WIRE - information

Copper & Resistance wires.

This sheet is to provide information and training about the various types of copper and resistance wires.

FLEXIBLES: Flexible wire is made of a number of fine strands that are twisted together and sheathed in PVC plastic on many different colours. The strands are copper but sometimes the strands are tin plated (silver colour) to reduce corrosion and for easier soldering.

Small flexibles may have about 7x or 10x strands of 0.2mm diameter copper. These are called CW7 or CW10. These small general purpose flexibles are used in electronics and are called 'hook up' wire. Other flexibles can have CW16 or perhaps CW24 (24x0.2) which is the size of the 7 amp cable inside a 3 core mains flex. Larger flexible cables might be CW32 and so on. For welding cables there may be hundreds of strands of 0.1copper. For special instrument purposes some very flexible or 'super flexible' wires might have 200 or many more strands of say 0.05 diameter copper.

THE OUTER SHEATH: Some of the common sheath materials are:

PVC (poly vinyl chloride) is the most usual sheath, but is not necessarily the best. It becomes stiff at low temperatures and soft at warm temperatures and it can easily melt during soldering. PVC is attacked by solvents and can become brittle after prolonged exposure to UV. Many other sheath materials are used:

SYNTHETIC RUBBER (Synthetic rubber could be any of Neoprene, Nitrile, Ethylene Propylene, Butyl, Viton and others) It is used for more flexibility and also higher temperature and chemical resistance.

SILICONE RUBBER for high flexibility and much higher temperatures. These are more expensive cables.

P/P (polypropylene) is very resistant to chemical attack, but it is a harder material and more slippery and less flexible than PVC.

PTFE (polytetrafluoroethylene) is used for very high temperature and corrosion resistance. Used extensively in the manufacture of aircraft. The DuPont trade name for this material is 'Teflon'. Almost totally resistant to chemical attack and is very slippery.

SOLID WIRES: (non flexible): These are wires that are a single soft copper core, often about 1mm to 2mm diameter and usually covered in a PVC insulation. A good example is 'building wire'. They can be bent several times but, if bent too much, the copper becomes harder and will break. P/P and PVC are both used for insulating building wire (wires used in building industry for lighting and power points etc.) and similar.

WHY IS COPPER NORMALLY USED ? Copper is used for most cables because it has a very low electrical resistance therefore, as current flows, there is very small voltage drop along the cable and only a small degree of heating occurs in the wire.

In some cases for transmission lines, an enormous weight and cost of thousands of kilometres of copper wire is reduced by using aluminium wire. This is about 1/3rd the weight of copper, but its resistance is higher and losses in voltage drop and heat is considerably increased.

If the temperature of the metal is reduced by passing liquid hydrogen or liquid helium around the metal wire or through hollow wire, its resistance approaches zero ohms so heating and losses also approach zero. This expensive technique is used in many technical applications.

GAUGES and PROPERTIES: Wire is measured in millimetres but it is common to specify the wire size in 'gauge'. There are two different gauge systems used. These are called SWG (Standard Wire Gauge) and B&S (Brown & Sharp). The more common is probably SWG.

The following tables show the diameters in both mm and gauges (both SWG and B&S) together with resistance per 100 metres length and length in metres on a 50g reel. These tables could be useful in the classroom to help teachers choose the correct gauges for certain experiments. There are many sizes available, but only the popular sizes used in the classroom are listed.

COPPER WIRE:

Diameter mm	SWG	Closest B&S	Ohms / 1,000m	Approx metres on 125g reel
2.03	14	12 (2.05mm)	5.34	4.25m
1.62	16	15 (1.45mm)	8.36	6.75m
1.22	18	16 (1.29mm)	14.85	11.75m
0.91	20	19 (0.91mm)	26.41	21.25m
0.71	22	21 (0.72mm)	43.65	35.25m
0.56	24	23 (0.57mm)	70.71	56.75m
0.46	26	25 (0.45mm)	105.6	85m
0.38	28	27 (0.36mm)	156.2	125m
0.32	30	28 (0.32mm)	222	177.5m
0.27	32	30 (0.25mm)	293	235m
0.23	34	31 (0.23mm)	404	325m
0.19	36	33 (0.18mm)	592	480m
0.05 **1 Amp fuse wire**	47		8,555	n/a **10m or 50m reel is normal**

RESISTANCE WIRES:

Resistance wire is made from alloys of different metals to deliberately create a high resistance wire. Sometimes the resistance wire is used for heating purposes (heating elements, electric kettles, and similar) but other times it is very important that the resistance does not alter as the wire heats. Sometimes the resistance wire needs to be insulated but, at red hot temperatures, most sheaths are useless. To make resistance wire insulating, it is specially processed to create a heavy oxidised layer on the surface. This oxide layer is black colour and is insulating.

CONSTANTAN: For example if a 10 ohm resistor is required for an experiment, it is usually most important that it remains 10 ohms when cold, warm or hot. In these cases, an alloy of 56% copper and 44% nickel is used and it's resistance value is almost unchanged with temperature change. The colour is silver, it does not easily oxidise and it is easy to solder because the metals that make the alloy are both easy to solder. There are several trade names for this wire including: Advance, Eureka, Constantan, Ferry, Cuprothal and others. This wire can be run very hot but it will soften and melt at around a full red temperature.

MANGANIN: 'Manganin' is an alloy with an almost perfect zero resistance change with temperature. It is better than 'Constantan' and, being quite expensive, is used mainly on meter shunts and in professional instruments and resistance coils.

'CONSTANTAN' RESISTANCE WIRE. 56% copper, 44% nickel.

Diameter mm	SWG	Closest B&S	Ohms / metre	Approx metres on 125g reel
2.03	14	12 (2.05mm)	0.151	4.25m
1.62	16	15 (1.45mm)	0.237	6.75m
1.22	18	16 (1.29mm)	0.420	11.75m
0.91	20	19 (0.91mm)	0.747	21.25m
0.71	22	21 (0.72mm)	1.234	32.25m
0.56	24	23 (0.57mm)	1.997	56.75m
0.46	26	25 (0.45mm)	2.987	85m
0.38	28	27 (0.36mm)	4.413	125m
0.32	30	28 (0.32mm)	6.288	177.5m
0.27	32	30 (0.25mm)	8.310	235m
0.23	34	31 (0.23mm)	11.394	325m
0.19	36	33 (0.18mm)	16.749	480m

NICHROME: When used for heating purposes and when the stability of the resistance value is not important, an alloy called 'Nichrome' is normally used. As it's common name suggests, it is an alloy of 80% Nickel and 20% Chromium. It is not easy to solder and, in industry, a special flux of phosphoric acid needs to be used. Because solder will melt when heated, Nichrome is usually welded to other metals to make electrical connection.

'Nichrome', when compared with 'Constantan', is harder to bend and is approximately double the resistance per metre.

Nichrome can be run up to very high temperatures where the wire can becomes bright red in colour. The electrical resistance rises with temperature. There are several different grades of 'Nichrome' for various applications.

To make Nichrome wire insulating, it is heavily oxidised and made black by a special chemical process.

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'NICHROME' RESISTANCE WIRE. 80% nickel, 20% chrome.

Diameter mm	SWG	Closest B&S	Ohms / metre	Approx metres on 125g reel
2.03	14	12 (2.05mm)	0.337	4.25m
1.62	16	15 (1.45mm)	0.526	6.75m
1.22	18	16 (1.29mm)	0.934	11.75m
0.91	20	19 (0.91mm)	1.661	21.25m
0.71	22	21 (0.72mm)	2.745	35.25m
0.56	24	23 (0.57mm)	4.441	56.75m
0.46	26	25 (0.45mm)	6.645	85m
0.38	28	27 (0.36mm)	9.817	125m
0.32	30	28 (0.32mm)	13.987	177.5m
0.27	32	30 (0.25mm)	18.486	235m
0.23	34	31 (0.23mm)	25.346	325m
0.19	36	33 (0.18mm)	37.258	480m

KARMA:

'Karma' is another resistance wire alloy that has a higher resistance per metre than Nichrome. It is used for winding higher value ohms of resistors and potentiometers. The smaller sizes (say 0.02mm diameter) are much smaller than a human hair and they can cost up to $10,000 dollars / kg. For 1 kg of weight, the length of 1 kilogram of some of these very thin wires can be 220 or more kilometres.

TUNGSTEN: Tungsten is another heating resistance wire used in lamps to glow at white hot temperatures. This is a very high resistance metal, it cannot be soldered and must be welded to other metal parts to make an electrical connection. If you inspect an incandescent lamp, you will see where the fine filament is welded to the metal support wires.

EXPANSION of METALS:

Almost all metals expand when heated, but these support wires used in lamps are made from a different alloy that does not easily oxidise when heated and is designed to expand at exactly the same degree as glass when heated.. The reason for this is that this wire must be sealed into molten glass to bring the wires to the lamp's electrical connection to the socket. If the wire expanded and then contracted differently from the glass or if the wire gained an oxide coating when heated, the glass could not bond and seal perfectly to the metal wire.

A Point of interest: A special alloy of Platinum and Iridium does not expand with temperature and this alloy was used for many years for making various master "standards of measure". The EXACTLY ACCURATE standard 1.0000 metre long rod kept in Paris remained exactly the same size whether warm or cool. These days the standards are made a different way.