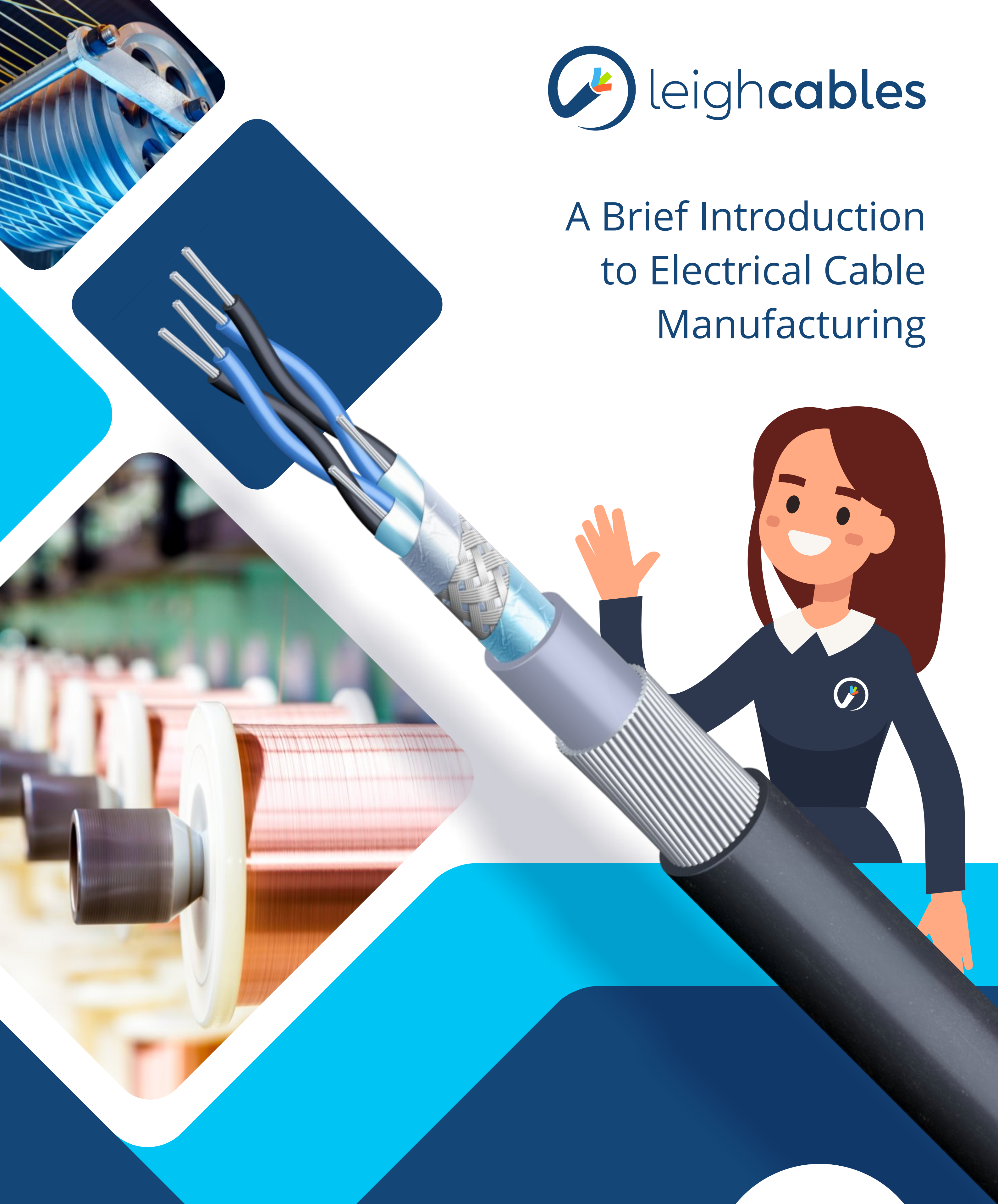


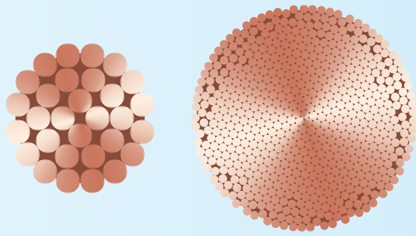
A Brief Introduction to Electrical Cable Manufacturing

Good for new starters and sales staff.

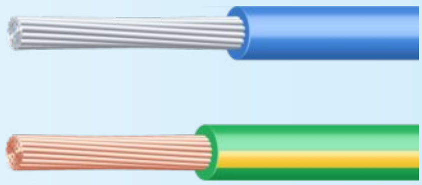
Conductors

Purpose

To transmit electrical power
To Transmit signals



Basic Types of Conductor



Metallic
Plain Annealed Copper (PAC)
Tinned Annealed Copper (TAC)
Composites (used in Thermocouple Cables)
Aluminium

Non Metallic
Optical Fibres

Size of Conductor

0.5 mm²	0.75 mm²	1.0 mm²	1.5 mm²	2.5 mm²	4.0 mm²
6.0 mm²	10 mm²	16 mm²	25 mm²	35 mm²	50 mm²
70 mm²	95 mm²	120 mm²	150 mm²	185 mm²	240 mm²
300 mm²	400 mm²	500 mm²	630 mm²	800 mm²	1000 mm²

The table above represents the typical range for power cables. The larger the size, the more current (amps) they can carry.

For example:

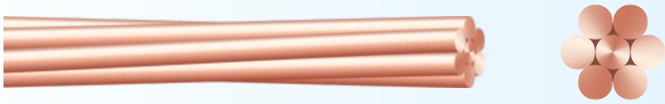
1.0 mm² conductor is used for household lighting
2.5 mm² conductor is used for household power sockets
4.0 mm² conductor is used for household cookers
6.0 mm² conductor is used for household electric showers

Other cables, typically communication cables/signalling cables can have conductors smaller than 0.5 mm² with 2.5 mm² being the maximum size.

Classes of Conductors

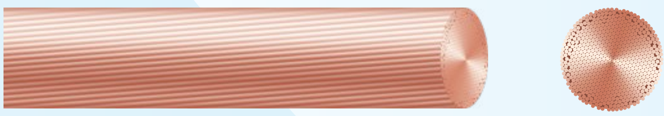
BS EN 60228 Class 1 **Rigid**

BS EN 60228 Class 2 **Stranded**



BS EN 60228 Class 5 **Flexible**

BS EN 60228 Class 6 **Extra Flexible**



Conductors come in many types of stranding, from a single wire up to many finer wires twisted together!

Why Class Options?

Class 1
Consists of one single wire (e.g. 1/1.38mm (1.5mm² CSA).
Most cost effective but with limited flexibility

Class 2
Consists of more than one wire, typically 7, 19, 37 or more depending upon the CSA.
The use of 7, 19, 37 wires is such that geometrically they all fit uniformly together (Stranded)

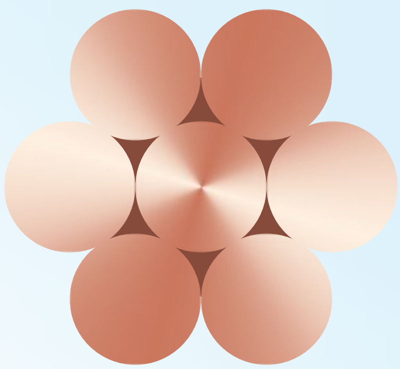
Class 5
Consists of even more wires where each individual wire is even smaller. The individual wires are put together randomly (Bunched). In the case of large conductors, more than one bunch are put together (Multi-Bunch).

Class 6
Consist of even more wires where each individual wire is even smaller, and thus more flexible.

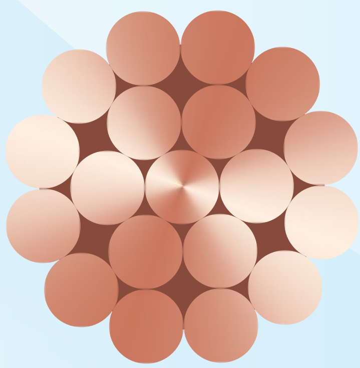
Here we can see a common selection of sizes by CSA (Cross-Sectional Surface Area) and the corresponding stranding in each class.

CSA	CLASS 1	CLASS 2	CLASS 5
0.5 mm²	1/0.80	7/0.31	16/0.20
0.75 mm²	1/0.97	7/0.37	24/0.20
1.0 mm²	1/1.13	7/0.44	32/0.20
1.5 mm²	1/1.38	7/0.53	30/0.25
2.5 mm²	1/1.78	7/0.67	50/0.25
4.0 mm²	1/2.25	7/0.85	56/0.30
6.0 mm²	1/2.76	7/1.04	84/0.30
10 mm²	1/3.57	7/1.35	80/0.40
16 mm²	1/4.50	7/1.70	126/0.40
25 mm²		7/2.14	196/0.40
35 mm²		7/2.52	276/0.40
50 mm²		19/1.78	396/0.40
70 mm²		19/2.14	360/0.50
95 mm²		19/2.52	475/0.50
120 mm²		37/2.03	608/0.50
150 mm²		37/2.25	756/0.50

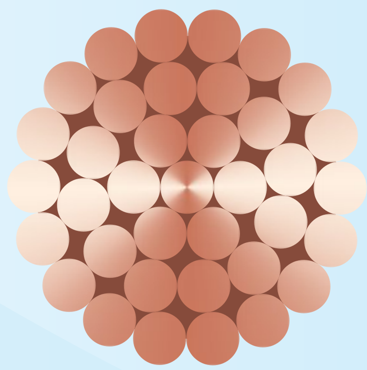
Looking below you can see how the individual strands are layered from the inside out.



7 Strands
1 / 6



19 Strands
1 / 6 / 12



37 Strands
1 / 6 / 12 / 18

Insulation

Purpose

- To provide electrical integrity. (Insulated conductors are commonly known as cores!)
- To ensure that the electric current or signal travels along the conductor much like a
- water pipe directs the water in the direction you want without leaking!

Insulation is the opposite of a conductor in that it has high resistance to electric current. Common insulating materials are -

Materials

There are many materials used to insulate wire, each offering specific properties such as Flame Retardance or Flexibility. The insulation is often coloured, striped or printed to help identify each core.

Common materials include:

PVC	Polyvinyl Chloride
PE	Polyethylene
XLPE	Cross Linked Polyethylene
EPDM (EPR)	Ethylene Polypropylene Diene Monomer (Ethylene Polypropylene Rubber)

Material Categories

There are two common categories of insulation (and sheathing) materials which differ in the way they are processed and how they perform in the finished product.

'Thermoplastic' Materials

PVC and PE are both thermoplastic materials.

This means that they can, with heat, be softened to a liquid form. While in liquid state they can be shaped, and in the case of a cable, extruded around a conductor. Upon cooling they revert back to a solid material. Thermoplastic material can usually be softened again and again using heat.

Advantages
Relatively low cost of manufacture

Disadvantages
If the cable gets hot e.g. power surge in a power cable, the material will melt.

'Thermosetting' Materials

XLPE and EPDM are both thermosetting materials.

Like Thermoplastic materials they can be softened to a liquid form with heat and shaped. However, the material is designed such that a chemical reaction can take place, locking the molecules inside the material together. This is known as Cross Linking. After this process the material is set and cannot be re-softened like a thermoplastic.

Cross Linking can be achieved by High Pressure Steam (HCV, VCV), Irradiation (Electron Beam), Silane Coupling (Moisture Cure). Cross Linking is also known as Vulcanisation and/or Curing.

Advantages
If the cable gets hot (like during a surge in a power cable) the material will not melt.

Disadvantages
Higher cost of manufacture. On this basis, PVC and PE tend to be used in communications/signal cables plus low voltage power cables. PE is very good in communication cables whereas XLPE and EPDM tend to be used in power cables.

Laying Up

Purpose

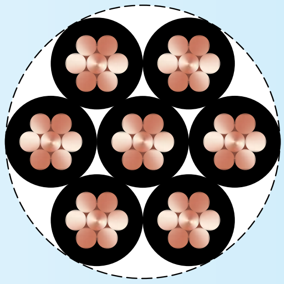
To group all cores together and provide multi-directional flexibility. If cores are laid straight, as in the case of a flat twin, it is only flexible in one direction much like a house wiring cable.

A full 360 degree twist is known as lay length and measured in mm e.g. “100mm lay”. The shorter the lay, the more flexible the cable.

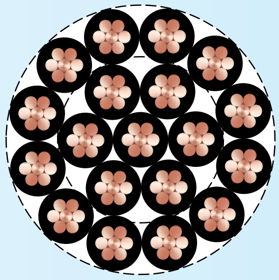
Because core sizes differ, as shown by conductor sizes, cable design engineers use a system where the lay length is proportional to the pitch diameter.

Examples

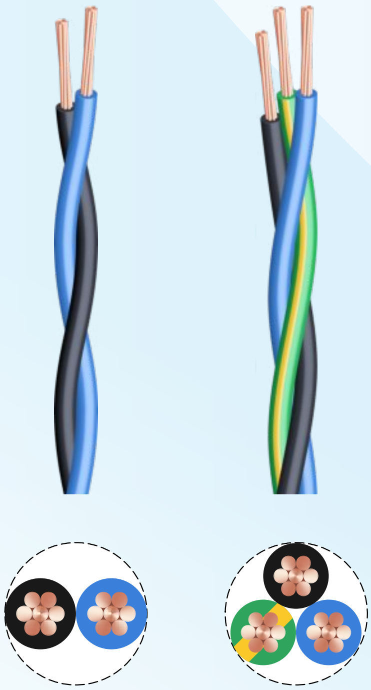
10 x PD (Short Lay, Very Flexible)
40 x PD (Long Lay, Less Flexible)



7 Core
1 / 6



19 Core
1 / 6 / 12



Power Cables

Power cables (apart from a single core) are known as multi-cores and are laid up to a balanced geometric pattern on the same basis as stranded conductors.

Instrumentation / Communication Cables

2 cores are known as a pair
3 cores are known as a triple
4 cores are known as a quad

When multiple units are laid up we get Multi-Pairs, Multi-Triples or Multi-Quads

Note

In power cables two cores are known as two core cables or twins, three cores as three core cables and so on. They are not referred to as Pairs or Triples.

Screening

Purpose

The operation of instrumentation/communication cables can be affected by internal and external electrical fields or forces

External Forces

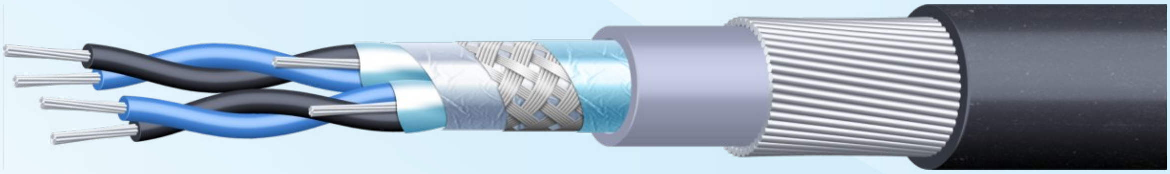
To reduce or prevent the undesired effects of external electrical fields the cables are collectively screened. A collective screen is a metallic layer wrapped around the outside of all the cores. As an example, the screen could be a copper tape or a copper wire braid, or both!

The most common method is to use a polyester tape with a thin coating of aluminium on it commonly known as a poly/al tape. The tape is spirally wound around the cores with a longitudinal drain wire inserted under the tape, usually TAC (Tinned Annealed Copper) for terminating (Earthing) the screen. In most cases the tape is applied conductive side in to make continuous contact with the drain wire.

Internal Forces

To prevent interference between individual pairs/triples/quads in a multi-pair/triple/quad cable the individual pairs/triples/quads are Individually screened.

The method of screening is the same as for collective screening. In principle, once a cable is individually screened, it does not need collective screening, but individually screened cables are often collectively screened as well. We call this “ICAT” screening.



Note

To reduce unwanted electrical interference (sometimes referred to as crosstalk) between unscreened pairs/triples/quads the pairs/triples/quads can be laid up with staggered lay lengths. This is standard practice. Individually screened cables do not need staggered lays.

Bedding or Inner Sheaths (Armoured Cables)

Purpose
To provide a protective layer between the cores and the armour.

Materials
Usually, but not always, the material used is similar to the final sheath in the polymer type. Physical properties, like tensile strength, do not tend to be as high as for the final sheath. This covering is usually applied by extrusion but some specifications allow manufacturers to use a helically wrapped tape.

Details of the material types are shown later in the final/outer sheath section.

Armour

Purpose
To provide a high level of mechanical protection.

Materials
In the UK, the favoured material is galvanised mild steel wire. The wire is galvanised to prevent the steel from rusting, a thin zinc coating is applied to the surface of the wire.

- Flexible cable types use a braided armour (GSWB)
- Less flexible types use helically applied wires (SWA)
- Some standards use wrapped or corrugated steel tapes.

Final / Outer Sheath / Jacket

Purpose

To provide a high degree of mechanical protection, physical protection from the environment and impart other desirable features.

Materials

Materials are referred to either by their polymer type (such as PVC, PE, EPDM, EPR) or their main characteristics (Such as LSZH, LSF, LSOH).

All materials contain additives. For example, in PVC there are plasticisers, fillers, anti-oxidants and pigments. In practice only 40-50% of the material is actually PVC. If fillers and plasticisers were not used the material would be rigid, think of PVC window frames!

PVC (Polyvinyl Chloride)

- Still very popular and a good all-rounder
- Quite tough
- Flame retardant
- Reasonable resistance to water and a wide range of chemicals

The biggest disadvantage with PVC is that although it is flame retardant it will burn and, in a fire, emit dense smoke and acidic gas due to the presence of a halogen (chlorine).

PVC is mainly used in outdoor applications.

PE (Polyethylene)

- Very tough and hard with limited flexibility
- Excellent water resistance
- Good resistance to a range of chemicals, especially acids.

PE is not fire retardant and burns readily however it has relatively low smoke levels and is Halogen free. Fire retardant versions are available but with the addition of halogen-containing chemicals.

PE exists in low density (LDPE), medium density (MDPE), and high density (HDPE). LDPE is typically used in insulation and the toughness increases with density.

Mainly used in water submersed applications and ducting .

PUR (Polyurethane)

- Very tough but flexible (feels like a rubber material)
- Some versions have excellent water resistance
- Some versions have good chemical resistance, especially oils and fuels.

PUR is not fire retardant and burns readily however it has relatively low smoke levels and is Halogen free. Fire retardant versions are available but with the addition of halogen-containing chemicals.

Mainly used in Industrial applications where flexibility and toughness are required.
Used more in Europe than UK.

LSZH (Low Smoke Zero Halogen)

Also known as
LSF (Low Smoke and Fume)
LSOH (Low Smoke and No (0) Halogens)

In reality these materials are also fire retardant and not necessarily completely halogen free. Trace elements of halogens may be present in the additives. The material specification allows for this and sets a maximum limit of 0.5%. Some manufacturers take advantage of this and intentionally add halogen containing material to enhance other properties.

- Not particularly tough or flexible
- Limited water and chemical resistance

Mainly used in enclosed public spaces such as Hospitals, London Underground and accommodation modules on oil rigs.

Other Materials

Thermoplastic
RP PVC (Reduced Propagation PVC)
TPV (Thermoplastic Vulcanisate)
TPE (Thermoplastic Elastomer)

Thermosetting
PCP (Polychloroprene rubber)
CSP (Chlorosulphonated Polyethylene)
CPE (Chlorinated Polyethylene)
EVA (Ethylene Vinyl Acetate)

Cable Specifications

Most cables are design to, or generally to, a standard. Many standards exist within industries and regions to regulate products and maintain consistency of performance and safety. Some examples of standards can be found below.

Industry Standards

- ENATS (Energy Networks Association Technical Specifications)
- Def Stan (Defence Standards)

National Standards

- BS (British Standards)
- VDE (Verband der Elektotechnik, Elektronik und Informationtechnik)

European Standards

- EN (European Norm, issued in UK as BS EN)

International Standards

- ISO (International Organisation for Standardisation)
- IEC (International Electro-technical Commission)

Popular Cable Specifications

- BS 5308
- BS EN 50288-7
- BS 5467
- BS 7629
- BS 7846
- IEC 60092
- IEC 60502

Cable specifications can "draw off" from many specifications, for example

Conductors	IEC 60228
Insulation/Sheathing Materials	BS 7655 & BS EN 50363
Cable Test Methods	BS EN 60811

Performance requirements, especially fire performance of cables with LSZH sheaths, are covered by a further range of specifications which are often quoted as a requirement.

Performance Requirements

IEC 60754-1
Tests on gases evolved during combustion of materials from cables
Part 1: Determination of the amount of halogen acid gas

IEC 60754-2
Tests 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 and conductivity

EN 61034-2
Measurement of smoke density of cables burning under defined conditions

IEC 60332-3
Tests on electric cables under fire conditions
Part 3: Tests on bunched wires or cables

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Measurement of smoke density of cables burning under defined conditions

IEC 60332-3
Tests on electric cables under fire conditions
Part 3: Tests on bunched wires or cables

Quite a lot to take in right?

The key thing to remember is that there are many methods of construction and materials used for different situations, and there are many standards that govern how a cable should be made, tested and perform.

Fortunately, you have us at Leigh Cables to help you with an enquiry if you get a bit lost in it all, and it's totally understandable if you do!