AC resistance @ 90°C		Reac-tance	Capacitance
	Copper	Aluminium	Trefoil	Flat 2)	(microF/km)	Copper	Aluminium	(50 Hz)	(microF/km)
	(Ohm/km)	(Ohm/km)	(Ohm/km)	(Ohm/km)		(Ohm/km)	(Ohm/km)	(Ohm/km)	
16						1.47	2.45	0.126	0.26
25						0.927	1.54	0.117	0.30
35						0.668	1.11	0.109	0.33
50	0.494	0.822	0.121	0.181	0.34	0.493	0.82	0.105	0.36
70	0.342	0.568	0.115	0.174	0.38	0.343	0.568	0.100	0.41
95	0.247	0.411	0.109	0.167	0.43	0.247	0.411	0.095	0.46
120	0.196	0.325	0.105	0.162	0.47	0.196	0.325	0.092	0.50
150	0.159	0.265	0.102	0.159	0.51	0.159	0.265	0.090	0.55
185	0.128	0.211	0.099	0.156	0.56	0.128	0.211	0.087	0.60
240	0.0982	0.162	0.096	0.153	0.61	0.0986	0.162	0.085	0.65
300	0.0791	0.130	0.094	0.151	0.62	0.0798	0.130	0.084	0.67
400	0.0632	0.102	0.092	0.149	0.65	0.0641	0.102	0.082	0.70
500	0.0510	0.0804	0.089	0.147	0.69				
630	0.0417	0.0639	0.086	0.144	0.77				

Note (1) : Aluminium wire armoured
Note (2) : Twice cable diameter spacing between cores

Electrical (AC Resistance , Reactance , Capacitance) of MV Cables
XLPE Insulated , 6/10 kV

Conductor size (mm^2)	Single-core cables [1]					3-core cables			
	AC resistance @ 90°C		Reactance (50 Hz)		Capacitance	AC resistance @ 90°C		Reac-tance	Capacitance
	Copper	Aluminium	Trefoil	Flat 2)	(microF/km)	Copper	Aluminium	(50 Hz)	(microF/km)
	(Ohm/km)	(Ohm/km)	(Ohm/km)	(Ohm/km)		(Ohm/km)	(Ohm/km)	(Ohm/km)	
16						1.47	2.45	0.134	0.21
25						0.927	1.54	0.124	0.24
35						0.668	1.11	0.116	0.26
50	0.494	0.822	0.127	0.185	0.26	0.493	0.822	0.111	0.28
70	0.342	0.568	0.120	0.177	0.30	0.342	0.568	0.106	0.32
95	0.247	0.411	0.114	0.171	0.33	0.247	0.410	0.100	0.36
120	0.196	0.325	0.109	0.166	0.36	0.196	0.325	0.097	0.39
150	0.159	0.265	0.106	0.163	0.39	0.159	0.265	0.094	0.42
185	0.128	0.211	0.103	0.160	0.43	0.128	0.211	0.092	0.46
240	0.0981	0.161	0.099	0.156	0.48	0.0984	0.161	0.089	0.51
300	0.0791	0.130	0.096	0.153	0.52	0.0797	0.130	0.086	0.56
400	0.0632	0.102	0.093	0.150	0.58	0.0639	0.102	0.083	0.62
500	0.0510	0.0804	0.090	0.147	0.66				
630	0.0417	0.0639	0.087	0.145	0.74				

XLPE Insulated , 8.7/15 kV

Conduc-tor size (mm^2)	Single-core cables [1]					3-core cables			
	AC resistance @ 90°C		Reactance (50 Hz)		Capacitance	AC resistance @ 90°C		Reac-tance	Capacitance
	Copper	Aluminium	Trefoil	Flat [2]	(microF/km)	Copper	Aluminium	(50 Hz)	(microF/km)
	(Ohm/km)	(Ohm/km)	(Ohm/km)	(Ohm/km)		(Ohm/km)	(Ohm/km)	(Ohm/km)	
16						1.47	2.45	0.143	0.17
25						0.927	1.54	0.132	0.19
35						0.668	1.11	0.124	0.21
50	0.494	0.822	0.132	0.190	0.21	0.493	0.822	0.118	0.23
70	0.342	0.568	0.125	0.183	0.24	0.342	0.568	0.112	0.26
95	0.247	0.411	0.119	0.176	0.27	0.247	0.410	0.106	0.29
120	0.196	0.325	0.114	0.171	0.29	0.196	0.325	0.102	0.31
150	0.159	0.265	0.111	0.168	0.31	0.159	0.264	0.100	0.34
185	0.128	0.211	0.107	0.164	0.34	0.128	0.211	0.097	0.37
240	0.0979	0.161	0.103	0.160	0.38	0.0982	0.161	0.093	0.41
300	0.0790	0.130	0.100	0.156	0.41	0.0794	0.130	0.090	0.45
400	0.0630	0.102	0.097	0.153	0.46	0.0636	0.102	0.087	0.50
500	0.0507	0.0802	0.093	0.151	0.51				
630	0.0413	0.0636	0.090	0.147	0.57				

Note (1) : Aluminium wire armoured
Note (2) : Twice cable diameter spacing between cores

Electrical (AC Resistance , Reactance , Capacitance) of MV Cables XLPE Insulated , 12/20 kV

Conductor size (mm^2)	Single-core cables [1]					3-core cables			
	AC resistance @ 90°C		Reactance (50 Hz)		Capacitance	AC resistance @ 90°C		Reactance	Capacitance
	Copper	Aluminium	Trefoil	Flat [2]	(microF/ km)	Copper	Aluminium	(50 Hz)	(microF/ km)
	(Ohm/ km)	(Ohm/ km)	(Ohm/ km)	(Ohm/ km)		(Ohm/ km)	(Ohm/ km)	(Ohm/ km)	
16									
25						0.927	1.54	0.139	0.17
35						0.668	1.11	0.130	0.18
50	0.494	0.822	0.137	0.192	0.18	0.493	0.822	0.124	0.20
70	0.342	0.568	0.13	0.185	0.21	0.342	0.568	0.118	0.22
95	0.247	0.411	0.123	0.178	0.23	0.247	0.410	0.111	0.24
120	0.196	0.325	0.118	0.173	0.25	0.196	0.325	0.107	0.26
150	0.159	0.265	0.115	0.170	0.27	0.159	0.264	0.104	0.28
185	0.128	0.211	0.111	0.165	0.29	0.127	0.211	0.101	0.31
240	0.098	0.161	0.106	0.161	0.32	0.098	0.161	0.097	0.34
300	0.079	0.130	0.103	0.158	0.35	0.079	0.130	0.094	0.37
400	0.063	0.102	0.0995	0.155	0.39	0.063	0.102	0.090	0.41
500	0.051	0.080	0.0959	0.152	0.43				
630	0.041	0.064	0.0923	0.149	0.48				

XLPE Insulated , 18/30 kV

Conductor size (mm^2)	Single-core cables [1]					3-core cables			
	AC resistance @ 90°C		Reactance (50 Hz)		Capacitance	AC resistance @ 90°C		Reactance	Capacitance
	Copper	Aluminium	Trefoil	Flat [2]	(microF/ km)	Copper	Aluminium	(50 Hz)	(microF/ km)
	(Ohm/ km)	(Ohm/ km)	(Ohm/ km)	(Ohm/ km)		(Ohm/ km)	(Ohm/ km)	(Ohm/ km)	
70	0.342	0.568	0.143	0.194	0.16	0.342	0.568	0.129	0.15
95	0.247	0.411	0.136	0.189	0.18	0.247	0.410	0.122	0.17
120	0.196	0.325	0.130	0.184	0.19	0.196	0.324	0.117	0.18
150	0.160	0.265	0.127	0.178	0.21	0.159	0.265	0.114	0.20
185	0.127	0.211	0.122	0.174	0.22	0.128	0.211	0.110	0.21
240	0.0976	0.161	0.117	0.169	0.24	0.0978	0.161	0.106	0.25
300	0.0785	0.129	0.113	0.166	0.26	0.0789	0.129	0.102	0.27
400	0.0624	0.101	0.109	0.162	0.29	0.0629	0.102	0.098	0.30
500	0.0500	0.0797	0.104	0.158	0.32				
630	0.0405	0.0630	0.100	0.155	0.35				
800	0.0388	0.0509	0.095	0.151	0.40				

Note (1) : Aluminium wire armoured
Note (2) : Twice cable diameter spacing between cores

Current Rating of PVC Insulated LV (0.6/1 kV) Power cables (Armoured)
Copper Conductor

Adjacent Circuits : At least 1.8 m apart

Depth of Laying 0.8 m Ground Thermal Resistivity : 1.2Km/W

Conductor size (mm^2)	In AIR (30°C)				In GROUND (20°C)			
	Single Core		2-Cores	3 or 4 Cores	Single Core		2-Cores	3 or 4 Cores
	Trefoil	Flat			Trefoil	Flat		
1.5			21	19			30	26
2.5			30	25			40	34
4			39	33			53	45
6			50	43			66	57
10	80	80	69	59	116	116	88	75
16	86	100	97	83	126	126	113	95
25	120	135	128	110	147	163	150	125
35	145	170	157	135	179	194	180	151
50	181	230	190	163	192	200	213	178
70	231	286	241	207	235	244	263	221
95	280	338	291	251	282	289	315	265
120	324	385	336	290	320	323	358	301
150	373	436	386	332	357	358	400	337
185	425	490	439	378	401	396	454	380
240	501	566	516	445	460	445	523	438
300	567	616	592	510	514	489	585	491
400	657	674	683	590	570	521	658	551
500	731	721			627	556		
630	809	771			684	595		
800	886	824			718	615		
1000	945	872			757	645		

Aluminium Conductor

Conductor size (mm^2)	In AIR (30°C)				In GROUND (20°C)			
	Single Core		2-Cores	3 or 4 Cores	Single Core		2-Cores	3 or 4 Cores
	Trefoil	Flat			Trefoil	Flat		
16			71	61			86	73
25			94	80			112	95
35			115	99			134	114
50	131	169	139	119	146	152	159	135
70	168	213	175	151	178	187	198	167
95	205	255	211	186	214	223	237	202
120	238	293		216	244	253		230
150	275	335		250	273	283		258
185	315	379		287	309	315		293
240	372	443		342	358	361		342
300	430	505		399	402	401		386

Current Rating of XLPE Insulated LV (0.6/1 kV) Power cables (Armoured)

Copper Conductor

Adjacent Circuits : At least 1.8 m apart

Depth of Laying 0.8 m Ground Thermal Resistivity : 1.2Km/W

Conductor size (mm^2)	In AIR (30^oC)				In GROUND (20^oC)			
	Single Core		2-Cores	3 or 4 Cores	Single Core		2-Cores	3 or 4 Cores
	Trefoil	Flat			Trefoil	Flat		
1.5			24	22			35	30
2.5			33	30			48	42
4			45	40			61	53
6			58	52			77	67
10	80	80	80	71	96	96	105	92
16	107	107	115	99	122	122	136	115
25	142	142	152	131	154	154	177	147
35	175	175	188	162	186	186	212	176
50	222	288	228	197	224	234	251	210
70	285	358	291	251	275	286	307	258
95	346	425	354	304	329	339	369	309
120	402	485	410	353	374	383	420	352
150	463	549	472	406	418	420	470	393
185	529	618	539	463	470	467	530	444
240	625	715	636	546	541	528	613	513
300	720	810	732	628	604	579	686	574
400	815	848	847	728	670	617	775	646
500	918	923			742	667		
630	1027	992			815	714		
800	1119	1042			861	737		
1000	1214	1110			913	773		

Aluminium Conductor

Conductor size (mm^2)	In AIR (30^oC)				In GROUND (20^oC)			
	Single Core		2-Cores	3 or 4 Cores	Single Core		2-Cores	3 or 4 Cores
	Trefoil	Flat			Trefoil	Flat		
16			85	74			104	88
25			112	98			133	112
35			138	120			160	134
50	162	215	166	145	171	179	190	160
70	207	270	211	185	211	220	232	196
95	252	324	254	224	252	261	279	236
120	292	372		264	287	296		269
150	337	424		305	321	328		301
185	391	477		350	362	368		342
240	465	554		418	420	421		396
300	540	626		488	471	468		447

Current Rating of MV Power cables with Rated Voltage 1.8/3kV (Armoured)

Copper Conductor - PVC Insulated

Adjacent Circuits : At least 1.8 m apart

Depth of Laying 0.8 m Ground Thermal Resistivity : 1.2Km/W

Conductor size (mm^2)	In AIR (30^oC)			In GROUND (20oC)		
	Single Core		3 Cores	Single Core		3 Cores
	Trefoil	Flat		Trefoil	Flat	
16			85			92
25			111			118
35			134			143
50	183	226	163	183	189	169
70	229	281	204	224	229	208
95	284	339	250	267	270	250
120	327	386	290	303	304	284
150	371	433	330	339	336	319
185	426	489	379	380	373	360
240	500	558	446	436	418	414
300	571	620	508	487	458	463
400	649	667	583	537	487	520
500	729	720		589	518	
630	817	780		644	552	
800	881	821		672	569	
1000	949	874		706	594	

Copper Conductor - XLPE Insulated

Conductor size (mm^2)	In AIR (30^oC)			In GROUND (20^oC)		
	Single Core		3 or 4 Cores	Single Core		3 or 4 Cores
	Trefoil	Flat		Trefoil	Flat	
16			108			110
25			143			142
35			170			169
50	230	287	204	215	223	200
70	288	357	257	262	270	246
95	353	434	315	314	321	294
120	411	492	365	355	357	334
150	468	553	415	396	396	375
185	534	622	476	446	440	422
240	630	715	560	512	496	486
300	717	793	640	571	543	546
400	817	851	734	631	577	614
500	924	929		698	621	
630	1041	1007		765	663	
800	1131	1054		806	681	
1000	1227	1121		853	712	

Current Rating of XLPE Insulated MV Power cables
Rated Voltages : 3.6/6 kV - 6/10 kV - 8.7/15 kV

Copper Conductor

Adjacent Circuits : At least 1.8 m apart

Depth of Laying 0.8 m Ground Thermal Resistivity : 1.2Km/W

Conductor size (mm²)	In AIR (30°C)			In GROUND (20°C)		
	Single Core		3 Cores	Single Core		3 Cores
	Trefoil	Flat		Trefoil	Flat	
25			137			135
35			166			164
50	223	280	209	213	223	203
70	270	351	256	261	271	247
95	342	432	313	310	324	291
120	394	494	356	349	368	329
150	446	570	408	397	417	368
185	513	655	465	441	470	417
240	608	779	541	514	543	475
300	703	893	617	582	620	523
400	798	1045	703	659	708	582
500	893	1216		727	805	
630	1054	1425		805	911	
800	1206	1653		892	1037	
1000	1330	1852		970	1144	

Aluminium Conductor

Conductor size (mm²)	In AIR (30°C)			In GROUND (20°C)		
	Single Core		3 or 4 Cores	Single Core		3 or 4 Cores
	Trefoil	Flat		Trefoil	Flat	
25			109			111
35			133			130
50	171	218	161	164	169	155
70	213	275	199	203	208	189
95	266	332	237	242	252	223
120	304	389	280	271	286	257
150	346	441	313	310	320	291
185	403	503	365	349	363	324
240	475	608	427	402	426	368
300	551	693	484	460	480	421
400	636	817	560	523	552	475
500	750	959		591	630	
630	864	1130		659	727	
800	1007	1263		746	834	
1000	1130	1510		824	940	

Current Rating of XLPE Insulated MV Power cables
Rated Voltages : 12/20 kV - 18/30 kV

Copper Conductor

Adjacent Circuits : At least 1.8 m apart

Depth of Laying 0.8 m Ground Thermal Resistivity : 1.2Km/W

Conductor size (mm^2)	In AIR (30°C)			In GROUND (20°C)		
	Single Core		3 Cores	Single Core		3 Cores
	Trefoil	Flat		Trefoil	Flat	
35			171			164
50	232	280	213	213	223	203
70	285	346	261	261	271	247
95	342	427	313	310	324	286
120	403	494	361	349	368	324
150	460	560	408	397	417	363
185	522	636	465	446	470	407
240	617	760	541	514	543	465
300	703	874	617	582	620	514
400	807	1016	703	669	708	572
500	931	1187		737	805	
630	1073	1377		824	921	
800	1225	1605		902	1037	
1000	1349	1833		979	1154	

Aluminium Conductor

Conductor size (mm^2)	In AIR (30°C)			In GROUND (20°C)		
	Single Core		3 or 4 Cores	Single Core		3 or 4 Cores
	Trefoil	Flat		Trefoil	Flat	
35			137			130
50	180	218	166	164	169	155
70	223	270	204	203	208	189
95	266	327	247	242	252	223
120	313	380	285	271	286	252
150	356	432	318	310	320	281
185	408	494	370	349	363	320
240	484	589	437	402	426	368
300	551	674	494	460	480	412
400	646	798	570	533	552	465
500	750	931		591	630	
630	874	1007		669	727	
800	1007	1301		746	834	
1000	1149	1491		834	940	

Short-Circuit Calculation for Power Cables

Insulation	Temperature (°C)		Current Density A/mm²	
	Continuous Rating	at the end of Short-Circuit	K (Cu)	K (Al)
PVC <= 300mm²	70	160	115	76
PVC > 300mm²	70	140	103	68
XLPE	90	250	143	94

Minimum acceptable conductor's cross section acc to short-citcuit current

$$S = \frac{Icc \ . \sqrt{t}}{k} \quad (t \leq 5 \text{ sec})$$

S = Conductor cross-section (mm²)
Icc = Short-Circuit current Raring (A)
K = Specific value of the short circuit current (A.Sec 0.5 / mm²)

Screen Short-Citcuit current capacity of XLPE insulated MV cables

Time of Short Circuit (Seconds)	Maximun Short-Circuit Current in Copper Screen Max .KA (Conductor Cross Section mm²)		
	16	25	35
0.1	9.7	15.1	21.2
0.2	6.9	10.7	15.1
0.3	5.7	8.9	12.5
0.4	5.0	7.7	10.9
0.5	4.5	7.0	9.8
0.6	4.2	6.4	9.0
0.7	3.9	6.0	8.4
0.8	3.5	5.6	7.9
0.9	3.4	5.3	7.5
1	3.3	5.1	7.1
1.5	2.7	4.2	5.9
2	2.3	3.6	5.1
3	1.9	2.9	4.2
4	1.7	2.6	3.6
5.0	1.5	2.3	3.2

KCI

Short-Circuit current capacity Tables of PVC Insulated Power Cables

Copper Conductor

Time of Short Circuit (Seconds)	Maximum Thermal Short-Circuit Current for PVC insulated (Specially MV) cables Max .KA (Conductor Cross Section mm²)											
	25	35	50	70	95	120	150	185	240	300	400	500
0.1	9.1	12.7	18.2	25.5	34.5	43.6	54.5	67.3	87.3	109.1	130.3	162.9
0.2	6.4	9.0	12.9	18.0	24.4	30.9	38.6	47.6	61.7	77.1	92.1	115.2
0.3	5.2	7.3	10.5	14.7	19.9	25.2	31.5	38.8	50.4	63.0	75.2	94.0
0.4	4.5	6.4	9.1	12.7	17.3	21.8	27.3	33.6	43.6	54.5	65.1	81.4
0.5	4.1	5.7	8.1	11.4	15.5	19.5	24.4	30.1	39.0	48.8	58.3	72.8
0.6	3.7	5.2	7.4	10.4	14.1	17.8	22.3	27.5	35.6	44.5	53.2	66.5
0.7	3.4	4.8	6.9	9.6	13.1	16.5	20.6	25.4	33.0	41.2	49.2	61.6
0.8	3.2	4.5	6.4	9.0	12.2	15.4	19.3	23.8	30.9	38.6	46.1	57.6
0.9	3.0	4.2	6.1	8.5	11.5	14.5	18.2	22.4	29.1	36.4	43.4	54.3
1.0	2.9	4.0	5.8	8.1	10.9	13.8	17.3	21.3	27.6	34.5	41.2	51.5
1.5	2.3	3.3	4.7	6.6	8.9	11.3	14.1	17.4	22.5	28.2	33.6	42.0
2.0	2.0	2.8	4.1	5.7	7.7	9.8	12.2	15.0	19.5	24.4	29.1	36.4
3.0	1.7	2.3	3.3	4.6	6.3	8.0	10.0	12.3	15.9	19.9	23.8	29.7
4.0	1.4	2.0	2.9	4.0	5.5	6.9	8.6	10.6	13.8	17.3	20.6	25.8
5.0	1.3	1.8	2.6	3.6	4.9	6.2	7.7	9.5	12.3	15.4	18.4	23.0

Aluminium Conductor

Time of Short Circuit (Seconds)	Maximum Thermal Short-Circuit Current for PVC insulated (Specially MV) cables Max .KA (Conductor Cross Section mm²)											
	25	35	50	70	95	120	150	185	240	300	400	500
0.1	6.0	8.4	12.0	16.8	22.8	28.8	36.0	44.5	57.7	72.1	86.0	107.5
0.2	4.2	5.9	8.5	11.9	16.1	20.4	25.5	31.4	40.8	51.0	60.8	76.0
0.3	3.5	4.9	6.9	9.7	13.2	16.7	20.8	25.7	33.3	41.6	49.7	62.1
0.4	3.0	4.2	6.0	8.4	11.4	14.4	18.0	22.2	28.8	36.0	43.0	53.8
0.5	2.7	3.8	5.4	7.5	10.2	12.9	16.1	19.9	25.8	32.2	38.5	48.1
0.6	2.5	3.4	4.9	6.9	9.3	11.8	14.7	18.2	23.5	29.4	35.1	43.9
0.7	2.3	3.2	4.5	6.4	8.6	10.9	13.6	16.8	21.8	27.3	32.5	40.6
0.8	2.1	3.0	4.2	5.9	8.1	10.2	12.7	15.7	20.4	25.5	30.4	38.0
0.9	2.0	2.8	4.0	5.6	7.6	9.6	12.0	14.8	19.2	24.0	28.7	35.8
1.0	1.9	2.7	3.8	5.3	7.2	9.1	11.4	14.1	18.2	22.8	27.2	34.0
1.5	1.6	2.2	3.1	4.3	5.9	7.4	9.3	11.5	14.9	18.6	22.2	27.8
2.0	1.3	1.9	2.7	3.8	5.1	6.4	8.1	9.9	12.9	16.1	19.2	24.0
3.0	1.1	1.5	2.2	3.1	4.2	5.3	6.6	8.1	10.5	13.2	15.7	19.6
4.0	1.0	1.3	1.9	2.7	3.6	4.6	5.7	7.0	9.1	11.4	13.6	17.0
5.0	0.8	1.2	1.7	2.4	3.2	4.1	5.1	6.3	8.2	10.2	12.2	15.2

Short-Circuit current capacity Tables of XLPE Insulated Power Cables Copper Conductor

Time of Short Circuit (Seconds)	Maximum Thermal Short-Circuit Current for PVC insulated (Specially MV) cables Max .KA (Conductor Cross Section mm²)											
	25	35	50	70	95	120	150	185	240	300	400	500
0.1	11.3	15.8	22.6	31.7	43.0	54.3	67.8	83.7	108.5	135.7	180.9	226.1
0.2	8.0	11.2	16.0	22.4	30.4	38.4	48.0	59.2	76.7	95.9	127.9	159.9
0.3	6.5	9.1	13.1	18.3	24.8	31.3	39.2	48.3	62.7	78.3	104.4	130.5
0.4	5.7	7.9	11.3	15.8	21.5	27.1	33.9	41.8	54.3	67.8	90.4	113.1
0.5	5.1	7.1	10.1	14.2	19.2	24.3	30.3	37.4	48.5	60.7	80.9	101.1
0.6	4.6	6.5	9.2	12.9	17.5	22.2	27.7	34.2	44.3	55.4	73.8	92.3
0.7	4.3	6.0	8.5	12.0	16.2	20.5	25.6	31.6	41.0	51.3	68.4	85.5
0.8	4.0	5.6	8.0	11.2	15.2	19.2	24.0	29.6	38.4	48.0	64.0	79.9
0.9	3.8	5.3	7.5	10.6	14.3	18.1	22.6	27.9	36.2	45.2	60.3	75.4
1.0	3.6	5.0	7.2	10.0	13.6	17.2	21.5	26.5	34.3	42.9	57.2	71.5
1.5	2.9	4.1	5.8	8.2	11.1	14.0	17.5	21.6	28.0	35.0	46.7	58.4
2.0	2.5	3.5	5.1	7.1	9.6	12.1	15.2	18.7	24.3	30.3	40.4	50.6
3.0	2.1	2.9	4.1	5.8	7.8	9.9	12.4	15.3	19.8	24.8	33.0	41.3
4.0	1.8	2.5	3.6	5.0	6.8	8.6	10.7	13.2	17.2	21.5	28.6	35.8
5.0	1.6	2.2	3.2	4.5	6.1	7.7	9.6	11.8	15.3	19.2	25.6	32.0

Aluminium Conductor

Time of Short Circuit (Seconds)	Maximum Thermal Short-Circuit Current for PVC insulated (Specially MV) cables Max .KA (Conductor Cross Section mm²)											
	25	35	50	70	95	120	150	185	240	300	400	500
0.1	7.4	10.4	14.9	20.8	28.2	35.7	44.6	55.0	71.3	89.2	118.9	148.6
0.2	5.3	7.4	10.5	14.7	20.0	25.2	31.5	38.9	50.4	63.1	84.1	105.1
0.3	4.3	6.0	8.6	12.0	16.3	20.6	25.7	31.7	41.2	51.5	68.6	85.8
0.4	3.7	5.2	7.4	10.4	14.1	17.8	22.3	27.5	35.7	44.6	59.5	74.3
0.5	3.3	4.7	6.6	9.3	12.6	16.0	19.9	24.6	31.9	39.9	53.2	66.5
0.6	3.0	4.2	6.1	8.5	11.5	14.6	18.2	22.5	29.1	36.4	48.5	60.7
0.7	2.8	3.9	5.6	7.9	10.7	13.5	16.9	20.8	27.0	33.7	44.9	56.2
0.8	2.6	3.7	5.3	7.4	10.0	12.6	15.8	19.4	25.2	31.5	42.0	52.5
0.9	2.5	3.5	5.0	6.9	9.4	11.9	14.9	18.3	23.8	29.7	39.6	49.5
1.0	2.4	3.3	4.7	6.6	8.9	11.3	14.1	17.4	22.6	28.2	37.6	47.0
1.5	1.9	2.7	3.8	5.4	7.3	9.2	11.5	14.2	18.4	23.0	30.7	38.4
2.0	1.7	2.3	3.3	4.7	6.3	8.0	10.0	12.3	16.0	19.9	26.6	33.2
3.0	1.4	1.9	2.7	3.8	5.2	6.5	8.1	10.0	13.0	16.3	21.7	27.1
4.0	1.2	1.6	2.4	3.3	4.5	5.6	7.1	8.7	11.3	14.1	18.8	23.5
5.0	1.1	1.5	2.1	2.9	4.0	5.0	6.3	7.8	10.1	12.6	16.8	21.0

Rating factor for various condition of cable installation

Multi-core cables with nominal S<= 10 mm^2

Soil Thermal Resistivity

Reduction factors for groups of more than one circuit of single-core cables To be applied to the current-carrying capacity for one circuit of single-core cables in free air

Reduction factors for groups of more than one circuit of multi-core cables To be applied to the current-carrying capacity for one circuit of single-core cables in free air

Reduction factors for more than one circuit cables laid in ducts in ground or directly in the ground

Rating factor for depth of laying other than 0.5 m (LV Cables)

Rating factor for depth of laying other than 0.8 m (MV Cables)

Rating factors for Thermal resistivity of SOIL (average values)

Rating factor for various condition of cable installation

Rating Factor For Variation of AIR Temperature	Air Temperature (°C)										
	10	15	20	25	30	35	40	45	50	55	60
PVC Insulated Cables	1.22	1.17	1.12	1.06	1.00	0.94	0.87	0.79	0.71	0.61	0.50
XLPE Insulated Cables	1.15	1.12	1.08	1.04	1.00	0.96	0.91	0.87	0.82	0.76	0.71

Rating Factor For Variation of SOIL Temperature	SOIL Temperature (°C)										
	10	15	20	25	30	35	40	45	50	55	60
PVC Insulated Cables	1.10	1.05	1.00	0.95	0.89	0.84	0.77	0.71	0.63	0.55	0.45
XLPE Insulated Cables	1.07	1.04	1.00	0.96	0.93	0.89	0.85	0.80	0.76	0.71	0.65

Rating factor for multi-core cables with nominal cross-sectional areas of conductors up to 10 mm^2

Number of loaded cores	Rating factor
5	0.75
7	0.65
10	0.55
14	0.50
19	0.45
24	0.40
40	0.35
61	0.30

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Soil Thermal Resistivity

Thermal Resistivity (Km/W)	Soil Conditions	Weather Conditions
0.7	Very moist	Continuously moist
1	Moist	Regular rainfall
2	Dry	Seldom rains
3	Very dry	Little or no rain

Guidance given in ERA Report on various load condition and it's effect on SOIL Resistivity

Type A - Cables carrying Constant load throughout the year

All soils except those below	1.5 Km/W
Chalk soil with crushed chalk backfill	1.2 Km/W
Peat	1.2 Km/W
Very stony soil or ballast	1.5 Km/W
Well-drained sand	2.5 Km/W
Made-up soils	1.8 Km/W

Type B - Cables with varying load and maximum in summer

All soils except those below	1.2 Km/W
Stony soil or ballast	1.3 Km/W
Well-drained sand	2.0 Km/W
Made-up soils	1.6 Km/W

Type C - Cables with varying load and maximum in winter

All soils except those below	1.0 Km/W
Clay	0.9 Km/W
Chalk soil with crushed chalk backfill	1.2 Km/W
Well-drained sand	1.5 Km/W
Made-up soils	1.2 Km/W

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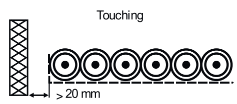
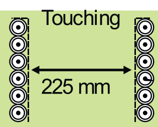
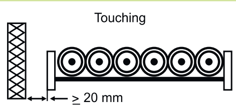
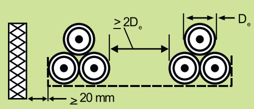
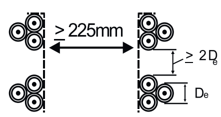
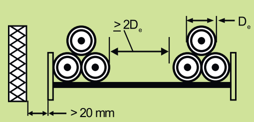
Reduction factors for groups of more than one circuit of single-core cables To be applied to the current-carrying capacity for one circuit of single-core cables in free air

Method of installation		Number of trays	Number of three-phase circuits (Note 5)			Use as a multiplier to rating for
			1	2	3	
Perforated trays (Note3)		1	0.98	0.96	0.95	Three cables in horizontal formation
		2	0.96	0.87	0.81	
		3	0.95	0.85	0.78	
Vertical perforated trays (Note4)		1	0.96	0.86	----	Three cables in vertical formation
		2	0.95	0.84	----	
Ladder supports cleats etc. (Note3)		1	1.00	0.97	0.96	Three cables in horizontal formation
		2	0.98	0.93	0.89	
		3	0.97	0.90	0.86	
Perforated trays (Note3)		1	1.00	0.98	0.96	Three cables in trefoil formation
		2	0.97	0.93	0.89	
		3	0.96	0.92	0.86	
vertical perforated trays (Note4)		1	1.00	0.91	0.89	
		2	1.00	0.90	0.86	
Ladder supports cleats etc. (Note3)		1	1.00	1.00	1.00	
		2	0.97	0.95	0.93	
		3	0.96	0.94	0.90	

Note 1 : Values given are average for the cable types and range of conductor sizes considered .
The spread of values is generally less than 5 % .

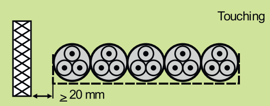
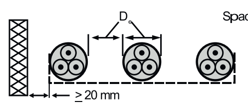
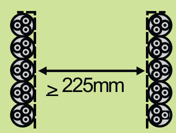
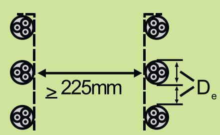
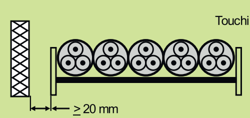
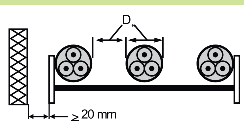
Note 2 : Factors are given for single layers of cables (or trefoil groups) as shown in the table and don't apply when cables are installed in more than one layer touching each other .
Values for such installations may be significantly lower and should be determined by an appropriate method.

Note 3 : Values are given for vertical spacing between trays of 300 mm . For closer spacing factors should be reduced.

Note 4 : Values are given for horizontal spacing between trays of 225 mm with trays mounted back to back.
For closer spacing , the factors should be reduced.

Note 5 : For circuits having more than one cable in parallel per phase , each three phase set of conductors should be considered as a circuit for the purpose of this table .

Reduction factors for groups of more than one circuit of multi-core cables To be applied to the current-carrying capacity for one circuit of single-core cables in free air

Method of installation		Number of trays	Number of three-phase circuits (Note 5)					
			1	2	3	4	6	9
Perforated trays (Note3)		1	1.00	0.88	0.82	0.79	0.76	0.73
		2	1.00	0.87	0.80	0.77	0.73	0.68
		3	1.00	0.86	0.79	0.76	0.71	0.66
		1	1.00	1.00	0.98	0.95	0.91	---
		2	1.00	0.99	0.96	0.92	0.87	---
		3	1.00	0.98	0.95	0.91	0.85	---
vertical perforated trays (Note4)		1	1.00	0.88	0.82	0.78	0.73	0.72
		2	1.00	0.88	0.81	0.76	0.71	0.70
		1	1.00	0.91	0.89	0.88	0.87	---
		2	1.00	0.91	0.88	0.87	0.85	---
Ladder supports cleats etc. (Note3)		1	1.00	0.87	0.82	0.80	0.79	0.78
		2	1.00	0.86	0.80	0.78	0.76	0.73
		3	1.00	0.85	0.79	0.76	0.73	0.70
		1	1.00	1.00	1.00	1.00	1.00	---
		2	1.00	0.99	0.98	0.97	0.96	---
		3	1.00	0.98	0.97	0.96	0.93	---

Note 1 : Values given are average for the cable types and range of conductor sizes considered . The spread of values is generally less than 5 % .

Note 2 : Factors are given for single layer groups of cables as shown above and don't apply when cables are installed in more than one layer touching each other . Values for such installations may be significantly lower and should be determined by an appropriate method.

Note 3 : Values are given for vertical spacing between trays of 300 mm and at least 20 mm between trays and wall .For closer spacing factors should be reduced.

Note 4 : Values are given for horizontal spacing between trays of 225 mm with trays mounted back to back. For closer spacing , the factors should be reduced.

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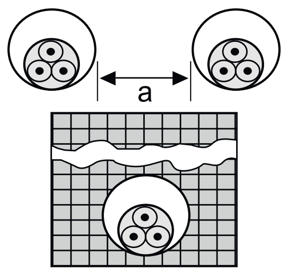
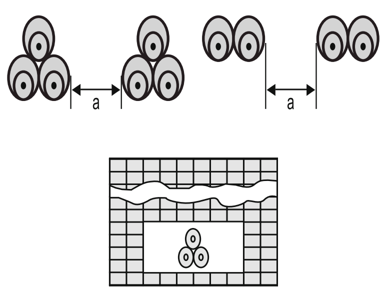
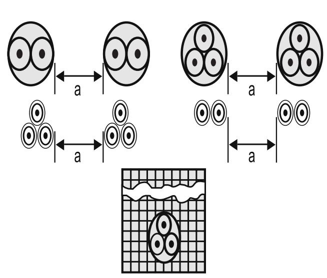
Reduction factors for more than one circuit cables laid in ducts in ground or directly in the ground

Method of installation	Number of cables	Duct to duct clearance			
		Nil (ducts touching)	0.25 m	0.5 m	1.0 m
Multi core cables in single way ducts 	2	0.85	0.90	0.95	0.95
	3	0.75	0.85	0.90	0.95
	4	0.70	0.80	0.85	0.90
	5	0.65	0.80	0.85	0.90
	6	0.60	0.80	0.80	0.90

Method of installation	Number of single core circuits of 2 or 3 cables	Duct to duct clearance			
		Nil (ducts touching)	0.25 m	0.5 m	1.0 m
Single core cables in single way ducts 	2	0.80	0.90	0.90	0.95
	3	0.70	0.80	0.85	0.90
	4	0.65	0.75	0.80	0.90
	5	0.60	0.70	0.80	0.90
	6	0.60	0.70	0.80	0.90

Method of installation	Number of circuits	Cable to cable clearance				
		Nil (cables touching)	One cable diameter	0.125 m	0.25 m	0.5 m
Multi core & Single core cables laid directly in the ground 	2	0.75	0.80	0.85	0.90	0.90
	3	0.65	0.70	0.75	0.80	0.85
	4	0.60	0.60	0.70	0.75	0.80
	5	0.55	0.55	0.65	0.70	0.80
	6	0.50	0.55	0.60	0.70	0.80

Note : Values given apply to an installation depth of 0.7 m and a soil thermal resistivity of 2.5 K m / W .
They are average values for the range of different cable size and type .
Where more precise values are required ,they may be calculated by methods given in IEC 60287 .

Rating factor for depth of laying other than 0.5 m (for Low Voltage Cables - 0.6/1kV)

Depth of Laying (m)	up to 50 mm^2	70 to 300 mm^2	Above 300 mm^2
0.5	1.00	1.00	1.00
0.6	0.99	0.98	0.97
0.8	0.97	0.96	0.94
1	0.95	0.94	0.92
1.25	0.94	0.92	0.90
1.5	0.93	0.91	0.89
1.75	0.92	0.89	0.87
2	0.91	0.88	0.86
2.5	0.90	0.87	0.85
3.0 or more	0.89	0.86	0.83

Rating factor for depth of laying other than 0.8 m (for Medium Voltage Cables)

Direct Buried Cables

Depth of Laying (m)	Single Core Cables Nominal Conductor Size mm^2		3 Core cables
	<= 185	>185	
0.5	1.04	1.06	1.04
0.6	1.02	1.04	1.03
1	0.98	0.97	0.98
1.25	0.96	0.95	0.96
1.5	0.95	0.93	0.95
1.75	0.94	0.91	0.94
2	0.93	0.90	0.93
2.5	0.91	0.88	0.91
3	0.90	0.86	0.90

Cables in ducts

Depth of Laying (m)	Single Core Cables Nominal Conductor Size mm^2		3 Core cables
	<= 185	>185	
0.5	1.04	1.05	1.03
0.6	1.02	1.03	1.02
1	0.98	0.97	0.99
1.25	0.96	0.95	0.97
1.5	0.95	0.93	0.96
1.75	0.94	0.92	0.95
2	0.93	0.91	0.94
2.5	0.91	0.89	0.93
3	0.90	0.88	0.92

Rating factors for Thermal resistivity of SOIL (average values)

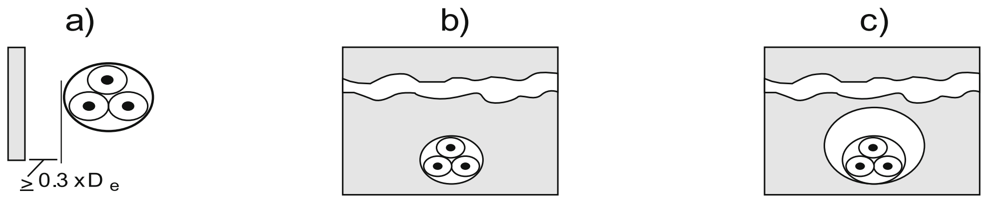
Rating Factor For Variation of AIR Temperature		Soil thermal resistivity (K m /W)						
		0.8	0.9	1	1.5	2	2.5	3
Single core cables	up to 150 mm^2	1.16	1.11	1.07	0.91	0.81	0.73	0.67
	from 185 to 400 mm^2	1.17	1.12	1.07	0.90	0.80	0.72	0.66
	from 500 to 1200 mm^2	1.18	1.13	1.08	0.90	0.79	0.71	0.65
Multi Core Cables	up to 16 mm^2	1.09	1.06	1.04	0.95	0.86	0.79	0.74
	from 25 to 150 mm^2	1.14	1.10	1.07	0.93	0.84	0.76	0.70
	from 185 to 400 mm^2	1.16	1.11	1.07	0.92	0.82	0.74	0.68

Methods of installation

Three-core cables

Current ratings are given for three-core cables installed under the following conditions :

a) single cable in air spaced at least 0.3 times the cable diameter from any vertical surface
b) single cable buried direct in the ground at a depth of 0.8 m (for MV cables) 0.5 m (for LV cables)
c) single cable in a buried earthenware duct having dimensions calculated in the same manner as for the single-core cables in ducts . The depth of burial is 0.8 m (for MV cables) , 0.5 m (for LV cables).



Methods of installation … continued

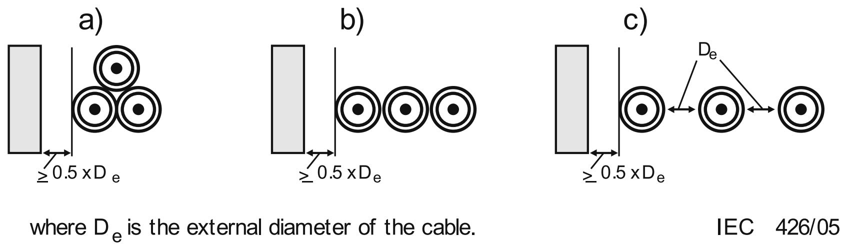
Single-core cables in air

The cables are assumed to be spaced at least 0.5 times the cable diameter from any vertical surface and installed on the brackets or ladder racks as follows:

a) three cables in trefoil formation touching throughout their length

b) three cables in horizontal flat formation touching throughout their length

c) three cables in horizontal flat formation with a clearance of one cable diameter

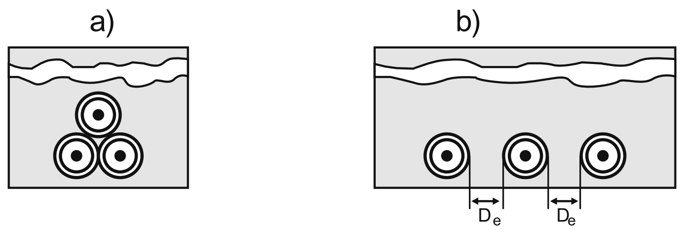


Single-core cables buried direct

Current ratings are given for cables buried direct in the ground at a depth of 0.8 m under the following conditions :

a) three cables in the trefoil formation touching throughout their length

b) three cables in horizontal flat formation with a clearance of one cable diameter , De

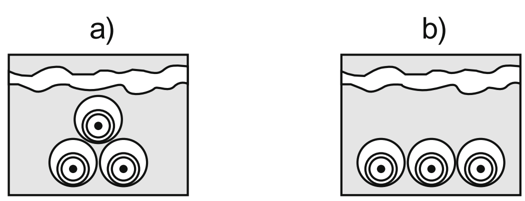


Single-core cables in earthenware ducts

Current rating are given for cables in earthenware ducts buried at a depth of 0.8 m with one cable per ducts as follows :

a) three cables in trefoil ducts touching throughout their length

b) three cables in horizontal flat formation , ducts touching throughout their length



The ducts are assumed to be earthenware having a inside diameter of 1.5 times the outside diameter of cable and a wall thickness equal to 6% of the duct inside diameter.

The ratings are based on the assumption that the ducts are air filled.

If the ducts have been filled with a material such as Bentonite , then it is usual to adopt the current ratings for the cables buried direct.

The tabulated ratings may be applied to cables in ducts having an inside diameter of between 1.2 and 2 times the outside diameter of cables .

For this range of diameters the variation in the rating is less than 2% of the tabulated value.

KCI

CABLING ; Tools , procedure , accessories , laying and handling

Cable Termination Fundamentals

Cable Stress Relief

Electrical Fields distribution around Termination

Typical Example Of Cable FIXINGS

Heat-shrinkable medium voltage terminations

Dimensional drawings for installation of cable termination

Cable accessories < 1 kV

Cable Joint Types

Cable CLEATS

Cable Pulling : PREPARATION FOR CABLE LAYING

Cable LAYING in Ground,Duct,Tunnel

Cable accessories / Preparation tools

Repair of Damage to Outer Sheath

Cable fault finding Guide

Cable Termination Fundamentals

Modern jointing

Today's jointing technology must achieve higher levels of reliability and flexibility to meet the demand of operators who are under increasing pressure to improve network efficiency.
In an environment with less engineering resources for product selection, outsourced services, emphasis on repair time and a variety of cable and conductor types in the network, a universal joint including range taking screw connectors ensures reliable application and service.

Shield continuity

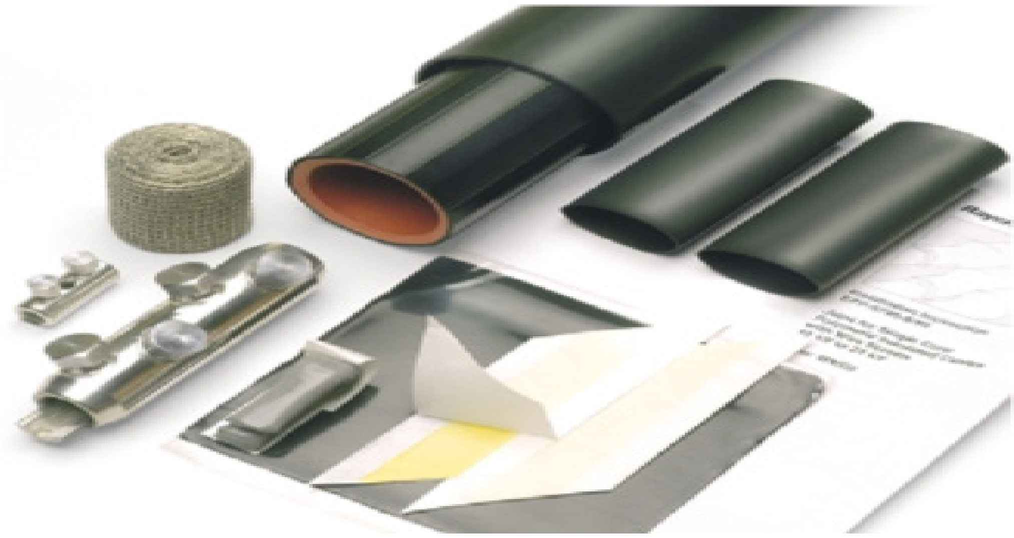
Typical shield wire cross sections up to 35mm^2 can easily be connected with the mechanical connector supplied in the kit. Positioned at the oversheath cut back, the connection provides a smooth profile and resists mechanical damage. There is no need for a crimping tool and its maintenance. Two shear bolts provide the required contact force in order to ensure safe installation and reliable performance during load cycling in service as well as during short circuit conditions. An additional layer of copper mesh is applied around the joint to provide satisfactory shielding and protection.

Mechanical shear bolt connectors
All joint kits incorporate a Raychem designed screw connector with shear head bolts to ensure a reliable pre-engineered electrical connection for the different conductor materials, shapes and types used in today's net- work. The preset shear torque of the bolts ensures that the correct contact pressure is always achieved. The specially designed contact surface on the inside of the connector breaks up any conductor oxide layer and ensures reliable service over the entire life time of the joint. The connectors have been tested in accordance with IEC 61238-1 class A.

Elastomeric insulation and screen
The heat shrinkable conductive layer of the screened elastomeric joint component holds the elastomeric insulation layer in its expanded stage when supplied. This enables the usage of a wide range of cable application diameters with only one kit. During the heat shrink installation process, the stored recovery force of the elastomer is released in addition to the recovery force of the heat shrinkable outer layer.

A pre-designed screen and thick layer of insulation is installed in one simple process. This allows extremely tight electrical interfaces due to the shrink force generated. The elastomeric insulation characteristic combined with the rigid outer heat shrinkable screen layer enables the joint to follow the thermally induced dimensional changes of the cable insulation.

Robust outer sealing and protection
Modern cable laying techniques require a robust oversheath replacement capable of withstanding high mechanical stresses during conventional cable laying as well as mechanical impact occurring during the entire cable life time. The thick-wall heat-shrinkable tubing is internally coated with a hot melt adhesive to ensure an effective moisture seal and corrosion protection for the joint. When installed, the joints provide the similar level of protection and thickness as modern cables with PE oversheath. All voltage sheath testing commonly used today after cable laying or as control test methods have easily been passed.



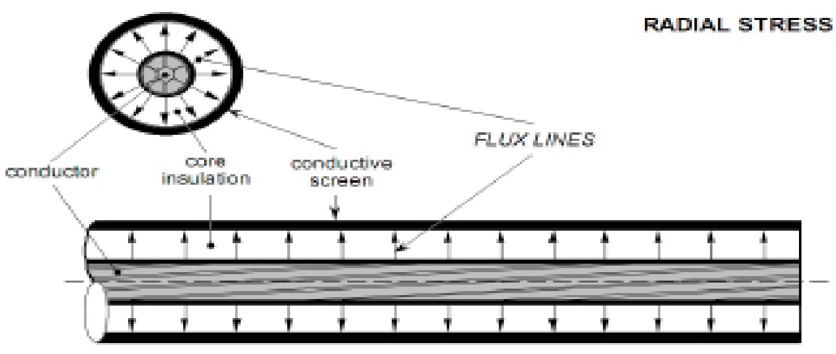
CABLE STRESS RELIEF

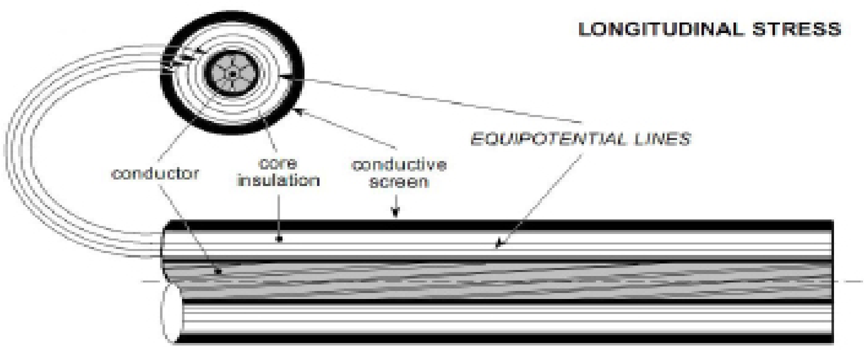
Electrical stress control

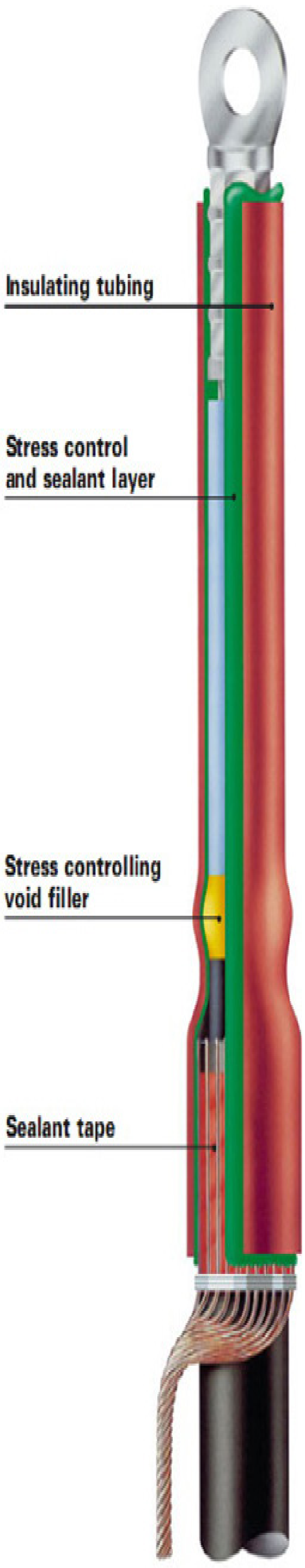
The stress control tubing at each cable end in combination with the yellow stress grading mastic at the screen cut provide a precisely defined impedance characteristic which smoothes the electrical field. For ease of installation, a stress control patch is applied around the mechanical connector to provide a similar function.

The design and construction of screened power cable is primarily based on two types of electrical stress :

A radial stress which can be represented by lines of flux and
a longitudinal stress which can be considered as lines of equipotential







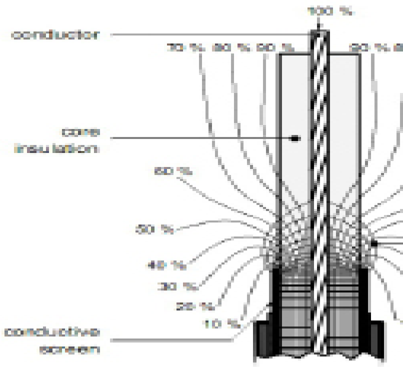
When the semi-conducting core screen is cut, the electrical field distribution changes radically. The surrounding air becomes overstressed as does the dielectric material in the cable immediately in the vicinity of the cut screen.

To prevent rapid breakdown of the cable it is necessary to apply a stress cone or a linear stress relief tube at the end of the screen.

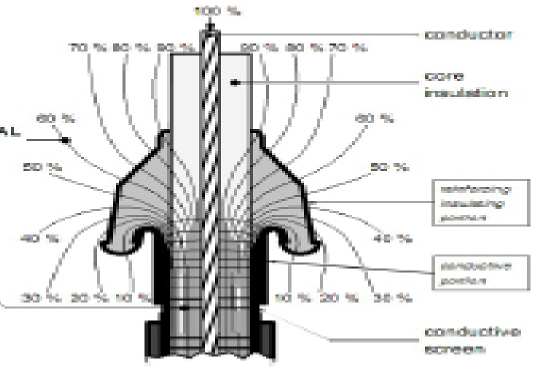
The cone has an insulating portion to reinforce the primary cable insulation and a conductive portion to mate with the semi-conducting core screen.

This controls the lines of equipotential so that when they finally emerge into the air they are sufficiently far apart not to cause ionisation.

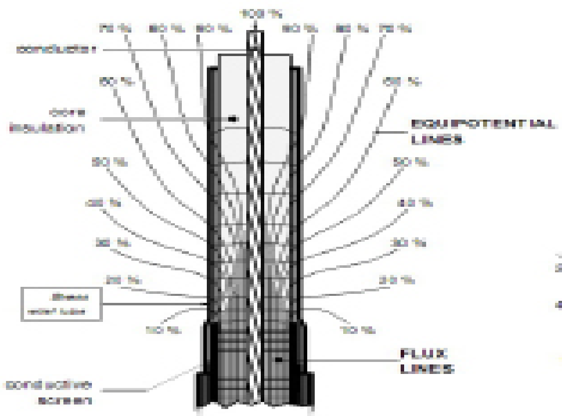
Electrical Fields distribution around Termination



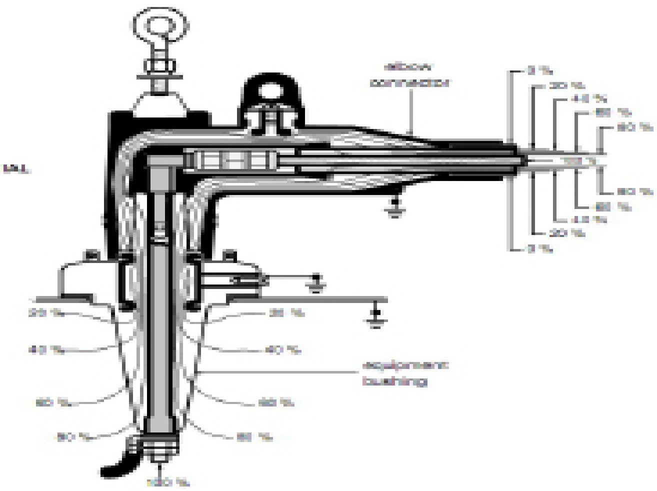
Without stress relief



Stress relief with a premoulded stress cone



Stress relief with a linear stress relief tube

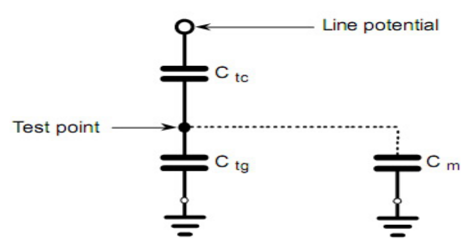


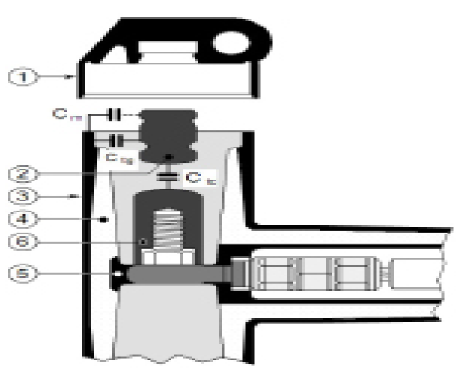
Stress distribution in a typical combination

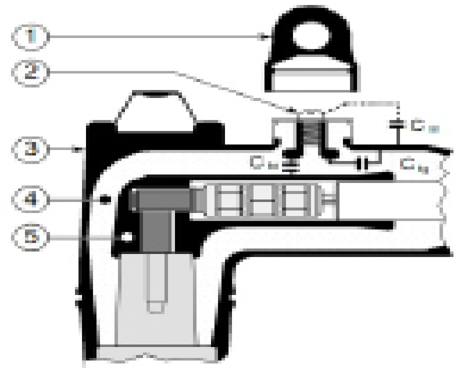
THE CAPACITIVE TEST POINT

The capacitive test point consists of a metallic insert moulded into the insulation and electrically connected to a convenient external terminal.

(1) Conductive rubber cap
(2) Metallic insert (capacitive test point)
(3) Conductive EPDM screen (earth potential)
(4) EPDM insulation
(5) Internal EPDM screen (line potential)
(6) Metallic insert (line potential)



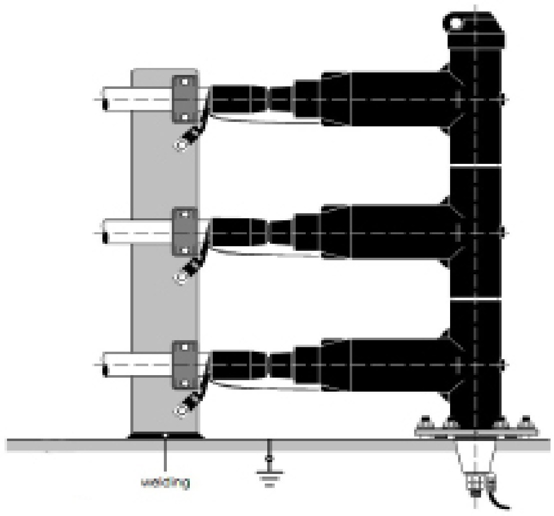


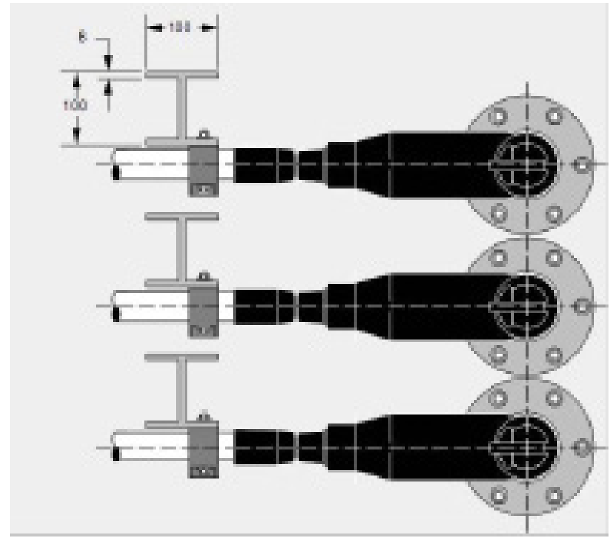


Kerman & Kavian Cable Industries (KCI)

Power Cables

TYPICAL EXAMPLE OF CABLE FIXINGS



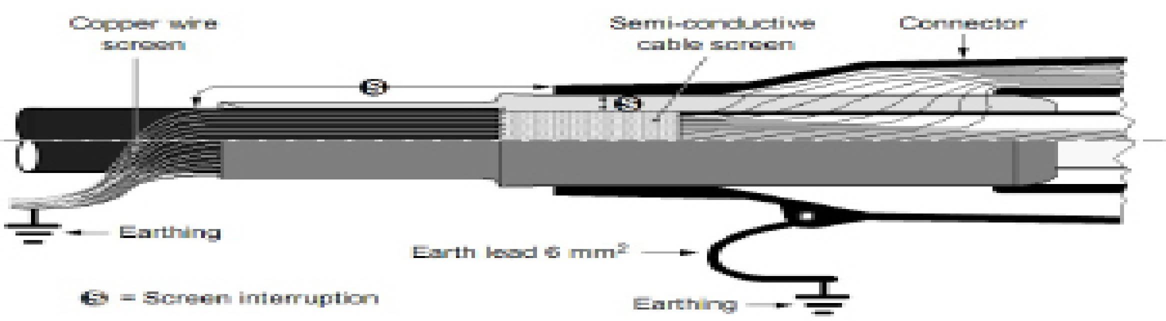


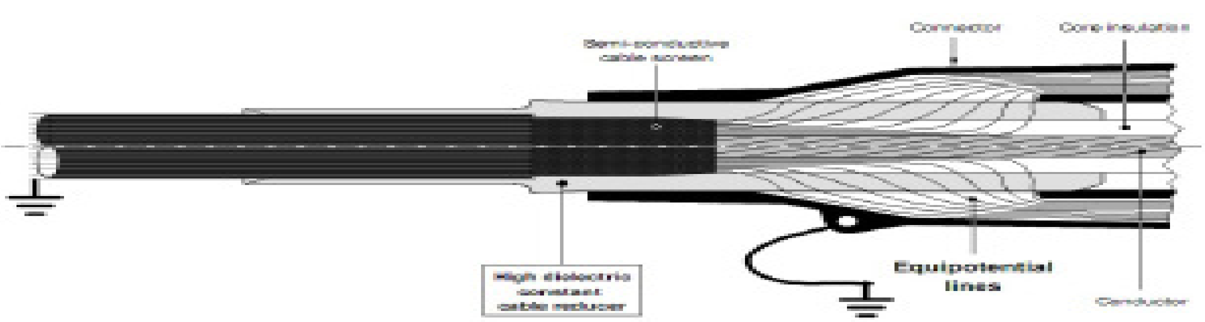
CABLE SCREEN ADAPTOR

APPLICATION
Terminates graphite tape or extruded screens with either flat metallic tape or wire current drain.

TECHNICAL DETAIL This unit
1) secures the tape and reinforces the graphite varnish
2) provides an interface similar to an extruded screened cable which readily accepts all accessories
3) is moulded from conductive EPDM rubber.

INSTALLATION
After cable preparation and with the aid of the silicone grease provided, the adaptor simply slides over the conductive screen and seats on the cable outer sheath.





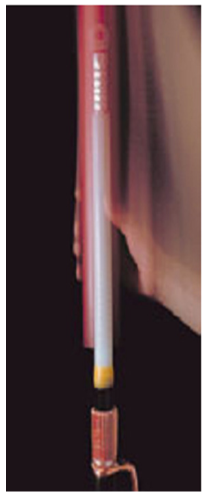
Heat-shrinkable medium voltage terminations

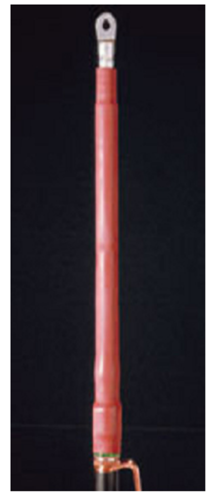
For indoor and outdoor applications for polymeric cables up to 30 kV

Designed for both indoor and outdoor use in all climate conditions, covers applications for polymeric cables up to 30 kV. The components combine to provide the important functions required for all medium voltage products: electrical performance, stress control and moisture sealing.

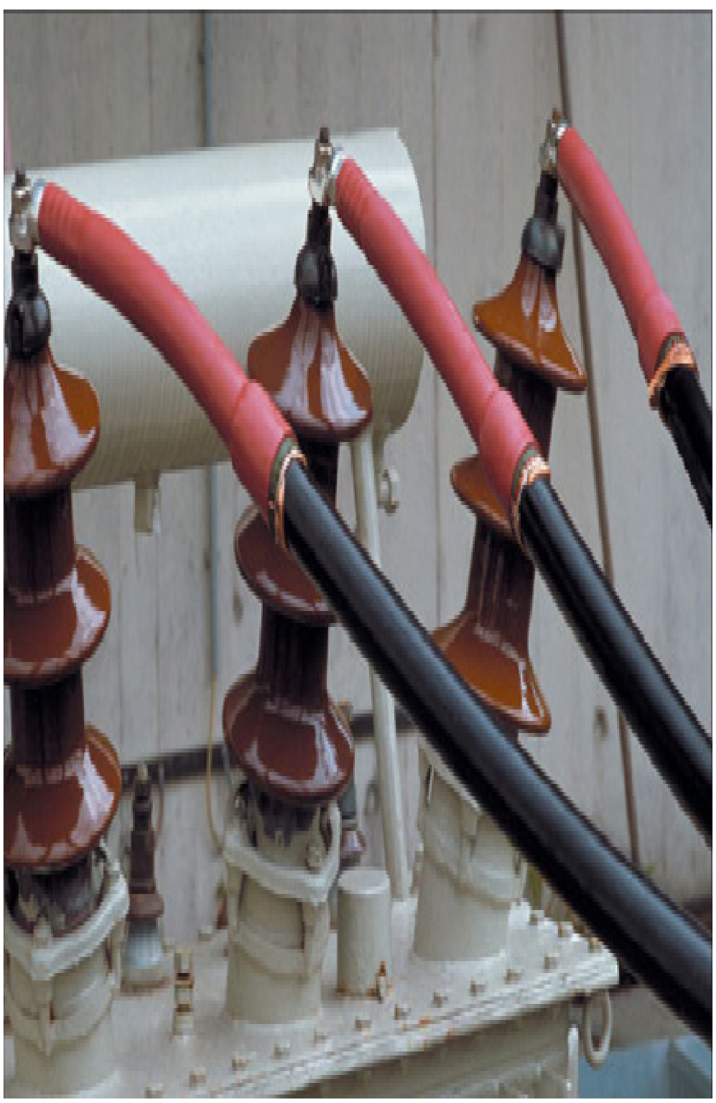
Benefits :

- Space saving
- Unlimited shelf life
- Minimal waste for disposal
- Simple and fast to install
- Superior application range





Application Examples

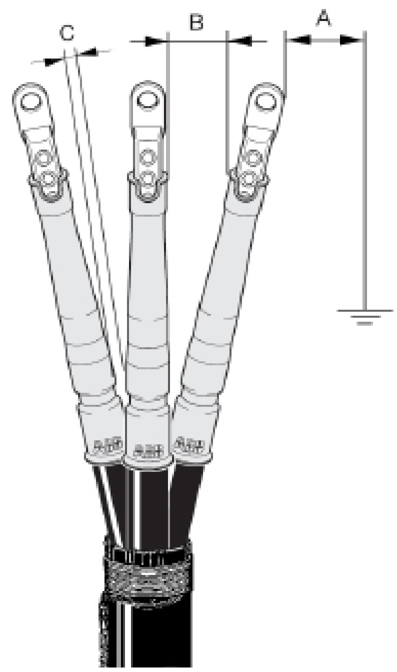


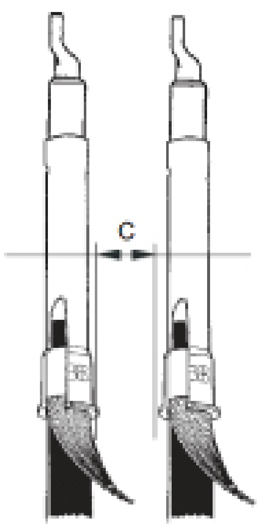
KCI

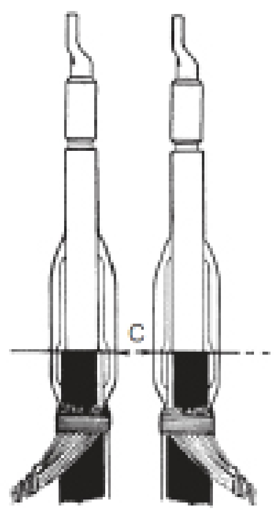
Dimensional drawings for installation of cable termination

Minimum air gap

Max voltage kV	Indoor			Outdoor	
	phase-earth A	phase-phase B	phase-phase C	phase-earth A	phase-phase B
10	90	90	10	130	130
12	120	120	10	160	160
24	220	250	30	270	270
36	320	370	50	380	380

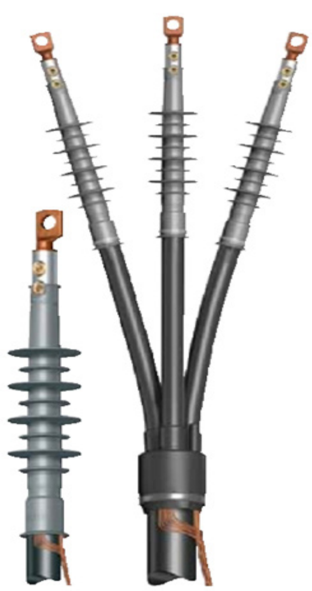






Minimum air gap
between cores in parallel

	10 kV	12 kV	24 kV	36 kV
C	10 mm	10 mm	30 mm	50 mm



Termination type for
Outdoor Installation

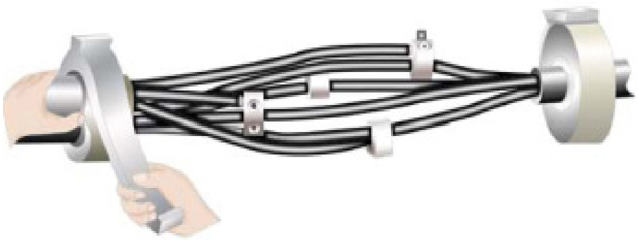
Termination type for
Indoor Installation

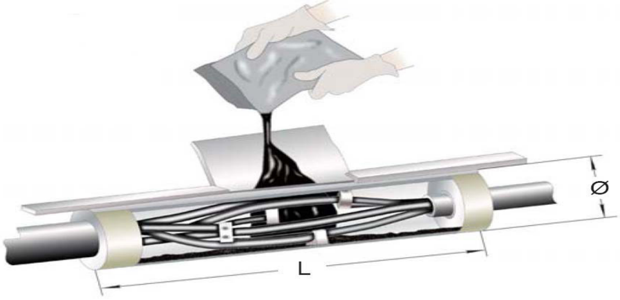
Cable accessories < 1 kV

The most important task of the accessories is to create a safe electrical connection, insulation and provide mechanical protection.
The product range includes accessories designed on different principles with different properties.
Accessories which utilize tape technology are simple to use, flexible and unaffected by the dimensions of the cable. Cable accessories which utilize heat- shrink technology offer a simple alternative.
Cast resin products are the obvious choice in slightly more challenging environments. The robust joint is able to cope with a depth of water of 10 m, for example, and can be used for both power and control cables. Cast resin is non-hazardous according to the Swedish Occupational Safety and Health Act's stipulated to marginal value for non-hazardous joint.

Cable joint, branch for plastic-insulated cable

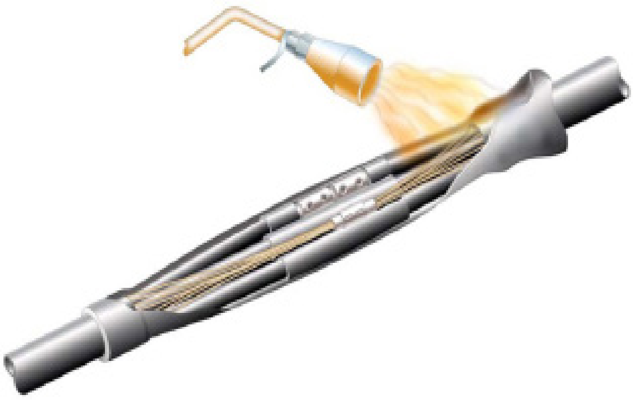
Design:
The joint consists of a transparent, impact- resistant casting mould with flexible sealing rings between the casting mould and the cable.
The cast resin and hardener are exactly measured in a two-part bag. The compound can be filled in the joint without any special protective measure.
Branching takes place with the help of clamps, which penetrate the insulation on the main cable. The clamps, which are included in the kit, are tightened with a torque wrench.





Cable joint, heat-shrink for plastic-insulated cable

Design:
The kit contains four inner sleeves and one outer sleeve.
The sleeves are made of cross-linked polyethylene.
The sleeves are coated internally with a hot-melt adhesive and are installed with heat.



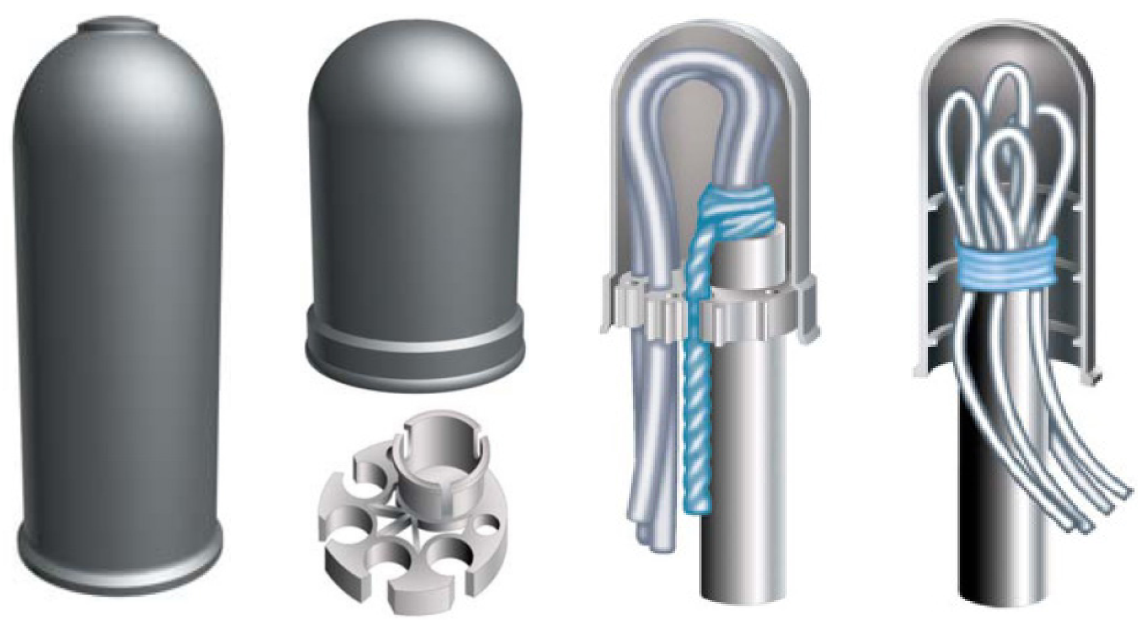
Cable accessories < 1 kV

Cable joint, tape for plastic-insulated cable

Use:
For jointing 1 kV plastic-insulated cable with 3-, 4- and 5-cores, with or without screen
Design:
The kit contains insulating vulcanizing tape and electrical tape. Also includes a copper net. Insulating vulcanizing tape is used for insulation of the connectors. The stripped cable sheaths and electrical tape are used as outer protection. The joints are packed in kits.

Cable termination Protective hood for plastic-insulated cable

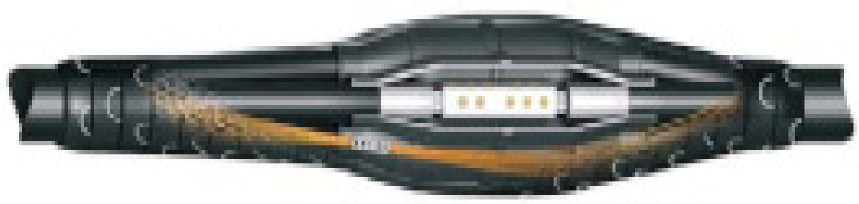
Use:
Termination outdoors for 1 kV plastic- insulated underground cable with 3-, 4- or 5-core, 2.5-95 mm2
Design:
The cable termination consists of a hood made of weather-proof and oil-resistant rubber. The cable cores are bent downwards and fixed with tape and are protected against UV-radiation with a type IS insulating hose. The hood is then pushed on.



Cable Joint Types

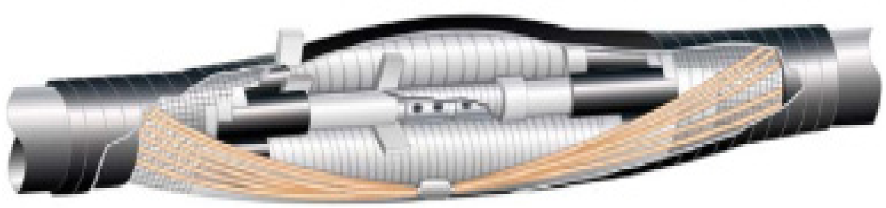
Cable joint, prefabricated with or without outer sheath

Use:
Prefabricated cable joint for XLPE-insulated 1- or 3-core cable with Al or Cu conductor for 12-24 kV.
Design :
The joint body is made of three layers of rubber - a conductive outer layer, an insulated and a conductive inner layer. Contains all mounting material.



Cable joint, tape

Use:
For jointing XLPE-insulated 1- and 3-core cables with Al or Cu conductors 12-36 kV
Design:
The joint kit consists of tapes, stress grading pads FSD and a copper net.
The connectors for the conductor and screen must be ordered separately. Welding of conductors will require welding equipment, which must be ordered separately



Accessories for Cable joint

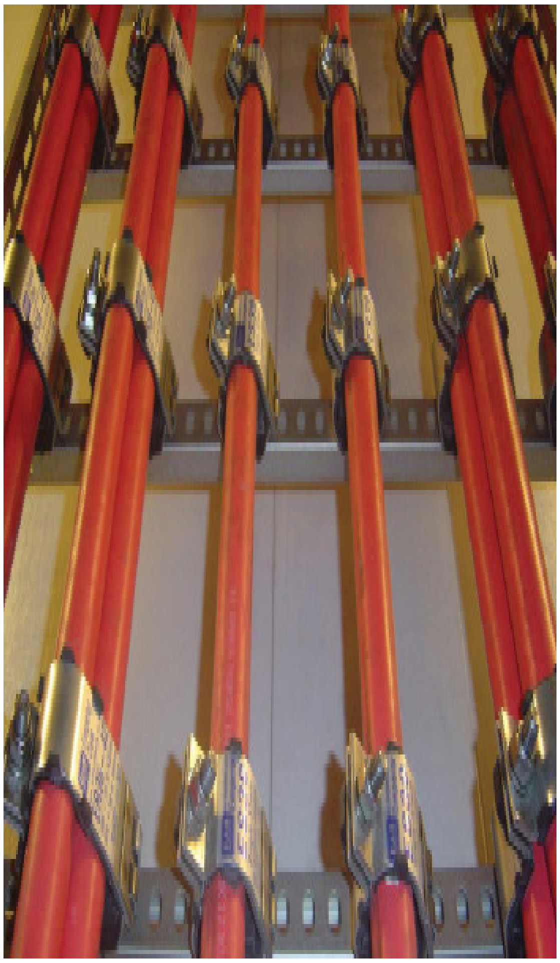
CABLE CLEATS

Why use cable cleats for securing cables?
Cable cleats are designed to fix, retain and support cables. In addition, where short-circuit faults are anticipated,
correct cleating will result in the containment of the cables during a fault and enable the circuit to be restored once the fault has been repaired.

When adjacent cables carrying three phase current suffer a short circuit fault, the induced magnetic fields result in the cables experiencing significant opposing forces, a safe installation requires well designed and thoroughly tested cable cleats.

Short circuits and short circuit testing :
Short circuit current is given either as a "peak" or an "rms" value. The peak current is the maximum current experienced by any of the phases and it occurs once within the first few milliseconds of the start of the fault. The rms current is a calculated value for the initial cycles of the fault. The relationship between peak current and rms current varies from installation to installation.

The forces experienced by a cleat during a short circuit are a function of short circuit current, cleat spacing and the distance between the cable centres (in the case of trefoil arrangements this is the cable diameter). When comparing short circuit test results for different products all three factors must be taken into consideration to compare the relative aggressiveness of the tests. The following formula taken from the draft Cenelec standard for cable cleats prEN 50368 calculates the force experienced by a cleat with cables arranged in trefoil formation .



IEC Standard for CABLE CLEATS

IEC 61914 (2009) : Cable cleats for electrical installations

This International Standard specifies requirements and tests for cable cleats and intermediate restraints used for securing cable in electrical installations.
Cable cleats provide resistance to electromechanical forces where declared.

This standard includes cable cleats that rely on a mounting surface specified by the manufacturer for axial and/or lateral retention of cables.

Classification :
A) According to material (part 6.1)
B) According to maximum and minimum temperature (part 6.2)
C) According to resistance to impact (part 6.3)
D) According to type of retention or resistance to electromechanical forces or both (part 6.4)
E) According to environmental influences (part 6.5)

A) According to material
6.1.1 Metallic
6.1.2 Non-metallic
6.1.3 Composite

B) According to maximum and minimum temperature

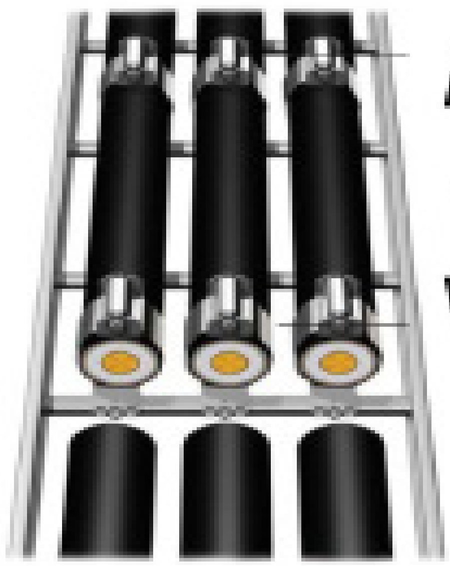
Table 1 – Maximum temperature for permanent application	Table 2 – Minimum temperature for permanent application
A. Maximum temperature	B. Minimum temperature
°C	°C
	5
40	− 5
60	− 15
85	− 25
105	− 40
120	− 60

C) According to resistance to impact
6.3.1 Very light
6.3.2 Light
6.3.3 Medium
6.3.4 Heavy
6.3.5 Very heavy

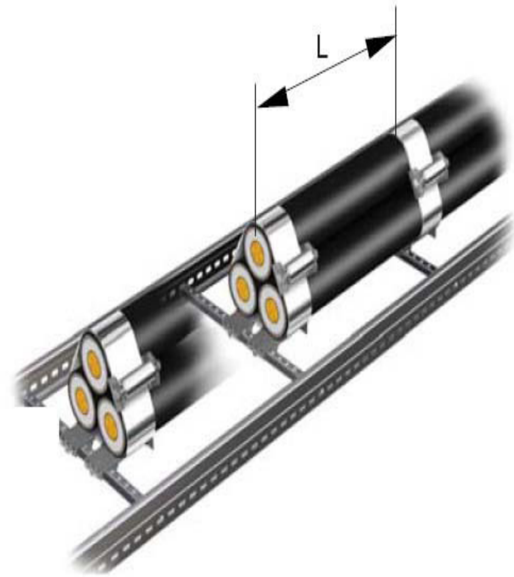
D) According to type of retention or resistance to electromechanical forces or both
6.4.1 With lateral retention
6.4.2 With axial retention
6.4.3 Resistant to electromechanical forces, withstanding one short circuit
6.4.4 Resistant to electromechanical forces, withstanding more than one short circuit

E) According to environmental influences
6.5.1 Resistant to ultraviolet light for non-metallic and composite components
6.5.1.1 Not declared
6.5.1.2 Resistant to ultraviolet light
6.5.2 Resistant to corrosion for metallic and composite components
6.5.2.1 Low
6.5.2.2 High

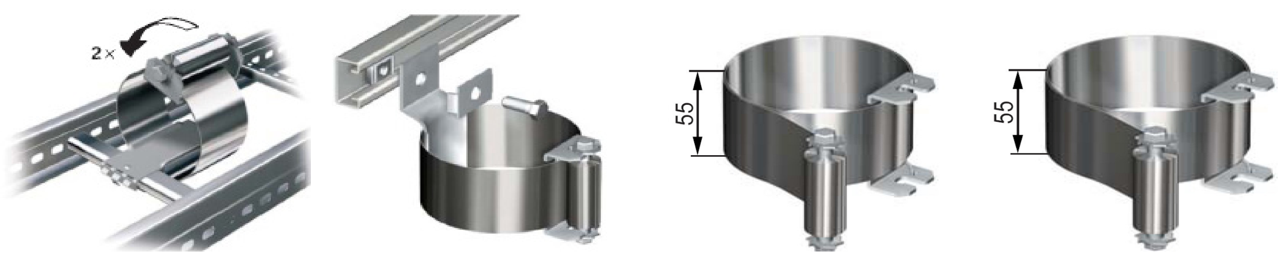
Examples of CABLE CLEATS for Flat and Trefoil formation



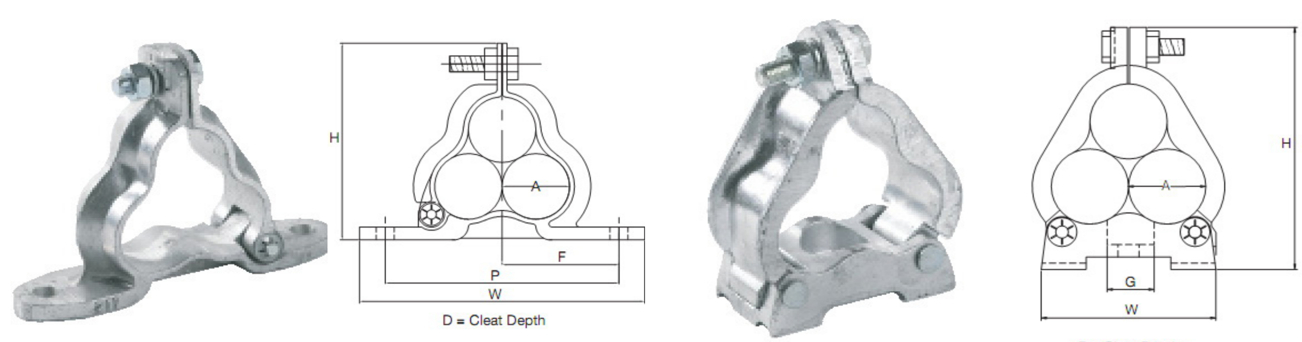
Flat Formation



Trefoil Formation

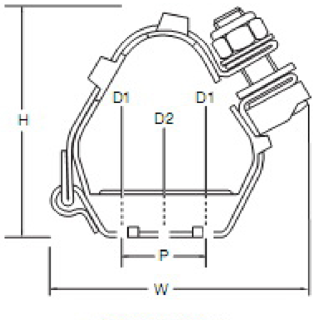


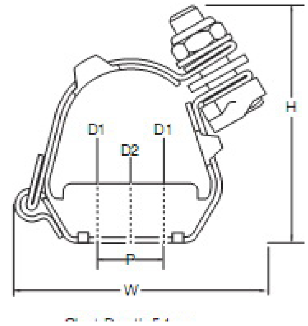
Most common cleats (IEC 148/09) IEC 61914(2009) / fastening on ladder



Aluminium Trefoil Cleats

Aluminium alloy castings to BS 1490: 1988. LM6. Natural finish with plated mild steel fasteners.
Black polyester powder coated finish either with or without stainless steel fasteners available to order

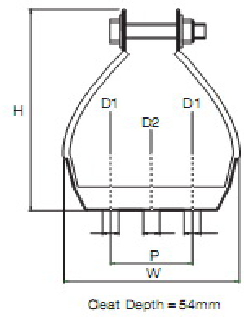



Trefoil and single cable Cleats

These cable cleats are available for trefoil and single cable applications where the highest levels of short circuit withstand are required. The unique patented design allows rapid installation. Manufactured in type 316 stainless steel the Emperor cleats offer ultimate protection against the harshest environmental conditions. To protect and cushion the cables during short circuit conditions, the cleat is supplied with an integral LSF Zero Halogen Polymeric liner and base pad. Recommended fixing methods include using either two 10mm bolts or a single 12mm bolt (available as extras). A Retention Strap can be fitted between wider spaced cleats for a more economical installation.





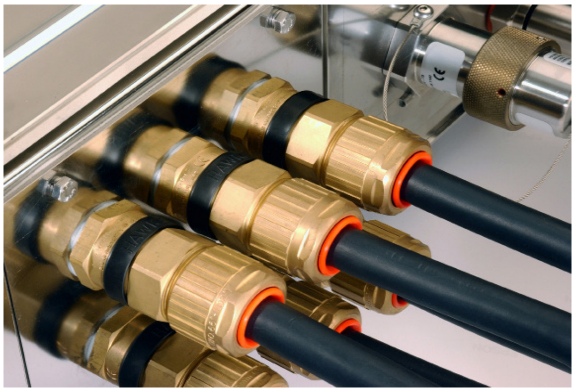
Cable Hanger

Cable clamps




CABLE GLANDS

What is a Cable Gland?

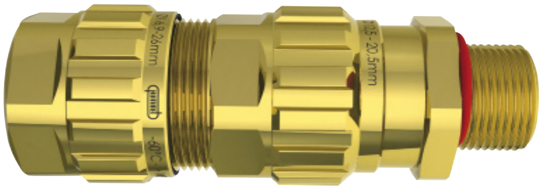


"A device designed to permit the entry of a cable into electrical equipment and which provides sealing and retention. It may also provide other functions such as earthing (or grounding), bonding, insulation, strain relief or a combination of these."

In addition to this a cable gland should maintain the overall integrity of the enclosure into which it is to be fitted .

How To Select The Correct Gland ?

Cable Glands can be viewed as either:
1) Industrial or
2) Ex Hazardous Area . Ex Hazardous Area glands are further subdivided into:
 2-1)Exd – Flameproof glands: meet both general requirements for hazardous areas plus the extra requirements for the flameproof standards and can therefore be used in both flameproof and increased safety applications.
 2-2)Exe – Increased Safety Glands: meet only the general requirements for hazardous areas.
 Within the Exd category we must also consider whether the use of a barrier gland is appropriate…



Barrier Glands vs. Elastomeric Seal Glands?

A barrier gland is an Ex d cable gland incorporating a compound filled chamber sealing around the individual cores of the cable to maintain the Flameproof integrity of the equipment into which it has been fitted.
A barrier gland must be used if it is thought that using a gland with elastomeric sealing will not maintain the Ex integrity of the flameproof equipment and also contain an explosion within the enclosure.

There are several important questions that must be asked to determine whether or not a barrier gland is necessary:
* Is the cable substantially round and effectively filled?
* Is the size of the Exd enclosure greater than 2L in volume?
* Is the installation to be in a zone 1 area?
* Does the installation have an internal source of ignition?
* Does the hazardous gas require IIC apparatus?

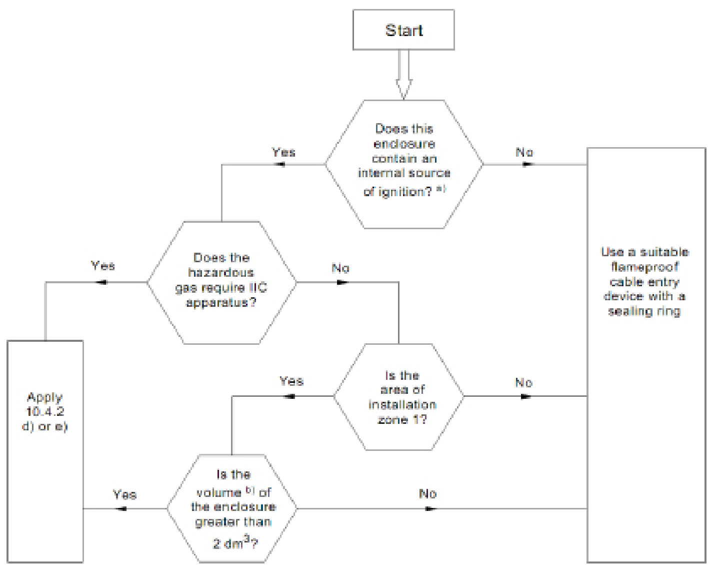
BW Type Cable Glands

CW Type Cable Glands

CABLE GLANDS

IEC 60079-14 (2007) , Part 14: Electrical installations design, selection and erection

(Part 10.4.2) **Selection of cable glands** : The cable entry system shall comply with one of the following:
a) cable glands in compliance with IEC 60079-1 and certified as part of the equipment when tested with a sample of the particular type of cable;
b) where a cable, in compliance with 9.3.1(a) is substantially compact; a flameproof cable gland, in compliance with IEC 60079-1, may be utilized, providing this incorporates a sealing ring and is selected.
c) mineral-insulated metal-sheathed cable with or without plastic outer covering with appropriate flameproof cable gland complying with IEC 60079-1;
d) Flameproof sealing device (for example a sealing chamber) specified in the equipment documentation or complying with IEC 60079-1 and employing a cable gland appropriate to the cables used. The sealing device shall incorporate compound or other appropriate seals which permit stopping around individual cores.
The sealing device shall be fitted at the point of entry of cables to the equipment;
e) Flameproof cable gland, specified in the equipment documentation or complying with IEC 60079-1, incorporating compound filled seals or elastomeric seals that seal around the individual cores or other equivalent sealing arrangements;



Industrial Cable Gland Specification :

The current European standard for cable glands, EN 50262, was published on March 1st 1999. As a result, the BS 6121 series of British Standards for cable glands was withdrawn.
It is important to understand that there has been a change in the basic methodology. The existing BS 6121, a physical dimensional standard, ensures a single and relatively high level of performance.
EN 50262 provides a design framework that ensures a product meets the minimum requirements for safety. The most basic products designed to meet EN 50262 may fall short of meeting the users requirements.

It is important to realise that although manufacturers will provide more information than before, but the user must now make more decisions regarding the suitability of the product for the application.
BW glands are no longer classified as a gland within this new standard.

General Issues :
Once it has been decided which classification of gland you are going to use, there are issues that need to be considered that are applicable to ALL cable glands, thus maintaining the overall integrity of the installation:
* The Type of Cable being used.
* The Gland Size
* The Entry Type/Thread Specification of the application
* The Ingress Protection required
* Material

CABLE GLANDS

Selection procedure of Cable GLANDS :

A- The Type of Cable:

A-1) Unarmoured cables will require the outer sheath seal within the gland to not only provide ingress protection but also a degree of retention.

A-2) Armoured cables require a gland that features a clamping mechanism to terminate the armour both mechanically and electrically. The gland will usually be required to provide ingress protection by sealing on the outer sheath and retention by clamping the armour.

Typically, armoured cables feature an inner sheath that the gland may be required to seal on.

B- Gland size :

The entry thread (i.e. M20) is not, as often perceived the gland size but simply the entry thread size and specification. It is important to understand that selection of the correct gland size is based solely on the following cable dimensions:

B-1) Outer Sheath Diameter ,and where applicable:

B-2) Inner Sheath Diameter (Under Armour)

B-3) Armour / Braid / Tape Thickness

All Peppers Cable Gland data sheets have tables including ranges for each of the above measurements

C- Cable entry - Entry type and/or thread specification :

If your installation has:

Clearance holes – Need to be drilled in accordance with Standard BS EN 50262.

A locknut will be required to fix the gland securely within a clearance hole. It is generally recommended that tapered threads should not be used with clearance holes.

D- Threaded Entries :

Glands can generally be supplied with a male thread to match the female enclosure thread. If this is not possible Thread Adaptors or Reducers can be used to match dissimilar threads. If the wall thickness will permit, the use of a locknut will provide additional security.

E- Ingress Protection :

It is essential when selecting cable glands and or accessories to ensure that the products will maintain the IP rating of the equipment and the integrity of the installation. IP codes are based on the IEC Standard 60529, degrees of protection provided by enclosures.

In most cases standard cable glands will maintain Ingress Protection of the equipment into which they are installed to. Please note that clearance holes must be drilled in accordance with EN 50262 table 1 and any gland without a integral "O" ring must have a suitable IP washer fitted in order to maintain greater than IP54.

F- A Common Misconception:

"The higher the IP number the better IP Protection offered." Truth: The different IP numbers refer to different ingress tests

G- Material :

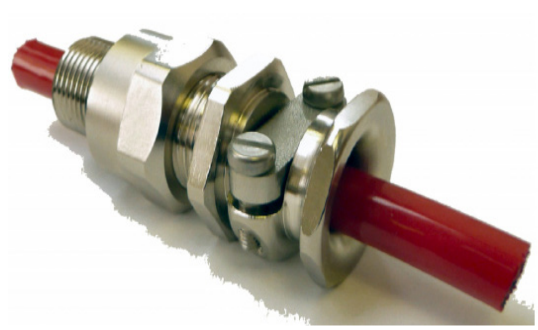
The selected gland should be manufactured from a material that is suitable for the surrounding environment. It is essential that the material of the gland you select will not react adversely with the material of the enclosure into which it is installed. As a particular example it should be noted that Brass, the standard material for metallic glands, can react adversely with Aluminium, if moisture becomes present bi-metallic corrosion may occur. When using brass glands sea water, H_2S, SO_2 and ammonia are the most problematic environments. Nickel, tin or zinc plating can be applied to brass to both minimize the potential for bi-metallic corrosion and provide a degree of protection from the surrounding environment.

CABLE GLANDS

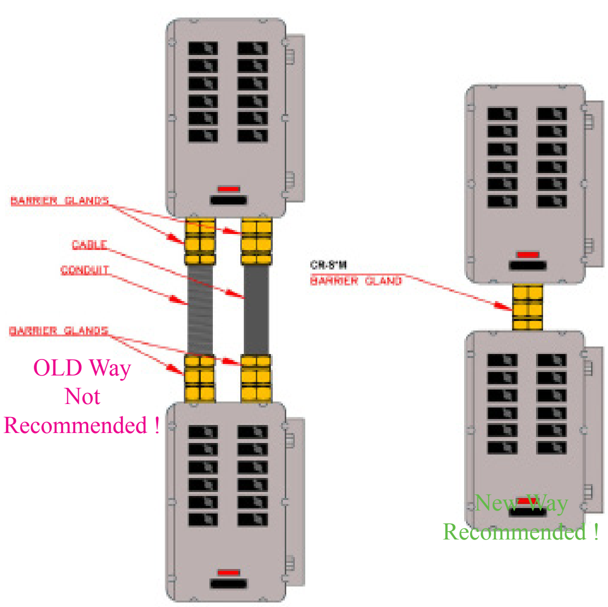
Other Issues for Selection of Cable GLANDS :

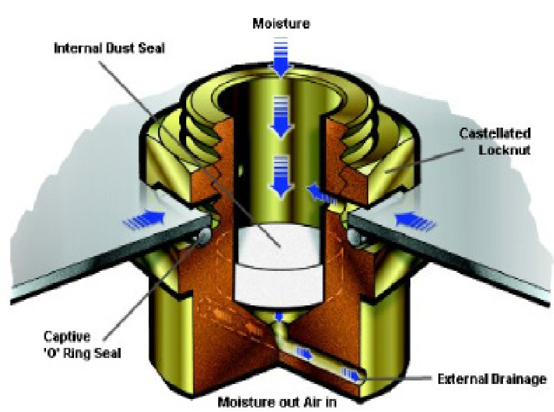
Operating Temperatures :
The metallic body of the gland is generally suitable for operating temperatures that glands are used at, meaning that the seal material and/or IP interface is generally the limiting factor.
Neoprene seals are suitable from –20°C to +85°C and can be used as low as –60°C but the structure of the material may be affected adversely and this could result in material breakdown. Meaning that for lower temperatures silicone seals should be considered.
Silicone seals are suitable for extended operating temperatures of –60°C to +180°C (–60°C to +135°C for barrier glands) and should be used for low temperature applications as the seal performance can be maintained throughout the lifetime of the installation.
To ensure that the surface temperature of the equipment will not ignite gases or vapours in the surrounding atmosphere, the equipment will specify a 'T' rating based on the maximum surface temperature that can occur during its operation.
As cable glands are passive and do not generate heat they have no effect on the 'T' rating of the equipment and does not need to be considered when selecting a gland.

Temperature class required by the area classification	Ignition temperature of gas or vapour in °C	Allowable temperature classes of equipment
T1	>450	T1 – T6
T2	>300	T2 – T6
T3	>200	T3 – T6
T4	>135	T4 – T6
T5	>100	T5 – T6
T6	>85	T6



New delevopments in Cable Glands :





Connect two Ex d – Flameproof enclosures :
Traditional practice has been to use a compound barrier gland mounted at the entry of both enclosures with a length of cable or conduit .
New barrier glands can now be installed directly between two Ex d enclosures that is more cost effective solution.

Breather Drain :
Breather Drain provides a method of effectively draining any moisture within an enclosure whilst allowing the air inside to breathe with the surrounding atmosphere .

Cable Pulling : PREPARATION FOR CABLE LAYING

Cable stockings:
A pulling rope has to be attached to the leading end of the cable, and a cable stocking is normally used for this purpose. This figure shows types with single and double thimbles.
The latter are normally preferred because there is less damage to the cap on the cable end if the pulling load is high.

Single Eye

Double Eye

Single Weave

Double Weave

Pulling eyes :
With a stocking, the load is initially taken by the external cable components and is transferred by frictional forces to the conductors. If the load is high it may cause stretching of the outer layers and to avoid this a pulling eye may be plumbed to the armour, sheath and conductors to ensure distribution of the load across the whole section.
Many designs of pulling eye are available for different types of cable. Some are tubular with the conductors being sweated inside the tube and the metal sheath plumbed to the outside. Following figure shows a pulling eye which can be adapted for most cable designs.
It is not a pulling eye in the strict sense, as it is only a means of anchoring the conductors and sheath in the cable end, and a stocking is necessary.

Power winches :

Power winches fall into two categories:

(a) compact lightweight designs utilising either a small petrol or compressed air engine as the power unit. Following figure shows a typical example which is suitable up to 2 tonnes safe working load with speeds of 5-8 m/min.

(b) medium weight designs suitable for 2-4 tonnes, the larger sizes having a diesel power unit. Instead of relying on a direct pull these larger units utilise a pair of 'bull wheels' for wire bond haulage as illustrated in following figure.

With winch pulling, it is important to take steps to keep the pulling load to a minimum. The drum position should be chosen so that the longest length of straight trench is at the pulling end with any severe bends as close as possible to the drum.

Lightweight winch

Diesel driven winch

Pulling tension in a wire bond can be reduced by passing the bond through a snatch block where the trench changes direction.

The pull is stopped just before the cable reaches the snatch block so that the bond can be removed from it. This arrangement also prevents the bond from causing damage by scoring the skid plates on the inside of the bend.

An alternative procedure for pulling by winch is the continuous bond method. Instead of attaching the bond to the leading end of the cable, the cable is lashed to the bond at about 1 m intervals. This method is mainly required for heavy cables and is seldom needed for distribution cables

mechanical actuated cable drum transport and laying trailer

cable laying machine pushing pulling

PREPARATION FOR CABLE LAYING

Preparation of the trench :

Preparation comprises the installation, as necessary, of skid plates, rollers etc., and paying out the winch rope if using power assistance. Typical rollers and dual purpose rollers are shown in following figure. Cable rollers are necessary to prevent the cable from touching the ground and should be spaced a maximum of 2 m apart for normal size cable. With heavy cables this spacing may need to be reduced to 1.2 m. Correct positioning is important to keep the friction load component to a minimum.

Ducts should be clean and smooth and fitted with bell mouths at entry, and also at exit if followed by a bend. The pulling tension is determined by a summation of the weights of cable up to a point of friction multiplied by the coefficient of friction at that point. Conditions vary widely according to cable type, cable finish and bend in a route, but a general average for the coefficient of friction is around 0.25. Under difficult conditions in ducts it may increase to 1.0, and in such situations graphite lubricants should be applied at duct entries to reduce the friction.

Cable Pulling :

The cable should preferably be drawn to its final position in a continuous manner. During stops, it will settle between rollers and may cause high strain on men and machines during re-starting. Whether the pull is manual or with a winch, it is necessary for one man to be stationed at the drum with a plank wedged against the wing so that over-running of the drum is prevented if pulling stops. Otherwise many loose turns can easily develop on the drum.

Heavy lead sheathed paper cables in long lengths may need very large gangs of men if winch pulling is. not used. However, because of the large reduction in cable weight, only four to five men are needed for a 200 m length of 11 kV cable with corrugated aluminium sheath for an average route. Polymeric cables having no metallic sheath are even easier to install.

When pulling by a winch it is advantageous for the cable end to be taken by hand as far as possible before attaching the winch rope. This allows the leading cable rollers, skid plates etc. to take the load and settle under well controlled conditions. The winch operator must carefully observe the dynamo meter to prevent overloading. On long pulls, good communication is essential, preferably by radio.

Cable Pulling accessories


Hook Sheave


Hook Type Sheave


Right Angle twine Yoke Type Sheave

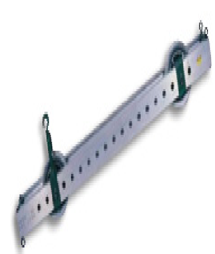

Radius cable Sheaves


Triple Sheave cable guide


Feeding Sheave


Tray Type Sheaves

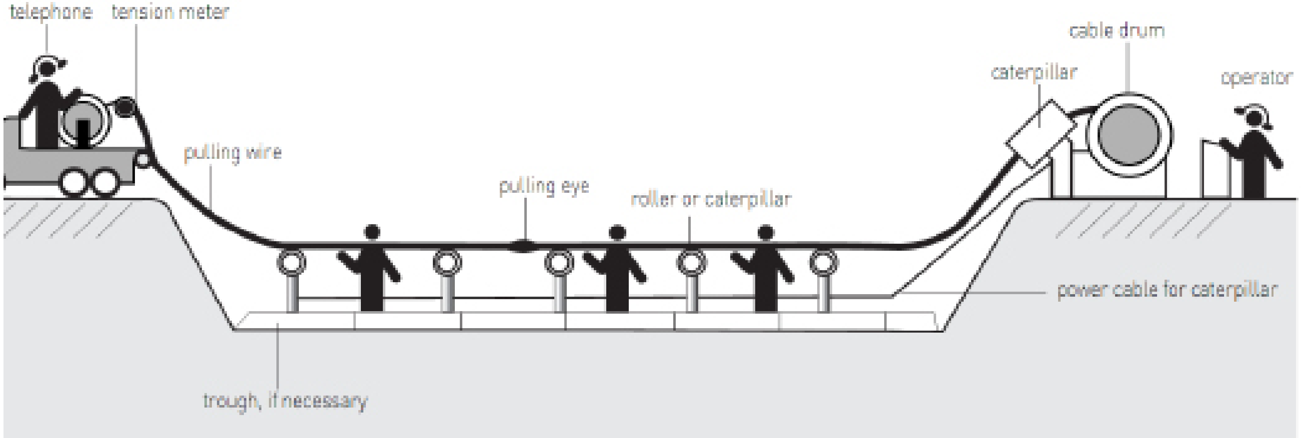

Cable Tray rollers


Manhole Sheave

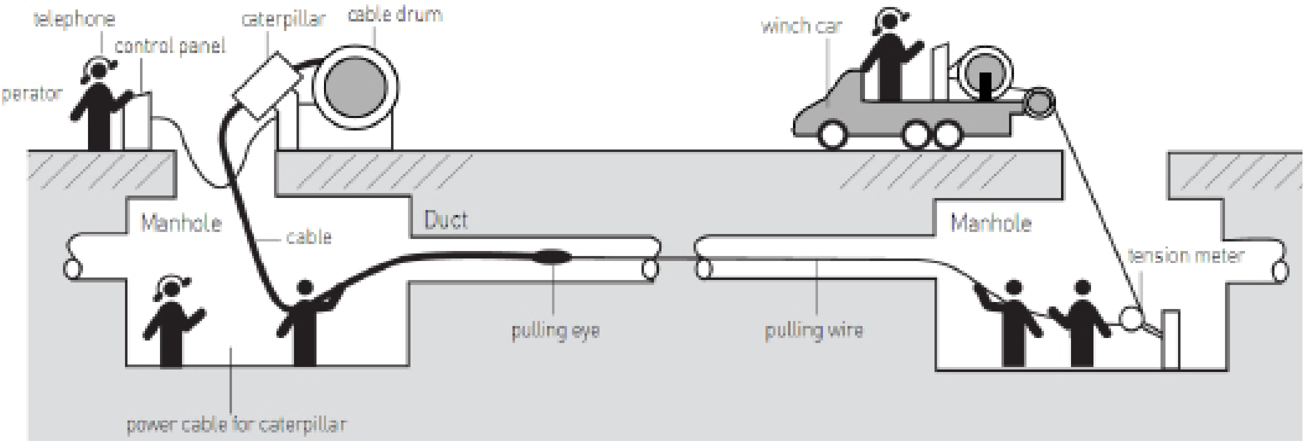

Cable guide

CABLE LAYING in Ground,Duct,Tunnel

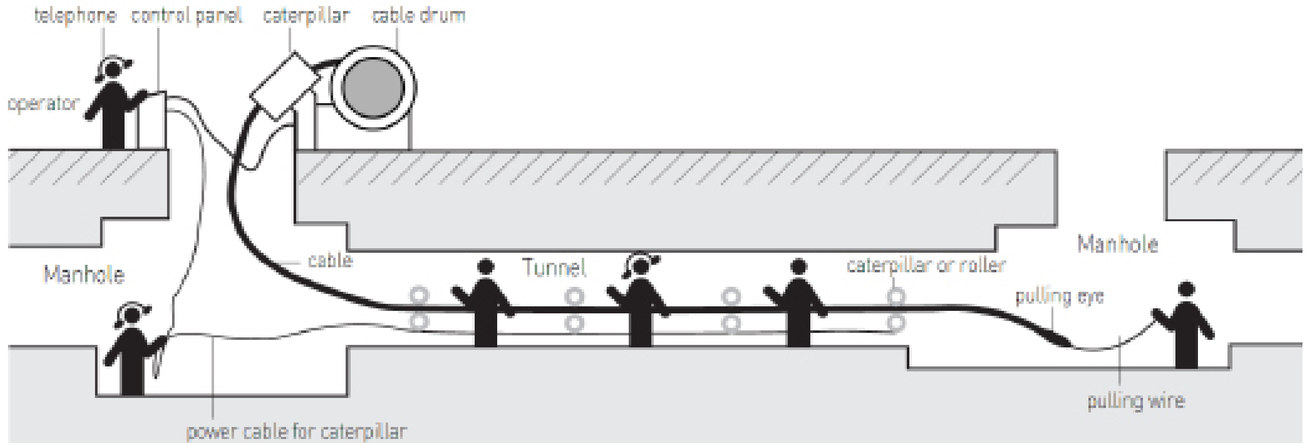
(A) Direct Burial



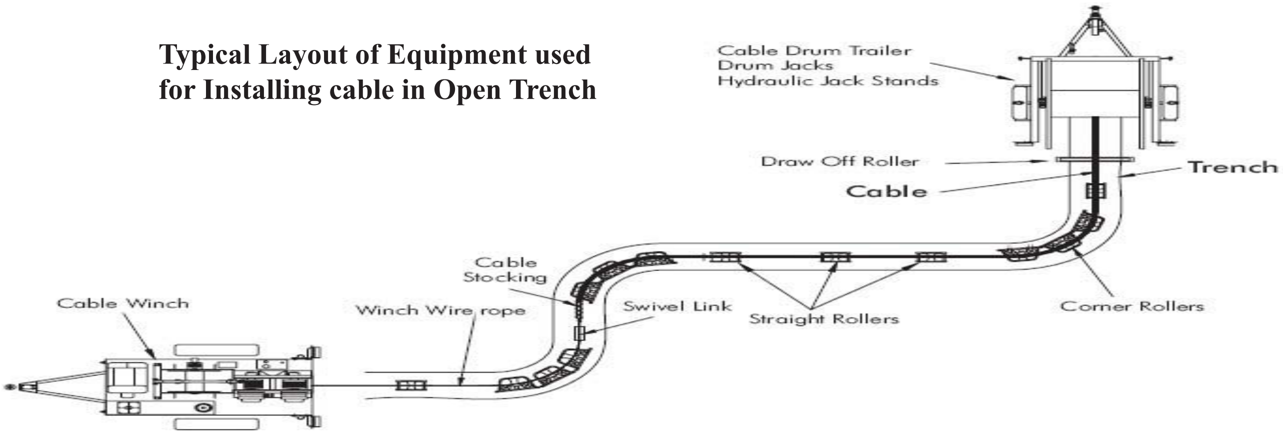
(B) Laying at Duct



(C) Laying at Tunnel

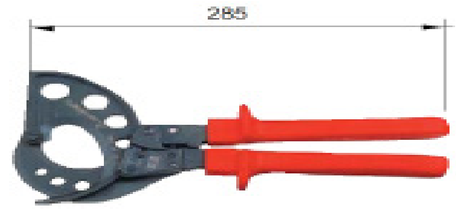


Typical Layout of Equipment used for Installing cable in Open Trench

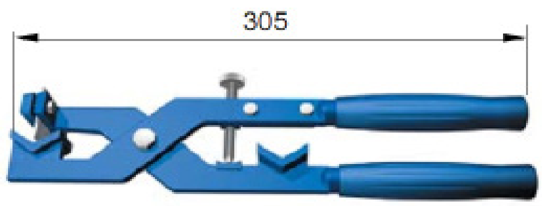


Cable accessories / Preparation tools

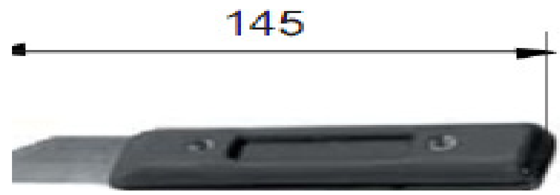
Torque wrench for screw connectors, screw cable lugs, overhead line clamps, etc. Supplied with 7 mm socket head, extension and 8 mm internal hexagon head. Torque range 6-50 Nm.



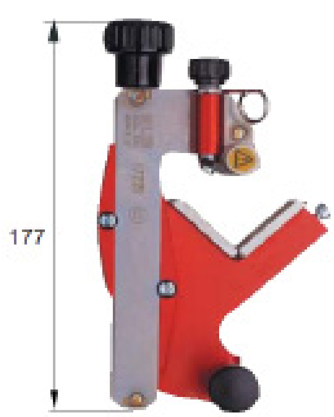
Cable shears for cutting cable 0 max 54 mm.



Splitting tool for longitudinal splitting off XLPE insulation with 0 10-55 mm.



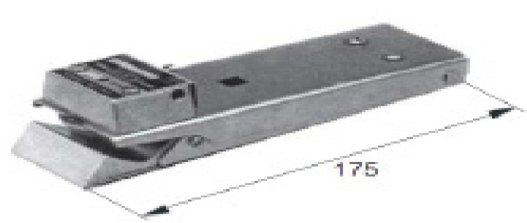
Cable knife - 30 mm blade



Stripping tool for the vulcanized, outer conducting layer of XLPE cable diameter of 10-52 mm.

Cutting tool for cable sheath and XLPE insulation for dimension of 15 to 50 mm ; cutting depth < 8 mm .

Sheath removing tool for PE-sheathed cable diameter > 20 mm.



Peeling tool for strippable outer conductive layer on XLPE insulated cable 13-51 mm.

KCI

Repair of Damage to Outer Sheath

Outer Sheath of Polyvinvlchloride (PVC) and Polyethylene (PE)
Dependant upon the degree of damage, the stressing of the cable sheath during installation in the ground on racks in ducts as well as the required voltage withstand of the sheath during corrosion protection testing
If the material of the outer sheath cannot readily be determined and neither can the cable type be established from the markings and relevant VDE specifications then a flame test may be necessary to establish whether the sheath material is of PVC or of PE.

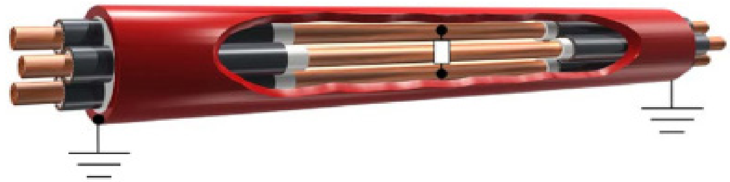
Repair with Shrink-On Sleeve
A shrink-on sleeve, which is particularly easy to instal, comprises a longitudinally split shrinkable tube and this is recommended as a universal method of repair. This type of sleeve must be cut sufficiently long such that after being shrunk on to the cable it extends beyond the damaged part to each side by a distance of / = 3 x cable outer diameter with a minimum of 100 mm
A longitudinal shrinking of some 10% must be allowed for.
The damaged area of the cable sheath must be cleaned with solvent, corresponding to the length of the sleeve and roughened with emery cloth. The repair sleeve is then laid around the damaged portion and the press stud snap locking engaged .

Cable fault finding Guide

Fault location on communication and power cables is a very specialized area of electrical technology. The performance of efficient fault location is very much dependant on good logistics and knowledge. Fast and reliable fault location is dependent on these factors if prelocation of a fault is to be done with high accuracy. The following pinpointing procedure, for the exact location of the fault location, can be done on a very short segment of the cable.
Cable testing, cable diagnosis and partial discharge measurements, will become of higher importance in the future. The condition based preventive maintenance of cable networks, will more and more replace the event oriented maintenance of cable installations.
A good detailed knowledge of the construction of cable networks, cable types and their accessories, simplifies the evaluation of the measured results considerably. Many of these are processes are the essential grounds for correct decisions to be made. The types of cable faults and the required steps to do a cable fault location or a diagnosis are one of the most important details that the technician must be aware of.

1) Fault Conductor - conductor (parallel Fault)

Connection between two or more conductors. The insulation resistance value of the fault can be between zero Ohms (low resistivity) or several M Ohms (high resistivity).

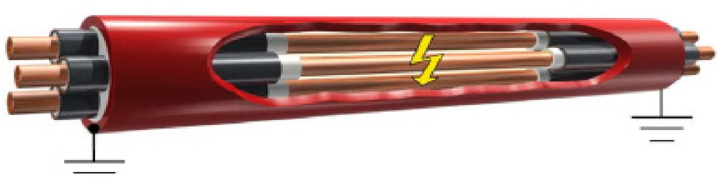


2) Fault Conductor - shield (parallel Fault)

Connection between Conductor and shield or Conductor/Conductor and shield. The insulation resistance value of the fault can be between zero Ohms (low resistivity) or several M Ohms (high resistivity). Experience has shown, that most faults are in this category.

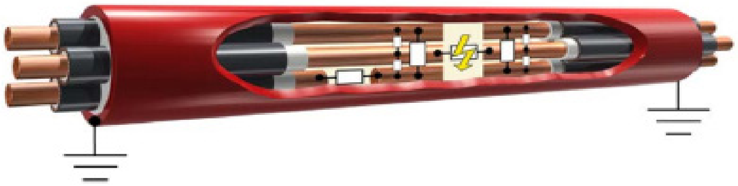
3) Flashing fault (parallel Fault)

Very high resistance fault. The cable can be charged. The flashover happens typically at some kV and is very often located in Joints. The cable acts comparable to an arc gap, where the distance between the electrodes determines the voltage. The insulation resistance of this fault is typically infinite up to the breakdown voltage.



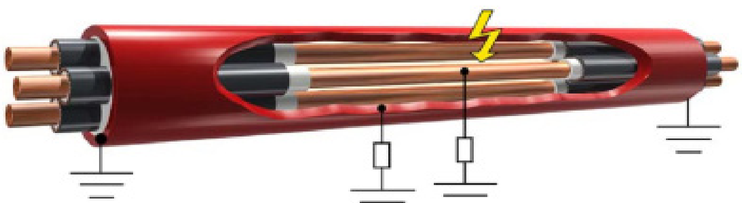
4) Serial fault (Open, Interrupt)

Faults of this type can be very high resistive up to infinite (complete cut). Very often these type of faults are a combination of serial and parallel insulation resistances. The reason for this being a complete cut of the cable, or it is pulled out of the joint, which interrupts everything, but also permits flashovers in all possible variations. If the conductor is partially burned off (Aluminium) we speak of longitudinal faults.



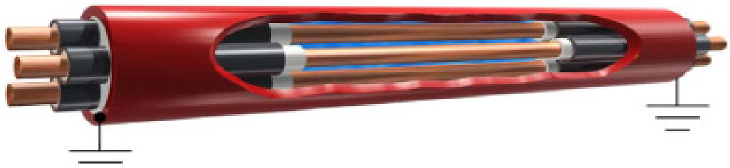
5) Earth faults, sheath faults

Faults between the metallic shield and surrounding soil in case of plastic insulated cables. Faults between the Conductor and surrounding soil on LV and plastic insulated cables. Especially for these type of faults the highest precaution must be taken when using high voltage, this is of utmost importance, since the voltage discharges directly to earth. Resulting an increased potential danger to man and animal.



6) Humid / wet faults

On multi core cables, often all conductors are affected. The flashover does not always appear at the position where the water entered the cable. The fault resistance is in the range of several k Ohms. At the fault location, impedance changes do occur. Depending on the cable construction (e.g. longitudinal water sealing) these faults can be punctual or widespread throughout the cable. Humidity faults are the most difficult faults to locate. They have the tendency to change during the fault location procedure, partially in a very drastic manner, which occurs especially in Joints, the fault can become high resistive again after one or two discharges and then cannot be localised anymore. The water gets blown out of the joint and dries up. Other forms of humidity faults are underwater faults. Here the water pressure prevents an effective ignition of the fault during the HV application. The location of these faults can be very difficult to.pinpoint.



Fire Performance of Cable

Fire Performance of Cable (Standards of Tests)

- IEC 60332-1
- IEC 60332-3
- IEC 60331
- IEC 61034
- IEC 60754

KCI Reduced Smoke PVC Certificates

- ASTM D.2843
- ASTM E 662
- ISO 4589-2 & 3
- IEC 60754-1
- IEC 60332-3-22
- UL 1581-1200 (UV Resistant)
- ICEA S-82-552 (OIL Resistant)

KCI Low Smoke Cable Certificates

- IEC 61034
- IEC 60754
- IEC 60331

Fire Performance of Cable

DURATION OF SYSTEM CIRCUIT INTEGRITY IN THE BUILDING LAWS :
The duration of the system circuit integrity depends on how long the supply of electrical services must continue in the event of a fire. National legislations in most countries provide requirements for safety systems which have to be met.

DEGREE OF ACIDITY OF COMBUSTION GASES :
Corrosive gases act with moisture to produce aggressive acids which corrode metal parts and cause extensive long-term damage, even though the fire damage may only be limited; this is because corrosive gases often spread throughout a building through the ventilation system or withing whole installations. The damage may not be limited to the area immediately affect ted by the fire. Electronic units and electronic contacts are particularly vulnerable, as are free-standing or concrete enclosed steel constructions.

The most popular plastic containing halogens is PVC (polyvinyl- chloride). In case of fire or at high temperature PVC starts to degradate. Hydrochloric acid and other fission products are generated and leads to extremely aggressive corrosion. Therefore the current trend is to replace the halogen containing plastics with halogen free ones. For instance PVC is currently being replaced at a large scale with polyolefin i.e. polyethylene.

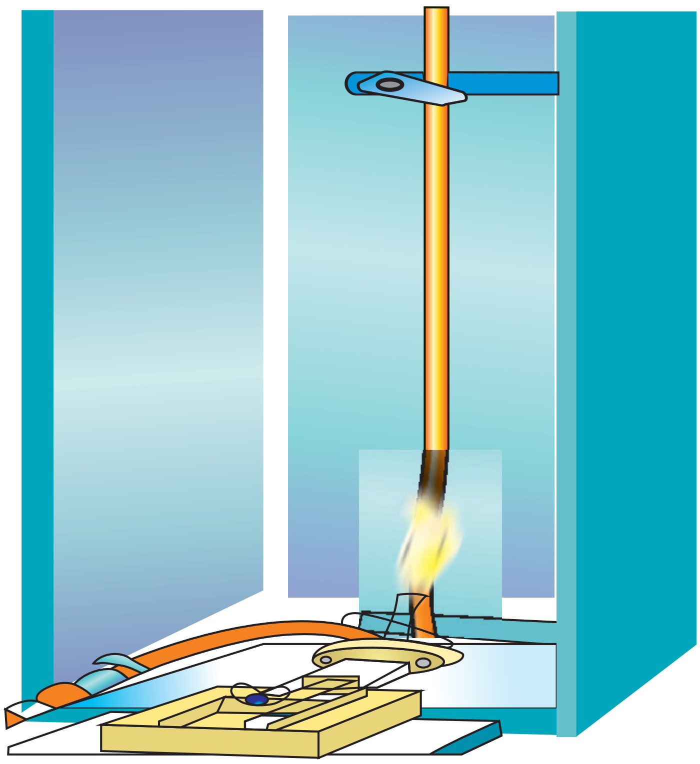
SMOKE DENSITY :
The formation of smoke has several unpleasant consequences. On one hand it considerably lowers the visibility in a fire event, thus impeding the people trapped inside closed rooms escape of and the efforts of the firemen to carry on their rescue and fire fighting actions. On the other hand it produces smoke poisoning because of the carbon monoxide. Regarding the formation of the combustion gases the PVC comes off quite badly.

Evacuation :
In many countries a duration of 30 minutes is considered sufficient for alarm and evacuation of people.
Compliance with this requirement with regard to the systems (fire alarm systems, emergency lighting, passenger hoists, smoke exhaust, voice alarm and acoustic signalling, escape route signalling) .
For special buildings like high-rise buildings, hospitals, tunnels, prisons, a duration of 60 to 90 minutes can also adequate.

Fire fighting :
Besides rescuing time for people extra time for the work of the fire brigades must be allocated. Mostly 90 minutes after the fire starts are regarded sufficient for fire fighting. The uninterrupted power supply of the electrical systems used for this (e.g. sprinkler water pumps, mechanical smoke exhausts, firemen lifts)

Planning :
Planning an electrical safety system means finding answers to the questions:
Which parts of the building requires which level of safety?
Which electrical system has to be supplied for how long?
Which circuits are involved (safety circuits)?
Which is the best cable routing for these circuits?
Are there restrictions concerning fire load, etc.?

Fire Performance of Cable (Standards of Tests)



IEC 60332-1

This standard is applied for general FLAME RETARANDCY test, on single vertical insulate wire or cable.

FLAME RETARDANT

Flame retardant cables are cables which, when installed as a single cable, although ignitable on exposure to flame source, will greatly reduce flame spread and self-extinguish once the flame source is removed.

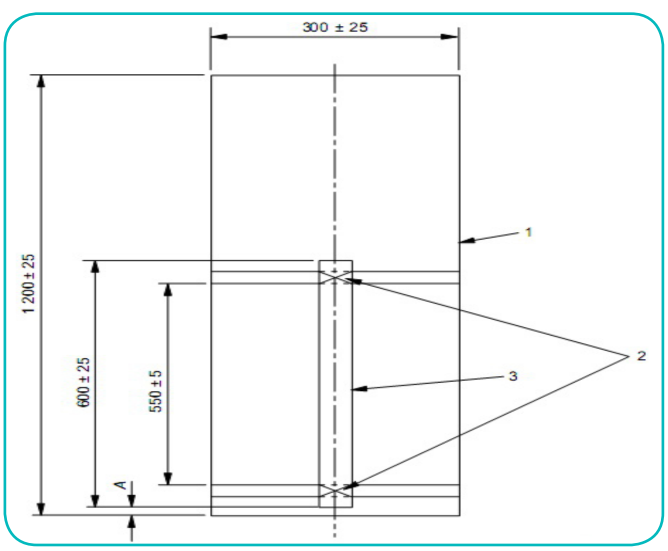
However in a vertical cable bundle, e.g. in vertical risers, fire can spread along the cables (chimney effect). In order to avoid this danger, the so called «non-flame propagating» cables should be used. Time of flame application is given in table 1 IEC 60332-1.

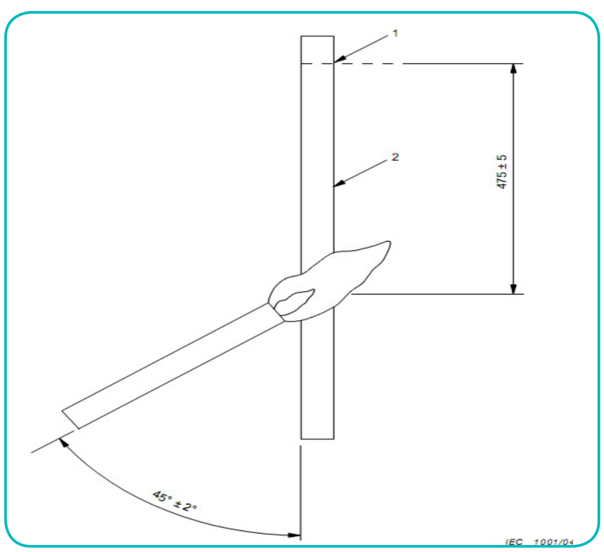
Standard Summary:
A sample of cable is fixed on a vertical support with length of 550+/-5 mm. A gas burner is ignited and applied on the cable at the angle of 45o and 475 mm far from upper grip. A lead wire or a cable is being aflamed with a propane-air- burner (1 kW flame).

The burning cable should self-extinguish as soon as the fire source has been removed. The fire damage may not be higher than 60 cm. The test is considered to be passed if:
The sample has not burned and the damage (carbonisation) has not reached any of the terminations of the sample (> 50 mm). standards IEC 60332-1, EN 60332-1

Overall diameter of test piece [a]	Time for flame application [b]
mm	s
D ≤ 25	60 ± 2
25 < D ≤ 50	120 ± 2
50 < D ≤ 75	240 ± 2
D > 75	480 ± 2

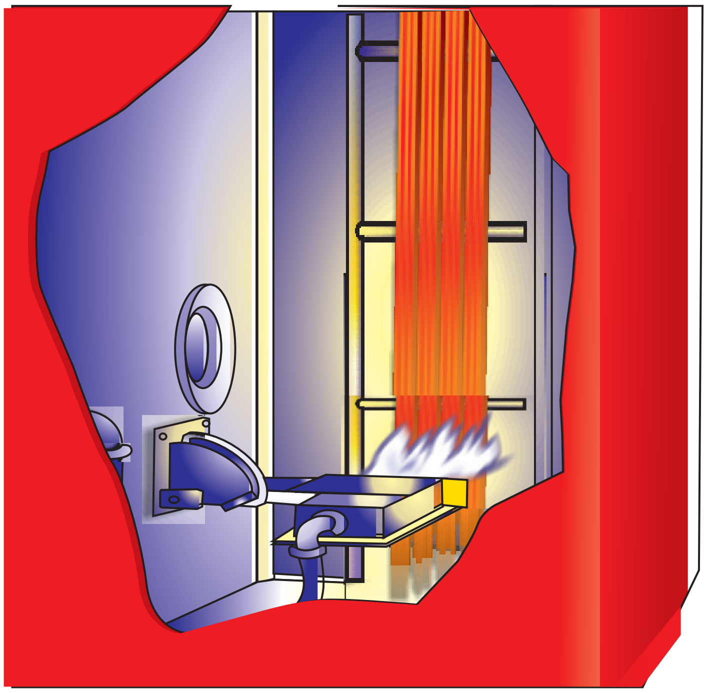
[a] W here non-circular cables (for example, flat-form constructions) are to be tested, the circumference shall be measured and used to calculate an equivalent diameter, as if the cable were circular.
[b] For flat cables having a ratio of major to minor axis greater than





Kerman & Kavian Cable Industries (KCI)

Fire Performance of Cable (Standards of Tests)



IEC 60332-3

The series of International Standards covered by Parts 3-10, 3-21, 3-22, 3-23, 3-24 and 3-25 of IEC 60332 specifies methods of test for the assessment of vertical flame spread of vertically-mounted bunched wires or cables, electrical or optical, under defined conditions.

It cannot be assumed that, because a wire or cable meets the requirements of IEC 60332 parts 1 and 2, a vertical bunch of similar cables or wires will behave in a similar manner. This is because flame spread along a vertical bunch of cables depends on a number of features, such as volume of combustible material exposed to the fire , the geometrical configuration of the cables , , the quantity of combustible gas released from the cables for a given temperature rise ,the construction of the cable , ...

Test procedures

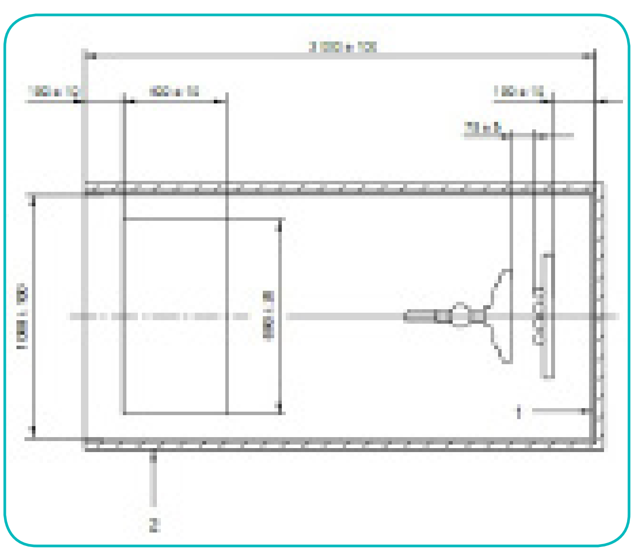
This test simulates the chimney effect in vertical cable installations.

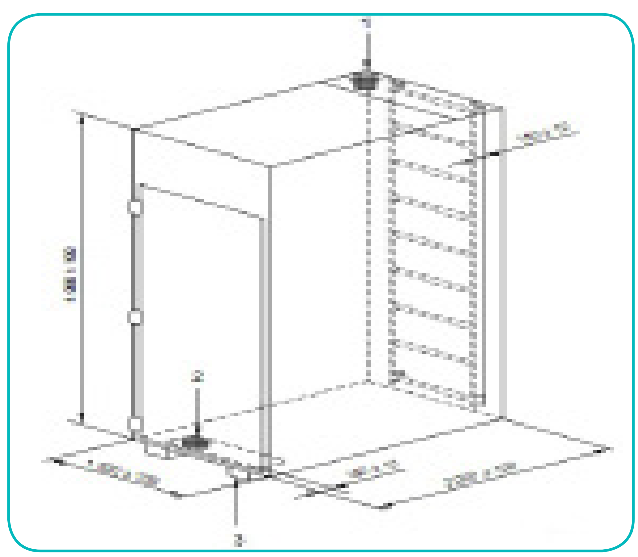
In a standardized cabinet the cable bundle is kept in a burner fire for 20 - 40 minutes (gas burner 75 ± 5 MJ/h). Thereby the temperature is kept constant to 750 °C. Depending on the volume of the non-metal (combustible) materials per running meter it can be differentiated in the categories A F/R, A, B, C and D .

The cables must self-extinguish after removing the fire source.

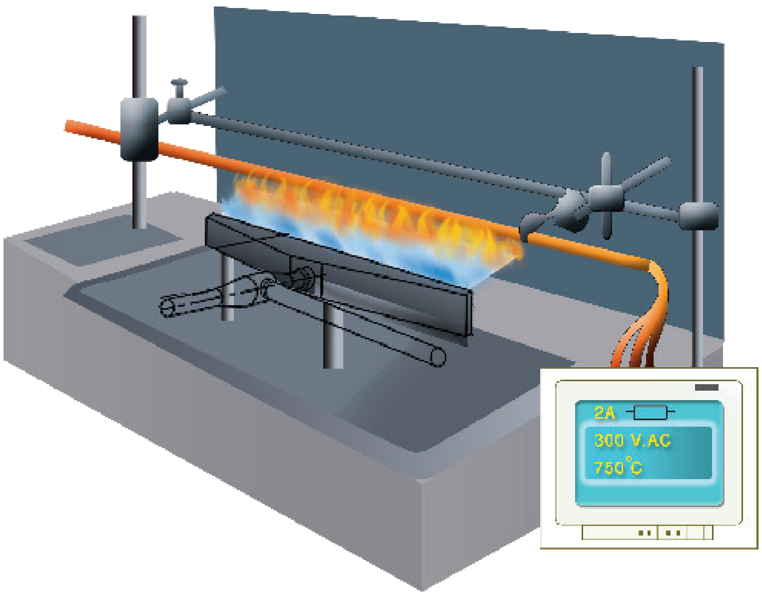
The fire may not have propagated any further than 2.5 m from the burner.

Category	Required Volume	Test Duration	IEC	EN	VDE 0482
A F / R	7 liter/meter	40 minutes	60332-3-21	50266-2-1	part 266-2-1
A			60332-3-22	50266-2-2	part 266-2-2
B	3.5 liter/meter		60332-3-23	50266-2-3	part 266-2-3
C	1.5 liter/meter	20 minutes	60332-3-24	50266-2-4	part 266-2-4
D	0.5 liter/meter		60332-3-25	50266-2-5	part 266-2-5





Fire Performance of Cable (Standards of Tests)



IEC 60331

IEC 60331-11 specifies the test apparatus to be used for testing cables required to maintain circuit integrity when subject to fire alone where the test condition is based upon a flame with a controlled heat output corresponding to a temperature of at least 750 °C.

IEC 60331-21 specifies the test procedure and gives the performance requirement, including a recommended flame application time, for cables of rated voltage up to and including 0.6/1.0 kV required to maintain circuit integrity when subjected to fire under specified conditions

Standard Summary:

The cable sample, as described in the relevant procedure in part 21 onwards of IEC 60331, shall be held horizontally by means of suitable supports at each end of the sheathed or protected portion .

The source of heat shall be a ribbon type propane gas burner with a nominal burner face length of 500 mm with Venturi mixer.

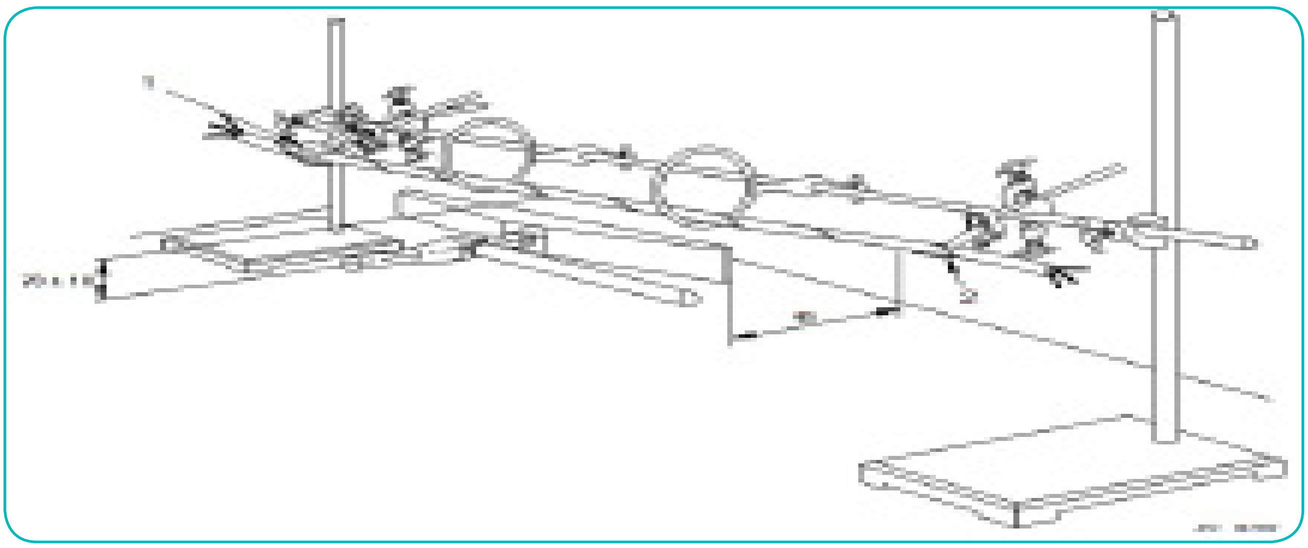
The burner face shall be positioned in the test chamber so that it is at least 200 mm above the floor of the chamber and at least 300 mm from any chamber wall.

The flame application time shall be as specified in the relevant cable standard. In the absence of such a cable specification, a 90 min flame application is recommended

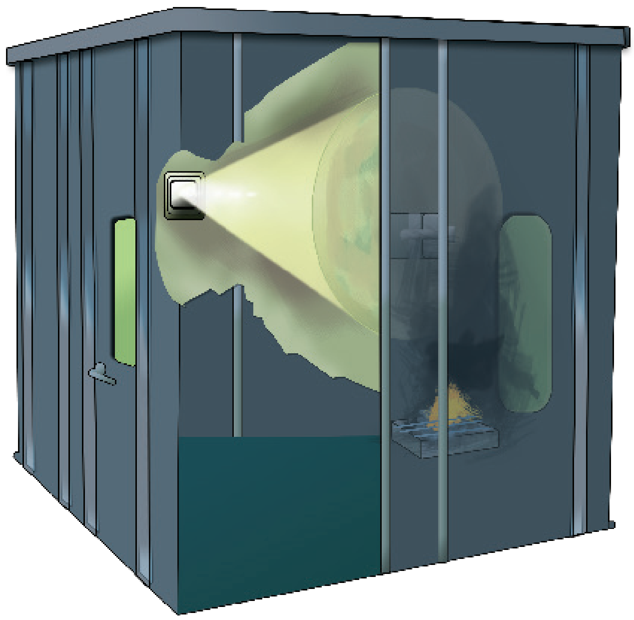
With reference to the test procedure ; the cable possesses the characteristics for providing circuit integrity so long as during the course of the test :

- the voltage is maintained i.e. no fuse fails or circuit-breaker is interrupted;
- a conductor does not rupture, i.e. the lamp is not extinguished.

Test standards : IEC 60331-11 and -21, DIN VDE 0472-814



Fire Performance of Cable (Standards of Tests)



IEC 61034

The measurement of smoke density is an important aspect in the evaluation of the burning performance of cables as it is related to the evacuation of persons and accessibility for fire fighting.

IEC 61034 is published in two parts, which together specify a method of test for measurement of smoke density of cables burning under defined conditions .

IEC 61034-2 provides details of the test procedure to be employed for the measurement of the density of smoke emitted from cables burning under defined conditions. It describes the means of preparing and assembling cables for test, the method of burning the cables, and gives recommended requirements for evaluating test results

Test procedures

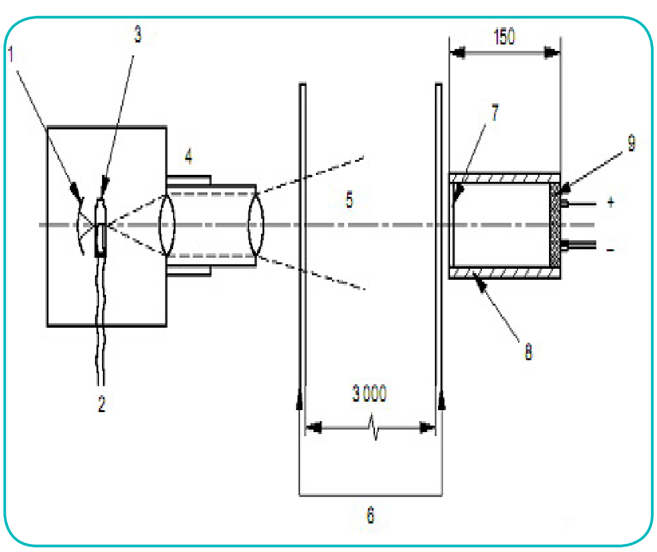
A length of 1 meter cable and the number of samples acc to table 5.2.1 of IEC 61034-2 are prepared and burnt in cubic room with 27m^3 volume. Light transmittance is measured for I_0 and I_t in 40 minutes of test duration.

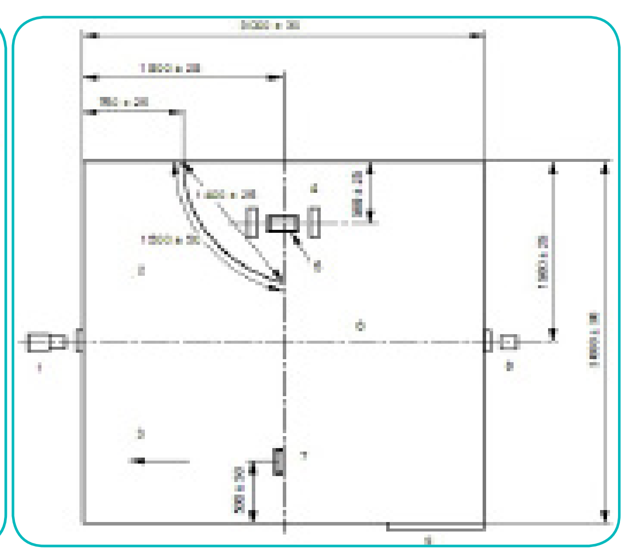
The density of smoke emission can be determined by measuring of the light penetrability. Cable samples are lit with alcohol in a test chamber (cubical with an edge length of 3 m). The so formed smoke is uniformly spread by a ventilator and influences the light measuring section.

The test is considered to be passed when the following light penetrability is reached to specified value.

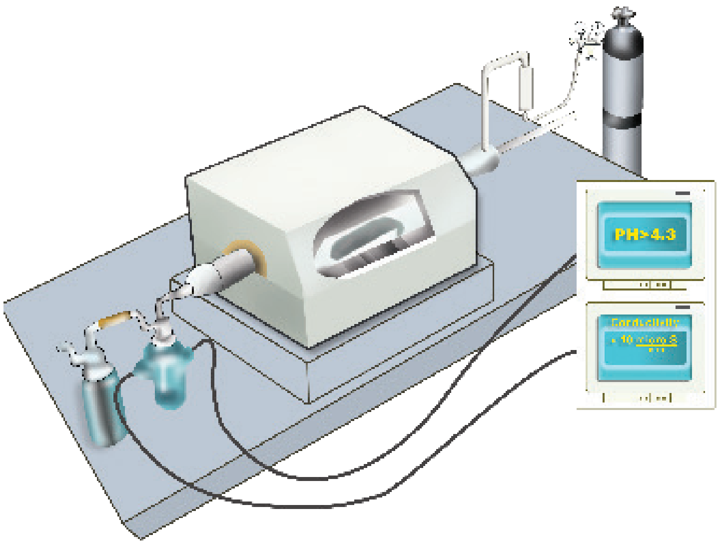
The performance requirements for a particular type or class of insulated conductor or cable should preferably be given in the individual cable standard. In the absence of any given requirement, it is recommended that a value of 60 % cable light transmittance is adopted as a minimum for any cable tested against this standard. Test standards IEC 61034, EN 61034

Overall diameter of the cable (D) mm	Number of test pieces
D > 40	1
20 < D ≤ 40	2
10 < D ≤ 20	3
5 < D ≤ 10	N1
The value of N1 = 45/D shall be rounded downwards to the integer to give the number of test pieces.	





Fire Performance of Cable (Standards of Tests)



IEC 60754

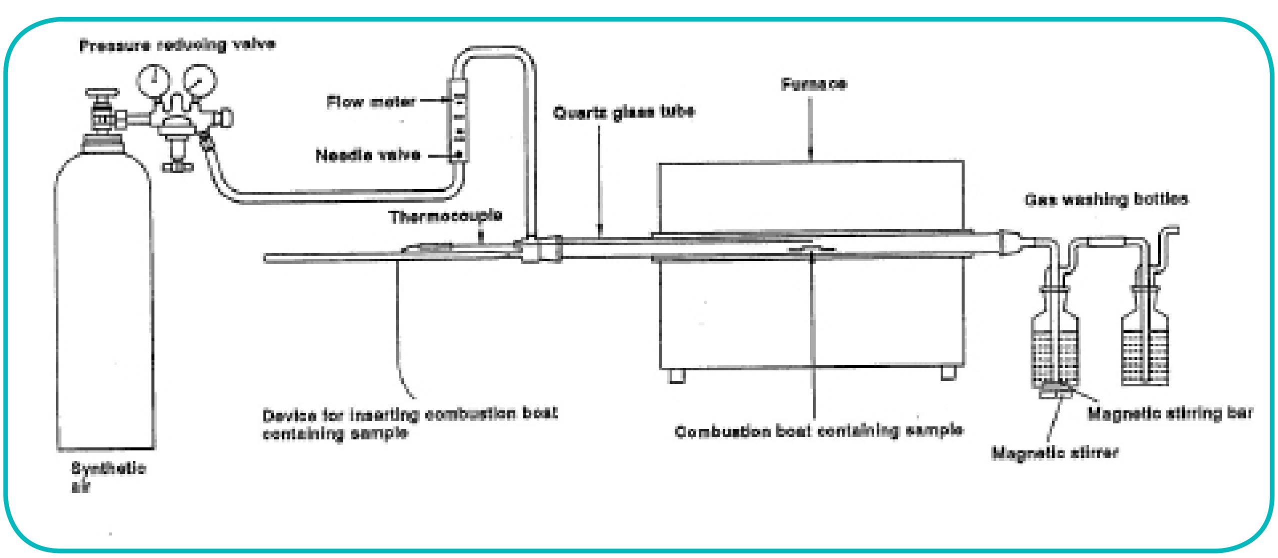
IEC 60754-1 specifies a method for the determination of the amount of halogen acid gas, other than hydrofluoric acid, evolved during the combustion of compounds based on halogenated polymers and compounds containing halogenated additives taken from cable constructions.
IEC 60754-2 specifies a method for the determination of the degree of acidity of gases evolved during the combustion of compounds taken from cable components. A pre-determined quantity of the test material is burned in a tube furnace. The evolved gases are trapped by bubbling through bottles filled with distilled or demineralized water. The acidity is measured by determination of pH value. The conductivity of the solution is also measured.

What is Halogen ?

The halogens are the elements of the 7th group in the Periodic Table of Elements: chlorine (Cl), fluorine (F), bromine (Br), iodine (I). Halogen free cables must be free of chlorine, fluorine and bromine (PVC cables contain halogen, PVC = Polyvinyl chloride).
The halogens are an integrated component of many acids :
HCl = Salt acid (hydrochloric acid) ; HF = Hydrogenfluorid ; HBr = Hydrogenbromid .

Test procedures :
1000 mg insulation material is burned in a combustion furnace at 935 °C with pre-defined air supply for over 30 minutes. By means of two gas washing containers, held in the airflow the conductivity and the pH-value are measured. Like that even small quantities of halogen containing substances can be detected and proven. The test is considered to be passed when the ph-value > 4.3 and the conductivity < 10 µS/mm .

Test standards
IEC 60754-2, EN 50267-2-2



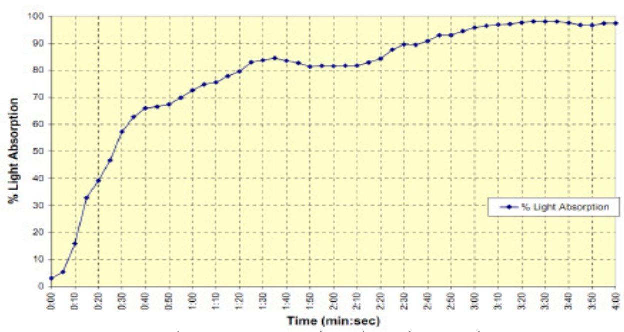
KCI Reduced Smoke PVC Certificates

Why reduced smoke PVC ?

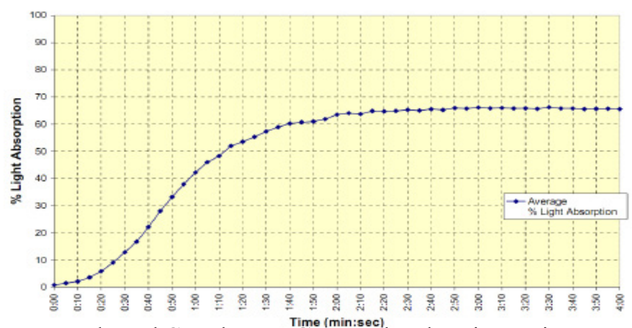
As PVC material makes considerable smoke comparing halogen free materials that means no international standard has referred to low-smoke test for such a cables and in the other hand some projects has requested for low smoke cables with PVC sheath , so KCI has developed reduced smoke PVC for such applications.
As PVC has stronger mechanical properties (tensile strength and also flexibility) comparing with halogen free materials , this kind of reduced smoke PVC has significant advantages for both having mechanical and safety issues for sensitive usages such as petrochemical plants , ...
It is very important to note that IEC 61034 is the main test for low smoke cables , but there are another test that is used just for material testing .

Scope of ASTM D 2843 :

This fire-test-response test method covers a laboratory procedure for measuring and observing the relative amounts of smoke obscuration produced by the burning or decomposition of plastics. It is intended to be used for measuring the smoke-producing characteristics of plastics under controlled conditions of combustion or decomposition. The measurements are made in terms of the loss of light transmission through a collected volume of smoke produced under controlled, standardized conditions.



Normal PVC , smoke density rating



Reduced Smoke PVC , smoke density rating

As you can see from above curves , smoke density rating of KCI reduced smoke PVC is less that Normal PVC . These materials are tested in "Architectural Testing" laboratory .

Architectural Testing

A3543.01-106-31
Page 3 of 4
Revision 1: 11/05/10

Data sheets, representative samples of test specimens, a copy of this test report will be retained by Architectural Testing, Inc. for a period of four years from the original test date. At the end of this retention period such materials shall be discarded without notice and the service life of this report by Architectural Testing will expire. Results obtained are tested values and were secured using the designated test methods. This report does not constitute certification of this product nor an opinion or endorsement by this laboratory. It is the exclusive property of the client so named herein and relates only to the specimens tested. This report may not be reproduced, except in full, without the written approval of Architectural Testing, Inc.

For ARCHITECTURAL TESTING, INC.:

Digitally Signed by: Rodney E. Holland
Rodney E. Holland - Technician II
Components / Materials Testing

Digitally Signed by: Gary Hartman
Gary Hartman, P.E. - Director
Components / Materials Testing

KCI

The another test method for comparing Normal and reduced Smoke PVC is ASTM E 662 standard .

Scope of ASTM D E 662 :

This fire-test-response standard covers determination of the specific optical density of smoke generated by solid materials and assemblies mounted in the vertical position in thicknesses up to and including 1 inch .

KCI reduced smoke PVC is tested in Exova warringtonefire laboratory .

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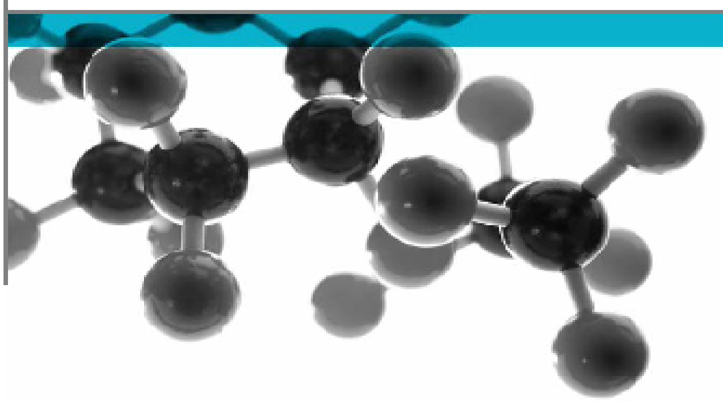
Exova Warringtonfire

ASTM E662 – 2009



Standard Test Method For Specific Optical Density Of Smoke Generated By Solid Materials

A Report To: Kerman Cable Industries (KCI)

Document Reference: 196754

Date: 27th September 2010

Issue No.: 1

Page 1

Testing
Advising
Assuring

UKAS TESTING 0249

KCI Reduced Smoke PVC Certificates

Improved flame retardancy evaluation by Oxygen Index :

What Is Oxygen Index Testing?
Measuring the amount of oxygen required to support sustained ignition gives an indication of the flammability of the material.

Test Method :
This part of BS EN ISO 4589 specifies methods for determining the minimum concentration of oxygen, in a mixture with nitrogen, that will support combustion of small vertical test specimens under specified test conditions. The test is performed at an ambient temperature of 23°C ± 2°C.

What Is Temperature Index Testing?
Measuring the temperature required to support sustained ignition gives an indication of the flammability of the material.

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Exova Warringtonfire

BS EN ISO 4589-2: 1999

Determination of Burning Behaviour By Oxygen Index

A Report To: Kerman Cable Industries (KCI)

Document Reference: 196748

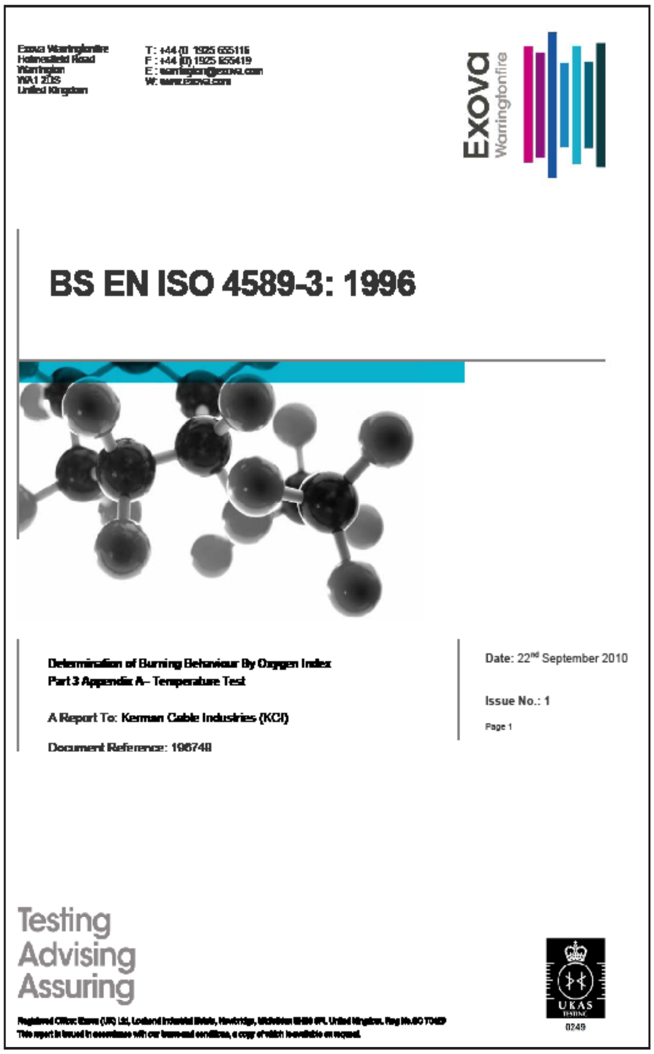
Date: 22nd September 2010

Issue No.: 1

Page 1

Testing
Advising
Assuring

UKAS TESTING 0249



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Exova Warringtonfire

BS EN ISO 4589-3: 1996

Determination of Burning Behaviour By Oxygen Index
Part 3 Appendix A– Temperature Test

A Report To: Kerman Cable Industries (KCI)

Document Reference: 196748

Date: 22nd September 2010

Issue No.: 1

Page 1

Testing
Advising
Assuring

UKAS TESTING 0249

.... KCI Reduced Smoke PVC Certificates

Reduced Halogen acid gas while burning :
Obviously PVC during burning makes considerable amount of Halogen (that is inside the polymer formulation polyvinyl - chloride).
For Halogen free materials the value of halogen gas is less than 0.5 %
whereas for Normal PVC is about 23 % !
One of another advantages of KCI reduced smoke PVC is lower amount of released halogen gas that is about half of Normal PVC.

This material is tested acc to IEC 60754-1 by Exova Warrringtone fire.

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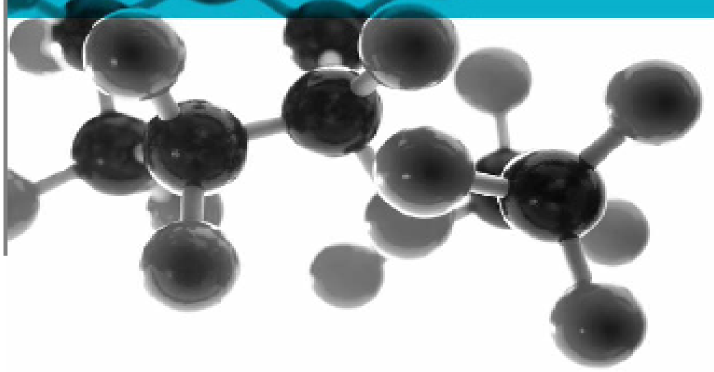
Exova Warringtonfire

IEC 60754-1: 1994



Test On Gases Evolved During Combustion Of Material From Cables, Part 1 - Determination Of The Amount Of Halogen Acid Gas

A Report To: Kerman Cable Industries (KCI)

Document Reference: 196752

Date: 22nd September 2010

Issue No.: 1

Page 1

Testing
Advising
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UKAS TESTING 0249

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Kerman & Kavian Cable Industries (KCI)

Power Cables

KCI

KCI Reduced Smoke PVC Certificates

Ultimate Improved flame retardancy ; IEC 60332-3-22 Category A :

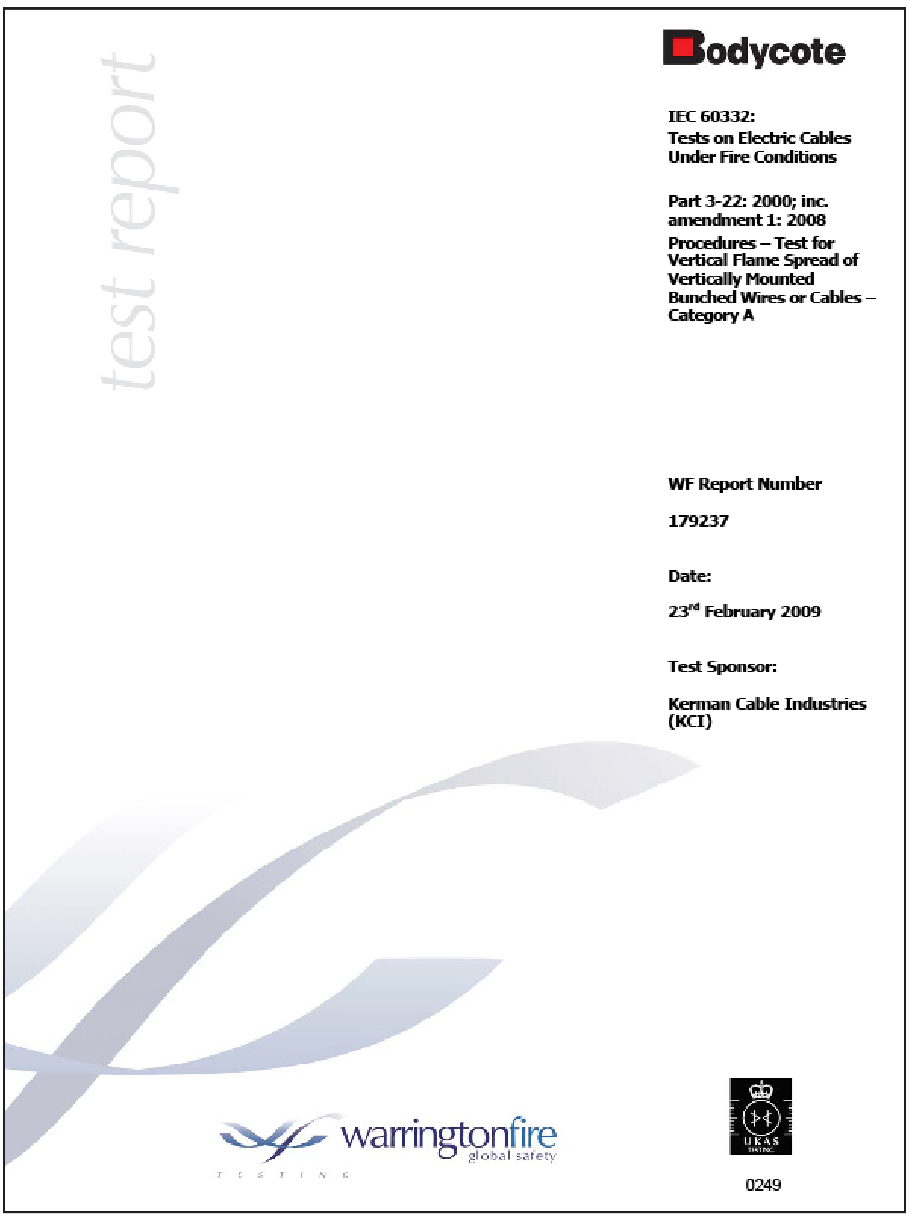
Scope of test : IEC 60332-3-22 specifies a method of test for the assessment of vertical flame spread of vertically mounted bunched wires or cables, electrical or optical, under defined conditions. Flame spread is measured as the extent of damage of the cable sample. This procedure may be utilised to demonstrate the cable’s ability to limit flame spread.

Part 3-22 of IEC 60332 covers **Category A** and relates to cables installed on the test ladder to achieve a nominal total volume of non-metallic material of 11 litres per meter of test sample. The flame application time is 40 min. The method of mounting uses the front of the standard ladder. The category is intended for general use where low volumes of non metallic material are required to be evaluated.

The test specimen, consisting of a number of 3.5m lengths of cable, is deemed to have met the requirements of the Standard if, after burning has ceased or flames extinguished, the extent of charred portion does not reach a height exceeding 2500mm above the bottom edge of the burner.

Results of test :

* The duration of after burn was 3 minutes.
* The maximum height of the cable charred, as measured from the bottom of the burner, was 1.19m.


test report

Bodycote

IEC 60332:
Tests on Electric Cables
Under Fire Conditions

Part 3-22: 2000; inc.
amendment 1: 2008
Procedures – Test for
Vertical Flame Spread of
Vertically Mounted
Bunched Wires or Cables –
Category A

WF Report Number

179237

Date:

23rd February 2009

Test Sponsor:

Kerman Cable Industries
(KCI)

warringtonfire global safety
TESTING

UKAS TESTING
0249

KCI OIL and UV Resistant PVC Certificates

KCI

Resistance to environmental conditions OIL Resistant / UV Resistant :

For some special projects , such as petrochemical plants , refineries , ... that the area is polluted with oil and hydrocarbon and also in hot climate zone that cable installed in sun-light exposure ;
The outer sheath of cable should be OIL and UV resistant.

KCI has developed several kinds of OIL and UV resistant PVC sheaths and has got certificates from Exova laboratories .

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Exova

Testing. Advising. Assuring.

Kerman Cable Industries (KCI)
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19656-13311
Tehran Iran

Attn: Mr. Mohammad Mohseni
+98(21) 22669500

Re: Testing to UL 1581 "*Reference Standard for Electrical Wires, Cables & Flexible Cords*", Section 1200

October 14, 2010

Mr. Mohseni,

At the request of *Kerman Cable Industries (KCI)*, Exova was retained to evaluate a PVC product identified as "LSG 15 (DFL 0244)" to UL-1581, Section 1200 for tensile properties before and after 300 hours of UVA-340 exposure.

Thirty (30) pieces of precut dumbell-shaped polymer specimens were submitted for testing, and labelled with Exova Sample No. 10-06-M0391-1 to -30. No verification was made that the material submitted for testing was prepared according to UL 1581, Section 1200.

Six (6) specimens were chosen randomly for UV-exposure. The details of the exposure parameters and duration are provided in Exova Solar & Weathering Certificate No. 10-06-M0391. A mild colour change was observed after exposure.

After exposure, the six (6) aged specimens and six (6) un-aged specimens were evaluated for tensile properties according to ASTM D 412-06, using ISO 527 compliant specimens. The details of the evaluation, test parameters and results are provided in Exova Report 10-05-228-12.

The results obtained for testing conducted as above are as follows:

	Tensile Strength, N/mm^2	**Ultimate Elongation**, %
Original Specimens *as received, precut by the client*	13.0	269
UV-Aged Specimens *after 300 hours of cyclical UVA-340 exposure*	13.2	268
Ratio (aged/unaged)	1.01	0.99
UL 1581 Requirements UL 1581 Section 1200 requirements for Tensile Strength & Ultimate-Elongation	≥ 0.85	≥ 0.85
Compliance Result	PASS	PASS

Based on the above results, the material complies with the 300-hour tensile strength and ultimate-elongation requirements of UL 1581, Clause 1200.9, tested as described in the aforementioned reports.

Oil-Aging Test of PVC Material
For Kerman Cable Industries (KCI)

Page 3 of 3
Report No. 10-05-2392-11

Exova

The following equipment was used for testing.

INSTRUMENT	**CALIBRATION STATUS (Valid until date)**
Conditioned Room (MII #A11354)	2011-01-15
5500R-upgraded 1125 Instron (MII #A03921)	2010-11-19
500 N load cell (MII #A13789)	2010-11-18
Elastomeric extensometer (MII #A06107)	2010-11-20
Digital thickness gauge SDL (MII #A13650)	valid at time of testing

Results for this test can be found in Table I.

TABLE I
Tensile Properties

Specimen Number	**Tensile Strength (MPa)**		**Elongation at Break (%)**	
	Original	**Oil-Aged**	**Original**	**Oil-Aged**
1	11.6	9.98	320	180
2	11.7	10.8	299	202
3	11.4	10.9	299	222
Median Value	**11.7**	**10.8**	**299**	**202**

Reported by:

Steven K. Haynes
Project Technologist
Polymer Characterization

Reviewed and Approved by:

Bryan Wickson, B.Sc. Eng.
Manager
Polymer Characterization

This report and service are covered under Exova Canada Inc's Standard Terms and Conditions of Contract which may be found on our company's website www.exova.com, or by calling 1-866-263-9268

KCI

KCI Low Smoke Cable Certificates

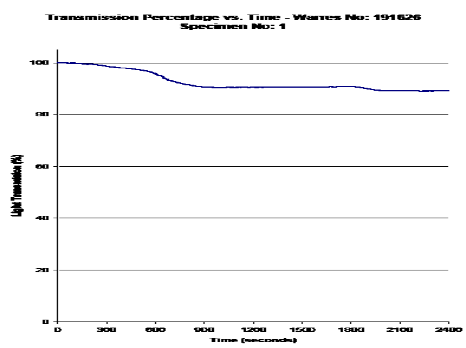
Low smoke cable acc to BS EN 61034-2: 2005 :

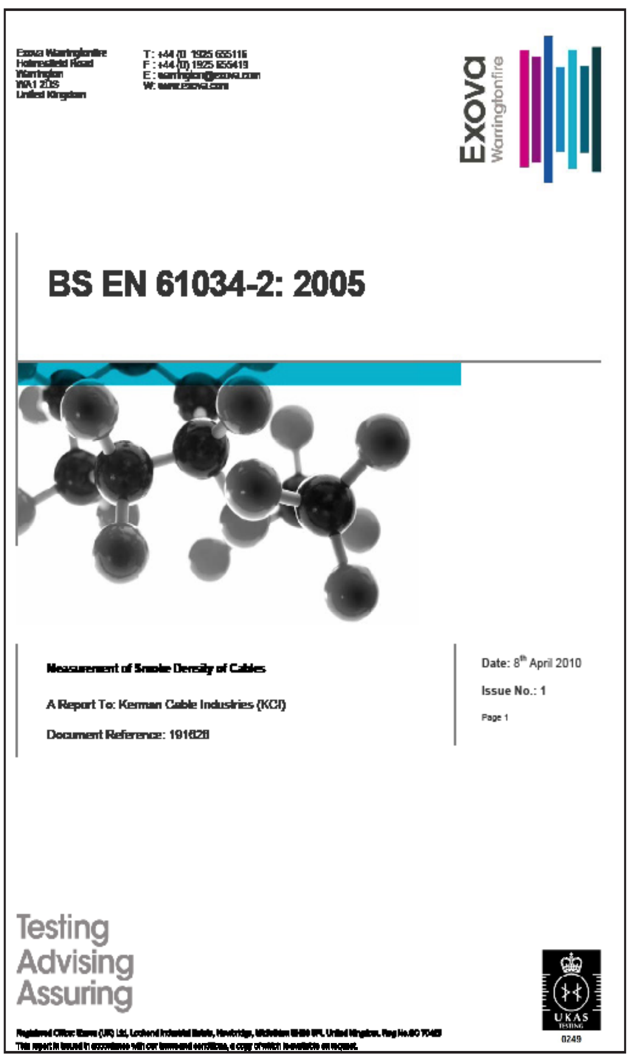
Purpose of test : To determine the performance of a specimen of a cable when it is subjected to the conditions of the test specified in BS EN 61034-2: 2005: "Measurement of smoke density of cables burning under defined conditions".
The test was performed in accordance with the procedure specified in BS EN 61034-2: 2005 and this report should be read in conjunction with that Standard.

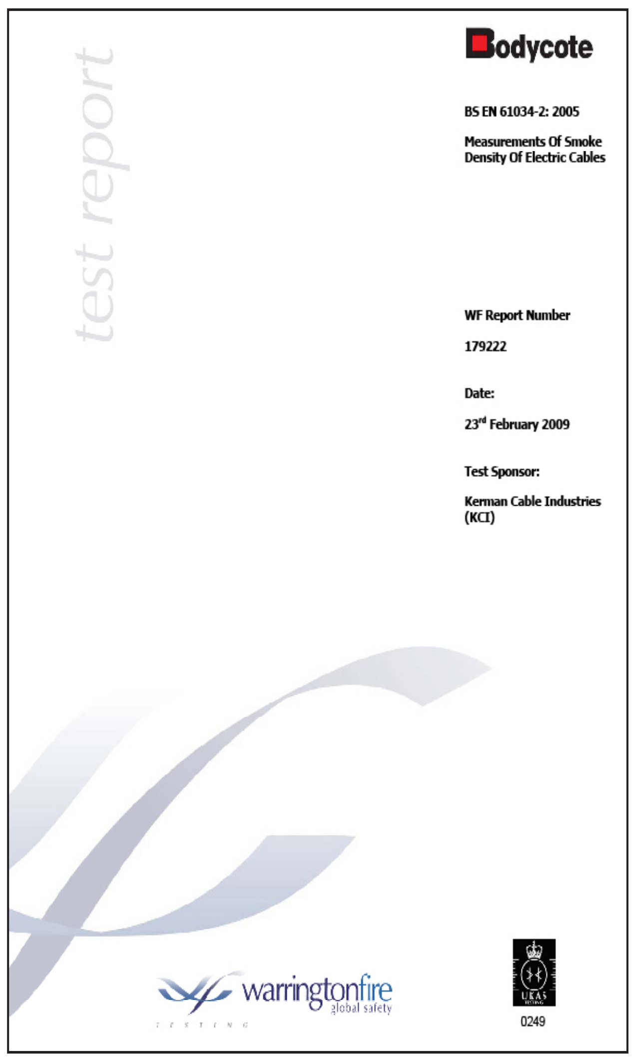
Scope of test BS EN 61034-2: 2005, details a method of test for the measurement of the density of smoke emitted from cables burning under the defined conditions of the test. The result is expressed as percentage light transmittance and is used to determine compliance with the criterion given in Section 7 of the Standard.
Test results :Two specimens were tested.

Specimen No	Minimum light transmittance (%)
1	89.11
2	86.41

Average minimum light transmittance 87.76%







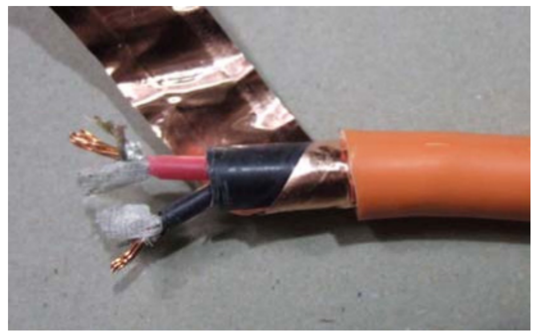
KCI Fire Resistant Cable Certificate

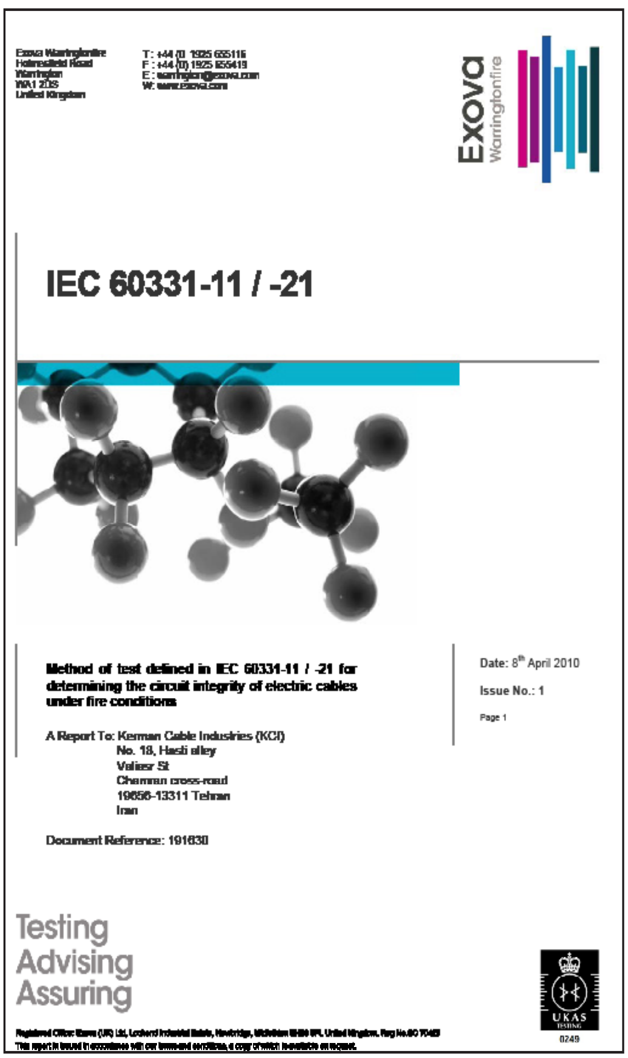
Determining the circuit integrity of electric cables under fire conditions ; IEC 60331-11 / -21:

Purpose of test : To determine the performance of a specimen of a cable when it is subjected to the conditions of test specified in IEC 60331-21: 1999, utilising the test apparatus detailed in IEC 60331-11:1999 + A1: 2009. The purpose of this test method is to determine whether a cable can maintain circuit integrity when it is exposed to the fire conditions described within the method.

Scope of test : IEC 60331-21: 1999 specifies a test procedure and gives a performance requirement, including a recommended flame application time, for cables of rated voltage up to and including 600/1000 V. It is intended to cover low voltage power cables and control cables with a rated voltage.
In accordance with section 7.1 of the test standard, a 90 minute flame application time was used.

Results of test : When tested in accordance with the procedures specified in IEC 60331-21: 1999, utilising the test apparatus detailed in IEC 60331-11: 1999 + A1: 2009, at a temperature of at least 750 ^{0}C and at a rated voltage of 1000 V-rms, the cable maintained it's circuit integrity for the full 105 minute test duration.
(Consisting of a 90 minute flame application period, plus a 15 minute cool down period).





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Exova Warringtonfire

IEC 60331-11 / -21

Method of test defined in IEC 60331-11 / -21 for determining the circuit integrity of electric cables under fire conditions

Date: 8th April 2010

Issue No.: 1

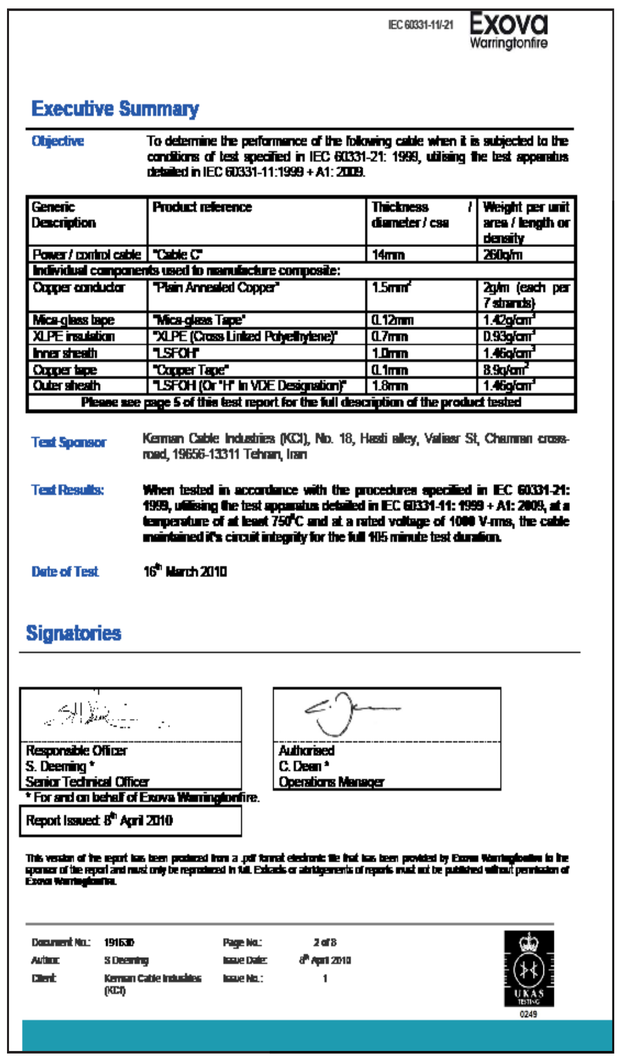
Page 1

A Report To: Kerman Cable Industries (KCI)
No. 18, Hasti alley
Valiasr St
Chamran cross-road
19656-13311 Tehran
Iran

Document Reference: 191630

Testing
Advising
Assuring

UKAS TESTING 0249



IEC 60331-11/-21 Exova Warringtonfire

Executive Summary

Objective To determine the performance of the following cable when it is subjected to the conditions of test specified in IEC 60331-21: 1999, utilising the test apparatus detailed in IEC 60331-11:1999 + A1: 2009.

Generic Description	Product reference	Thickness / diameter / csa	Weight per unit area / length or density
Power / control cable	"Cable C"	14mm	260g/m
Individual components used to manufacture composite:			
Copper conductor	"Plain Annealed Copper"	1.5mm²	2g/m (each per 7 strands)
Mica-glass tape	"Mica-glass Tape"	0.12mm	1.42g/cm³
XLPE insulation	"XLPE (Cross Linked Polyethylene)"	0.7mm	0.93g/cm³
Inner sheath	"LSFOH"	1.0mm	1.46g/cm³
Copper tape	"Copper Tape"	0.1mm	8.9g/cm³
Outer sheath	"LSFOH (Or "H" In VDE Designation)"	1.8mm	1.46g/cm³
Please see page 5 of this test report for the full description of the product tested			

Test Sponsor Kerman Cable Industries (KCI), No. 18, Hasti alley, Valiasr St, Chamran cross-road, 19656-13311 Tehran, Iran

Test Results: **When tested in accordance with the procedures specified in IEC 60331-21: 1999, utilising the test apparatus detailed in IEC 60331-11: 1999 + A1: 2009, at a temperature of at least 750°C and at a rated voltage of 1000 V-rms, the cable maintained it's circuit integrity for the full 105 minute test duration.**

Date of Test 16th March 2010

Signatories

Responsible Officer S. Deeming * Senior Technical Officer	Authorised C. Dean * Operations Manager

* For and on behalf of Exova Warringtonfire.

Report Issued: 8th April 2010

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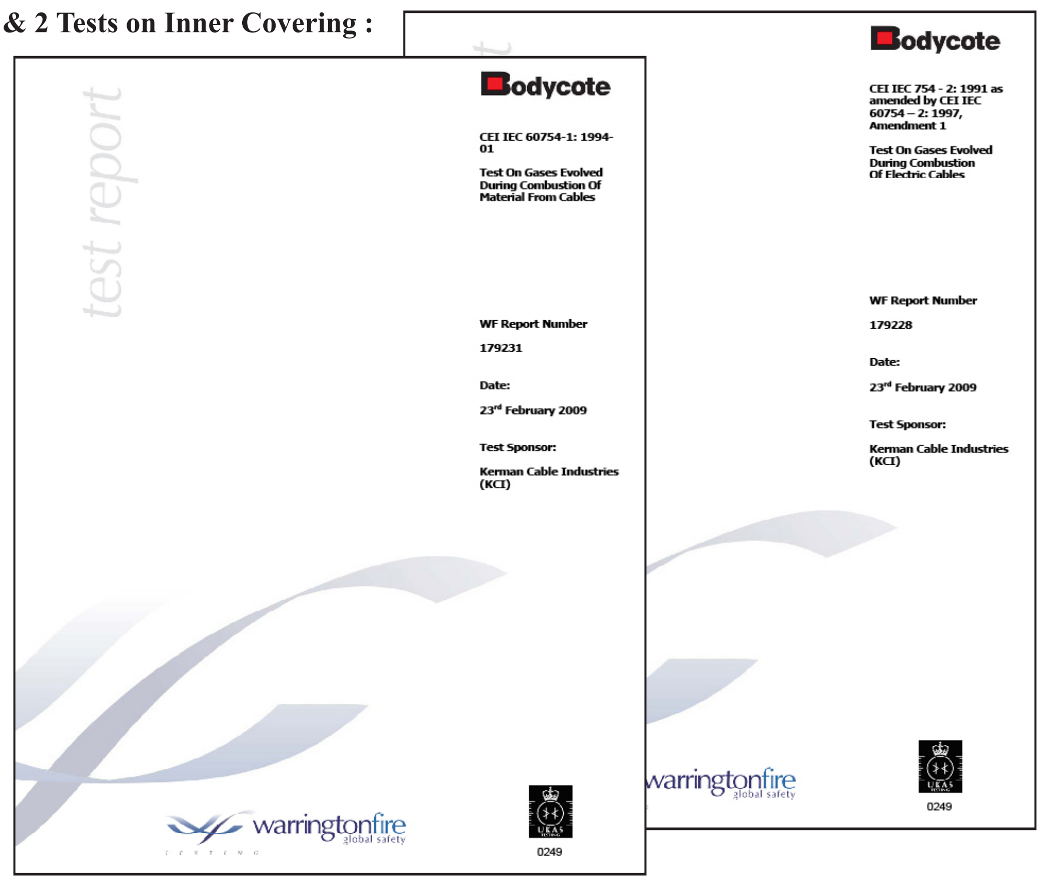
Document No.:	191630	Page No.:	2 of 8
Author:	S Deeming	Issue Date:	8th April 2010
Client:	Kerman Cable Industries (KCI)	Issue No.:	1

UKAS TESTING 0249

KCI Halogen Free Cable Certificates

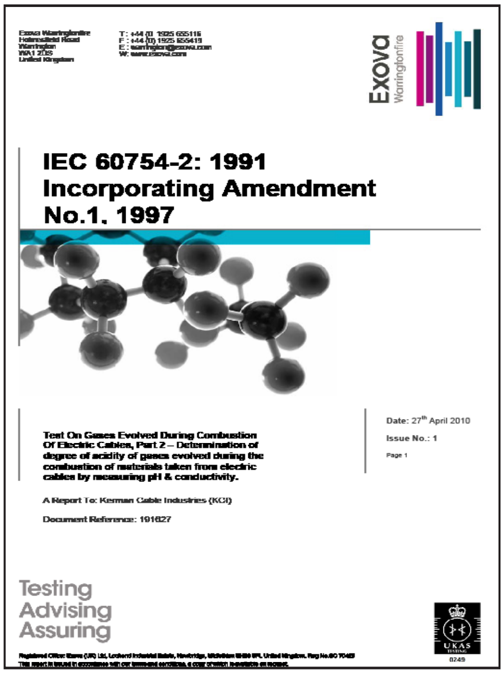
IEC 60754-1 & 2 Tests on Insulation :

IEC 60754-1 & 2 Tests on Inner Covering :



KCI Halogen Free Cable Certificates

IEC 60754-1 & 2 Tests on Outer Sheath :



Exova Warringtonfire

IEC 60754-2: 1991 Incorporating Amendment No.1. 1997

Test On Gases Evolved During Combustion Of Electric Cables, Part 2 – Determination of degree of acidity of gases evolved during the combustion of materials taken from electric cables by measuring pH & conductivity.

A Report To: Kerman Cable Industries (KCI)

Document Reference: 191627

Date: 27th April 2010

Issue No.: 1

Page 1

Testing Advising Assuring

0249

test report

Bodycote

CEI IEC 60754-1: 1994-01

Test On Gases Evolved During Combustion Of Material From Cables

WF Report Number

179230

Date:

23rd February 2009

Test Sponsor:

Kerman Cable Industries (KCI)

warringtonfire global safety

0249

Bodycote

CEI IEC 754 - 2: 1991 as amended by CEI IEC 60754 – 2: 1997, Amendment 1

Test On Gases Evolved During Combustion Of Electric Cables

WF Report Number

179229

Date:

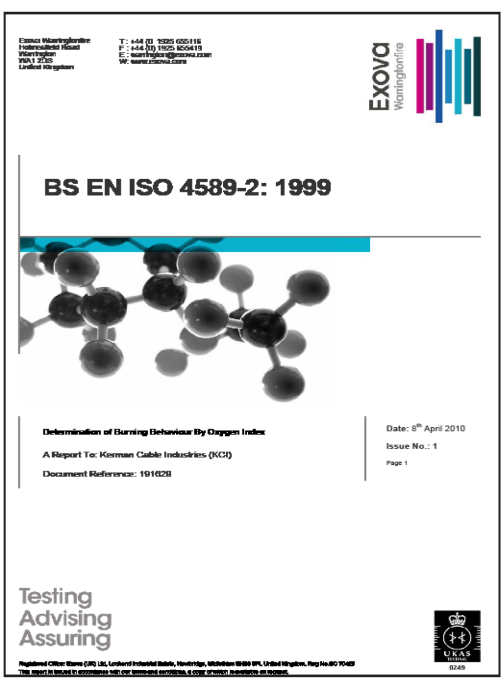
23rd February 2009

Test Sponsor:

Kerman Cable Industries (KCI)

0249

ISO 4589-2 (for improved flame retardancy verification) Tests on Outer Sheath :



Exova Warringtonfire

BS EN ISO 4589-2: 1999

Determination of Burning Behaviour By Oxygen Index

A Report To: Kerman Cable Industries (KCI)

Document Reference: 191628

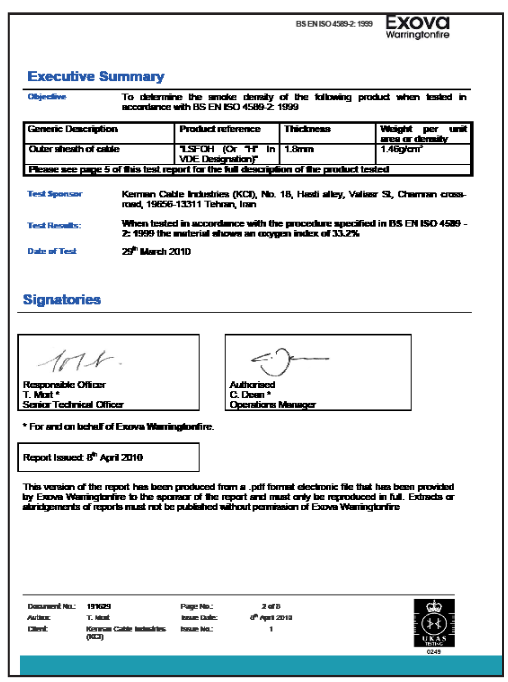
Date: 8th April 2010

Issue No.: 1

Page 1

Testing Advising Assuring

0249



BS EN ISO 4589-2: 1999 Exova Warringtonfire

Executive Summary

Objective: To determine the smoke density of the following product when tested in accordance with BS EN ISO 4589-2: 1999

Generic Description	Product reference	Thickness	Weight per unit area or density
Outer sheath of cable	"LSFOH (Or "H" In VDE Designation)"	1.8mm	1.46g/cm³
Please see page 5 of this test report for the full description of the product tested			

Test Sponsor: Kerman Cable Industries (KCI), No. 18, Hasti alley, Valiasr St, Chamran cross-road, 19656-13311 Tehran, Iran

Test Results: When tested in accordance with the procedure specified in BS EN ISO 4589-2: 1999 the material shows an oxygen index of 33.2%

Date of Test: 25th March 2010

Signatories

Responsible Officer T. Mort * Senior Technical Officer

Authorised C. Dean * Operations Manager

* For and on behalf of Exova Warringtonfire.

Report Issued: 8th April 2010

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Document No.: 191628 Page No.: 2 of 8

Author: T. Mort Issue Date: 8th April 2010

Client: Kerman Cable Industries (KCI) Issue No.: 1

0249

KCI

Cable Drum Handling Procedure

Moving Drums with Lift-truck

Moving Drums with Crane

Rolling Drums on the Ground

Putting Drums on the Truck and Ground

Unpacking - Packing Drums

Fastening Drums on the truck

Unloading Drums from truck

Rewinding Cable on another Drum

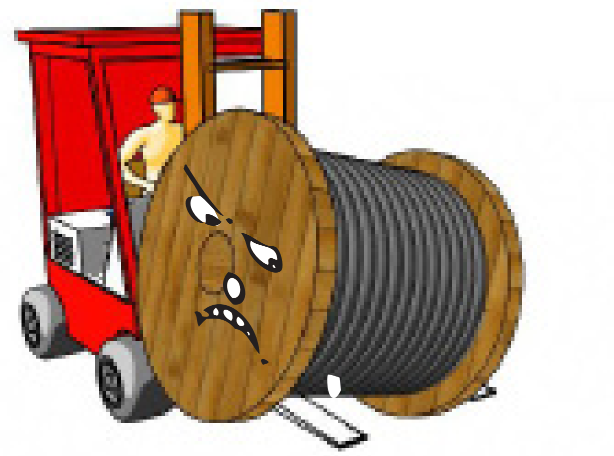
Unwinding Cable from Drum on the Ground

Pulling Cable from Drums

Drum Handling Procedure

Moving Drums with Lift-truck

Lift the drums by their flanges or through spindle hole



Never lift drums by their protective boardings

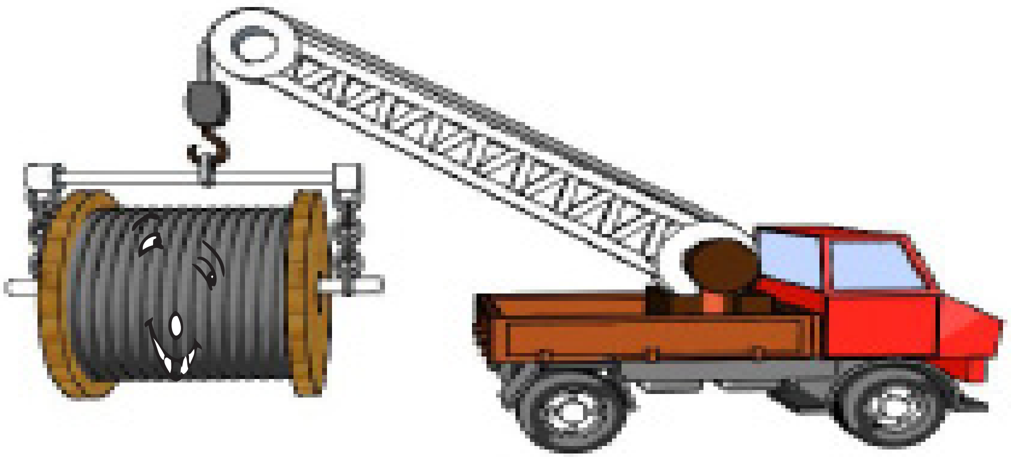
Never lift the drum with it’s flange

Never allow forks to touch cable surface or reel wrap

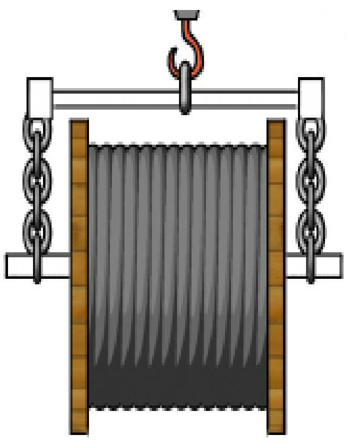
Drum Handling Procedure

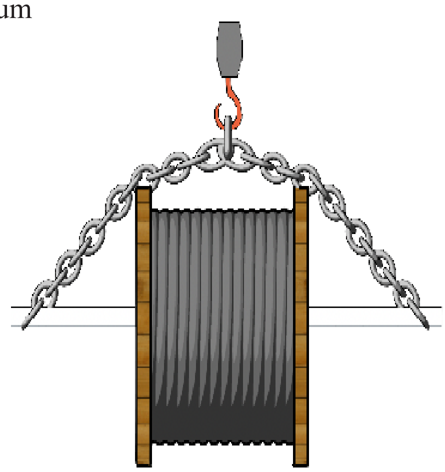
KCI

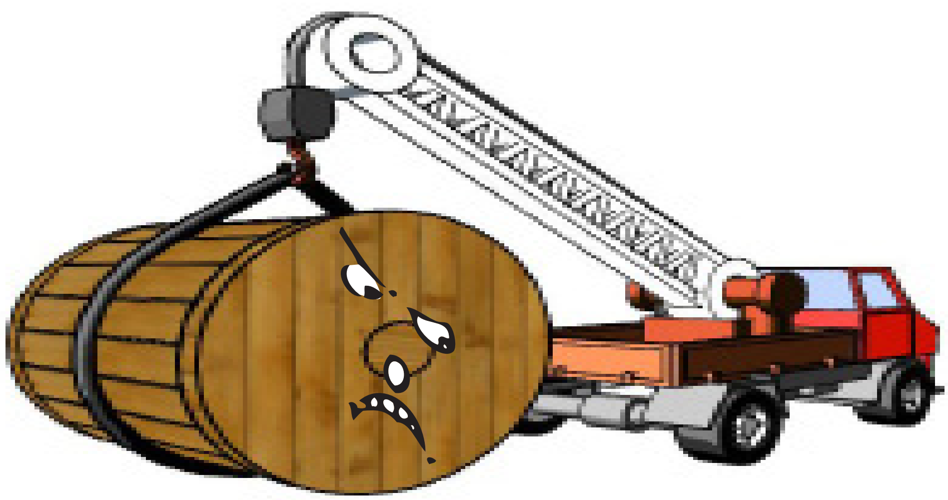
Moving Drums with Crane



Lift the drum by a spindle or sling through the middle of drum





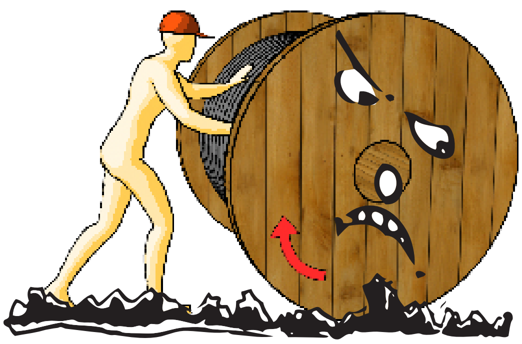


Never use sling around the drum

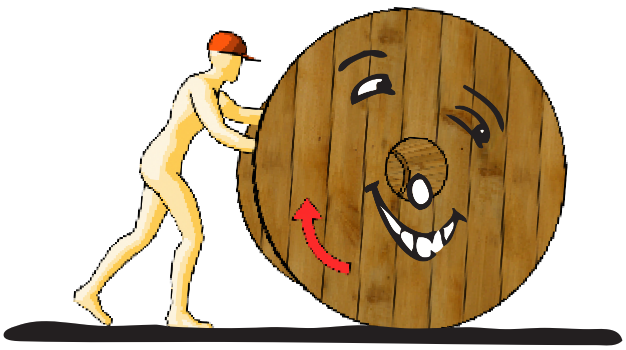
Drum Handling Procedure

Rolling Drums on the Ground

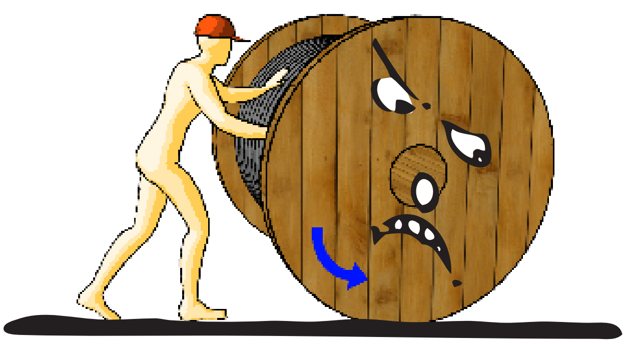
Roll drums on smooth surfaces



Never roll drums on over sharp objects



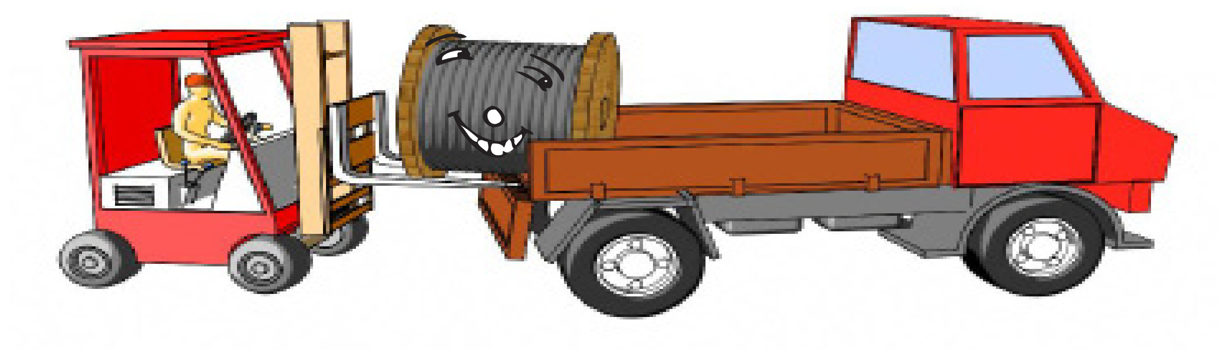
Roll drums in the direction of arrow

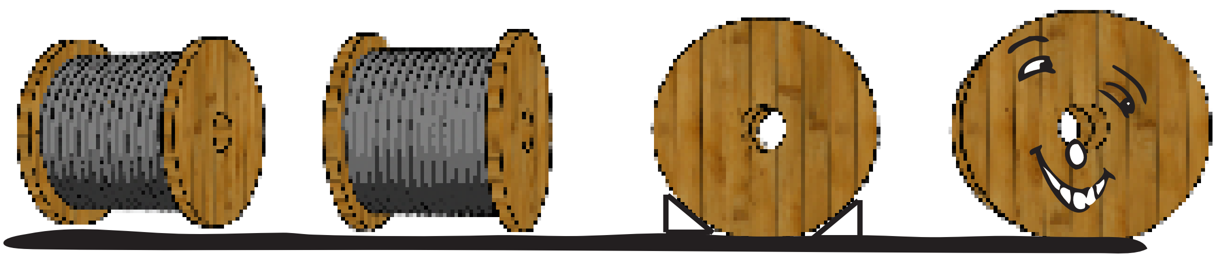


Never Roll drums in opposite direction of arrow
it makes cable hard to roll off .

Drum Handling Procedure

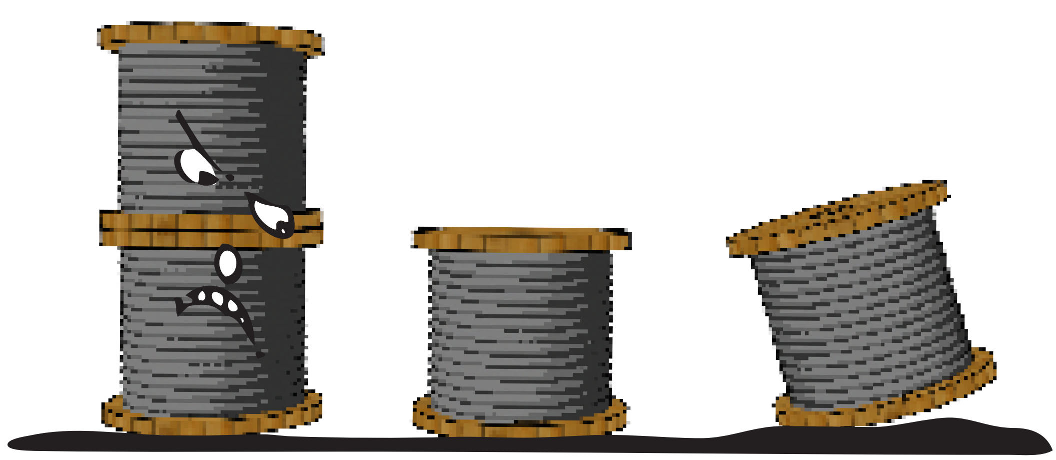
Putting Drums on the Truck and Ground





Store drums on hard drained smooth surface

Keep distance between drums or secure them by blocks

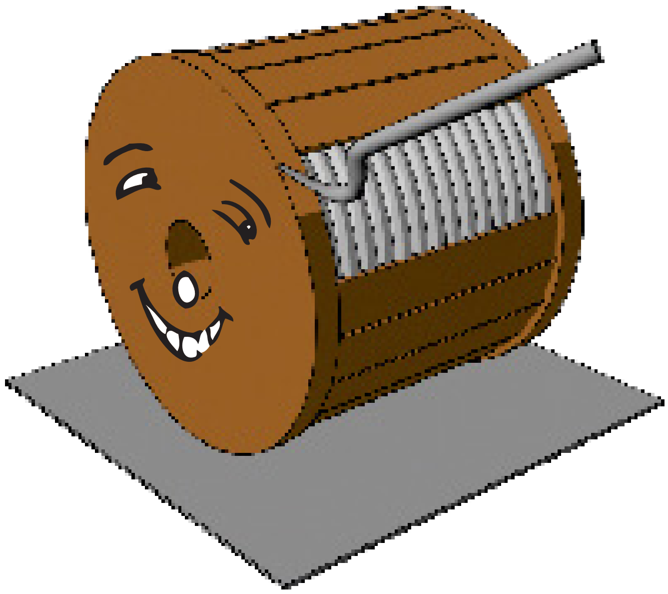


Never store drums on surface of flanges or stack them

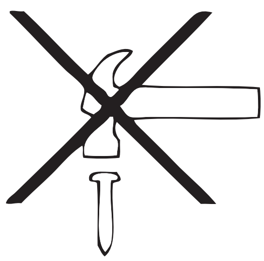
Drum Handling Procedure

KCI

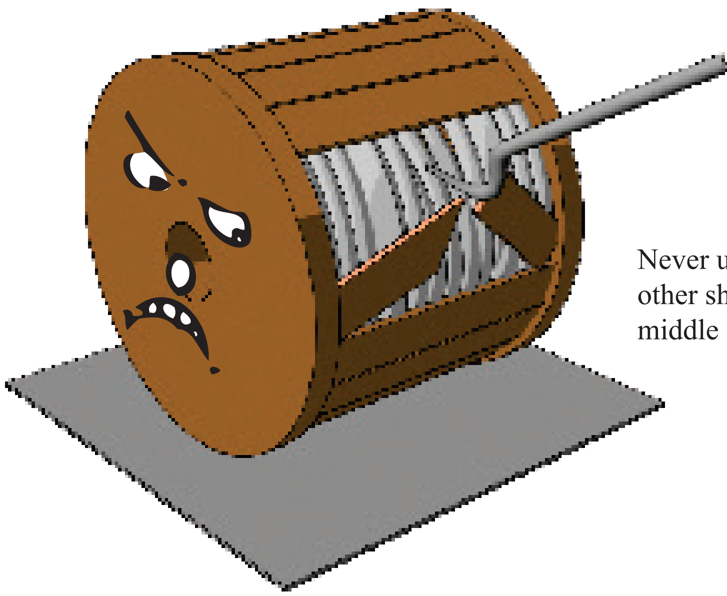
Unpacking - Packing Drums



Use a crowbar as shown to remove boarding at the end of boards



Avoid driving nails into cable drums

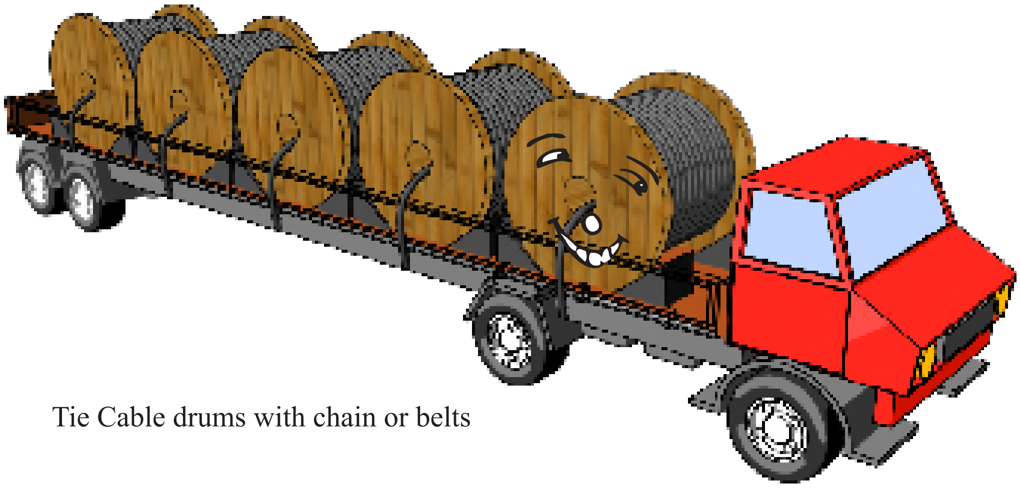


Never use a crowbar or other sharp tools in the middle of boards

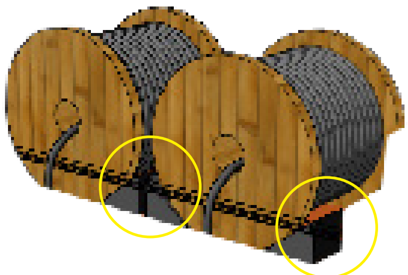
If Reinforced Sheet Plast (PP thick papers) are used instead of Cover Logs ; Drum's Cover can be easily removed by cutting it's fastener.

Drum Handling Procedure

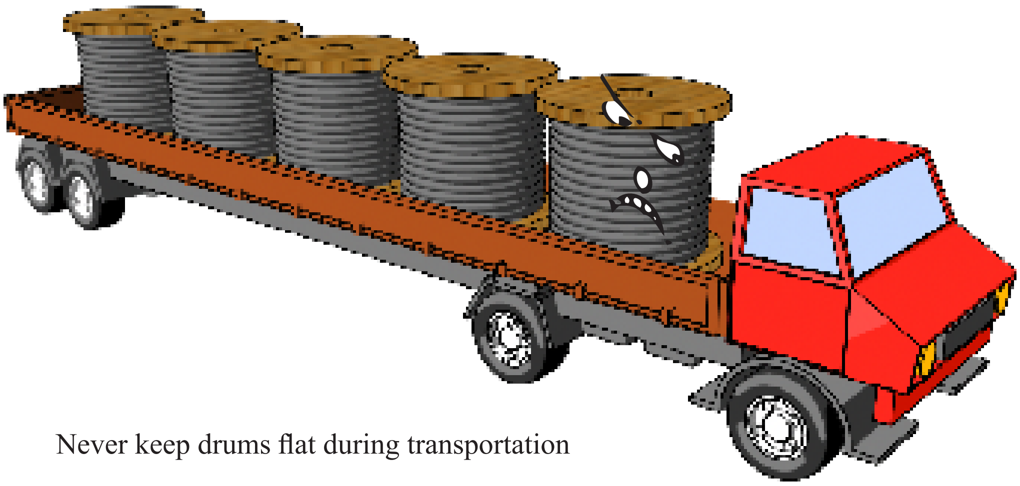
Fastening Drums on the truck



Tie Cable drums with chain or belts



Keep wooden blocks in between each drum
flanges to avoid movement during transportation

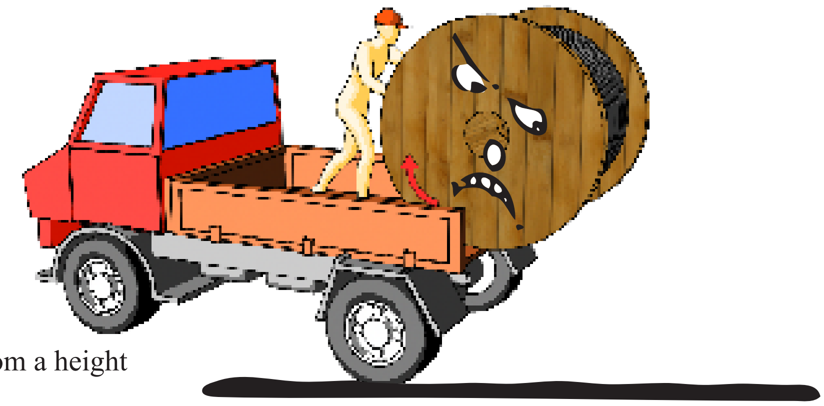


Never keep drums flat during transportation

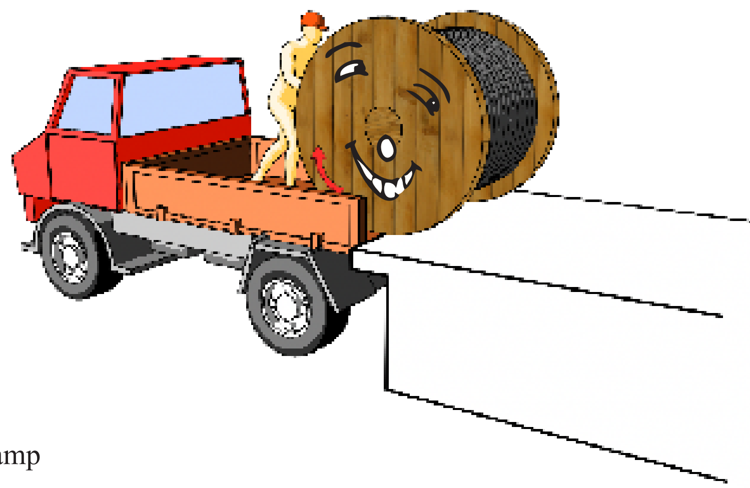
KCI

Drum Handling Procedure

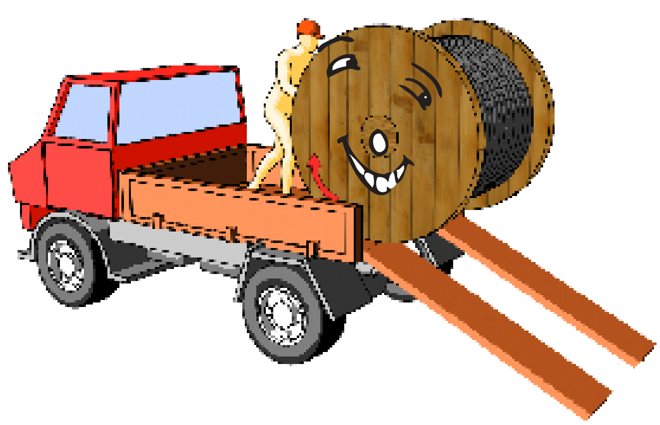
Unloading Drums from truck



Never drop the drum from a height



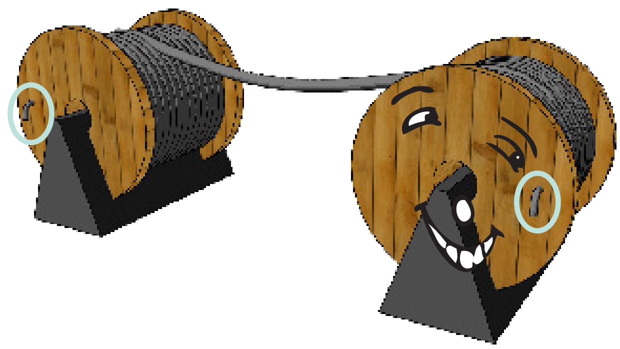
Use a loading bay or ramp



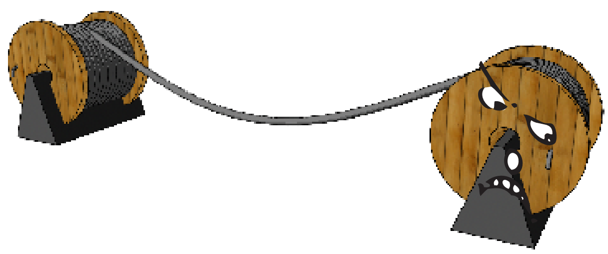
Drum Handling Procedure

KCI

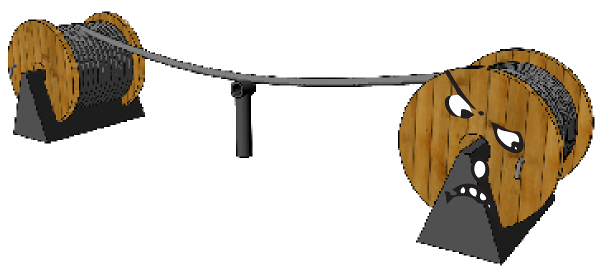
Rewinding Cable on another Drum



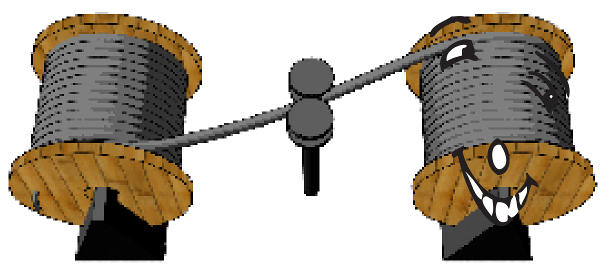
For proper re-winding cable , fasten the cable ends from the flange hole by rope and staple .



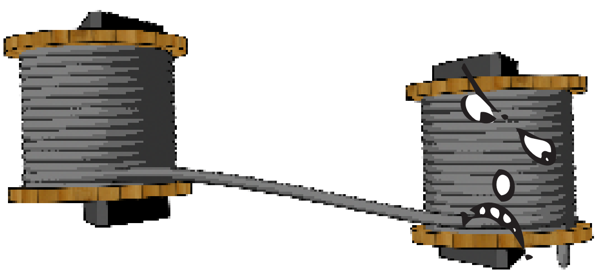
Never pull cable across long unsupported spans



Never drag cable across sharp edges



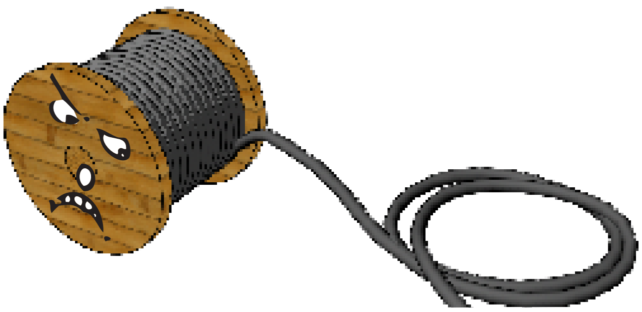
Align drums before cable rewinding
Use stoppers to prevent drum lateral movement
Use free rotation roller guides



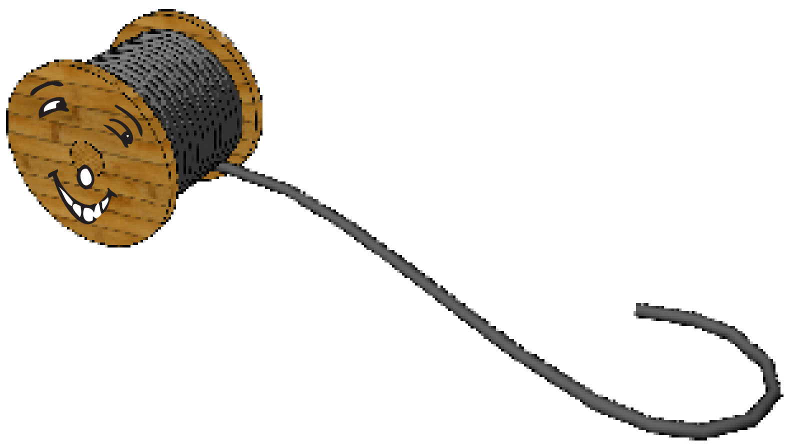
Never drag cable against drum flanges

Drum Handling Procedure

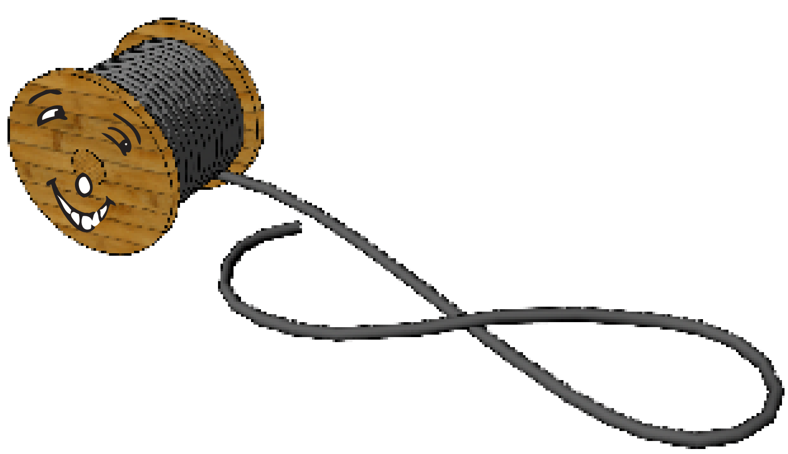
Unwinding Cable from Drum on the Ground



Never attempt coiling of cable on the ground

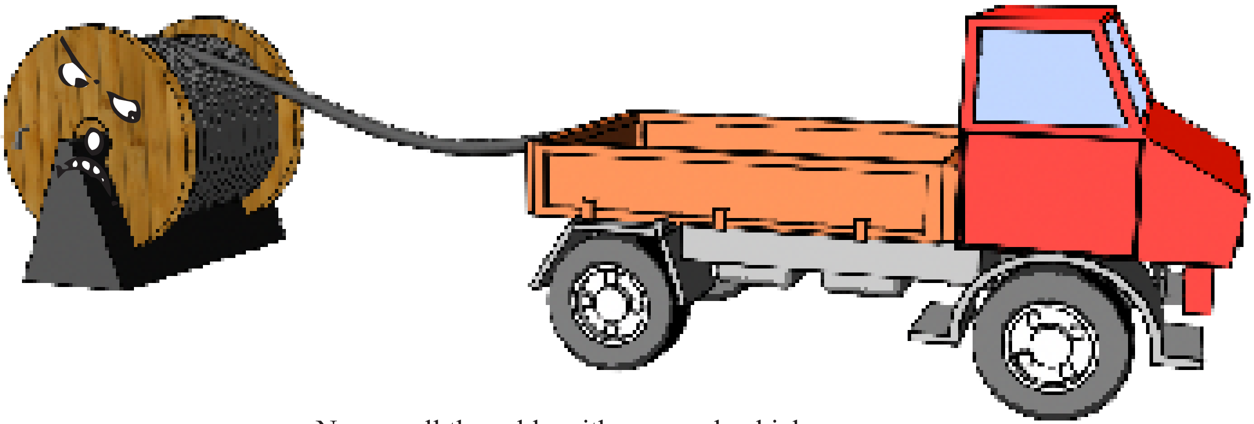


On the ground , cable can be flacked in a figure of eight “8” formation

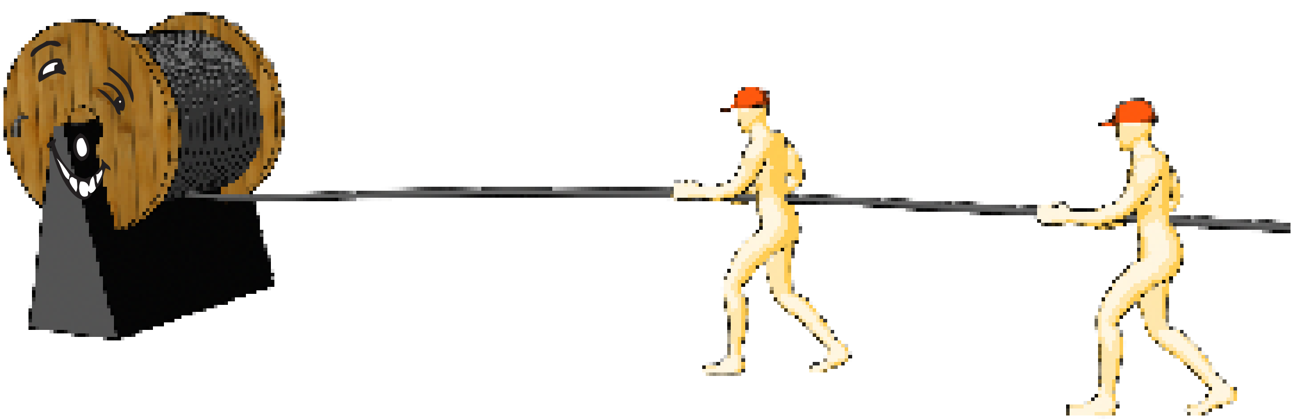


Drum Handling Procedure

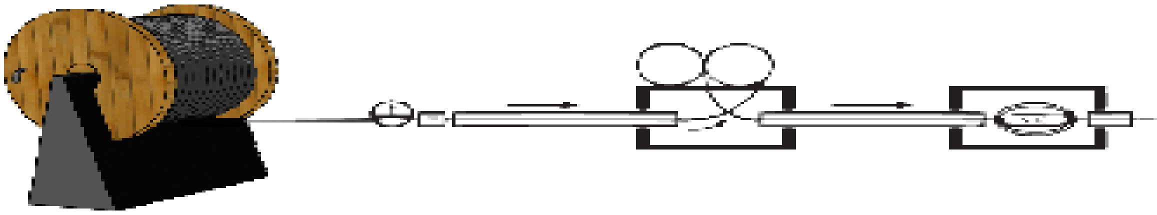
Pulling Cable from Drums



Never pull the cable with powered vehicles



Maintain pulling force beyond the standard proposed values



KCI

Guide to the Wiring Regulations

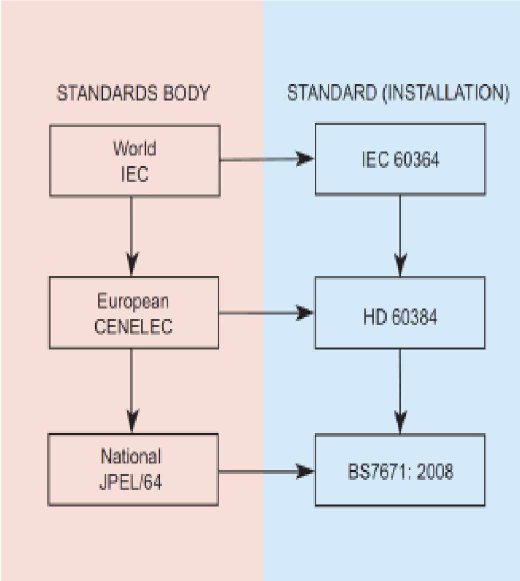
Guide to the Wiring Regulations

17th Edition IEE Wiring Regulations (BS 7671: 2008)

This chapter of catalogue discusses the requirements of BS 7671: 2008, also known as the IEE Wiring Regulations 17th Edition, published during January 2008.
The aim of the guide is to provide an explanation of the theory and reasons behind the Regulations, their meaning and the intent of their drafting. This chapter provides advice and guidance, demystifying the 'requirements' wherever possible. Practical and original solutions have been provided, which are often not found in other industry guidance.
The guide is a valuable resource for all users of BS 7671 including apprentices, electricians who perhaps want to 'dig a bit deeper' into the background of the Regulations, together with electrical technicians, installation engineers and design engineers. Most individuals who have any involvement with BS 7671 will find this of considerable help and benefit in their everyday work.

Introduction to BS 7671: 2008

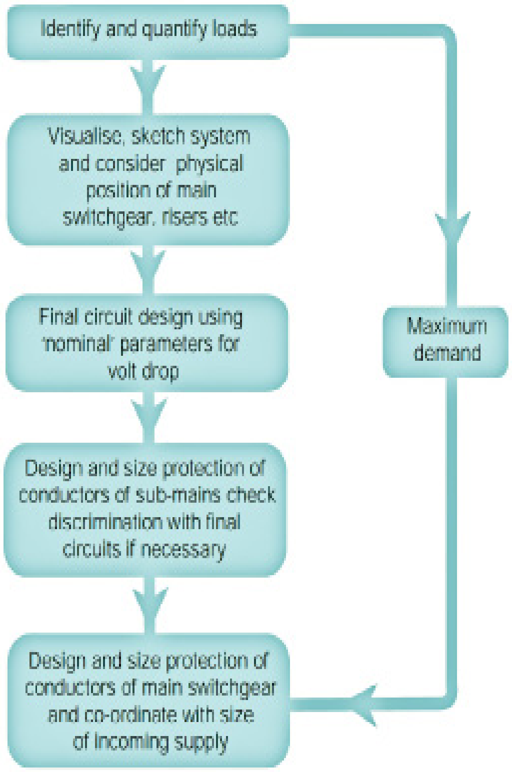
BS 7671: 2008 was published during January 2008 as a significant new Edition of this fundamental Standard.
Although the document is a British Standard, it is also known as (and jointly labelled as) the IEE Wiring Regulations . In essence, BS 7671: 2008 is virtually a European document. In fact, two parent documents as parts of the corresponding IEC standard have been used or adapted.
Both IEC and CENELEC have 'wiring regulation' standards or rules for electrical installations.
The general structure of IEC, CENELEC and BS 7671 is illustrated in This Figure.
Many parts of the document originate in CENELEC in a 'harmonized document' (HD). The parent document is known as HD 60384 and comprises virtually all parts of the installation standard.



Circuitry and Related Parts of BS 7671: 2008

Design procedure overview

The procedure of carrying out an electrical system design of an installation can be quite involved and often a number of drafts and subsequent adjustments are necessary.
This flow diagram shows the logical order of steps in the design process.
To provide for a cost-effective and efficient design it helps if the main incoming supply point is close to the load centre of the installation, and hence discussions with the electricity distributor should be started at an early stage.
It is not essential that the main distribution board(s) are positioned close to the intake point, and their position has an effect on voltage drop on the whole installation including the submain cables.
This point of 'positioning' is also true of final circuit distribution boards which need to be carefully considered in terms of voltage drop in large installations with highly loaded final circuits. The concept of how to achieve this will become clearer when this chapter has been read.

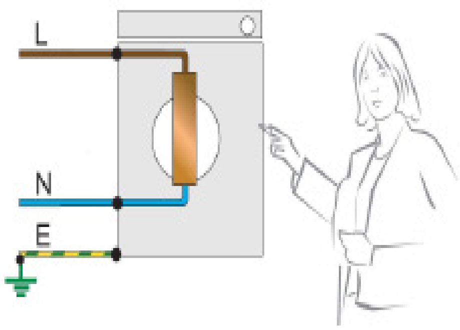


Guide to the IEE Wiring Regulations

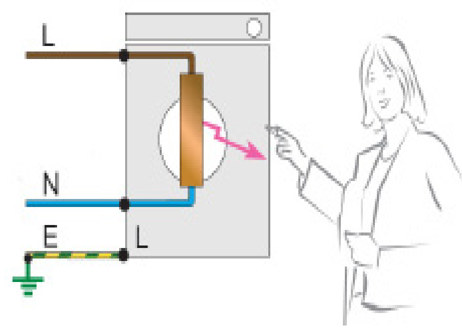
Introduction and protective measures

A significant change for BS 7671: 2008 is the introduction of new terminology . The previously very familiar terms ‘direct contact’ and ‘indirect contact’ are replaced by the terms ‘basic protection’ and ‘fault protection’ respectively; these terms in themselves introduce no technical changes.
The ‘basic protection’ protective measure is achieved by selecting equipment complying with relevant product standards.

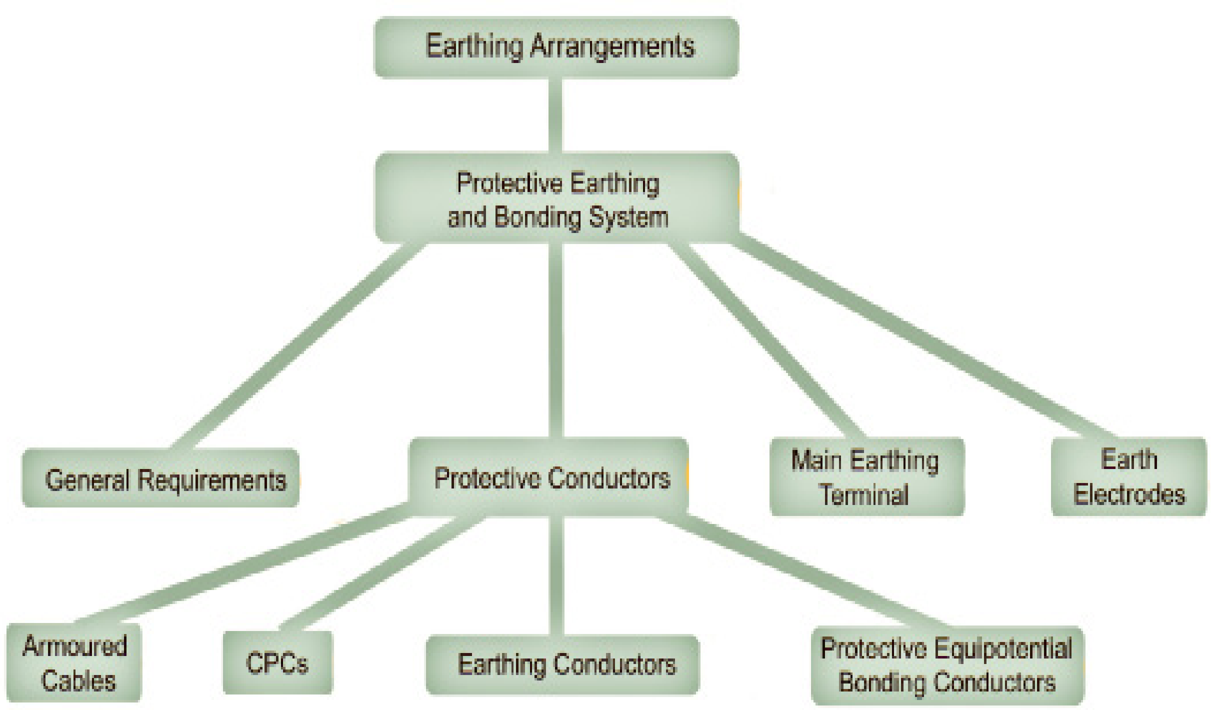
With Basic Protection



With Fault Protection



Earthing and Bonding :
The subject of earthing and bonding in terms of installation power supplies and BS 7671 is not a highly complicated subject . The interaction of the facets of an earthing system, which includes protective equipotential bonding, together with references to sections of this text, is represented in following Figure .



Guide to the IEE Wiring Regulations

Earthing arrangements

IEC terminology : International standard IEC 60364 distinguishes three families of earthing arrangements, using the two-letter codes TN, TT, and IT.

The first letter indicates the connection between earth and the power-supply equipment (generator or transformer):

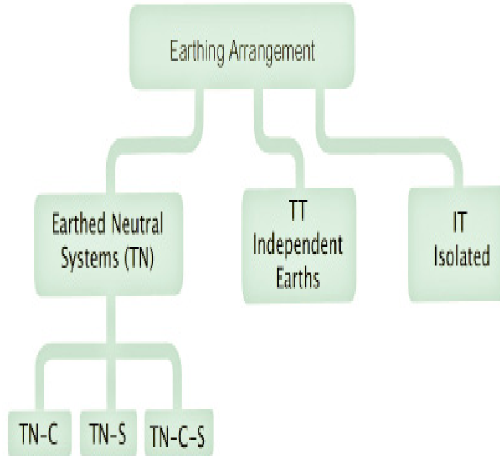
T : Direct connection of a point with earth ;

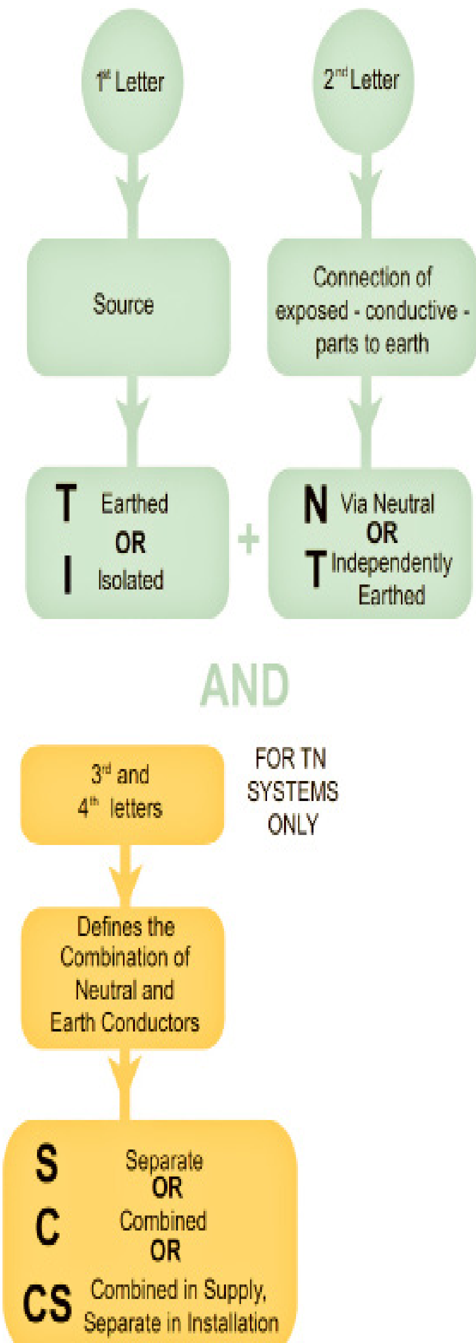
I : No point is connected with earth (isolation), except perhaps via a high impedance.

The second letter indicates the connection between earth and the electrical device being supplied:

T : Direct connection of a point with earth

N : Direct connection to neutral at the origin of installation, which is connected to the earth





TN networks :
In a TN earthing system, one of the points in the generator or transformer is connected with earth, usually the star point in a three-phase system. The body of the electrical device is connected with earth via this earth connection at the transformer

The conductor that connects the exposed metallic parts of the consumer is called protective earth (PE). The conductor that connects to the star point in a three-phase system, or that carries the return current in a single-phase system, is called neutral (N). Three variants of TN systems are distinguished :

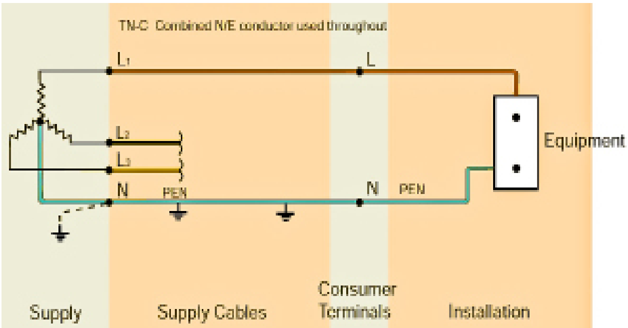
TN−S: PE and N are separate conductors that are connected together only near the power source.
TN−C : A combined PEN conductor fulfills the functions of both a PE and an N conductor (Rarely used) .
TN−C−S : Part of the system uses a combined PEN conductor, which is at some point split up into separate PE and N lines. The combined PEN conductor typically occurs between the substation and the entry point into the building, and separated in the service head.

TT network : In a TT earthing system, the protective earth connection of the consumer is provided by a local connection to earth, independent of any earth connection at the generator.
The big advantage of the TT earthing system is the fact that it is clear of high and low frequency noises that come through the neutral wire from various electrical equipment connected to it. This is why TT has always been preferable for special applications like telecommunication sites that benefit from the interference-free earthing. Also, TT does not have the risk of a broken neutral.

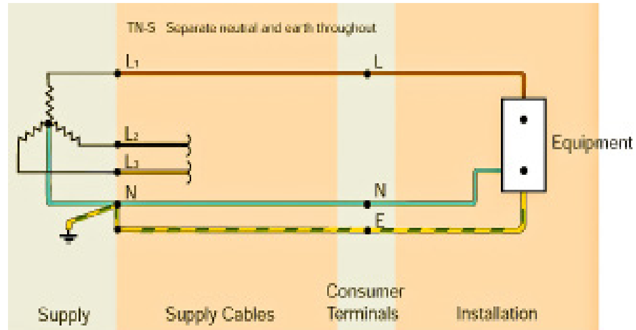
IT network : In an IT network, the distribution system has no connection to earth at all, or it has only a high impedance connection. In such systems, an insulation monitoring device is used to monitor the impedance. For safety reasons this network is not accepted under European norms

Guide to the IEE Wiring Regulations

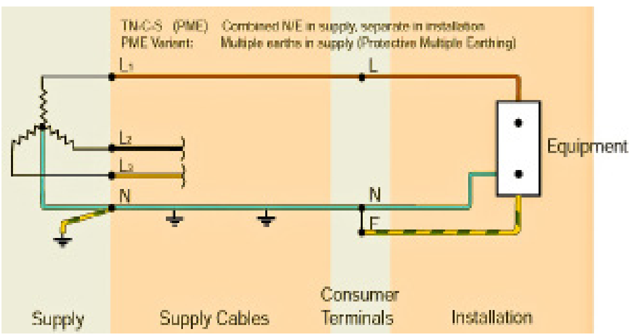
Earthing arrangements (Schematics)



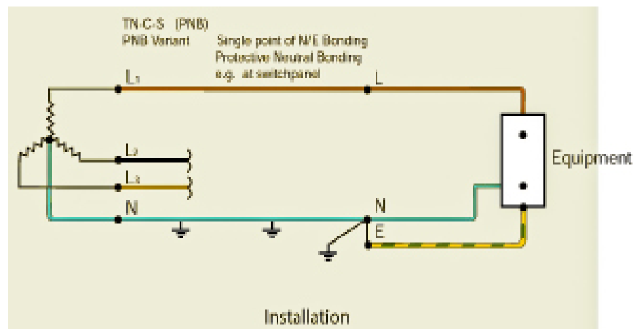
TN-C System earthing



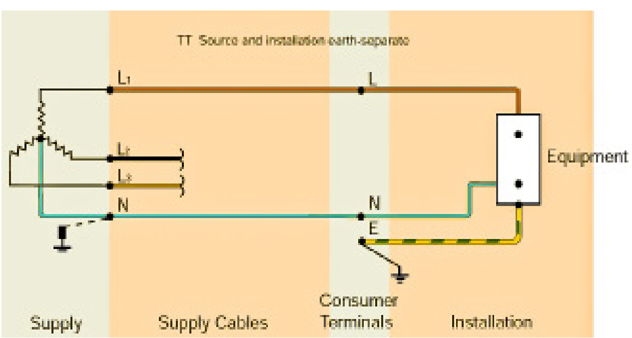
TN-S System earthing



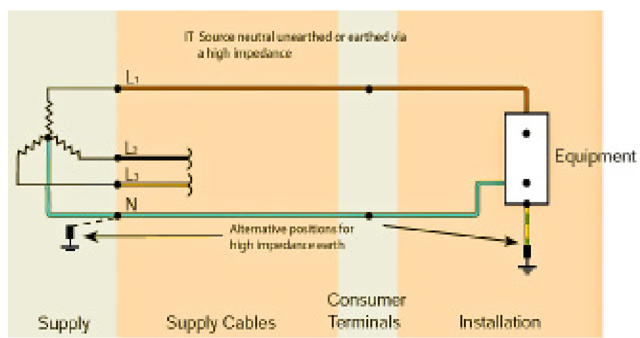
TN-C-S System earthing with PME



TN-C-S System earthing with PNB



TT System earthing



IT System earthing

Cost :
TN networks save the cost of a low-impedance earth connection at the site of each consumer. Such a connection (a buried metal structure) is required to provide protective earth in IT and TT systems.
TN-C networks save the cost of an additional conductor needed for separate N and PE connections. However, to mitigate the risk of broken neutrals, special cable types and lots of connections to earth are needed.

Application examples :
* Most of modern homes in Europe have a **TN-C-S** earthing system .
* Laboratory rooms, medical facilities, construction sites, repair workshops, mobile electrical installations, and other environments that are supplied via engine-generators where there is an increased risk of insulation faults, often use an **IT** earthing arrangement supplied from isolation transformers .
* In remote areas, where the cost of an additional PE conductor outweighs the cost of a local earth connection, TT networks are commonly used in some countries

Guide to the IEE Wiring Regulations

Automatic disconnection of supply

The ‘protective measure - automatic disconnection of supply’ is the standard method used in most applications and almost by default .

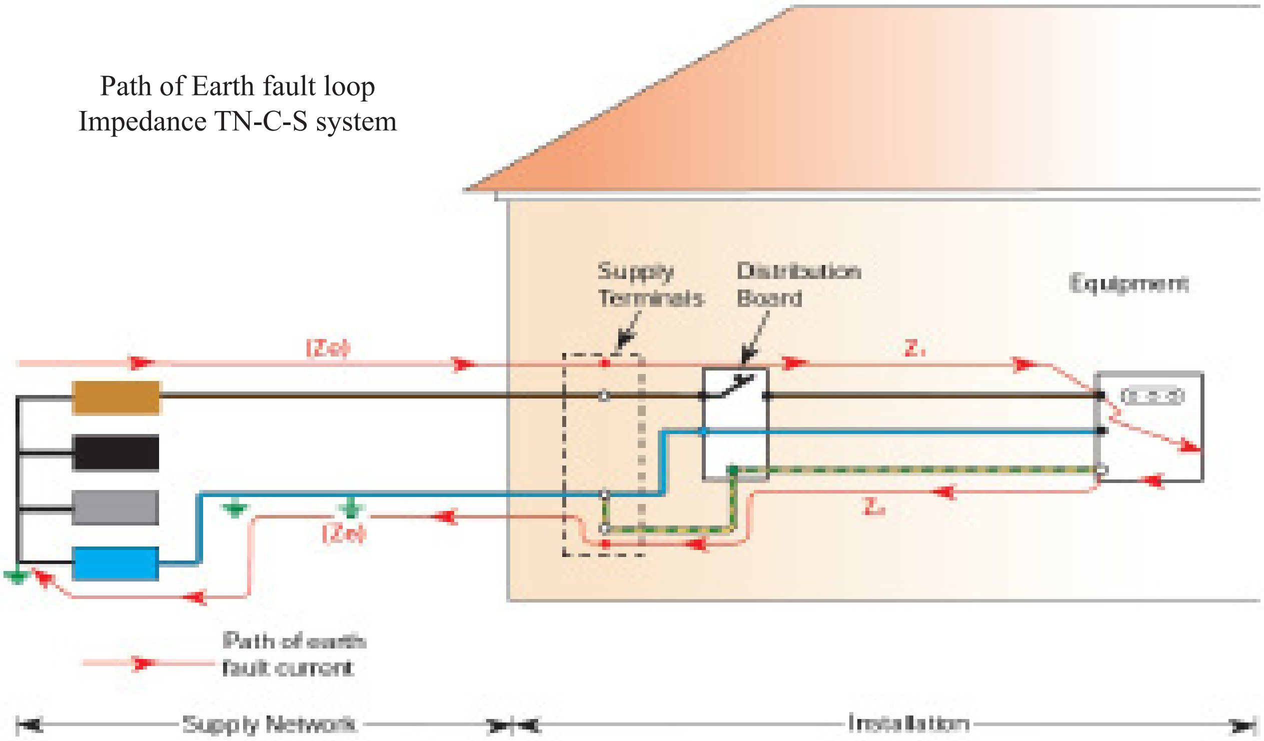
To comply with the ‘protective measure’, the following are required:

1 - basic protection; and

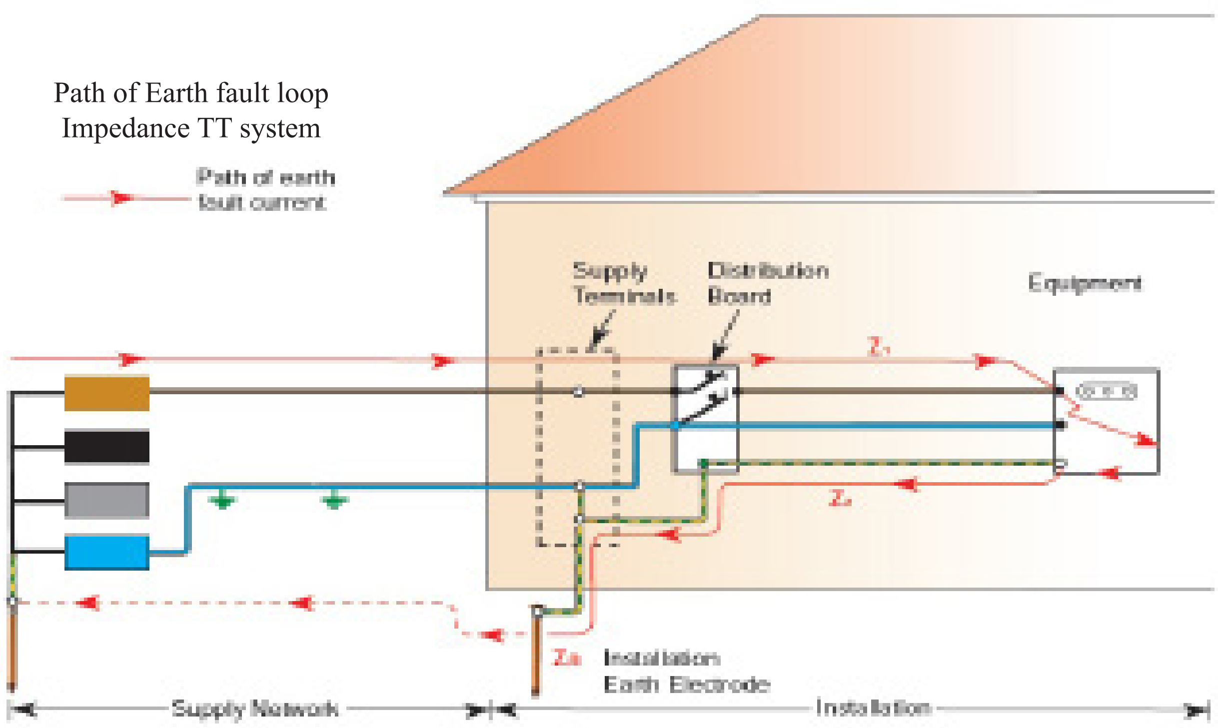
2 - protective earthing and protective equipotential bonding; and

3 - automatic disconnection in the event of a fault.

Path of Earth fault loop
Impedance TN-C-S system



Path of Earth fault loop
Impedance TT system

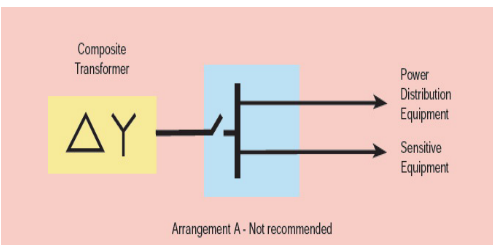


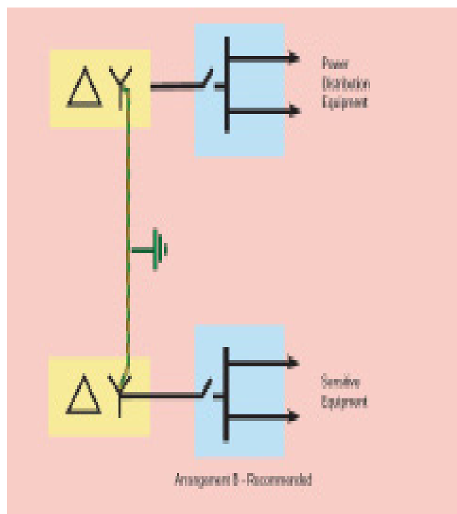
Guide to the IEE Wiring Regulations

Cable management and EMC (Electro-Magnetic Compatibility)

EMC cable separation - power, IT, data and control cables General :
Firstly it must be stated that the majority of power installations installed to BS 7671 will exhibit no EMC problems between the power system and 'sensitive' data type installation. Indeed, it is interesting to note that many data IT installation EMC problems have been discovered to be infringements of BS 7671, particularly poor earthing. In spite of this, the following guidance is recommended where 'sensitive' equipment is installed ('sensitive' equipment means IT data and communications equipment). Some of the recommendations will have to be balanced against cost and performance.

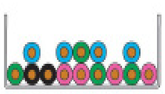
Recommendations - cable separation for sensitive equipment :
The following optional solutions may be considered to mitigate the effects of EMC on sensitive equipment:
* Separate power transformers ;
* Size neutral for unbalanced load and triple harmonic currents ;
* Balance loads;
* Oversizing the power transformer to lower the source impedance (in extreme cases)



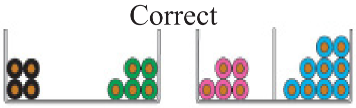


The separation distances given in following Table are for backbone cabling from end to end. However, for horizontal cabling where the final circuit length is less than 35 metres no separation is required in the case of screened cabling.

Not Recommended !

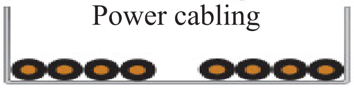


Correct

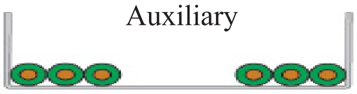


Preferred- Best

Power cabling



Auxiliary



IT cabling

Sensitive circuits

Type of installation	Minimum separation distance		
	Without divider or non-metallic divider [1]	Aluminium divider	Steel divider
Unscreened power cable and unscreened IT cable	200 mm	100 mm	50 mm
Unscreened power cable and screened IT cable [2]	50 mm	20 mm	5 mm
Screened power cable and unscreened IT cable	30 mm	10 mm	2 mm
Screened power cable and screened IT cable [2]	0 mm	0 mm	Separation by distance or by screening

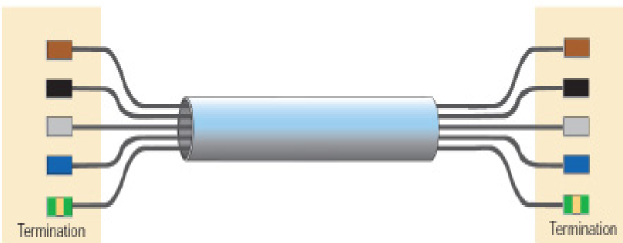
[1] It is assumed that in case of metallic divider, the design of the cable management system will achieve a screening attenuation related to the material used for the divider.

[2] The screened IT cables shall comply with EN 50288 series.

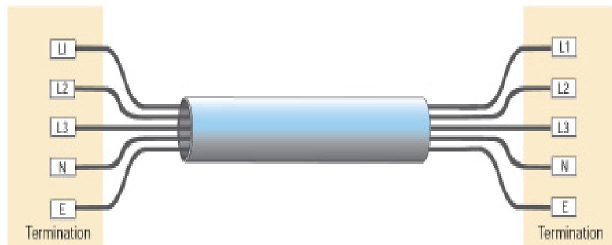
Guide to the IEE Wiring Regulations

Principle of required identification

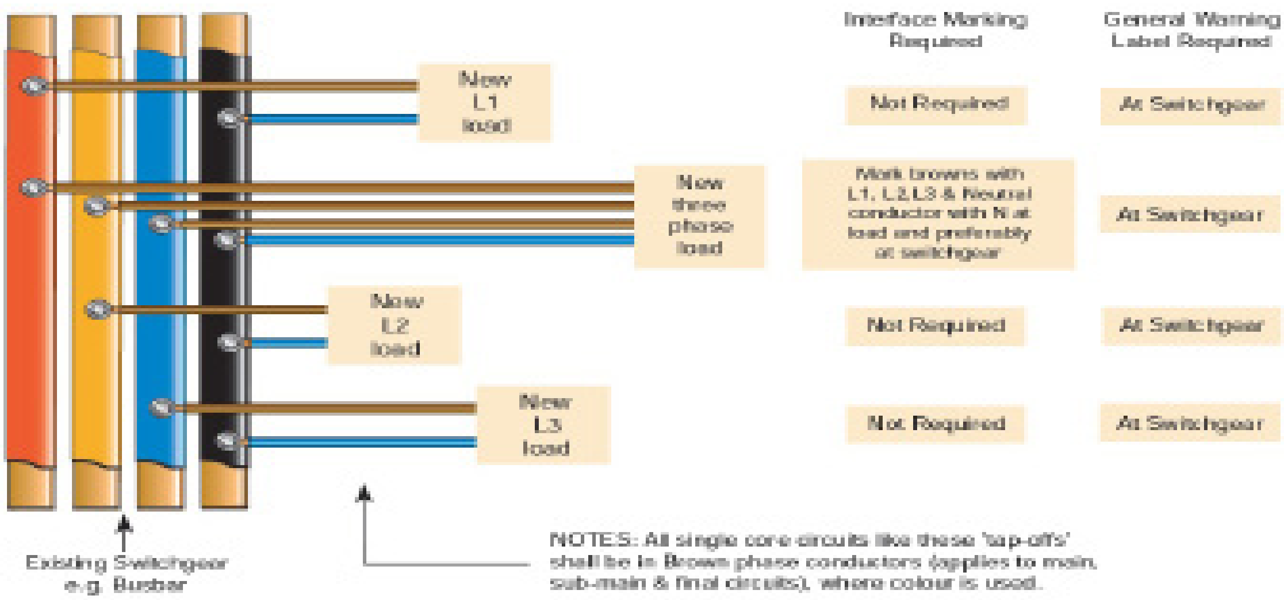
It is most important to understand the principle behind the drafting of the 17th Edition in respect of cable identification. Cable cores shall be identifiable at their terminations either by colour or by alphanumeric characters .



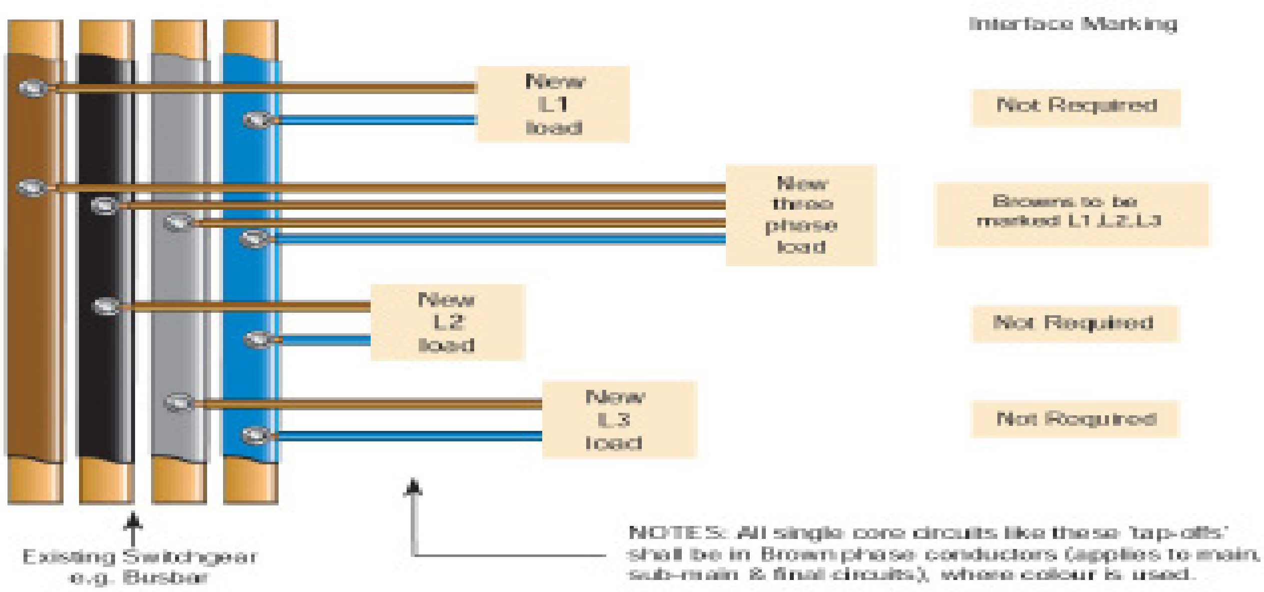
Principle of colour identification.



Principle of identification by characters



Typical extension interface marking



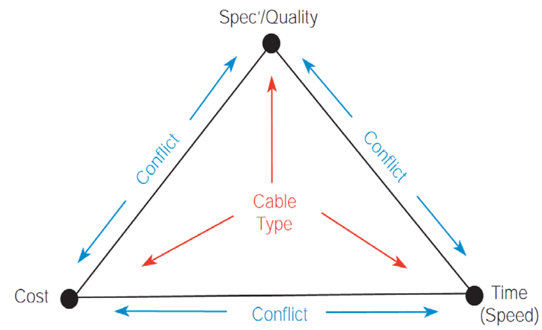
New installation interface identification

Guide to the IEE Wiring Regulations

The choice of wiring systems

The choice of wiring system will depend on a number of factors that the installation designer will need to consider, depending on the particular type of installation, its use, the environment and also any economic constraints.

The selection of an appropriate wiring system can be represented as a balancing act between specification, cost and time, as depicted in the balance this triangle.



The balance of any one of the three selection parameters is in conflict with the other two, and in selecting any one cable type, compromises will need to be made. Maintenance considerations are not shown on this diagram but should be considered under the specification parameter. The complex criteria of specification will be very much affected by environmental factors and the use by operators. With this in mind, the following points will need to be considered in the specification parameter:

* Type of installation, domestic/commercial/industrial and impact protection;
* Temperature of installation and local heat sources;
* Effects of dust and water;
* Effects of chemicals, fumes and gases; animals including vermin;
* Movement and mechanical vibrations; corrosion including electrolytic corrosion;

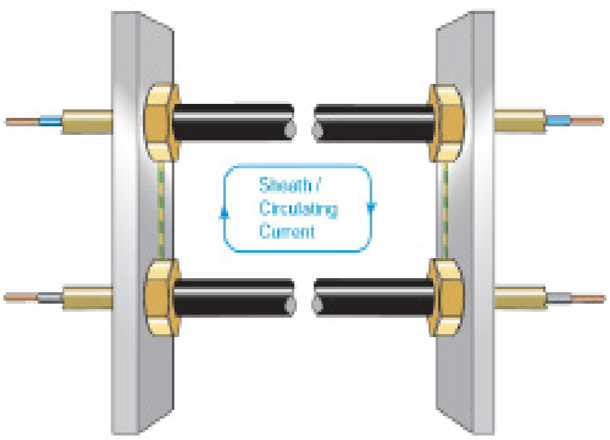
other environmental factors including wind, seismic effects, solar radiation, hygiene and mould growth.

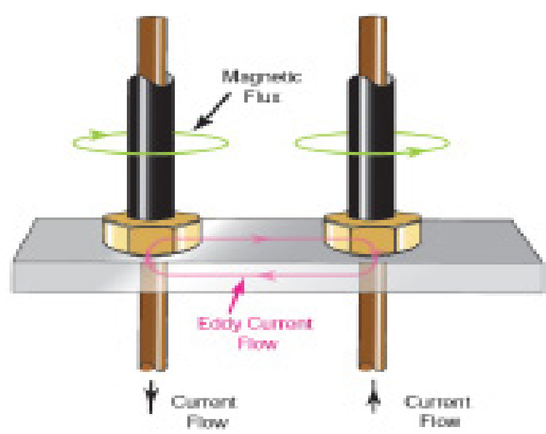
Circulating currents and eddy currents in single-core installations

Single-conductor non-ferrous metal sheathed or armoured cables need careful consideration due to the problems of sheath currents and eddy currents.

Circulating (sheath) currents

Circulating or sheath currents flow in the metal sheaths or armour of single-core cables. All single-core metallic-sheathed cables have a sheath current induced by the a.c. magnetic field surrounding each conductor. The metallic sheaths and armoured cables are often earth-connected to equipment at both ends, providing a closed circuit path through metal gland plates, enclosures and other metallic paths where sheath currents are permitted to flow, as shown in Figure below . Induced sheath currents cause a heating effect and temperature rise in metal sheaths or armour of single-conductor cables. This is transferred to the cable insulation and depending on the general circuit loading, this additional heat may cause the cable to suffer premature insulation damage.





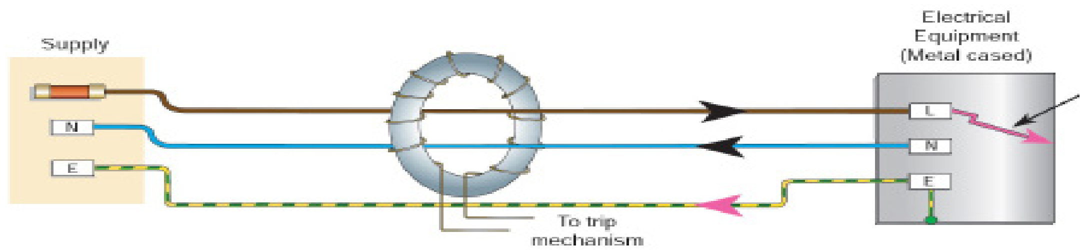
Eddy currents :

The same magnetic fields that surround single-conductor cables can also produce eddy currents in the steel enclosures, which completely surround the cables Eddy currents can overheat iron or steel cabinets, locknuts or bushings or any ferrous metal that completely encircles the single-conductor cables. This presents no problem in multi-conductor cables, where the magnetic fields tend to cancel each other out. For single-core cables, it is recommended that these cables enter metal enclosures through a non-ferrous plate (e.g. aluminium)

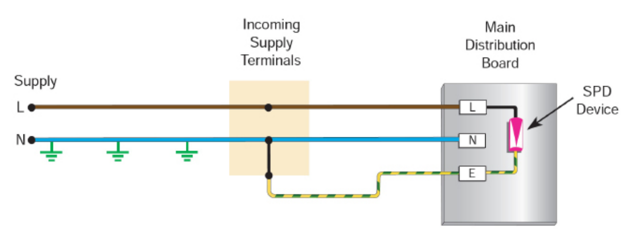
Guide to the IEE Wiring Regulations

Residual current and Surge protection of system

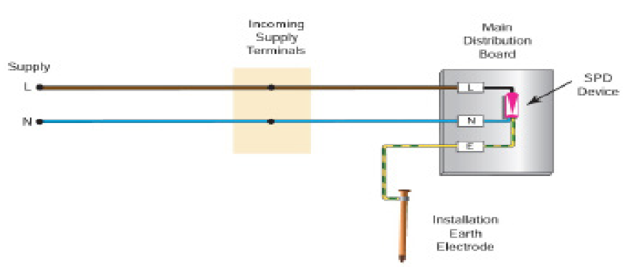
When an earth fault or earth leakage is present on a circuit, a small ‘imbalance’ is set up in the detection coil and, at a certain level, causes a trip of the circuit breaker mechanism . Residual current devices monitor the instantaneous current flowing along the line and neutral conductors in a circuit by means of a sensitive coil. The coil or ‘core’ measures the instantaneous resulting sum of these currents. . A diagrammatic representation of this is shown in following Figure :



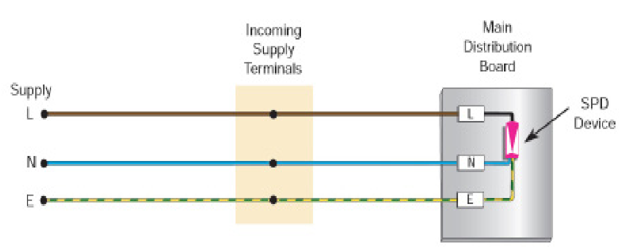
Surge protective devices (SPD) :
Surge protective devices (SPDs) may optionally be specified. If you are the designer you may feel that they add a certain security to an installation. SPD selection and installation comes down to a few simple rules, summarized as follows:
* Choose SPDs complying with IEC 61643 series.
* In TN-C-S installations connect device between line conductors and earth.
* In TN-S and TT installations connect device between line conductors and both neutral and earth.



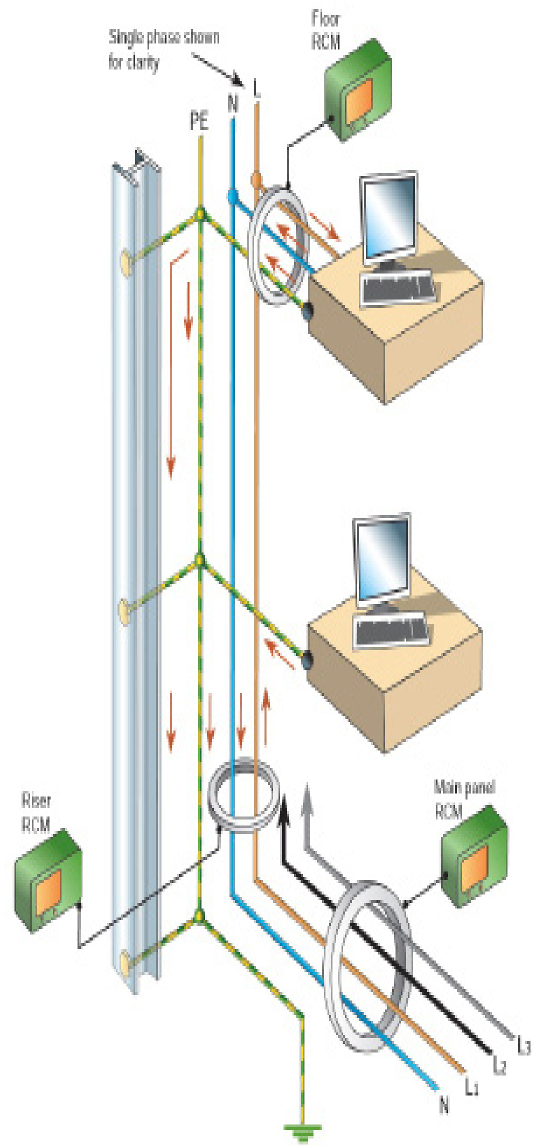
Connection of SPD in TN-C-S system (PME).



Connection of SPD in TT system



Connection of SPD in TN-S system.



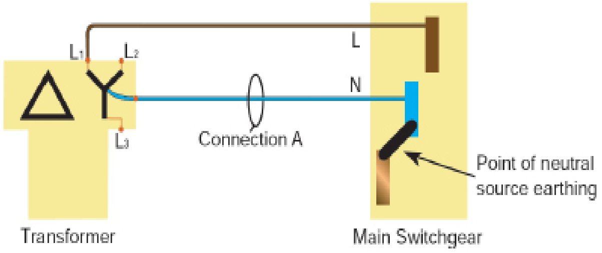
Application examples of residual current monitors (RCM) :
In a larger installation a three-phase RCM device positioned in the main distribution board will be extremely useful.
These devices can be widely used and above Figure indicates examples of where RCMs are used in mains, riser and final distribution board positions.

Guide to the IEE Wiring Regulations

General requirements of earthing and bonding

The protective measures for general application are:
* Automatic disconnection of supply;
* Double or reinforced installation;
* Electrical separation;
* Extra-low voltage provided by SELV or PELV

The protective measure 'automatic disconnection of supply' is by far the most common and makes specific requirements for both protective earthing and protective bonding.

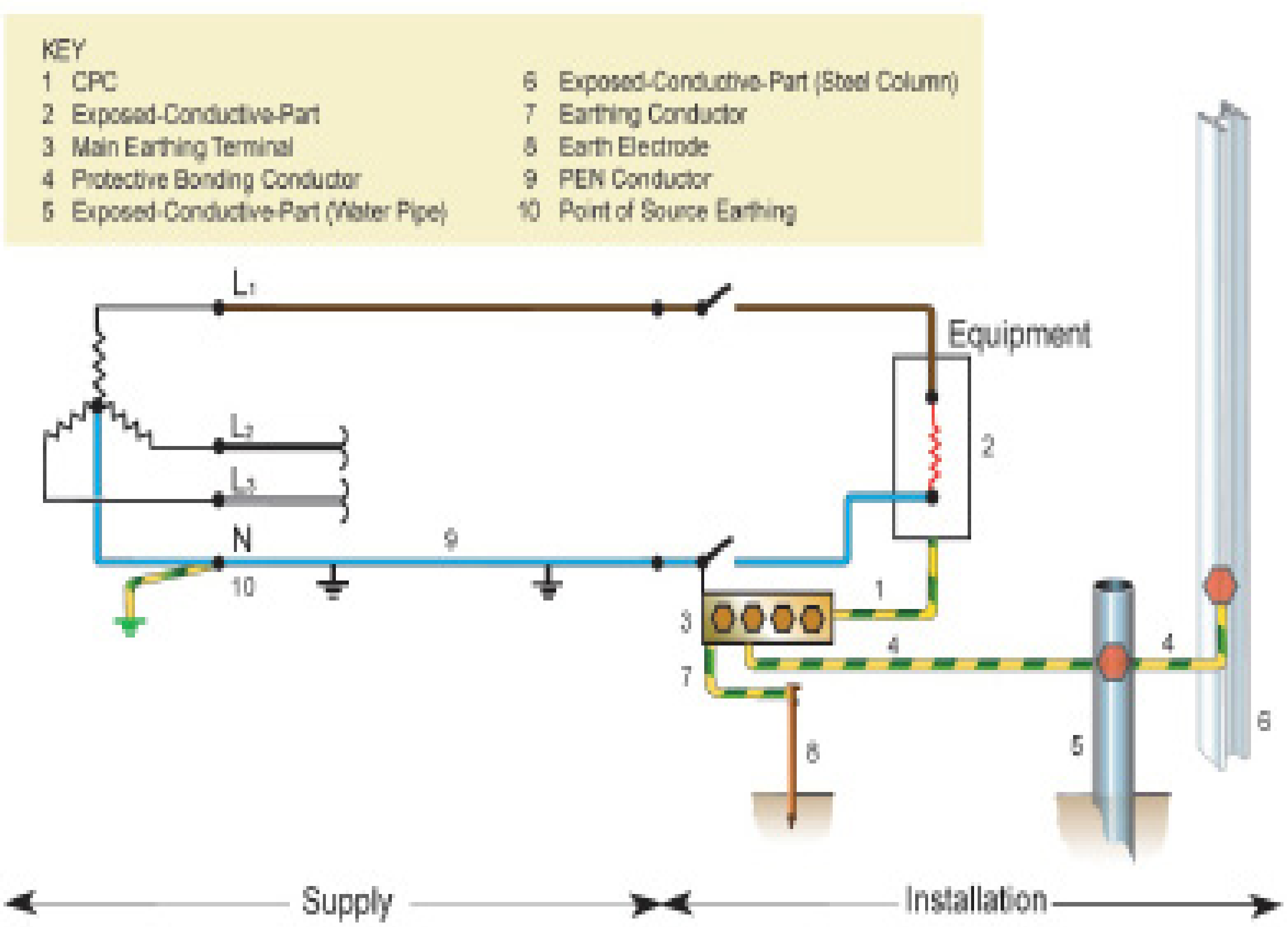


A typical arrangement for an on-site transformer with the neutral earth link made in the main switchgear

Again, we need to briefly review the requirements of the protective measure in order to establish earthing and bonding requirements. The basis of the measure is as follows.

* **Basic protection** (protection against direct contact) is protection from contact with live parts provided by basic insulation, or by barriers or enclosures.
* **Fault protection** (protection against indirect contact) is provided by protective earthing, protective equipotential bonding and automatic disconnection in case of fault.

In the event of a fault between a live conductor and an exposed-conductive- part of equipment, sufficient fault current flows to operate (trip or fuse) the overcurrent protection.
For the protective measure to work, protective conductors are required to connect all exposed-conductive-parts (of equipment) to the earthing terminal. This is protective earthing and includes circuit protective conductors and the earthing conductor. To reduce shock voltages (touch voltages during a fault), and to provide protection in the event of an open circuit in the PEN conductor of a PME supply, protective equipotential bonding is also required. A simple installation with both circuit protective conductors and protective bonding conductors is shown in Following Figure :



Guide to the IEE Wiring Regulations

Protective conductors

Protective earthing requires exposed-conductive-parts (of electrical equipment, likely to become live in the event of a fault) to be connected (by protective conductors) to the main earthing terminal of the electrical installation. In the event of a fault, sufficient current will flow around the earth fault loop to cause the operation of the fault protective device (fuse, circuit breaker or RCD) and disconnect the fault.

Protective bonding conductors reduce the magnitude of voltages during fault conditions.
It should be remembered that the following are all types of protective conductor:
* Circuit protective conductors (cpc);
* Protective bonding conductors;
* Earthing conductors.

It is important to establish and use the correct terminology; earthing conductors are often confused with cpcs.

Conductor	Recommended for use as cpc	Recommended for use as bonding conductor	Recommended for use as earthing conductor	Notes
Single core cable	Yes	Yes	Yes	If less than 10 mm², shall be copper
Conductor in cable	Yes	Yes	NO	
Insulated or bare cable in enclosure with live conductors	Yes	Yes	Yes	
Fixed insulated conductor	Yes	Yes	Yes	cpc should be run in close proximity to line conductors. EMC reduction is better when run in enclosure or cable. If less than 10 mm² shall be copper
Fixed bare conductor	Yes	Yes	Yes	
Cable sheaths or armouring	Yes	Yes	Possible	Possible with consideration
Metal conduit, trunking and ducting	Yes	Yes	NO	----------------
Metal tray	Possible	Yes	NO	Possible with consideration
Metal support systems	NO	Yes , see note	NO	For use, continuity and size to be assured and precautions taken against removal
Structural metal	Possible	Yes , see note	Yes	
Metal water and service pipes, HVAC services and general metalwork	NO	Yes , see note	Yes	

* Always use metal conduit or trunking as a cpc where it is installed.
* If cable tray or ladder rack is used to support cables use it as a main bonding conductor.
* Utilize as much of other services and constructional material as possible for bonding.
* Utilize the structural steel for bonding.

Guide to the IEE Wiring Regulations

(Earth) Bonding solutions for the modern installation

The question still remains as to how to carry out bonding in a modern installation . It was common to bond all exposed metalwork, including such items as metal window frames, individual metal floor or ceiling tiles and cross bonding to virtually everything . The modern trend is now well away from this, but the question remains of what to do about continuity of, say, the structural steel, or air conditioning ductwork systems.

Commercial and industrial installations :

See following Figures and accompanying notes. Using constructional elements for bonding

Figure 1.

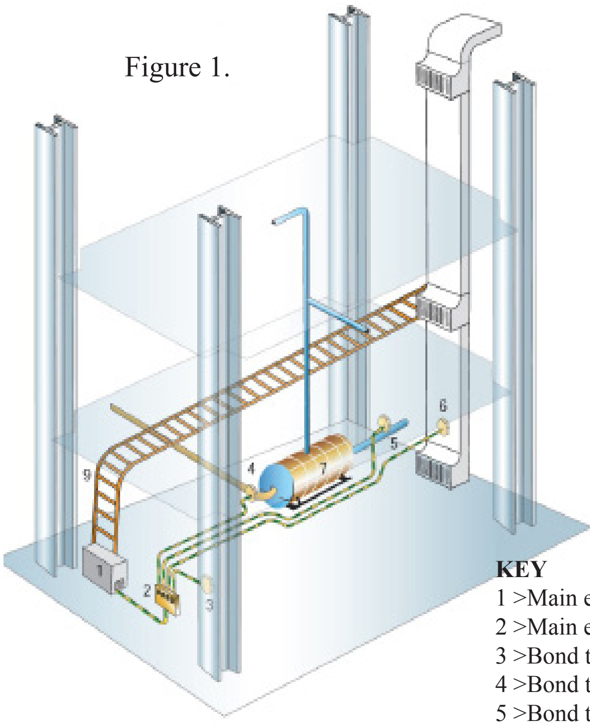
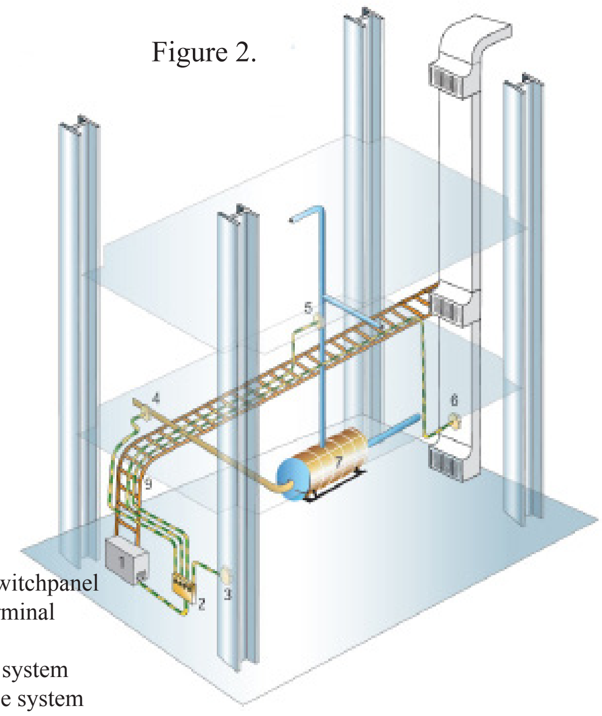


Figure 2.



KEY

1 >Main electrical switchpanel
2 >Main earthing terminal
3 >Bond to structure
4 >Bond to gas pipe system
5 >Bond to waterpipe system
6 >Bond to A/C ductwork
7 >Boiler
9 >Cable tray or ladder rack

Figure 3.

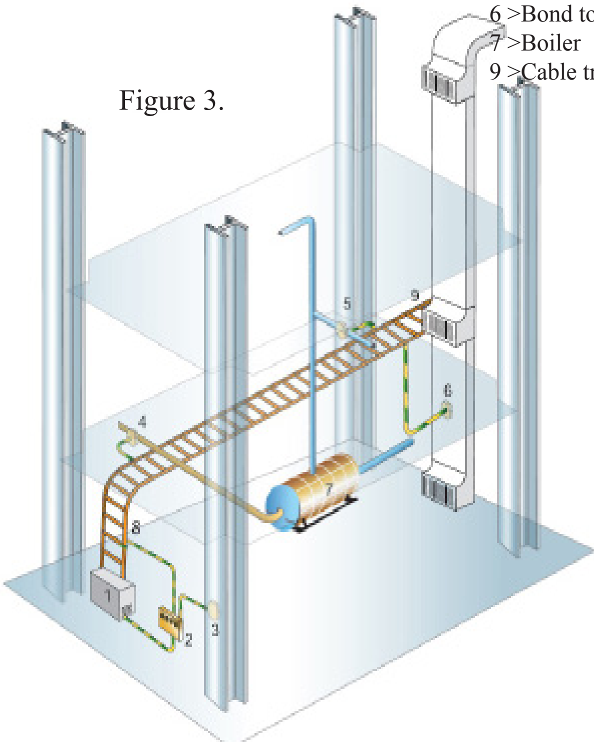


Figure 4.

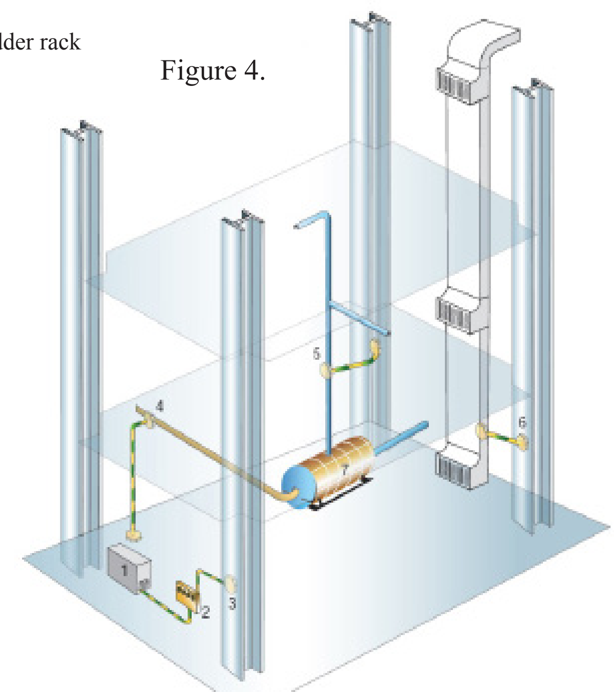


Figure.1 shows a typical solution which involves running separate bonding conductors to the extraneous-conductive-parts. This is unnecessary.
Figure.2 shows a typical solution which involves running separate bonding conductors to the extraneous-conductive-parts but now installed on metal cable tray or ladder rack. This is often undertaken whether or not the tray or ladder rack was installed for power cables.
Figure.3 shows a much better and more economic solution, where the cable tray or ladder rack has been used as a protective conductor.

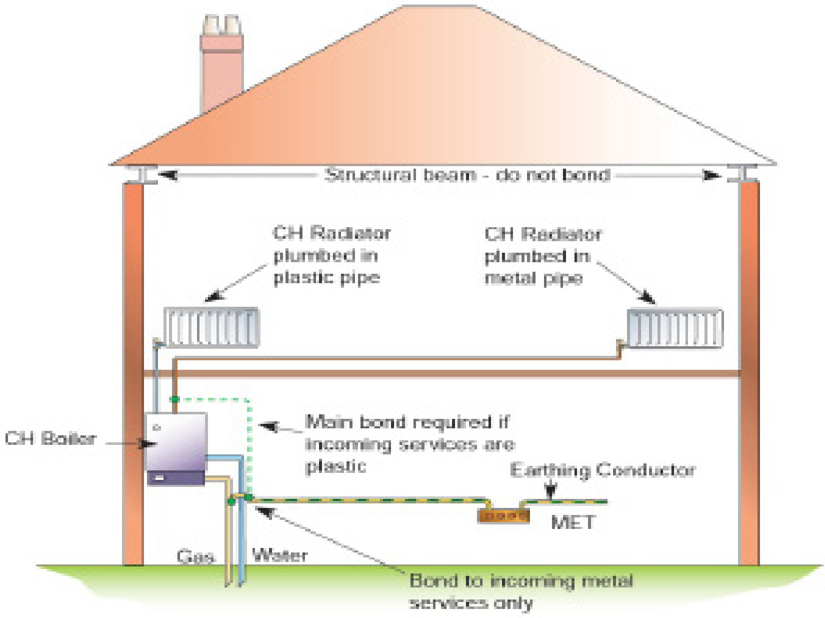
Figure.4 shows the best solution for most installations of this nature. The building structure has been used as a protective conductor. The cable tray is not shown on this diagram as it may have been installed for just a few cables, which have now been clipped directly to the structure. Unfortunately, this technique is under-utilized, mainly due to custom and practice. If the diagrams are considered again, it is obvious that the structure and metal services will form part of the bonding network whether you like it or not .

Guide to the IEE Wiring Regulations

KCI

Domestic installations - (Earth) Bonding solutions

* Take one bond to incoming metallic water and gas pipes.
* If there is a metallically piped central heating system, bond it in one location.
  This is not necessary where any metallic pipe, bonded elsewhere (e.g. metallic water pipe), is connected and tests satisfactorily for continuity.
* If the structure is metallic, take a bond to one location; this is not necessary for intermediate metallic stud partitions or individual metal beams and the like.
* The central heating system will probably not need a cable bond connection if connected by metallic gas or water pipes which have themselves been bonded (see following Figure).



Sizing protective bonding conductors :

This is due to the fact that the suggested minimum sizes relate to the size of the line and earthing conductor for TN-S supplies, and the supply neutral conductor for TN-C-S (PME) supplies.
Following Tables provide an easy look up for main protective bonding conductor sizes.

TN-S, PNB, TT main protective bonding conductor sizes.

	Line Conductor Size (mm^2)												
	25	35	50	70	95	120	150	185	240	300	400	500	630
Earthing conductor min. size (mm^2)	16	16	25	35	50	70	95	95	120	150	240	300	300
Bonding conductor min. size (mm^2)	10	10	16	16	25	25	25	25	25	25	25	25	25

PME (TN-C-S) main protective bonding conductor sizes.

	Supply neutral conductor size (mm^2)							
	25	35	50	70	95	120	150	Over 150
Earthing conductor min. size (mm^2)	10	10	16	25	25	35	35	50
Bonding conductor min. size (mm^2)	10	10	16	25	25	35	35	50

Guide to the IEE Wiring Regulations

KCI

Domestic protective equipotential bonding layouts

This section provides diagrams of typical protective equipotential bonding layouts. It has been added to provide further guidance on typical layouts of bonding conductors, and also assists with recognizing earthing arrangements. Many other layouts are, of course, possible.
Figure 1. shows the main earthing terminal connected via the earthing conductor to the utility cut-out stud terminal (TN-C-S).
Figure 2. shows the main earthing terminal connected via the earthing conductor to the sheath of the utility supply cable (TN-S).
Figure 3. shows the main earthing terminal connected via the earthing conductor to the installation earth electrode (TT). The earthing conductor in a TT installation may only need to be 6 mm^2 although it is shown as 16 mm^2 in this diagram.

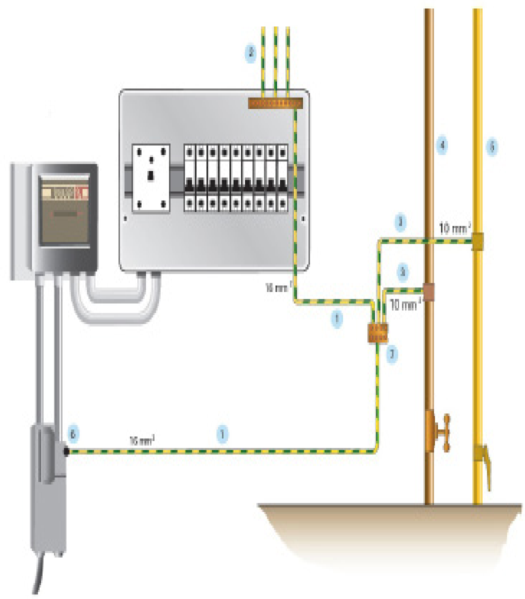


Figure 1.

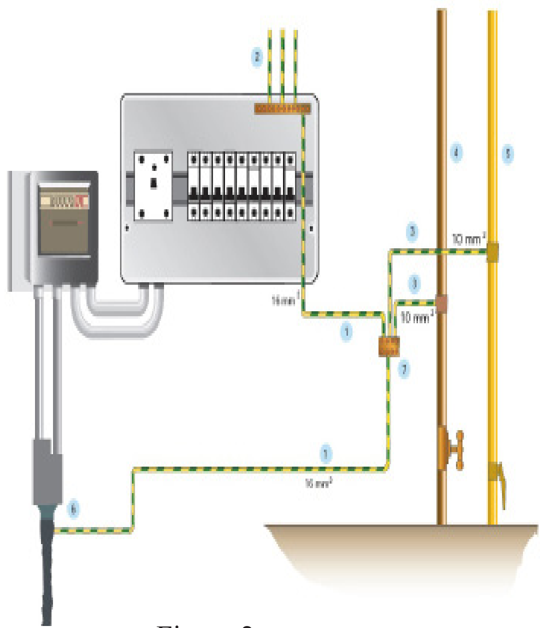


Figure 2.

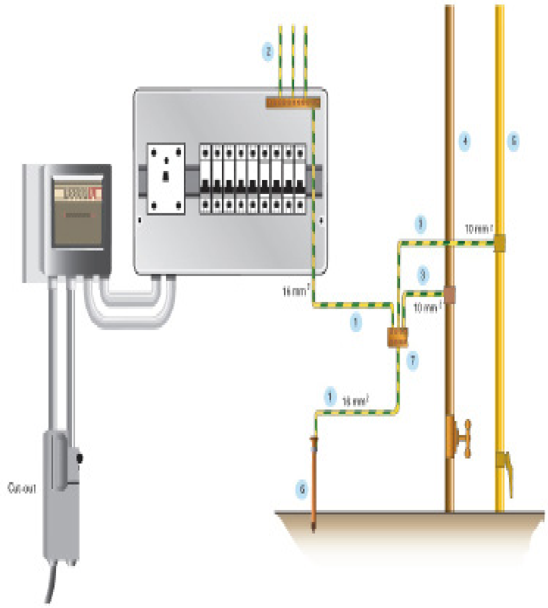


Figure 3.

KEY
1 >Earthing conductor
2 >CPCs
3 >Main protective bonding conductor
4 >Metal water pipe
5 >Metal gas pipe
6 >Cut-out earth terminal
7 >Main earthing terminal

Supplementary equipotential bonding :
Supplementary bonding is additional protection to fault protection, and may be required where the disconnection standard time cannot be achieved. However, the use of supplementary bonding does not exclude the need to disconnect the supply for other reasons, for example, for protection against overcurrent.
Supplementary bonding may also be required for special locations such as:
* locations with a bath or shower;
* swimming pools and other basins;
* locations with livestock;
* conducting locations with restricted movement

Guide to the IEE Wiring Regulations

Inspection, Testing and Certification

This procedure comprises three main parts as follows;
* Initial Verification;
* Periodic Inspection and Testing;
* Certification and Reporting.

Inspection and testing - an integrated procedure :
The activities of carrying out visual inspection and of then carrying out testing should be considered as complementary procedures. These procedures should not be considered to be separate functions carried out by separate individuals or organizations; this is particularly true of the inspection confirmation part of the inspection and testing.
To illustrate this point: in general there would be little point in carrying out a continuity test on a cable if it had been found that some of its connection terminals were loose. The defect would need to be remedied before the test was conducted.
It is suggested, for larger organizations, that a system be created that allows the installer to confirm facts about the visual inspection

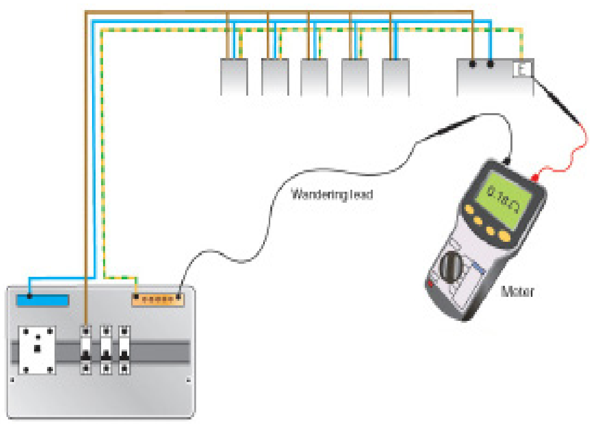
Visual inspection :
The visual inspection part of the initial verification is the process of assessing the installation prior to testing.
Regulation specifies the purpose of the visual inspection, summarized as follows:
* Equipment complies with a product standard;
* Equipment is correctly selected and erected;
* Equipment is not damaged.
Following Table summarizes the requirements for the inspection part of the initial verification

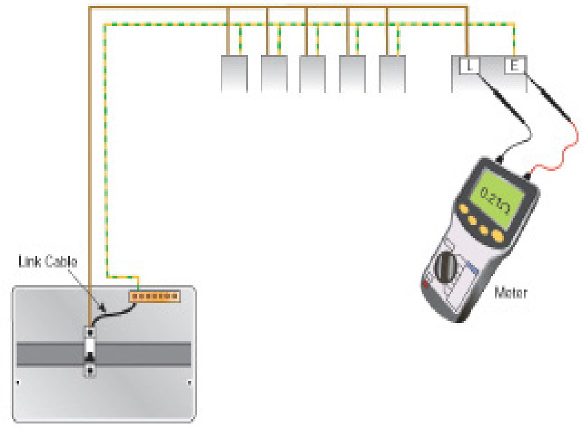
Inspection	Should have automatic tick	At 'installed' stage	Confirmed separately at final 'testing' stage	Notes
Erection methods	Yes	Yes	Not required	
Conductor terminations	Yes	Yes	Not required	
Identification (colour/labelling of cables)	Yes	Yes	Not required	
Installation of cables (mechanical protection, etc.)	Yes	Yes	Not required	
Cable size as design specification	Yes	Yes	Not required	
Building sealing around cables and trunking etc.	----	Yes	Not required	Spot checks may be useful
Presence of means of earthing	Yes	Yes	Not required	
Presence of protective conductors, cpcs and bonding	Yes	Yes	Not required	
Isolation	Yes	Yes	Not required	
Warning notices	Yes	Yes	Not required	
Diagrams	Yes	Yes		
Equipment to standards, and IP	Yes	Yes	Not required	Spot checks may be useful
Detrimental influences	----	Yes	Spot checks may be useful	
Adequate access to switchgear	Yes	Yes	Not required	Spot checks may be useful
Overcurrent devices correctly sized as specified	Yes	Yes	Not required	
Presence of RCD protection where required	Yes	Yes	Not required	
Undervoltage devices where required	----	Yes	Check	

Guide to the IEE Wiring Regulations

Inspection, Testing and Certification ; Continuity testing

This is the first suggested test as it is important for the safety of the circuit, and it helps confirm a reference for the remainder of the tests. Continuity testing is carried out on all protective conductors including cpcs, main and supplementary protective bonding conductors. The test is carried out with a low d.c. voltage continuity tester, and this may detect loose and unsound connections; other instruments may be used.This brings us to the two popular methods for continuity testing, namely:
1- Wandering lead method;
2- Utilization of circuit cable by 'shorting' R1+R2 method .





Wandering lead method

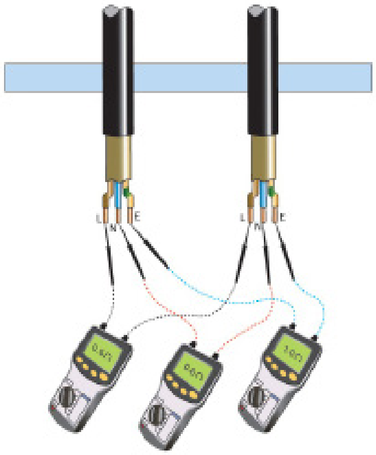
You will notice by studying the figure that the cpc has not been removed from the earth terminal at the distribution board. This is due to the fact that there are parallel metallic earth return paths and removal of this conductor will not change this.

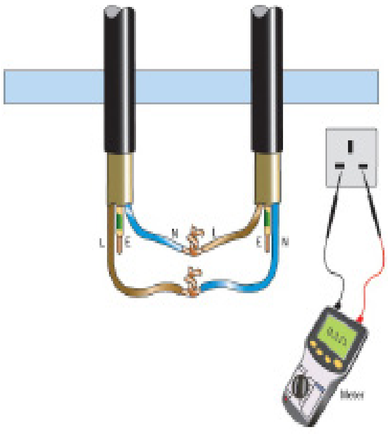
Utilizing the circuit cable and R1 + R2 method

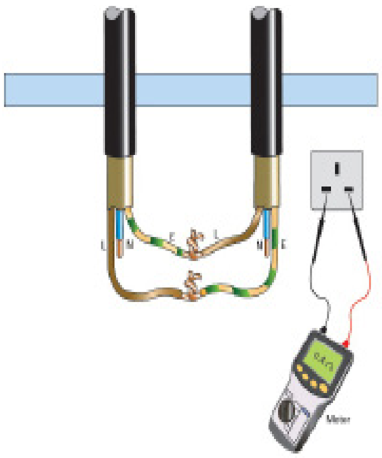
The method is simple enough, and if the line conductor is used, this method can be used to record the circuit's Rl + R2 value . The method does find favour with some, and can be used to establish a circuit's earth fault loop impedance.

Ring continuity

The continuity of ring final circuits is something that is a little more involved. Methods have evolved over the years to establish whether the rings are indeed wired as ring circuits, and not 'shorted' forming a 'figure of eight' layout and similar.







Stage 1 - open loop resistances :
Measure the end-to-end resistance of each conductor, Rl (line), Rn (neutral) and R2 (cpc) respectively . An open circuit result would suggest either the incorrect conductors have been selected or the circuit is incorrectly terminated. As phase and neutral conductors will be of the same cross-sectional area, the resistance values obtained for both conductors should be similar

Stage 2 - interconnected L-N :
With phase and neutral interconnected, measure resistance between phase and neutral conductors at each socket outlet using a continuity tester or similar instrument. If the ring is not interconnected the measurements taken on the ring circuit will be similar. The measurements obtained will be approximately one quarter of the resistance of the sum of the open loop resistances from stage 1,
that is (Rj + Rn)/4.

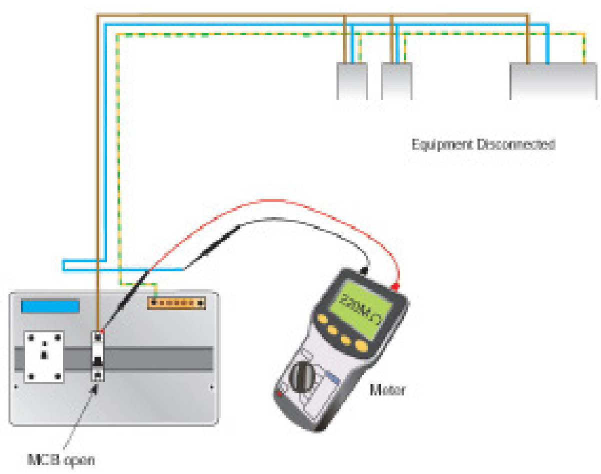
Stage 3 - interconnected L-cpc (for all insulated systems) :
With phase and cpc interconnected, measure resistance between phase and cpc conductors at each socket outlet using a continuity tester or similar instrument. If the ring is not interconnected the measurements taken on the ring circuit will be similar. The measurements obtained will be approximately one quarter of the resistance of the sum of the open loop resistances from stage 1,
that is (R1 + R2)/4.

Guide to the IEE Wiring Regulations

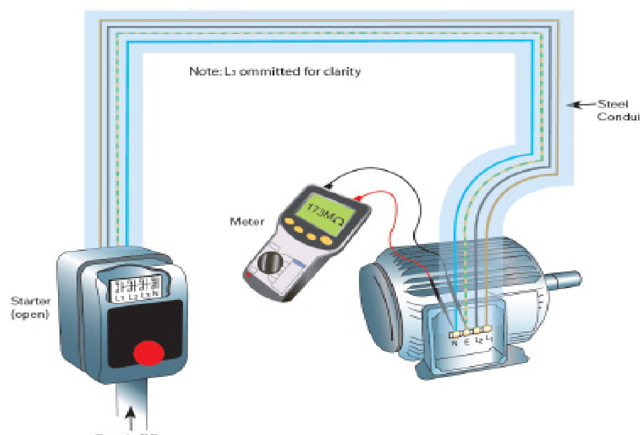
Inspection, Testing and Certification ; Insulation testing

Insulation testing is fundamental and will be used as cables are being installed. On completion of the circuit and before energization, the circuit insulation is again checked. The tests show faults or shorts as well as low insulation caused by moisture and similar. Electrical equipment and appliances such as controlgear and lamps should be disconnected prior to testing. Many such devices if left in-circuit would show as an insulation failure; also, sensitive electronic equipment such as dimmer switches and electronic ballasts could be damaged in the test. Insulation resistance is measured between:

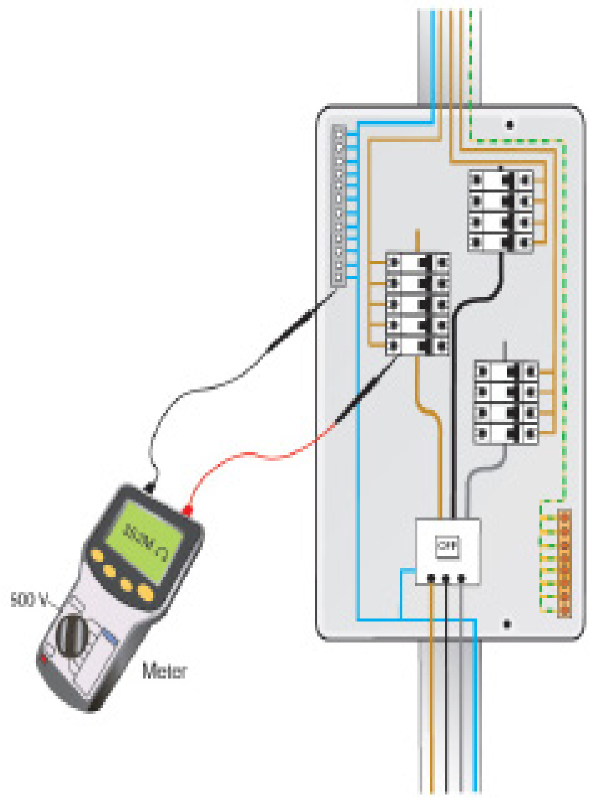
* Live conductors, including the neutral;
* Live conductors and the protective conductor connected to the earthing arrangement.



ESSENTIALS (of Insulation Testing) :
Tests : with CPC connected to each system
Test :between all live conductors to neutral and to earth
Readings : should be approximately tens of MOhm



Insulation testing of a motor circuit



Insulation testing a group of circuits

It should be noted that Regulation states that insulation testing is to be made between the live and protective conductors with the protective conductors connected to the earthing arrangement.
This is an additional requirement compared with previous editions of the Standard where, for example, cable could be tested to its cpc and then terminated. This procedure may catch you out as you may not be accustomed to carrying it out.
The minimum values of insulation resistance of 1 MOhm is an increase from the 0.5 MOhm of the IEE 16th Edition. For most new circuits values would be way in excess of this, usually approaching the maximum scale on the meter.

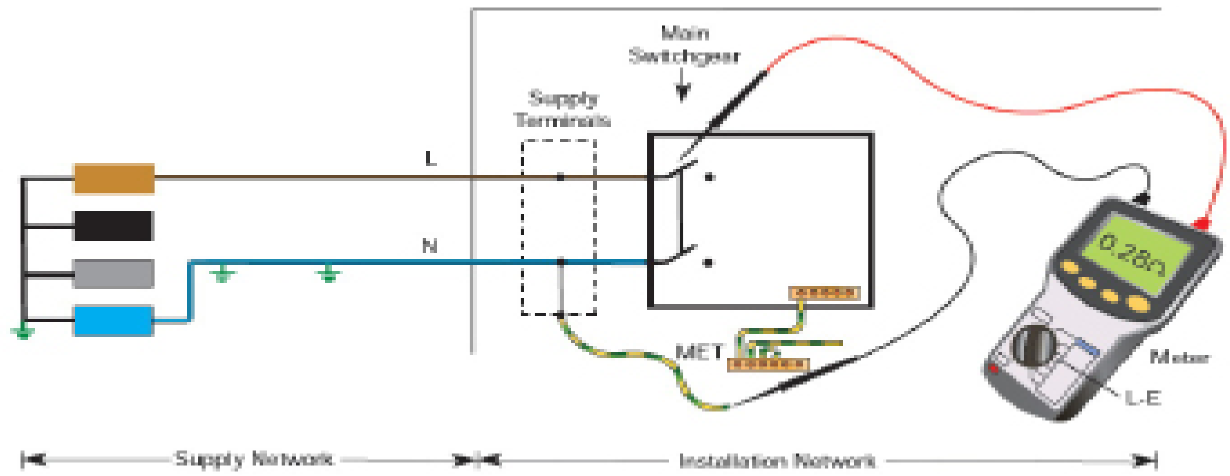
Perhaps an underused technique is that of carrying out insulation testing on groups of circuits together as shown in above Figure, and it is recommended that this is limited to 50 outlets per test.

Guide to the IEE Wiring Regulations

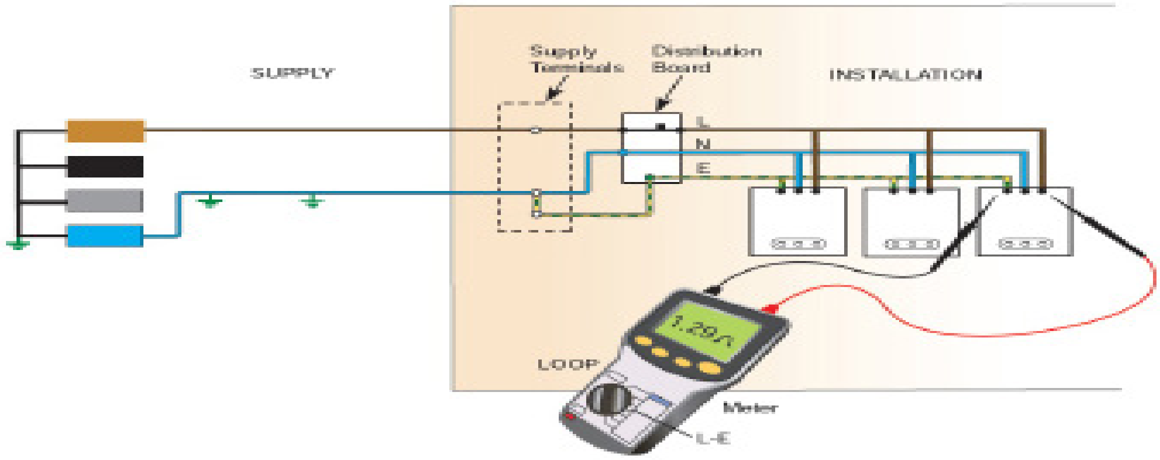
Inspection, Testing and Certification ; Earth fault loop impedance (ELI) testing

Earth fault loop impedance is required to be checked at various places throughout the installation, and generally at every point where a protective device is installed.
For final circuits, there are two alternative methods of determining the earth fault loop impedance:
1- Direct measurement of total ELI.
2- Measurement of the circuit Rl + value and addition to the ZDB (earth fault loop impedance at the local distribution board).

Type of System	External Earth fault loop Impedance Ze (Ohm)
TN-C-S	0.35
TN-S	0.8
TT	21



External earth fault loop impedance (Ze) :
Measurement of external ELI is necessary in LV supplies to confirm the supply earth condition. External ELI is measured live at the intake position, or close to it, with the means of earthing disconnected from the installation and the loop tester connected to it . The supply to the installation will need to be isolated. Above Figure is a typical arrangement; in this case for a TN-C-S PME supply .



Testing for total earth fault loop impedance (Zs) :
earth fault loop impedance may be required at various points throughout the installation and will generally need to be measured at every level of protective device.
For confirmation of final circuit disconnection times where RCDs are not installed, measured total earth fault loop impedance is usually required for all circuits.
Zs may be carried out by direct measurement at the extremity of a circuit.
The physical measurement of ELI is generally as shown in above Figure , and it should be remembered that RCDs in circuit will trip unless the test instrument has a facility to block unwanted tripping. Some ELI testers can test at such small current levels that they are below the threshold of tripping. Alternatively, the RCD must be linked-out of the circuit.

KCI

Glossary

Abbreviations used for cable's designation
(Acc to DIN/VDE standard)

Glossary of Terms: Cable and Wires

Abbreviations used for cable's designation
(Acc to DIN/VDE standard)

A) General

Y : Polyvinyl Chloride (PVC) For Insulation or Sheath
Yw : Heat Resistant Polyvinyl Chloride (PVC) For Insulation or Sheath (90°C or 105°C)
Yfl : Improved Flame Retardant & Reduced Smoke Polyvinyl Chloride (PVC)
2Y : Polyethylene (PE) For Insulation or Sheath
2X : Cross-linked Polyethylene (XLPE)
K : Lead cover (LC)
R : Round steel wires (SWA)
B : Steel tape (STA)
AWA : Aluminum wires (used for Armouring)
ATA : Aluminum tapes (used for Armouring)
Gb : Counter open helix tape
(F) : Water blocking tape
H : Flame retardant, Low smoke & Halogen Free (FRLH)
O : Oil resistant outer sheath (Hydrocarbon resistant) Acc to VDE 0472-803
Q : Steel Braid Wire Armour
vzn : Tinned Copper

B) Power and Control Cables

N : Copper conductor (CU) (DIN VDE Standard)
NA : Aluminum conductor (AL) (DIN VDE Standard)
-O : Cable core hasn›t green-yellow (Earth) wire
-J : Cable core has green-yellow (Earth) wire
S : Copper tape in common screen (CTSC)
C : Concentric copper wires in common screen (CWSC)
S : Screen of copper in common (SC) ; for MV
SE : Screen of copper over each individual core (SC) ; for MV

C) Instrument & Telephone & Signaling Cables

A- : Outdoor telecommunication cables
AJ- : Outdoor telecommunication cables with induction protection
Generally used for railway signaling cables
SLg : Signalling cables
D : Concentric copper wires (Railway-Signal cables)
D : Spiral tinned copper wires (Equipment & Electronics cables)
02YS : FPE with skin layer of PE
J- : Indoor telephone cables
JE- : Industrial electronic cables
S- : Switchboard cables
RE- : Instrumentation cables (stranded conductor)
RD- : Instrumentation Rehnomatic cables
Li : Equipment wires and cables (flexible conductor)
Generally used for special and sensitive electronic usage
(St) : Static screen ; Al.foil or Copper tape (OSC : Overall screen)
Consist of Aluminum polyester tape with a drain wire.
(L) : Aluminum co-polymer (OSC : Overall screen) usually applied longitudinally.
F : Jelly-Filled compound
PiMF/TiMF : Pair/Triple in metallic foil (ISC : Individual screen)
Each element has individual screen
PiMFY/TiMFY : Pair/Triple in metallic foil + Pair/Triple Jacket
Each element has individual screen and jacket

Glossary of Terms: Cable and Wires

A

Aerial cable : A cable suspended in the air on poles other overhead structure.
Armoured cable : A cable provided with a wrapping of metal for mechanical protection.
ASTM : Abbreviation for the American Society for Testing and materials.
Attenuation : The power drop or signal loss in a circuit, expressed in decibels (db). generally attenuation increases (signal level decreases) with both frequency and cable length. The reduction in amplitude of an electrical signal due to a transmission line or other network.
Abrasion Resistance : Ability of a material or cable to resist surface wear.
ACR : attenuation to crosstalk ratio, a measure of how much more signal than noise exists in the link, by comparing the attenuated signal from one pair at the receiver to the crosstalk induced in the same pair.
Anneal : The process of controlled heating and cooling of a metal to achieve predetermined characteristics as to tensile strength and elongation. Annealing copper renders it less brittle.
Accelerated aging: A test that simulates long-time environmental conditions in a relatively short time

B

Bit : A binary digit, smallest element of information in binary system.
Bit rate : The number of bits of data transmitted over a phone line per second.
Breakdown Voltage : The voltage at which the insulation between two conductors will break down .
Building Wire : Insulated wires used in building for light and power, 600 volts or less, usually not exposed to outdoor environment.
Bandwidth : The maximum amount of data that a connection can transmit in a given period of time, generally measured as bits per second (bit/s). A digital telephone line has a bandwidth of 64000 bits per second(64 kbit/s). An analogue telephone line has a bandwidth equivalent to 9600 bits per second. However, the effective bandwidth of an analogue line can be increased by the attachment of a modem employing data compression.
Bending radius : minimum radius a cable can be bent without permanent damage.
Bunch Stranding : A group of wires of the same diameter twisted together without a predetermined pattern.
Buried cable : A cable installed directly in the earth without use of underground conduit. Also called " direct burial cable."
Braid : A group of textile or metallic filaments interwoven to form a tubular structure which may be applied over one or more wires.

C

Cable : Multicore stranded insulated wires under protective sheath to conduct electrical energy e.g.power cable, telecommunication cable, installation cable, data cable etc.
Cable core : the portion of an insulated cable lying under the protective covering.
Capacitance : Tat property of a system of conductors and a dielectric which permits the storage of electricity when potential difference exists between the conductors. A capacitance value is always positive.
Capacitive Coupling – Electrical interaction between two conductors caused by the capacitance between them.
CEE : European standards agency ; International commission on Rules for the Approval of Electrical Equipment.
Cellular insulation – Insulating material in foamed or sponge form with the cells closed or interconnected.
CENELEC : European standards agency ; European committee for Electrotechnical Norms.
Circular Mill (CM) : Used to define cross-sectional areas of conductors. Area of a circle 1/1000 inches in a diameter.
1 mil (0.001 inch) is equal to square mil x 0.78540
Coaxial Cable : A cable consisting of two cylindrical conductors wit a common axis, separated by a dielectric. The outer conductor or shield is commonly used to prevent external radiation from affecting the current flowing in the inner conductor.
Color Code : A system of identifying different insulated cores by means of colours, numbers, printing etc.
Concentric lay : Cable core composed of a central core surrounded by one or more layers of helically laid insulated wires or cores.

Glossary of Terms: Cable and Wires

Conductor – A material capable of easily carrying an electrical conductivity . A wire or combination of wire not insulated from one another , suitable for carrying electric current.
Control Cable : A multi – conductor cable made for operation in control of signal circuits.
Copper weld – Copper cover steel wire. Copper and steel welded together. The trade name of Flexo Wire Division (Copper weld Steel Corp.)For their copper-clad steel conductors.
Cord : A small, flexible insulated cable.
Core : In cables, a component or assembly of components over which other materials are applied, such as additional components, shield, sheath, or armour.
Corona : A discharge due to ionization of air around a conductor with a potential gradient exceeding a certain critical value. A high voltage electrical discharge that attacks insulation.
Cross-Linked : Setting up the chemical links between the molecular chains. A from of polyethylene material whose moleculars are more closely linked to produce a greater balance of physical and electrical properties. (XLPE – compound)
Crosstalk : Interference caused by audio frequencies. Undesired electrical currents in conductors caused by electromagnetic electrostatic coupling from other conductors or from external sources. Also leakage of optical power from one optical conductor to another.
Current : Flow of electricity measured in amperes. Practical unit is the ampere which represents the transfer of one coulomb per second.
Current rating : The maximum continuous electrical flow of current recommended by a given wire in a given situation, expressed in amperes.
CCTV : closed circuit television, commonly used for security.
Cable TV : Previously called Community Antenna Television.
CATV : A communications system which distributes broadcast programs and original programs and services by means of coaxial cable.
Conduit : A channel for holding and protecting conductors and cables made of metal or an insulating material, usually circular in cross section, as in pipe.
Continuity Check : A test to determine whether electrical current flows continuously through out the length of a single wire or individual wires in a cable .
Cross-Sectional Area : The area of a conductor exposed by cutting the conductor perpendicular to its longitudinal plane, expressed in circular mils, square inches, or square millimetres.

D

DB : see decibel
D.C. : Abbreviation for direct current (d.c), Electricity that flow in one direction only.
Decibel (dB) : One-tenth of a bel. Unit to express differences of power level. Example: The decibel is 10 times the common logarithm of the power ratio. It is used to express power gain in amplifiers or power loss in passive circuits or cables.
Dielectric Strength : The maximum voltage insulation can withstand without rapture. Usually expressed as a voltage gradient, e.g. Volts per mil.
Drain Wire : An uninsulated wire used as an earth connection. This is generally laid over the component or under the screening, braiding etc.
Duct : An underground or overhead tube or conduit for carrying electrical cables. Derating Factor : A factor used to reduce the current carrying capacity of a wire when used in environments other than that for which the value was established.
Dielectric Constant (K) : The ratio of the capacitance of a condenser with dielectric between the electrodes , to the capacitance when air is between the electrodes. Also called permittivity and specific inductive capacity.
Drawing : In wire manufacturing, pulling the metal through a die or series of dies to reduce diameter to a specified size.

E

EIA : Abbreviation for Electronic industries Association.
Elastomer : Any material that will return to its original size after stretching. Elastomer is a rubber or rubber-like material which will stretch repeatedly to 200 percent or more and return rapidly wit force to its approximate original shape.
Electromagnetic Induction : The production of a voltage in a coil due to a change in the number of magnetic lines of force (flux linkages) passing through the coil.
Elongation – The fractional increase in the length of a material stressed in tension.
EMC : Electromagnetic Compatibility (EMV)
EMI : Any electrical or electromagnetic

Glossary of Terms: Cable and Wires

interference that causes undesirable response, degradation, or failure in electronic equipment. Optical fibers neither emit or receive EMI.
EPR : Ethylene-propylene copolymer rubber. The copolymer is chemically cross-linked.
EIA/TIA 568 standard : a voluntary standard developed by vendors insure interoperability of equipment used on network cabling.
Eccentricity : Like concentricity, a measure of the center of a conductors location with respect to the circular cross-section of the insulation. Expressed as a percentage of displacement of one circle within the other.
Embossing : A marker identification by means of thermal indentation leaving raised lettering on the sheath material of cable.
Electrostatic : Pertaining to static electricity, or electricity at rest. An electric charge for example .

F
Filled Cable : A telephone cable construction in which the cable core is filled with a material that will prevent moisture from entering or passing through the cable.
Flammability : The measure of the materials ability to support combustion.
Foil : A thin supporting film of continuous sheet such as plastic foil, metal foil, laminated foil etc. For static shielding, contacts and other electrical applications. **Ferrous** : composed of and/or containing iron. A ferrous metal exhibits magnetic characteristics.

G
Gauge : A term used to denote the physical size of a wire.
Ground Conductor : An electrical conductor for the connection to the earth, making a complete electrical circuit.
Ground (GND) : An electrical connection to earth, generally through a ground rod . Also a common return to a point of zero potential, such as the metal chassis in radio equipment.

H
Helix : A continuous spiral winding.
Hertz (Hz) : A unit of measurements of the frequency equal to one cycle per second.
Hi-Pot- A test designed to determine the highest voltage that can be applied to a conductor without electrically breaking down the insulation.
Hook-up Wire – Single conductor used to hook-up electrical parts of instruments for low current and voltage (under 1000 volts).

I
ICEA : Abbreviation for insulated Cable Engineers Association.
IEC : European Standardization agency ;International Electrotechnical Commission.
Impedance : Resistance to flow of an alternating current at a particular frequency, expressed in oms. It is a combination of resistance R and reactance X, measured in ohms.
Insulation : A non – conducting substance, named as dielectric, surrounding the conductor.
ISDN : Integrated Services Digital Network. A standard protocol for digital telecommunication transmissions.

J
Jacket : An overall covering of a cable, called also sheath which protects against the environment and stress.
Jumper : A short length of conductor used to make a temporary connection between terminals, around a break in a circuit, or around an instrument.

K
KV : Abbreviation for kilovolt = 1000 volts.

L
Laminated Tape : A tape consisting of two or more layers of different materials bonded together.
LAN : Local Area Network – A network located in a localized area e.g. In an office, building, complex buildings whose communication technology provides a high-bandwidth, low-cost medium to which many nodes can be connected.
Loop Resistance : The total resistance of two conductors in a closed circuit, measured round trip from one end.
Loss Factor : The loss factor of an insulating material is equal to the product of its dissipation and dielectric constant. Longitudinal Wrap: Tape applied longitudinally with the axis of the core being shielded.

M
MCM : Cross-section of greater Awg-sizes. 1MCM=1000 circular mils=0.5067 mm² .
Mho : The unit of conductivity. The reciprocal of

Glossary of Terms: Cable and Wires

an ohm.
Mutual Capacitance : Capacitance between two conductors when all other conductors are connected together to shield and ground .
Mylar : Du Pont trademark for polyester material.
Messenger : The linear supporting member, usually a high-strength steel wire, used as the supporting element of a suspended aerial cable. The messenger may be an integral part of the cable, or exterior to it.

N

National Electric Code (NEC) : A set of regulations governing construction and installation of electrical wiring and apparatus in the United States, established by the American National Board of Fire Underwriters.
NEMA : National Electrical Manufacturers Association.
Neper – An electrical unit similar to decibel, used to express the ratio between two amount of power existing at two distinct points. 1 Neper=8,686 decibels.
Nylon : A group of polyamide polymers, used for wire and cable jacketing with good chemical and abrasion resistance.
NEXT : Near end crosstalk, measure of interference between pairs in UTP cable.
Noise : The word “ noise” is a carryover from audio practice. Refers to random spurts of electrical energy or interference.

O

Ohm : The electrical unit of resistance. The value of resistance through which a potential difference of one volt will maintain a current of one ampere.
Overlap : A certain portion of a foil or band which laps over the leading edge of a helical or longitudinally wrapping tape. Overall Diameter: finished diameter over wire and cable.

P

Pair : 2 insulated wires twisted together in a certain lay-length to built a single circuit of transmission line.
Patch Cable : A cable with plugs or terminals on each end of the conductors to temporarily connect circuits of equipment together. In the IBM Cabling System, a length of Type 6 cable with data connectors on both ends.
PH : The measure of acidity or alkalinity of a substance. PH values are described from 0 to 14. Value 7 indicate the neutrality. Numbers below 7 result increasing acidity and number greater than 7 increasing alkalinity.
Polyester (PETP) : A resin formed by the reaction between a dibasic acid and a dithydroxy alcohol. Polyethylene terephthalate, used extensively as a moisture resistant cable core wrap.
Polyethylene (PE) : This material is basically pure hydrocarbon resins with excellent dielectric properties, i.e. low dielectric constant, low dielectric loss across the frequency spectrum, mechanically rugged and resists abrasion and cold flow. The insulating materials derived from polymerization of ethylene gas.
Polymer : A material of high molecular weight formed by polymerization of lower molecular weight molecules.
Polyolefin : A group of thermoplastics based upon the unsaturated hydrocarbons, know as olefins. When combined with butylenes or styrene polymers, the form compounds such as polyethylene and polypropylene.
Polypropylene (PP) : A thermoplastic similar to polyethylene but stiffer and having higher softening point (temperature); excellent electrical properties.
Polyurethane (PUR) : Class of polymers known for good abrasion and solvent resistance. A copolymer of urethane is similar in properties to neoprene, usually used as a cold curing moulding compound.
Polyvinyl Chloride (PVC) : This is a group of thermoplastic compounds composed of polymers of polyvinyl chloride or its polymer, vinylacetate, in combination with certain stabilizers, fillers, plasticizers, pigments etc., Widely used for wire and cable insulation and several jackets.
Power Cable : Cables of several size, construction, and insulation, single or multi-conductor, designed to distribute primary power to various types of equipment, such as cables >=0.6/1 kV.
Power Factor : The ratio between the true power in watts and the apparent power in volts – amperes.
Propagation : Delay time required for an electrical wave to travel between two points on a transmission line.
Pulling Eye : A device fastened to a cable to which a hook may be attached in order to pull the cable into or from a duct.

Glossary of Terms: Cable and Wires

R

Resistance : Property of an electric circuit which determines for a given current the rate at which electric energy is converted into a heat and has a value, is measured in ohms.
RG/U : Abbreviation for Radio Government, Universal. RG is the military designation for coaxial cable in Mil-C-17. R=Radio, G=Guide, U=Utility.
RMS : (Root Mean Square) – The effective value of an alternating current or voltage.

S

Solid Conductor : A conductor consisting of a single wire.
Spark Test : A test designed to locate pinholes in an insulated wire by application of an electrical potential across the material for a very short period of time while the wire is drawn through an electrode field.
STP : Shielded twisted pair cable, where each pair has a metallic shield to prevent interference.
Skin effect :The tendency of alternating currents to increasingly flow nearer the surface of a conductor as frequency increases.
Self-Extinguishing: The characteristic of a material whose flame is extinguished after the igniting flame is removed .
Shield : A metallic layer placed around a conductor or group of conductors to prevent electrostatic interference between the enclosed wires and external fields .
Sunlight Resistance : The ability of a conductor or cable insulation to resist degradation caused by exposure to ultraviolet rays.

T

Temperature Rating : The maximum temperature at which an insulating material may be used in continuous operation without loss of its basic properties.
Thermoplastic : A material which softens when heated and becomes firm on cooling .
Triaxial Cable : A three-conductor cable constructed in three coincident axes, of which one conductor in the centre , seconds circular conductor concentric with the first and the third circular conductor insulated from the concentric with the first and second, usually with insulation, a braiding and a outer jacket.
Twisted Pairs : A cable composed of two small insulated conductors twisted together without a common covering. **Tinned Copper** : Tin coating added to copper to aid in soldering and inhibit corrosion.

U

UL : Abbreviation for Underwriters Laboratories, Inc.
Ultraviolet : Optical radiation for which the wavelengths are shorter than those for visible radiation, that is approximately between 1 nm and 400 nm.
Unilay Stranding : A conductor constructed in bunch form having more than one layer in a concentric standing with a common length and direction of lay and contains 19,27,37 and any number of strands.

V

VDE : Germany approval agency.
Velocity of Propagation : Ratio of speed of flow of electric current in an insulated cable to the speed of light Usually expressed in percentage.
Voltage Drop : The amount of voltage loss from original input to point of electrical device.

W

Wall Thickness : The thickness of the applied insulation or jacket.
Wire : A conductor , either bare or insulated. A slender rod of metal usually referring to a single conductor, such as size 9 AWG and smaller.

X

XLPE : Cross-linked polyethylene.