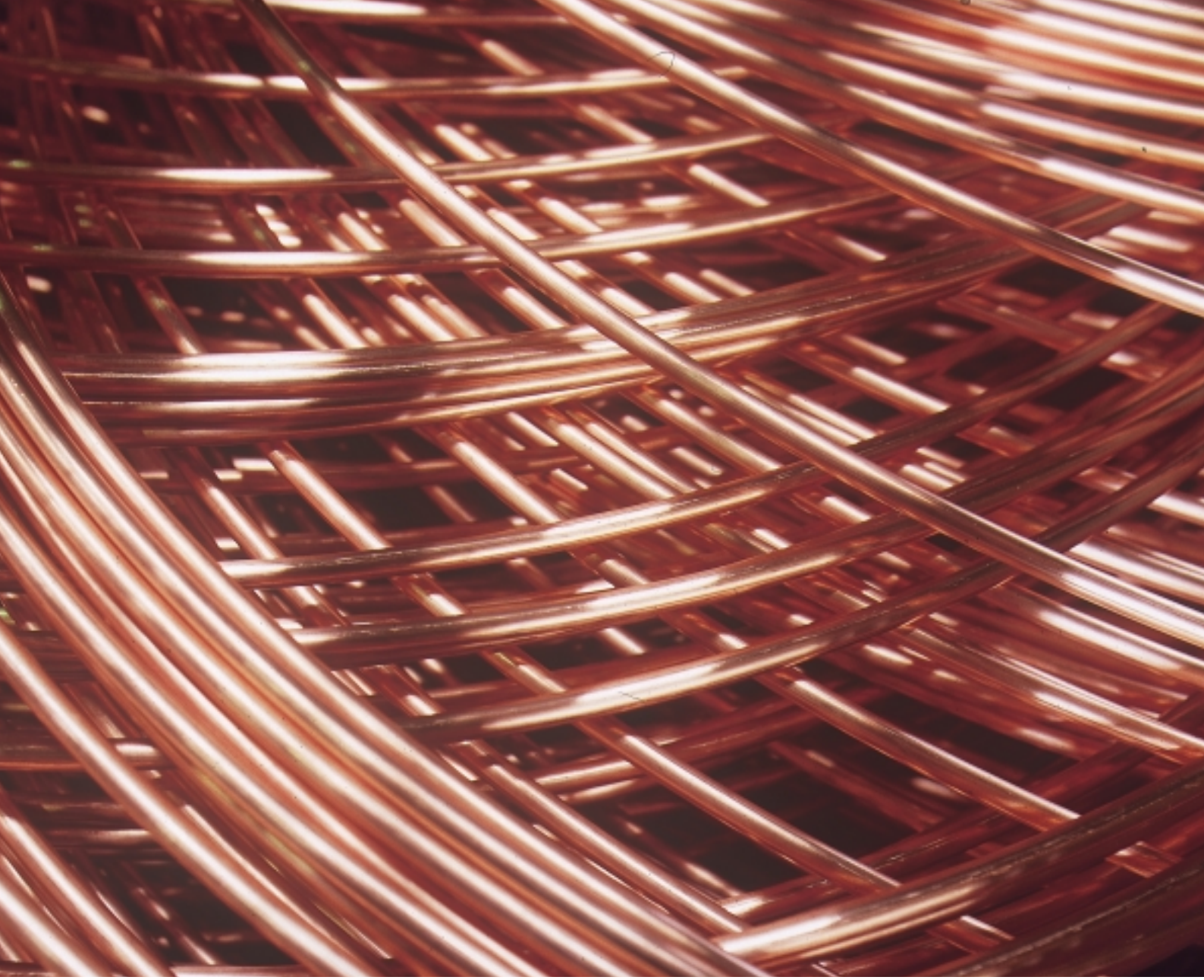
CONDUCTORS

Nexans



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CONDUCTORS MATERIALS.

The metallic materials used for the production of electrical conductors shows the following characteristics:

- An excellent electrical conductivity in order to minimize the losses due to the heatings of the Joule effect
- Excellent resistance in aggressive environments
- Permanent reliability of the electrical contact
- Easy use and recycling

Only a small number of elements are able to satisfy these properties. Mainly, it is copper, aluminium (and their alloys), materials that are available in huge quantity in nature.
Sometimes, the basic properties of the material are not sufficient and it is necessary to add a plating to improve the performance of the material.
So, platings such as tin, silver, nickel improve some properties as solderability, oxidation resistance, heating resistance during the further process (insulation..).

The Nexans continually reinforced selective policy in cathodes ensures a conductivity over 100% IACS.

1) Physical properties of copper

Density	8,90
Electrical resistivity (μΩ.cm)	1,7241
Electrical conductivity (% IACS)	100
Temperature coefficient of the Resistance	0,0039
Thermal conductivity at 20°C (W/m.K)	400
Coefficient of linear expansion (K^{-1})	$17x10^{-6}$
Tensile stress (annealed) (MPa)	220/290
Tensile stress (hard) (MPa)	350/450
Elastic modulus (MPa)	120000
Hardness (annealed)	50
Hardness (hard)	110

The copper qualities generally used for the production of conductors are:

Nexans offers both copper qualities.

a) ETP copper, or Cu-a1, with oxygen content between 200 and 300 ppm.
b) OF copper, oxygen-free or Cu-c1, with very small content in oxygen (20 ppm max.) able to resist to hydrogen brittleness during a heating.

2) Definition of the conductors

A conductor is a wire or a group of wires, no insulated, to transport electrical current. The conductor can be produced by single or multiwire process. The multiwire process gives a product commonly called "kock". The various types of conductors require an explanation of the vocabulary.
See: Vocabulary, page 10.

3) Types of conductors

The most simple conductor is the round single wire. It shows the greater metallic section with the smallest outside diameter. But its flexibility, its ability to be shaped, is generally insufficient for many uses. So, conductors composed of wires with the same diameter assembled together are preferred. These conductors have various configurations and the use confirmed the following classification:

CONCENTRIC STRANDED CONDUCTORS

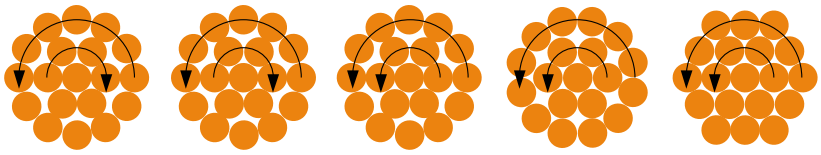
These conductors are composed of a central wire surrounded by one or several adjacent layers of wires being laid helically. The central wire is always the same and the wires layers are distinct and concentric. For the conductor having only one wire diameter, the classic construction is :
1 + 6 +12 + 18 + etc...,
The layer n+1 includes 6 wires more than the layer n.
Inside this group, it is possible to establish 5 types of concentric stranded conductors:

- Conventional
- Equilay
- Uni-directional
- Round unilay
- Hexagonal unilay

According to the customer requirements, Nexans can offer all the 19 wires constructions.

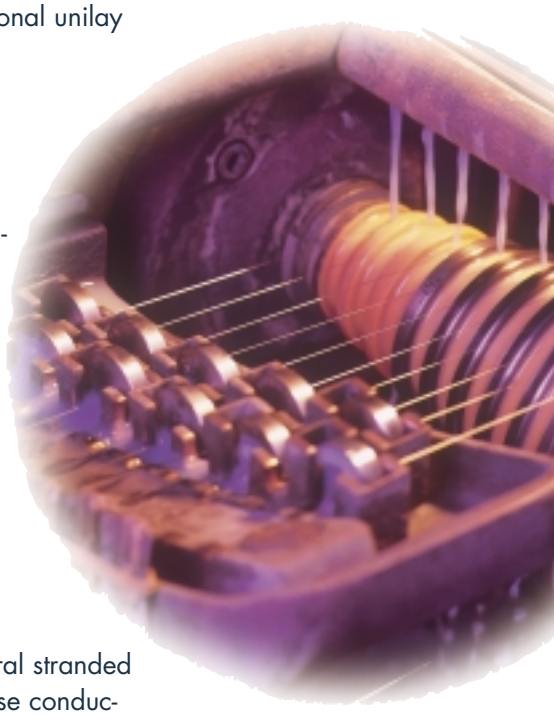
Type	1st Layer Lay length = L1		2nd Layer Lay length = L2		Diameter D of the conductor for (1 + 6 + 12) d
Conventional	Z	L1	S	L2 > L1	5 d
Equilay	Z	L1	S	L2 = L1	5 d
Unidirectional	S	L1	S	L2 > L1	5 d
Round Unilay	S	L1	S	L2 = L1	4,86 d
Hexagonal Unilay	S	L1	S	L2 = L1	5 d

S : left direction
Z : right direction



Conventional Equilay Unidirectional Round Unilay Hexagonal Unilay

These conductors show a precise and constant diameter, an increased metallic section for the round unilay and a very smooth surface quality. Only the unilay can be stranded in one single step, but its production requires a twist of the 12 wires layer of a 15° angle and therefore it is more difficult to produce and it shows less stability than hexagonal unilay construction.



BUNCHED CONDUCTORS

The bunched conductors are composed of wires assembled together helically, in same direction and with the same lay, without forming definite layers. On principle, a bunched conductor cannot be as round as a concentric stranded conductor and the following figure shows the cross section of a bunched conductor..

24 x 0,15 mm

MULTIPLE STRANDED CONDUCTOR

Multiple stranded conductors are conductors composed of several stranded or bunched conductors assembled in one or several layers. These conductors have the same lay. The ASTM standards distinguish the conductor produced from concentric stranded conductors (ASTM B173) from the conductor produced from bunched conductors (ASTM B172).

Nexans offers the complete range of standard or specific compositions.

The arrangements of these conductors are defined according to the lay direction of the basic stranded and bunched conductors.

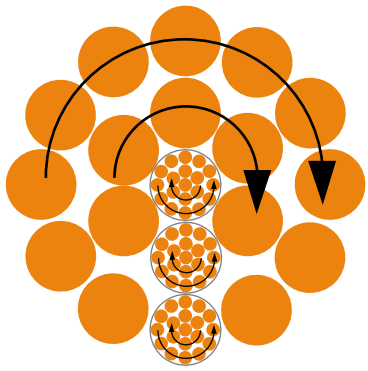
The designation of these conductors uses the method proposed in the ASTM standard, you have to describe :

- in a first step the number of components which make up the multiple stranded conductor.7,19,37 or 61.
- after, separated by the word "by", the number of components assembled from concentric stranded or bunched conductors.
- Finally, separated by the word "by", the number of wires which constitute the basic concentric stranded or bunched conductor..

Example :

A multiple stranded conductor of "19 by 19 by 7" means that:

- 7 wires have been stranded to give a conductor of 7 wires.
- 19 conductors of 7 wires have been stranded to give a 19x wires element.
- 19 elements of 19x7 wires have been stranded in concentric layers to give a multiple stranded conductor of 19 by 19 by 7.



19 x 19 x 7

So, this conductor is composed of 2527 wires. The lay directions of the different elements could be different of this of the basic element or of the upper element, as shown in the following table.

Just give us your flexibility specification and our technicians will design for you the best construction.

	Core	1st Layer	2nd Layer	3rd Layer ...
Unit stranded element	S -	S S	S S	S S
Unit stranded element	Z -	S S	Z Z	S S
Unit stranded element	Z -	S Z	Z S	S Z

4) Main characteristics of the conductors

The characteristics necessary to select a conductor are mainly:

- its diameter
- its linear resistance
- its linear mass.

They are necessary to calculate the dimensions of the conductor and its nominal intensity. Its ability to be shaped and its flexibility are determined by the composition.

DIAMETER

The diameter is depending on the wires diameter. This is not sufficient because the wires arrangement has an effect too. Therefore it is necessary to classify firstly the several arrangements seen previously. The concentric arrangement allows an easy determination of the diameter while the bunched compositions need the use of empiric formulas with an uncertain reliability.

- Concentric constructions

Construction	Number of wires with diameter d	Diameter of conductor
Concentric Equilay/unidirectional	7	3 d
	19	5 d
	37	7 d
	61	9 d
	91	11 d
Concentric unilay	19	4,86 d
	37	6,76 d

- Bunched and multiple stranded constructions

The calculation of the diameter is more uncertain because depending largely on the cabling method, and the art of the cable manufacturer, etc...

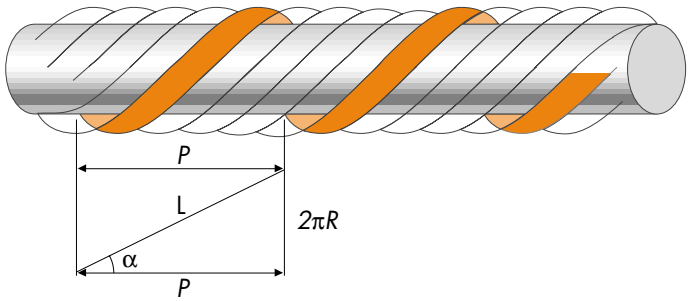
It exists an empiric formula to use with care but it gives an idea :

$D = Kd \cdot \sqrt{N}$

with D : average conductor diameter in mm
d : single wire diameter in mm
N : total number of wires
K : 1,13 for bunched, 1,18 for the multiple stranded conductors

LINEAR MASS:

The wires are helically assembled and therefore there is an overlength which increases the linear mass of the conductor. This overlength depends on the lay length used : the shorter the lay length is, the higher is the overlength. The following figure indicates the helix properties to take into account for the calculations :



with : P : lay length
α : cabling angle
D : core diameter
L : wire length
d : wire diameter
R : layer radius equal to $\left(\frac{D + d}{2}\right)$

herefore: $L = \sqrt{P^2 + (2\pi R)^2}$

$\alpha = \text{Arc tg}\left(\frac{2\pi R}{P}\right)$

ELECTRIC LINEAR RESISTANCE:

This property is the starting point of the choice of the conductor because it determines the carrying capacity of the conductor. It mainly depends on metal or alloy, of metallurgical state and of the presence of a coating.The nominal resistance of the various materials used in the conductors production is given page 3.

a) Metallurgical state

The annealed material shows the minimum electrical resistivity. The hard worked material increases the resistivity due to mechanical deformations induced in the structure.

b) Coated material

In order to improve some properties, some metal could be plated with another material showing properties suitable for some precise goal. For instance:

- Tin on copper in order to improve the solderability, the corrosion resistance, and an inertness with insulating materials.
- Silver on copper to improve the electrical conductivity for high frequency current , the solderability and the resistance at high temperature during the heating of special insulating materials.
- Nickel on copper and on aluminium to improve the resistance of the copper at high temperature and the contact resistance of aluminium.

Except to silver, the other materials, tin and nickel, increase the resistance and this fact shall be taken into account to calculate the linear resistance.

	Revêtement	Revêtement	Revêtement
PROPERTY	TIN	SILVER	NICKEL
Conductivity	Poor	Improved for high frequency current	Poor
Heat resistance	Poor , due to the formation intermetallic compounds	Good for exposures up to 200°C.	Good for exposures up to 270°C.
Solderability	Good but decreases during the storage	Good	Poor

c) Configuration of the conductor
The electrical resistance of a material is proportional to its length and inversely proportional to its section. The cabling has the same influence on the resistance as on the linear mass due to the overlength of the stranded wires.Therefore, the coefficients given for the linear mass calculation are the same for the calculation of the electrical resistance.

Some formulas exist which take into account these three factors and this one for copper conductor is extracted from NFC 31.111 standard.

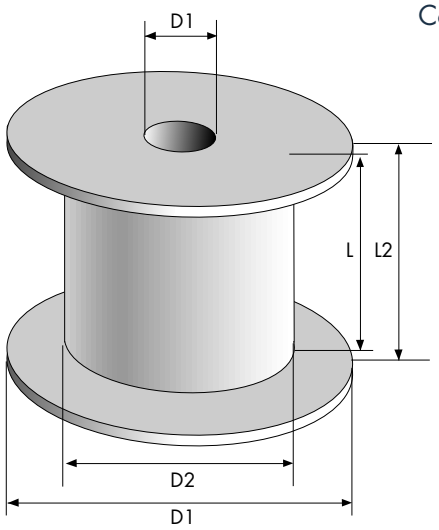
QUALITIES AND DEFECTS OF THE VARIOUS ARRANGEMENTS

In addition to the diameter and the linear resistance, the user shall estimate a lot of criterias for the choice of a type of conductor. The following table summarizes some main properties of the conductors according to their various uses.

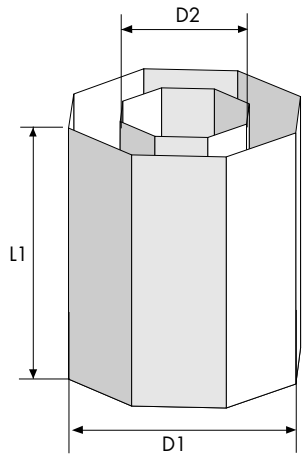
Characteristic	Concentric Unilay	Conventional Bunched	Conductor	Multiple Stranded Conductor
Diameter control	Excellent	Good	Fair	Fair
Linear mass control	Excellent	Good	Fair	Fair
Flexibility	Good	Fair	Fair - Depend of wires number	Excellent due to wires number
Crimp terminality	Excellent	Excellent	Fair	Fair
Conclusions	Invariability of diameter and linear mass. Excellent for thin insulation	Invariability of diameter and linear mass. Excellent for thin insulation	Common uses for common insulation	Common uses or common insulation Great flexibility

PACKAGING.

Spools:



Containers:



	TYPE	Flange Diameter (mm) D1	Barrel Diameter (mm) D2	Bore Diameter (mm) D3	Traverse Hole (mm) L1	Overall Width (mm) L2	Capacity Maxi Kg	Material
Spools	DIN 160	160	100	22	128	160	5	Plastic
	F 200	200	140	102	150	190	15	Plastic
	F 250 or DIN 250	250	160	22 à 127	160	200	20	Plastic
	Al 250	250	150	127	150	190	25	Aluminium
	Al 400	400	224	127	250	300	120	Aluminium
	K 400	400	250	36 à 127	200	240	65	Plastic
	E 400	400	224	127	250	280	100	Steel
	DIN 450	450	250	127	280	310	150	Steel
	ST 500	500	200	56	315	375	220	Steel
	E 560	560	315	127	355	395	330	Steel
	K 560	560	280	127	330	400	260	Plastic
	DIN 560	560	315	127	520	556	980	Steel
	ST 630 or DIN 630	630	355	127	400	445	350 500	Steel
	ST 710	710	355	80	420	480	730	Steel
	DIN 800	800	502	200	520	556	980	Steel
	B 80	800	400	90	458	611	2196	Wood
	B 1025	1025	460	90	600	763	2468	Wood
	DIN 1000	1000	630	200	630	674	1900	Steel
	R 40	1040	700	127	440	472	1000/Cu	Steel
	DIN 1250	1250	630	82	630	780	2500	Steel
	DIN 1600	1600	800	82	1000	1150	5000	Steel
Braiding spools	A.B.N à J.B.N	750 à 3000					500 à 700	Wood
	A.F.N à J.F.N	750 à 3000					250 à 640	Steel
	Spirka 75	75	23	10,1	70	100	1,5	Plastic
	Wardwell 70	66,3	34,5	13,5	69,2	82,3	0,85	Plastic
Other packaging	CCPB (Octogonal Cardboard Case)	880	460		1350	1500	1100	Cardboard box
	CCP (Octogonal Cardboard Case)	1100	550		930	1100	1850	Cardboard box
	Container	1091	565		1351	1526	1400	Cardboard box
	Returnable or non returnable container	500	315		750		250	Cardboard box
	Octogonal container, non returnable	800	464		1000	1150	900	Cardboard box
	Plywood container 600	800	450		650	750	600	Plywood
	Plywood container 850	800	450		845	945	850	Plywood
	Panier	1350	812		1860	2080	3000	Steel
	Steel A container	900	450			1720	1800	Steel
	Coils	1180	720		758	933	3000	
	Spoolless Pack	1000				750	2000	
	Stator	895				1500	1500	
	Stator	1070				2125	2000	

Vocabulary

The various types of conductors require an explanation of the vocabulary ; the following terms are given in IEV 50 (466), section 461-01.

Wire Strand of metal drawn, with a constant circular section.

Bunched conductor A conductor composed of wires assembled together helically, in the same direction and with the same lay, without forming defined layers.

Concentric stranded conductor A conductor composed of a central wire surrounded by one or several adjacent layers of wires being laid helically in same or opposite directions.

Conductor Wire or group of wires, not insulated, to transport electrical current. The conductor can be produced by single or multiwire process. The multiwire process gives a product commonly called "lock".

Stranded Conductor Conductor composed of several wires generally assembled together helically. It could be circular or shaped.

Solid Conductor Conductor composed of a single wire. It could be circular or shaped.

Multiple Stranded Conductor Conductor composed of several stranded or bunched conductors assembled together in one or several layers.

Flexible Conductor Conductor composed of fine wires assembled together so that it can be used in a flexible cable.

Concentrically Stranded Circular Conductor Conductor composed of one or several concentric distinct layers of wires being laid helically in generally opposite directions.

Compacted Conductor Conductor composed of several wires in which the voids between the wires are reduced by mechanical compression or drawing or by an appropriate selection of shape and arrangement of the wires.

Plain Conductor Conductor composed of wires not plated by a metallic protective material.

Metal-Plated Conductor conductor composed of wires plated by a thin layer of an other metallic material.

Metal-Clad Conductor conductor with wires composed of a central core cladded by an other metal with metallurgical bond between the two metals.

Conductor with wires of same diameter This conductor shows wires of one diameter only.

Lay Length The axial length of one complete turn of the helix formed by an individual wire in a stranded conductor.

Direction of Lay The direction of twist of a layer of wires in relation to the conductor axis.

GLOSSAIRE

FRANÇAIS

- Alésage
- Alliage d'aluminium
- Ame ACSR (Fils d'aluminium câblés autour d'un fil central en acier)
- Ame câblée
- Ame circulaire
- Ame circulaire à couches concentriques
- Ame en cuivre
- Ame en torons
- Ame massive
- Ame non rétreinte
- Ame nue
- Ame plaquée de métal
- Ame profilée
- Ame rétreinte
- Ame sectorale
- Ame souple
- Ame tordonnée
- Application électrique
- Application mécanique
- Argenté
- Bobine
- Câble
- Coefficient de dilatation linéique
- Coefficient de température
- Conditionnements
- Conducteurs souples
- Conducteurs ultra-souples en cuivre
- Conductivité I.A.C.S.
- Conductivité thermique
- Densité
- Diamètre de la joue
- Diamètre du tambour
- Dureté
- Etamé
- Fils de soudage
- Ligne aérienne
- Module d'élasticité
- Multifils
- Nickelé
- Nu
- Recuit
- Résistance à la traction
- Résistance électrique
- Tordon
- Toron
- Touret

GLOSSARY

ENGLISH

- Bore
- aluminium alloy
- Aluminium conductor steel reinforced (ACSR)
- Stranded conductor
- Circular conductor
- Concentrically stranded circular conductor
- Copper conductor
- Multiple stranded conductor
- Solid conductor
- non-compacted conductor
- Bare conductor , plain conductor
- Metal-claded conductor
- Shaped conductor
- Compacted conductor
- Sector-shaped conductor
- Flexible conductor
- Bunched conductor
- Electrical application
- Mechanical application
- Silver plated
- Coil , spool
- Cable
- Coefficient of linear expansion
- Temperature coefficient
- Packagings
- Flexible stranded copper conductors
- Extra flexible stranded copper conductors
- I.A.C.S. conductivity
- Thermal conductivity
- Density
- Flange diameter
- Barrel diameter
- Hardness
- Tinned
- Welding wire
- Overhead line
- Modulus of elasticity
- Multiwires
- Nickel plated
- Bare
- Annealed
- Tensile strength
- Electrical resistance
- Bunched wire
- Stranded wire
- Drum

GLOSSAR

DEUTSCH

- Bohrung
- Aluminiumlegierung
- ACSR-Leiterseil (Al-Leiter um einen Stahlkerndraht verseilt)
- Mehrdrähtiger Leiter
- Rundleiter
- Rundleiter aus konzentrisch verseilten Drahtlagen
- Kupferleiter
- Mehrfach verseilte Leiter
- Eindrähtiger Leiter , Massivleiter
- Nicht verdichteter Leiter
- Blanker Leiter
- Metallumhüllter Leiter
- Profilleiter
- Verdichteter Leiter
- Secktorleiter
- Flexible Leiter
- Litzenleiter
- Elektrische Anwendung
- Maschinell Anwendung
- Versilbert
- Spule
- Kabel
- Linearer Ausdehnungskoeffizient
- Temperaturbeiwert
- Verpackung
- Flexible Kupferlitzen
- Hochflexible Kupferlitzen
- I.A.C.S.-Leitfähigkeit
- Wärmeleitfähigkeit
- Dichte
- Flanschdurchmesser
- Kerndurchmesser
- Härte
- Verzinnt
- Schwei(draht
- Freileitung
- Elastizitätsmodul
- Mehrfachdrähte
- Vernickelt
- Blank
- geglüht
- Zugfestigkeit
- Widerstand
- Bündel-litzen
- Litze
- Trommel

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