: H 1:

CONDUCTORS FOR SIGNAL TRANSMISSION AND MEASUREMENT:

The following table is a summery of characteristics of the most usual conductor materials.

Conductor	continuous Temperature in Operation upto	Electrical Conductivity	Soldering Characteri-stics	Corrosion Resistance	Bending Capacity
Plain Copper	+ 130° C + 270° F	very good	good	good	very good
Tinned Copper	+ 180° C + 360° F	very good	very good	very good	good
Silver Coated	+ 205° C + 400° F	very good	very good	sufficient	good
Nickel Plated Copper	+ 260° C + 500° F	good	adequate	very good	sufficient
Nickel	+ 500° C + 930° F	sufficient	soldering not possible	very good	sufficient

INSULATION MATERIAL PROPERTIES:

	Polyvinylchloride (PVC) High Density LDPE / HDPE	Polyethylene Low Density/ XLPE	Cross-linked Polyethylene
Dielectric Characteristics	good good	very good	very good
Σr	4.4 – 8	2.3	2.3
Thermal Performance	softening at high temp. becomes brittle at low temp.	softening at high temp. low temp. resistant	good form stability at low temp. resistant
Flammability	self- extinguishing	inflammable	inflammable
Specific } 20° C Volume }at 25° C Resistivity *} 70° C Ohms.cm	10^{14} - 10^{15} 5. 10^{13} - 5. 10^{14} 10^{11} - 10^{12}	$>10^{16}$	$>10^{16}$

* The specific volume resistivity is the resistance in Ohm per 1 cm cube.
From the specific volume resistivity and the geometry of the insulated conductor the insulation resistance Can be assessed.

: H 2 :

COPPER CONDUCTORS

AWG : AMERICAN WIRE GUAGE

Cross-section area	AWG	No.of Wires	Single wire diameter	Conductor diameter	Elect. Resist. of single conductor at 20°C (IEC 334)
mm^2			mm	mm	Ω/km
0.033	32	1	0.203	0.203	559
0.034	32	7	0.079	0.237	559
0.051	30	1	0.254	0.254	357
0.057	30	7	0.102	0.306	326
0.080		10	0.10	0.400	244
0.081	28	1	0.320	0.320	221
0.089	28	7	0.127	0.381	210
0.128	26	1	0.404	0.404	139
0.140		18	0.100	0.500	136
0.141	26	7	0.160	0.480	132
0.155	26	19	0.102	0.510	120
0.205	24	1	0.511	0.511	86.6
0.227	24	7	0.203	0.609	82.3
0.241	24	19	0.127	0.635	77.5
0.250		14	0.150	0.660	75.4
0.325	22	1	0.643	0.643	54.7
0.340		7	0.250	0.750	54.3
0.355	22	7	0.254	0.762	52.6
0.382	22	19	0.160	0.800	48.8
0.500		1	0.800	0.800	35.3
0.500		7	0.310	0.930	35.3
0.500		16	0.200	0.940	37.1
0.519	20	1	0.813	0.813	34.2
0.563	20	7	0.320	0.960	32.5
0.616	20	19	0.203	1.015	30.3
0.750		7	0.370	1.110	24.3
0.750		24	0.200	1.200	24.7
0.785		1	1.000	1.000	22.6
0.824	18	1	1.024	1.024	21.6
0.897	18	7	0.404	1.212	20.4
0.963	18	19	0.254	1.270	19.4
01.00		1	1.130	1.130	17.7
01.00		7	0.430	1.290	18.0
01.30	16	1	1.290	1.290	13.6
01.43	16	7	0.510	1.530	12.8
01.22	16	19	0.287	1.435	15.2
01.50		1	1.380	1.380	11.9
01.50		7	0.530	1.590	11.8
01.50		48	0.200	1.680	12.4
01.93	14	19	0.361	1.805	9.40
02.08	14	1	1.628	1.628	8.53
02.50		1	1.790	1.790	7.06
02.50		7	0.670	2.010	7.41
02.50		50	0.250	2.100	7.60
03.08	12	19	0.455	2.275	5.92
03.30	12	1	2.052	2.052	5.37
04.00		1	2.260	2.260	4.43
04.00		56	0.300	2.700	4.71
04.74	10	37	0.404	2.828	3.86
05.00	10	49	0.361	2.946	3.65
05.26	10	1	2.588	2.588	3.38
06.00		1	2.760	2.760	2.97
06.00		84	0.300	3.210	3.14
08.36	8	1	3.264	3.264	2.12
08.57	8	133	0.287	3.820	2.17
10.00		1	3.570	3.570	1.77
10.00		80	0.400	4.164	1.82
13.30	6	1	4.110	4.110	1.33
13.55	6	133	0.361	4.805	1.34
16.00		1	4.520	4.520	1.11
16.00		128	0.400	5.800	1.14
21.59	4	133	0.455	6.856	0.84
21.00		200	0.400	7.700	0.72
36.69	2	665	0.254	8.700	0.55
35.00		280	0.400	8.800	0.52
41.39	1	817	0.254	9.500	0.45
50.00		400	0.400	10.400	0.36
52.95	0	1045	0.254	10.900	0.35

These values increase by stranding the conductors to form the cable core.

: H 3 :
BASIC FORMULAE

Conductor Resistance

conductor resistance for fine wire conductors (Exerpt from VDC 0295 and in agreement with international rules e.g.IEC 228). Decisive for the make-up of conductors is the max single wire - dia. and the max conductor resistance.

nominal cross section	conductor resistance at 20°C for 1 km in 0 (max value)			
	tinned copper wires		bare copper wires	
mm²	class 1+2	class 5+6	class 1+2	class 5+6
0.08		~250		~243
0.14		~142		~138
0.25		~ 82		~ 79
0.34		~ 59		~57
0.5	36.7	40.1	36.0	39.0
0.75	24.6	26.7	24.5	26.0
118.2	20.0	18.1		19.5
1.5	12.2	13.7	12.1	13.3
2.5	7.56	8.21	7.41	13.3
44.70	5.09	4.61		4.95
63.11	3.39	3.08		3.30
10	1.84	1.95	1.83	1.91
16	1.16	1.24	1.15	1.21
25	0.734	0.795	0.727	0.780
35	0.529	0.565	0.524	0.554
50	0.331	0.393	0.387	0.386
70	0.270	0.277	0.268	0.272
95	0.195	0.210	0.193	0.206
120	0.154	0.164	0.153	0.161
150	0.126	0.132	0.124	0.129
185	0.100	0.108	0.0991	0.106

POWER RATING

Permitted power rating for insualted cables up to 30°C ambient temperature. (Exerpt from VDE 0100 section 430 and section 523 and in according with other VDC regulations).

Nominal cross section mm²	Group 1 Max. load A	Group 1 Fuse A	Group 2 Max. Load A	Group 2 Fuse A	Group3 Max . load A	Group3 Fuse A
0.08	0.8	-	1	-	1.5	-
0.14	1.5	-	2	-	3	-
0.25	3.0	-	4	-	5	-
0.34	4.6	-	6	-	8	-
0.50	7.0	-	9	-	12	-
0.75	9	-12	6	15	10	
1	11	6	15	10	9	10
1.50	15	10	18	16	24	20
2.50	20	16	26	20	32	25
4	25	20	34	25	12	35
6	33	25	44	35	54	50
10	45	35	61	50	73	63
16	61	50	82	63	98	80
25	83	63	108	80	129	100
35	103	80	135	100	158	125
50	132	100	168	125	198	160
70	165	125	207	160	245	200
95	197	160	250	200	192	250
120	235	200	292	250	344	315
150	-	-	335	250	391	315
185	-	-	382	315	448	400

CALCUATION OF RESISTANCE

Resistance R
(Direct current resistance, Ohmic resistance)

$$R = C \cdot \frac{1}{A} \text{ in } \Omega$$

C = Specific resistance in $\frac{\Omega \text{ mm}^2}{\text{m}}$

l = Cable length in m

A = Cable cross section in mm²

$\frac{1}{C}$ = X - Conductance in $\frac{\text{m}}{\text{mm2}}$ for copper - 58.0 for aluminium - 34.5

REACTIVE RESISTANCE X_c of capacity C condensance)

$$X_c = \frac{10^6}{C} \text{ at } 50 \text{ HZ} = 314 \text{ C} = \text{Capacity in } \mu\text{F}$$

REACTIVE RESISTANCE X_L of an Inductivity L (Inductance)
$X_L = L\ 10^{-3}$ at $50\ \Omega = 314$ L = INDUCTVITY IN mH

RATE RESISITANCE Z (A.C . RESISTANCE, IMPEDANCE)
$Z^2\text{-}R^2 + (X_L\text{-}X_C)^2$ (R,L AND C IN SERIES CONNECTION)

Resistance and conductance terminology
in A.C. Technology

Resistance	- Active resistance
Resistance	- Reactive resistance
Condensance	- Capacitive reactive resistance
Industance	- Inductive reactive resistance
Impedance	- Rated resistance complex resistance
Conductor	- Active conductivity
Susceptance	- Inductive reactive conductivity
Capazitance	- Capacitative reactive conductivty
Admittance	- Apparent conductivity complex conductivity

Series connection of Resitances and Inductance
$R = R_1 + R_2 + R_3 \ldots\ L = L_1 + L_2 + L_3 + \ldots\ldots$

Series connection of capacities

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$$

Paralled Connection of Active Resistnce and Inductivities

$$\frac{1}{R} + \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \qquad \frac{1}{L} + \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}$$

Parallel connection of capacities: $C = C_1 + C_2 + C_3 + \ldots\ldots$

Note on Power Rating

Group 1 One or several single core cable laid in conduit e.g H 05 V-U or H 07 V-U

Group 2 Multi -core cable eg: sheathed cables conduit wires lead sheathed cables moblile cables.

Group 3 Single core open air laid cables where these cables are laid at intervals of at least the cables diameter as well as single core wiring in switch gear and distrubutors.

VDE 0.100, Section 523 table 3
permitted power rating of insulated cables at ambient temp. from 30°C - 55°C

Ambient temperature °C	continuous loading in % of nominal values rubber insulated (max 60°C)	synthetic insulation (max 70 °C)
above 30 to 35	91	94
above 35 to 40	82	87
above 40 to 45	71	79
above 45 to 50	58	71
above 50 to 55	41	61

VDC 0100 SECTION 523 TABLE 4
Permitted power rating of HEAT -RESISTANCE cable ambient temperature over 55°C

Abient temperature for cables with a thresshold temperature max.100 °C	max 180°C	continous loading in % of
above 55 to 65	above 55 to 145	100
above 65 to 70	above 145 to 150	92
above 70 to 75	above 150 to 155	85
above 75 to 80	above 155 to 160	75
above 80 to 85	above 160 to 165	65
above 85 to 90	above 165 to 170	53
above 90 to 95	above 170 to 175	38

: H 4 :

SPECIAL CABLE CONSTRUCTION

CABLES WITH BRAIDS (METALLIC TO TEXTILE)

One of the many developments in cables for machine tool engineering is cables with braids various different materials are used appropriate to the task and field of application.

CABLES WITH COPPER WIRE BRAIDS

For heaviest demands on flexibility and electrical protection against interference from external electrical fields as protection against short circuits and earth leakage as well as electrical screening to protect other cables.

CABLES WITH STEEL WIRE BRAIDS

For good mechanical protection and high flexibility as well as protection against short circuits and earth leakage in special cases also as stress relief.

CABLES WITH GLASS-FIBRE AND ASBESTOS BRAIDS

As thermal protection against contact with hot surfaces as substitute sheath on high temperature cables.

CABLES WITH WIRE or FLAT WIRE ARMOURING (OF STEEL WIRE)

For highest grade mechanical protection in conditions of transverse stress as stress relief element during laying or in permanent installations.

WOVEN COPPER WIRE BRAID

Concentric conductors used as earth protective and neutral conductors as well as contact protection or screen against electrical interference braid can surround the whole cables as well as its individual compounds. The major cables in our standard range are available from stock with for example copper braided our special cables service means that we can supply you with all standard range cables with the braiding of your choice.

SPECIAL CONDUCTOR MATERIALS

Copper remains the standard material for electrical conductors plain electrolytic copper is effective up to conductor temperature of + 150°C (strand conductor) or + 180°C (solid conductor) if exposed to oxygen however gradual oxidization occurs this leads to increased resistance and at the same time increases conductor temperature which in turn accelerate oxidation by tinning the copper conductor these effects are reduced and permanent temperature of up to 200°C are possible silver –plated copper wires with a plate thickness of roughly 0.002 mm can be used at temperature up to 260°C a layer of nickel approximately 0.114 mm thick extends the temperature range to single wire conductors are suitable only for permanent installation cables subjected to stress through flexing or vibrations must have multi wire fine or super fine wire conductors depending on the stress involved.

POLYURETHANE

Depending on the choice of materials, it is possible to produce polyurethane with various mechanical properties for the most diverse field of application for insulation and sheaths a thermoplastics PUR elastomer is used the macro moleculer make up produces a highly elastic material as this is achieved without the addition of plasticizer migration. In addition to the high elasticity, PUR is highly wear-resistant as a result of minimal abrasion losses high tearing strength and high level from recovery. Besides its resistance to mineral fats and oil PUR is insoluble in most solvents with the appropriate additives high flame resistance and resistance against microbial and hydrolytic corrosion is ensured.

POLYCHLOROPRENE-RUBBER (NEOPRENE)

The basic material polychloroprene is produced systhetically and mixed with various fillers antioxidants and vulcanizing agents after vulcanizing a very flexible abrasion and weather resistant material is produced which is particularly suitable for heavy duty cable sheaths the temperature range for flexible application from –30°C (in limited cases down to –35°C) upto +70°C matches approximately that of a cold resistant PVC –compound it has flame resistant characteristics and extinguishes once the flame is remove because of its relatively inferior electrical quantities polychloroprene rubber as an insulation can only be used for low voltages.

PVC INSULATING COMPOUNDS

On account of the chain structure of its molecules pure PVC has high rigidity and strength through the addition of plasticizer almost any desired grade of flexibility can be achieved even at low temperature special plasticizer and stabilizers mean that the compound can be used at temperature just over 100°C other types of plasticizer make the pvc compound remarkable oil resistant pre disintegrate at temperature over 150°C it only burns in flame and extinguishes once the flame is removed through the addition of other material it is possible for example to make flame resistance even better or to particularly hinder lubricants filler and pigments which ensure high quality and long life the compounds electrical characteristics determined by the plasticizers used make it suitable for use as insulating material for low and medium voltage low frequency cables.

POLYETHYLENE INSULATION

The method of production determines the characteristics of the polyethlene (PE) High density PE has a low specific weight and is particularly suitable for use as outer sheathing low density PE has a higher specific weight and because of its durability is suited amongst other things for use as conductor insulations PE largely retains its good qualities in a temperature range from –50°C to + 70°C when ingnited by flame burns with a bluish flame forming droplets it is therefore not recommended for use as sheathing material in interior environments polyethylene has outstanding electrical properties and can be used on high frequency cables it is perfectly safe to use it is contact with food and drinking water.

SILICON RUBBER

The basic material silicon rubber is blended with bonding agents and other active fillers these additives form approximately 30% of the compound after extrusion and vulcanizing it shows rather lower mechanical resistance at room temperature then other elastomers in areas of high and low temperature silicon rubber is comparatively better the constant temperature resistance reaches from –60°C to 180°C (intermittently +220°C) cilicone rubber is incombustible in flame an insulating silicones –di-oxide shield (sio2) develop the electrical properties of silicon rubber are far better than those of polychloroprene rubber and make it suitable for use on high voltage ignition cable for vehicles.

FEP

This material is thermostatically processes and given very consistent results it is impact and abrasion resistant besides being chemically resistant I LP can be used without problem from –190°C to + 205°C only at temperature of over +280°C does this non inflammable material begin to melt in case of fire it does not give off any corrosive gases. Even in the high frequency sector its electrical properties remain excellent.

PTFE

This material has the greatest temperature range of all synthetics (-190°C to + 260°C) it is incombustible and is outstandingly light and weather resistant thanks to its impact and abrasion resistance, ideally suited for use in extreme condition.

The illustration show further special cables belonging to our highly complex range of cable constructions the innumerable variations possible in this field range from simple cables without a protective conductor across single colour number coded cable in all basic colours coil cords with PVC or neoprene sheathing and cable with additional polyurethane outer sheath up to the illustrated special construction with unusual make up combined sheathing qualities and special screening braids.

The wide range of special cables is completed by cables constructed to foreign regulations or even licensed abroad (e.g. to UL or Mil regulations.)

All the advice needed on technical requirements construction and production or special cables is provided by our high quality special cables construction services our knowledge and practical experience gained through working with many thousands of customers in all branches of industry the world over has given us important advantage please let us know your own special requirements so that you too can benefit from our expertise we shall be glad to advise you.

: H 7 :

PROPERTIES OF INSULATTION MATERIALS

MATERIAL	ABV.	DIELECTRIC INDEX @ 800Hz	SPECIFIC RESISTANCE Ω.cm	LOSS FACTOR 10^{-3}	BREAKDOWN VOLTAGE KV/mm	RADIATION RESISTANCE cj/kg (rad)
Polyvinylchloride	PVC	4.0	10^{13}	100	10	8 -10^{7}
Polyvinylchloride heat resistant	HR PVC	3.5	10^{13}	100	20	1-10^{8}
Polyethylene	LD LDPE	2.29	10^{17}	0.2	75	1-10^{7}
Polyethylene	HD HDPE	2.32	10^{17}	0.3	100	7-10^{6}
Polystyrene	PS	2.5	10^{16}	0.2	30	5-10^{8}
Polyamide	PA	4.0	10^{14}	30	25	1-10^{7}
Polytetraflour-oethylene	PTFE	2.1	10^{18}	0.3	25	1-10^{5}
Fluorine-Ethyelne -Propylene	FEP	2.6	10^{16}	0.3	20	3-10^{5}
Ethlenetetra flouroethylene	ETFE	2.6	10^{16}	0.6	30	1-10^{7}
Polypropylene	PP	2.3	10^{17}	0.2	20	5-10^{5}
Polyurethane	PUR	6	10^{12}	30	30	1-10^{7}
Polyethylene-Terephtalate	PETP	3.3	10^{16}	10	20	8-10^{7}
Natural Rubber	NR	4	10^{12}	20	20	2-10^{7}
Styrene-Butadiene	SBR	4	10^{12}	20	20	2-10^{7}
Silicon Rubber	SIR	3.2	10^{15}	10	20	1-10^{7}
Ethlene proylene rubber	EPR	3.5	10^{14}	10	20	1-10^{8}
Ethlene-Vinyl-acetate	EVA	5	10^{12}	30	30	1,10^{7}
Polychloprene	CR	8	10^{10}	50	20	2-10^{7}
Cross linked plyethylene	VPE	2.4	10^{16}	0.5	50	1-10^{7}

PROPERTIES OF INSULATION MATERIALS

MATERIAL	DENSITY	FLEXIBILTY	TENSILE STRENGTH	BREAKING ELONGATION	WATER ABSORPTION	WEATHER VAPOUR PERMIABILITY	Weather resistance	FLAMABILITY
	g/cm²		N/mm²	%	$^{0}/_{00}$			
Polyvinychloride	1.35	GOOD	15	250	1	AVG.	GOOD	s.v.
Polyvinychloride heat resistant	1.35	GOOD	18	200	1	AVG.	GOOD	s.v.
Polyethylene LD	0.9	AVG.	10	400	0.03	LOW	GOOD	e.
Polyethylene HD	0.9	LOW	20	500	0.03	LOW	GOOD	e.
Polystyrene	1.06	AVG	55	3	1	LOW	GOOD	e.
Polyamide	1.1	AVG	50	200	5	AVG	GOOD	s.v.
Polytetraflour-ethylene	2.17	LOW	40	350	0.1	V.LOW	V.GOOD	n.e.
Fluorine-Ethylene-Propylene	2.15	AVG	20	250	0.1	V.LOW	V.GOOD	n.e.
Ethylenetetra flouroethylene	1.70	AVG	45	200	1	V.LOW	V.GOOD	n.e.
Polypropylene	0.91	AVG	30	500	0.1	LOW	GOOD	e
Polyurethane	1.20	GOOD	30	400	5	V.LOW	V.GOOD	s.v..
Polyethylene-Terephtalate	1.40	V.GOOD	100	50	3	LOW	GOOD	n.e.
Natural Rubber	1.6	V.GOOD	10	350	0.1	LOW	GOOD	e.
Styrene-Butadiene Rubber	1.6	V.GOOD	5	250	0.1	LOW	GOOD	e.
Silicon Rubber	1.25	V.GOOD	5	200	5	V.LOW	GOOD	s.e.
Ethlene-Proylene Rubber	1.45	V.GOOD	5	200	0.2	LOW	GOOD	e.
Ethylene-Vinyl-acetate	1.40	V.GOOD	6	300	0.1	AVG	GOOD	e.
polychlroprene	1.55	GOOD	15	300	10	AVG	GOOD	s.v.
Cross linked ply plyethylene	0.92	AVG	22	300	0.33	LOW	GOOD	e.

Key to Symbols :

- n.e. - non flammable
- s.e. - Flame-retardent
- s.v. - self extinguishing
- e. - flammable

TEST AND QUALITY CONTROL

A)	**FOR CONDUCTOR :**		
			TEST EQUIPMENT
	i) Elongation & Tensile strength	:	Tensile Tester
	ii) Conductor Resistance	:	Digital LCRTZ Meter
	iii) Dimensional Test	:	Micrometer
B)	**FOR INSULATION & SHEATH MATERIAL :**		
	i) Thickness test	:	Travelling Microscope
	ii) Tensile strength & elongation before / after ageing	:	Tensile Tester
	iii) Insulation Resistance	:	Insulation Tester
	iv) Heat Shock & Shrinkage loss of mass	:	Ageing Oven / Steady state humidity chamber. (upto 300°C)
	v) Hot deformation	:	Hot deformation test apparatus
	vi) Thermal stability	:	Thermal stability test apparatus
	vii) High Voltage test in water	:	DC High Voltage tester
	viii) High Voltage test at room temp.	:	AC High voltage tester
	ix) Flammability test	:	Flammability test apparatus
C)	**FOR ENVIRONMENTAL TESTS :**		
	i) Cold bend / Cold impact test	:	High/Low temp. test chamber (-65 °C to +50 °C)
D)	**FOR FRLS TEST :**		
	i) Flammability test	:	Swedish Chimney
	ii) Acid test (HCL emmision)	:	Halogen Acid test apparatus
	iv) Smoke density rating	:	Smoke density apparatus
	v) Temparature & Oxygen Index	:	By arrangement with M/s.HCL.,Hyd (Own equipment expected shortly)
E)	**ELECTRICAL & ELECTRONICS TEST :**		
	i) Capacitance/Inductance/Resistance	:	Digital LCRTZ Meter
	ii) DC High Voltage leakage test	:	High Voltage Break down (flash) Tester
	iii) High Voltage negative impulse break down of insulation (8KV)	:	High Voltage Negative Pulse Generator.
	iv) Velocity of Propagation and Ch. Impedance, Short/Break test	:	TDR Cable Tester (Tecktronics make)
	v) Cross-talk/Attenuation upto 600 KHz	:	Selective level meter/Level Generator.
	vi) Structural Return Loss	:	Net work Analyzer
	vii) Dielectric Carona test	:	Carona Tester
	ix) Surface Transfer Impedance	:	Surface Transfer Impedance Test Equipment
	x) Time-Voltage-Noise Frequency	:	Oscilloscope
	xi) Pulse Frequency 50 Hz -1 MHz	:	Pulse Generator
	xii) Noise level test	:	Charge Amplifier
	xiv) Insulation Resistance	:	High Resistance Tester