ASTA
ENERGY TRANSMISSION COMPONENTS

PPE
A member of ASTA Group

CATALOG

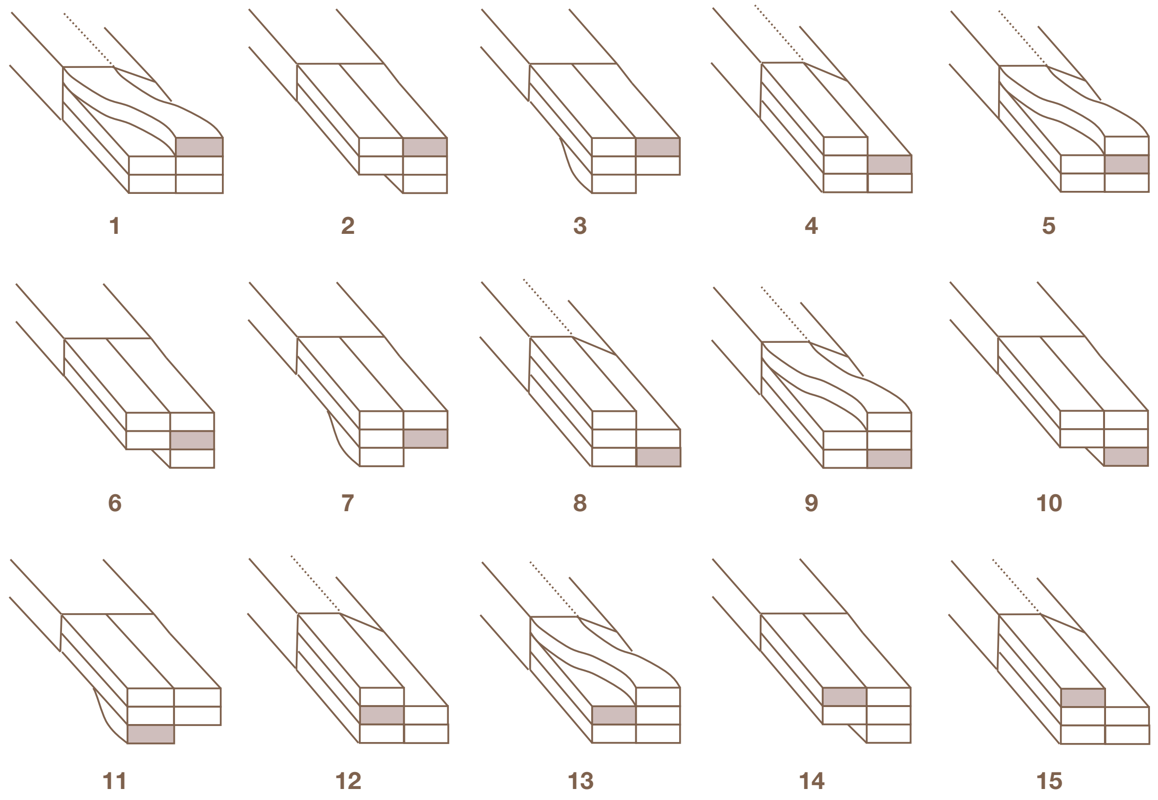
CTC Product

Continuously Transposed Conductor

Continuously Transposed Conductor - CTC – is an assembly of two parallel adjacent stacks, composed by an odd number of enamelled insulated rectangular single conductors. The different type of enamels provide the insulation of each single conductor. The number of conductors can be an odd number from 5 up to 61.

The main CTCs' feature is that each conductor, successively and repeatedly, is transposed through every possible position in the entire conductor cross-section, in a rotating movement. During the transposition, each single conductor stays parallel to the others, without any twist

TRANSPOSITION PROCESS



PAPER INSULATED CTC

After the transposition, the CTC can be over wrapped with an appropriate number of pure cellulose insulation paper tape layers, spirally applied, to provide insulation to the adjacent layers in the coil and surroundings. The number of paper layers wrapped as external insulation can be up to 32 allowing increases of the overall insulation between 0.8 mm and 6 mm (insulation thickness between 0.4 mm and 3 mm).

CTC WITHOUT PAPER

A - STRINGEX

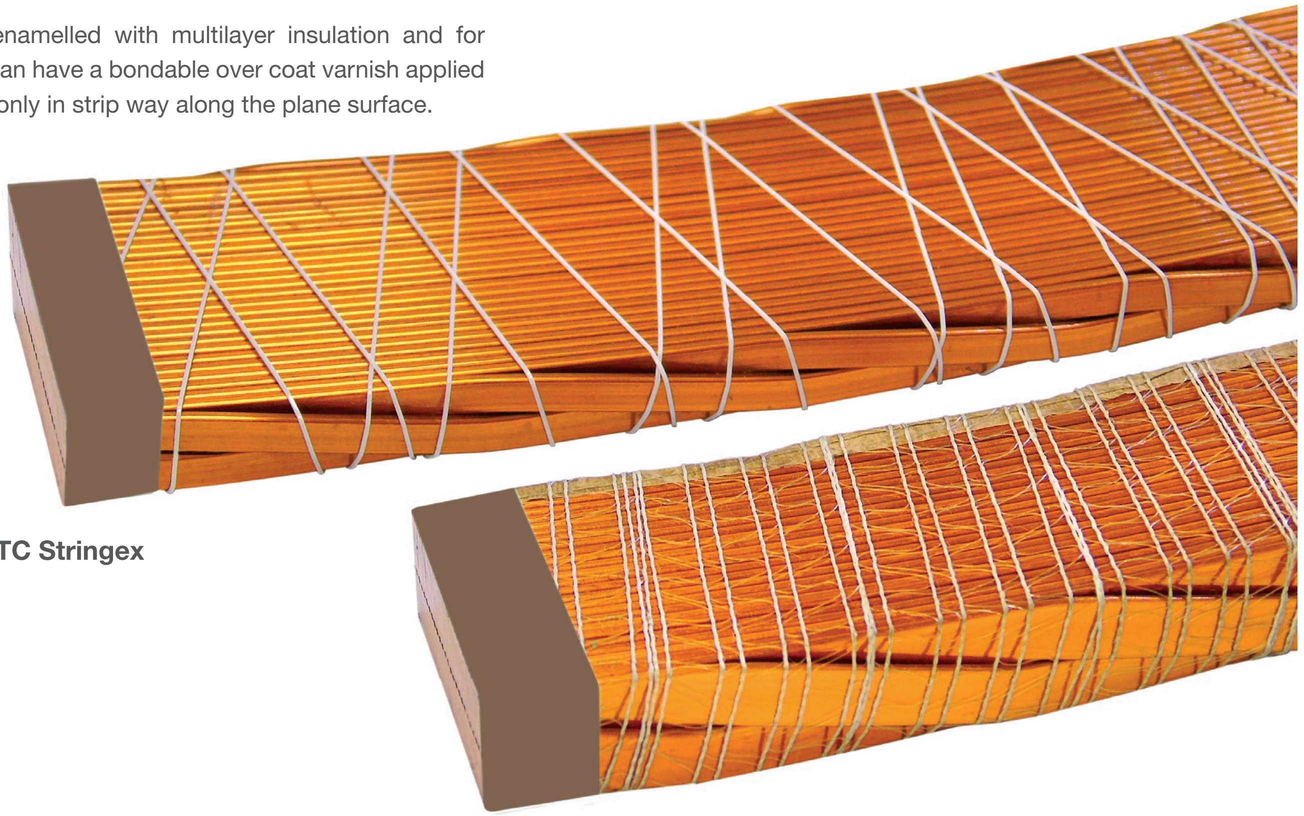
Manufactured without paper, using a tie cord replacing the paper tape wrap.

B - NETTING TAPE

As (A) and the polyester net is used in the place of tie cord.

SINGLE CONDUCTOR CONSTRUCTION

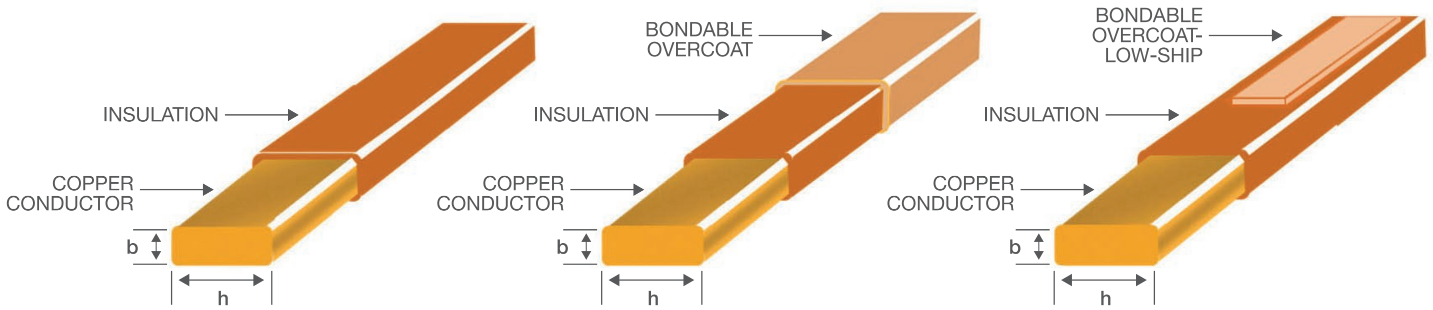
The conductor is enamelled with multilayer insulation and for some applications can have a bondable over coat varnish applied along all surface or only in strip way along the plane surface.



CTC Stringex

CTC Netting Tape

CONDUCTOR CONSTRUCTION



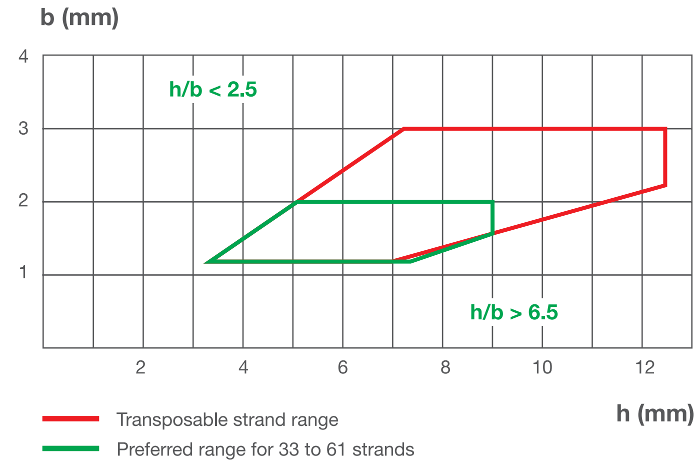
ENAMELLED WIRE **ENAMELLED BONDABLE WIRE** **ENAMELLED BONDABLE WIRE**

SINGLE CONDUCTOR DIMENSION AND MECHANICAL PROPERTIES

Conductor dimensions must be in the range defined by:
THICKNESS “b”: from 1.3 mm up to 3.0 mm (*)
WIDTH “h”: from 3.2 up to 12.5 mm;
RATIO “h/b”: from 2.5 up to 6.5.

(*) Upon request, depending on the general CTC parameters, for thickness can be between 1.0mm and 1.30mm, the maximum width 7.0mm. In this case, the maximum proof stress shall be 170 N/mm².

The single conductor is made of copper. Aluminium conductor is feasible: please, consult PPE by e-mail **esmaltados@ppefios.com.br** for details. The figure on the side shows the range where the single conductors must be.



SINGLE CONDUCTOR MECHANICAL PROPERTIES ACCORDING TO BS 1432

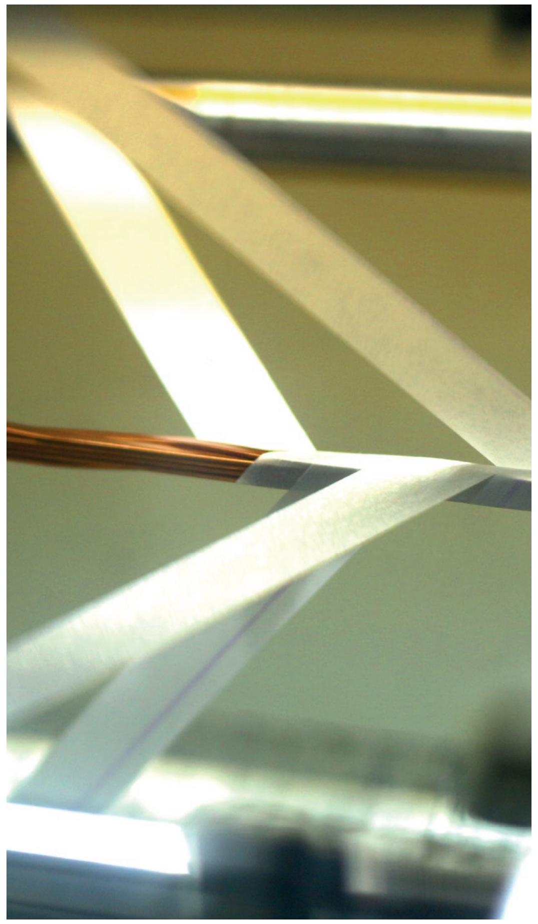
Single conductor with controlled yield strength can be produced according to British Standard BS 1432 (CPR Rp 0.1% designation) or to other designation (Rp 0.2%).

Table 1

CONTROLLED PROOF STRESS COPPER SINGLE CONDUCTOR (BS 1432)

Rp (0.2%)		Rp (0.1%)	
DESIGNATION	VALUE (MPa)	DESIGNATION	VALUE (MPa)
Annealed	60 - 100	CPR1	140 - 220
CPR05	100 - 140	CPR2	170 - 220
		CPR3	220 - 260

Controlled proof stress over CPR3, until maximum 320 N/mm², can be produced under previous consultation. If the minimum yield strength is 250 MPa, a special silver copper alloy shall be used.



SINGLE CONDUCTOR INSULATION

Single conductors can be insulated with different enamels.

Table 2

DESIGNATION	ENAMELS	DIMENSIONS INCREASE (mm)
INVEFORM 120	Polyvinyl formal resins	0.11 ± 0.02
INVETERM 180	Polyesterimide resins	0.11 ± 0.02
INVEMID 220	Polyamideimide resins	0.11 ± 0.02

Over all the enamelled resins an bondable resin overcoat can be used with 0.04+/-0.01mm increase.

Three insulation thermal classes are available: Inveform 120°C, Inveterm 180°C and Invemid 220°C. Enamelled single rectangular conductors are produced according to the standards IEC 60851 test methods, IEC60317-0-2 General Requirements, IEC 60317-18 (INVEFORM 120) and IEC 60317-28 (INVETERM 180) and NEMA-MW 38C (INVEMID 220).

The bondable over coating allows adhesion of the strands after heat treatment at 120°C 24 h. The bondable over coat has a shelf life up to 8 months (or up to 6 months for treatment at 110°C 48 h) for storage at temperature not greater than 32°C. Good bonding result is achieved in laboratory specimens after treatment at 130°C for 16 hours or 120°C for 24 hours or 100°C for 48 hours.

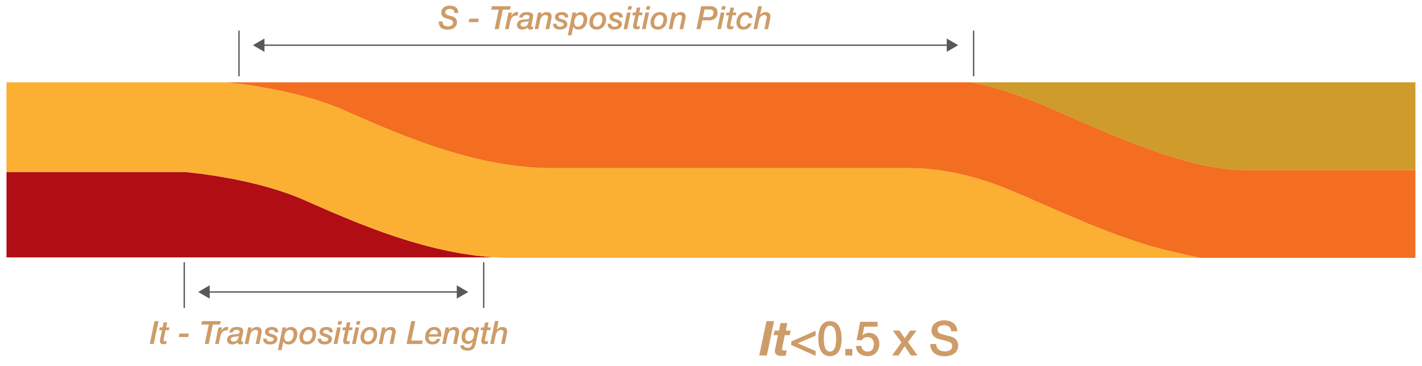
SINGLE CONDUCTOR ASSEMBLAGE: TRANSPOSITION

Windability of CTC on the transformer core is the first property to be satisfied.

Generally the length in which there is a complete transposition of one strand (called stranding pitch) should be at least the perimeter of the inner circumference of the core. This requirement is to assure a minimum flexibility to the CTC to avoid possible damage on the CTC structure.

Three elements must be defined: transposition pitch, transposition length, stranding pitch.

CTC TRANSPOSITION PITCH AND TRANSPOSITION LENGHT



Note
This rule is applied when the transposition pitch S is equal or higher than 56 mm. if the transposition pitch S is less than 56 mm this rule is not applied.

Transposition Pitch (S)
The transposition pitch is the distance between two transpositions. The transposition pitch ***S*** must be greater than ***40 mm***.

Transposition Length – (It)
Transposition length (called also as crossover) is the length required to the strand to go from one side to the other side on the CTC between stack during transposition.

Stranding Pitch
Stranding Pitch is the length where all the strands are transposed.

STRANDING PITCH = **S x n**

S = Transposition pitch
n = Number of single conductors in the cable

Minimum winding diameter
The minimum winding diameter can be calculated with the dimensional characteristics and the stranding pitch by the following formula:

$$\text{MINIMUM WINDING DIAMETER} \quad Di = \frac{S \times n}{\pi}$$

FEASIBILITY OF THE CTC

The following conditions must be checked to define if a certain CTC is feasible:

Minimum Transposition Pitch S

The transposition pitch S must be greater than 40 mm.

It is advisable to calculate the Transposition Pitch according to the transformer minimum winding diameter. The following formula must be used:

MINIMUM WINDING DIAMETER $Di = \frac{S \times n}{\pi}$

Thus, to calculate the maximum Transposition Pitch:

MAXIMUM TRANSPOSITION PITCH $S = \frac{Di \times \pi}{n}$

This maximum transposition pitch must be greater than 40 mm.

Transposition Factor (M)

The feasibility of the CTC is defined by the Transposition Factor M that is calculated as:

TRANSPOSITION FACTOR $M = \frac{S}{h}$

Where
S = Transposition pitch
h = Single conductor width

According to M value the feasibility of the CTC is:
- **M** ≥ **8** - The CTC is feasible;
- **6 < M < 8** - The CTC is possibly feasible but it is critical;
- **M** ≤ **6** - The CTC is not feasible.

Table 3

SINGLE CONDUCTOR ENAMELLED RECTANGULAR WIRE		CONTINUOUSLY TRANSPOSED CONDUCTOR CTC	
Max. Width (h)	12.5	Number of strands (n)	5 up to 61 strands
Min. Width (h)	3.5	Separator thickness (ip)	0.09 0.105
Max. Thickness (b)	3.0	Max. radial dimension (B)	60 [1]
Min. Thickness (b)	1.3 [2]	Min. radial dimension (B)	4
Preferred ratio h/b	2.5 - 6.5	Max. axial dimension (H)	25
		Min. axial dimension (H)	6
Ratio h/b	$\frac{h}{b} = \frac{\text{Width}}{\text{Thickness}}$	Preferred ratio B/H $B/H = \frac{(n + 1) \times (b + iE)}{4 \times (h + iE)}$	Radial/Axial radio less or equal to 8

All dimensions in millimetres (mm)

Notes
1) Dimension without insulation paper.
2) Depending on the preferred ratio value.

Continuously Transposed Conductor

CTC PAPER INSULATION

The CTC can be finished by wrapped paper insulation. The papers used in the insulation can be seen in the table 4.

Table 4

INSULATION PAPERS MAIN CHARACTERISTICS

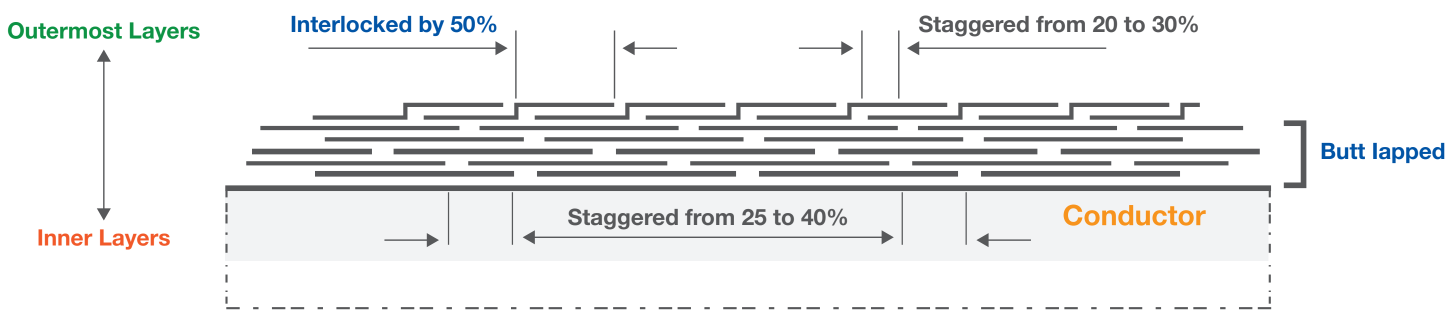
TYPE OF PAPER	RECOMMENDED THICKNESS (mm)	APPLICATIONS	MAIN PROPERTIES
Calendered kraft paper	0.065 - 0.105	General purpose	High tan δ, high density and dielectric strength
Calendered crepe paper	0.076	Inner and outermost layers	High mechanical characteristics
Upgraded paper	0.06 - 0.09	Inner and outermost layers	High thermal properties
Wound cord	0.45	Paper-less application	No bulging of the paper; CTC free from oil pocket among the windings; Better cooling efficiencies; Better space factor of the windings; Smaller O.D. of the transformer
Polyester Net	0.56		

Notes
A - All papers for electrical applications according to IEC554;
B - Other types of insulation may be analysed upon request.

PAPER ARRANGEMENT

Unless otherwise agreed with Customer, the insulation shall consist of three layers of 0,09 mm upgraded paper at least. The paper covering shall be applied according to the following arrangement:
- Papers are wound in the same direction.
- The inner layers papers' shall be butt lapped and staggered from 25% to 40%. The two outmost layers shall be wound interlocked by 50%.

Agreement with the Customer will be required in case of change of thickness of one or more papers or the type of arrangement, in order to reach the required paper insulation thickness.



Continuously Transposed Conductor

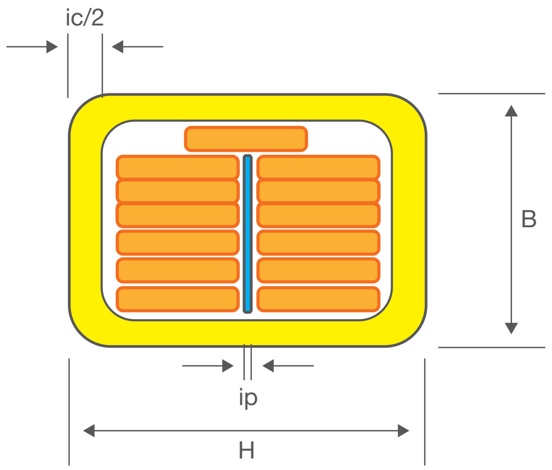
CALCULATION OF THE PAPER INSULATED CABLE OUTER DIMENSIONS

Maximum dimension in axial direction:

$$H = 2 \times (h + iE) + ip + ic + Kh \qquad (1.1)$$

Maximum dimension in radial direction:

$$B = \left[\left(\frac{n+1}{2}\right) \times (b + iE)\right] + ic + Kb \qquad (1.2)$$



Where:
H = Axial cable dimension;
B = Radial cable dimension
h = Axial bare single conductor dimension;
b = Radial bare single conductor dimension
Kh = Maximum plus tolerance 0.10 mm for axial dimension
Kb = Maximum plus tolerance for radial dimension (values in table 5)
n = Number of single conductors in the cable
iE = Increase in dimensions due to enamel (0.12 for PVF and 0.17 for PVF plus Epoxy)
ip = Thickness of separator between the stacks
ic = Paper covering (in case of cable without paper **ic/2** is the thickness of the plastic wire or polyester net)

Table 5

Kb VALUES

NUMBER OF STRANDS	S/h ≥ 7 and b < 2mm and Rp02 < 180MPa	ALL OTHER CASES
Up to 21	0.20	0.30
From 23 to 27	0.25	0.50
Form 29 to 35	0.35	0.60
Greater than 35	0.70	1.00

Unless specified by the Customer, the minimum outer dimension is: **H:** +0 / -0.5mm;
B: + 0 / -0.5mm

Interleaving paper

An interleaving paper between the two stacks is inserted if required by the Customer. We suggest 0.105 mm thickness if there is no specified value by the Customer.

The width (W) of the interleaving paper is calculated by the following formula:

$$W = \frac{(n-3) \times (b+3)}{2}$$

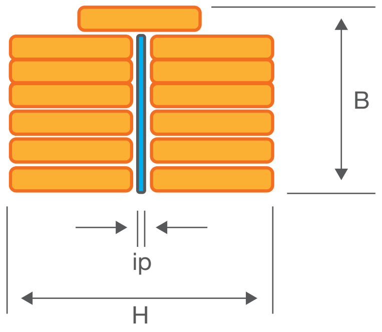
Width of the paper is the W value with approximation to the lowest pair unit (example: if W = 7.36 we choose 6 mm paper). The minimum width of the interleaving paper is 6 mm.

External Dimensional Tolerances

External dimensions, obtained by formulas (1.1 and 1.2), are tested under pressure of 100 N/cm² or other pressure value required by the Customer.

STRINGEX OR NETTING TAPE DIMENSIONAL PROPERTIES

Calculation of the axial and radial dimension is according to the following:



Maximum dimension in axial direction:

$$H = k \times 2 \times (h + iE) + ip + ic^* \pm TOLL$$

Tolerance ±0.15 mm

n	k´	ic	icn	iP
11 - 61	1.01	0.45	0.56	0.105

b ≥ 2.10 mm   h ≤ 9.30 mm k = 1.02

Maximum dimension in radial direction:

$$B = k' \times \left[\left(\frac{n+1}{2}\right) \times (b + iE)\right] + cB + ic^* \pm TOLL$$

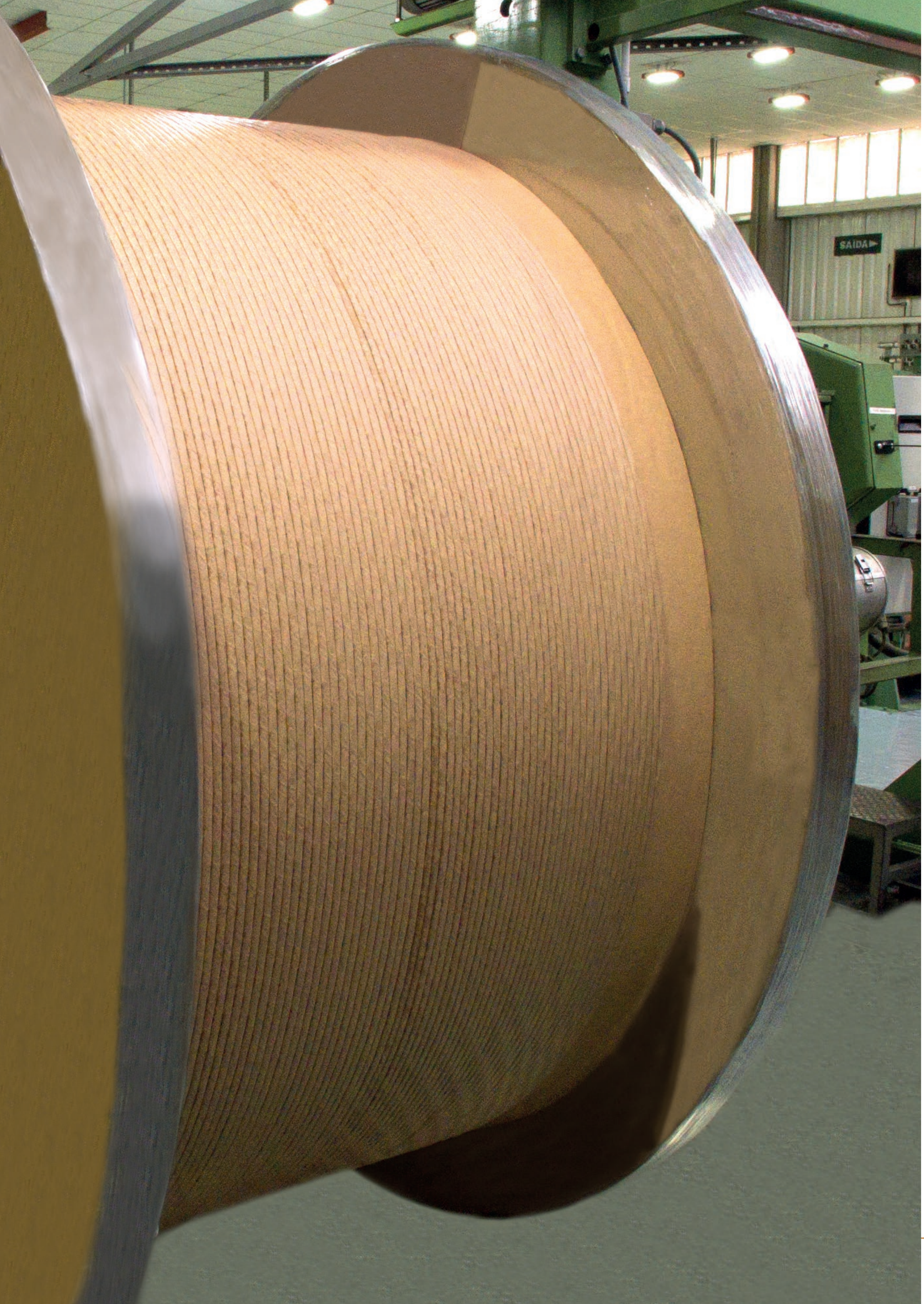
(*) ic or icn

Tolerance ± 0.50 mm.
For single conductor with **h** ≤ 6.0 mm tolerance is + 0.30 mm – 0.80 mm

n	k´	ic	icn
11 - 21	1.04	0.45	0.56
23 - 27	1.035	0.45	0.56
29 - 37	1.03	0.45	0.56
39 - 49	1.025	0.45	0.56
51 - 61	1.015	0.45	0.56

Where:
H = Axial cable dimension (100 N/cm²)
B = Radial cable dimension (100 N/cm²)
h = Axial bare single conductor dimension
b = Radial bare single conductor dimension
k = 1.01 Axial shape factor (for b > 2.10 mm and h > 9.30 mm k =1.02)
k' = Radial shape factor (values in table)
n = Number of strands in the cable
iE = Increase in dimensions due to enamel (0.12 mm for enamelled strands and 0.17 mm for enamelled + epoxy coated strands)
ip = Thickness of separator between the strands stacks (Upgraded 0.09 mm or Upgraded High Density 0.105 mm paper or according to Customer requirements)
ic = plastic wire covering (0.45 mm)
icn = polyester net covering (0.56 mm)
cB = thickness of the bottom separator (generally is used calendered crepe paper or Nomex® paper)
TOLL = tolerance (axial or radial)

A protection paper (sacrifice paper) is applied in order to avoid contamination the cable and this is removed before the winding point just pulling a plastic wire inserted along the transposed conductor. An adhesive tape takes together the cut sacrifice paper.



Drums for Transposed Conductors

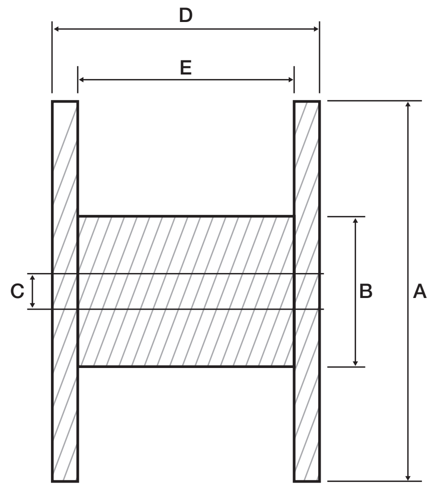


Table 6

STANDARD WOODEN DRUMS

TYPE	MAX CONTENT (Kg)	DIMENSIONS (mm)				
		A	B	C	D	E
B050	200	800	500	84	350	250
B060	400	1000	600	84	350	250
B100	1100	1350	1000	82	610	486
B130	2100	1650	1290	82	810	686
B140	4000	2000	1400	82	1010	860
B160	3000	2000	1600	82	1010	860

Drums type B100 - B130 - B140 - B160 may be fitted with separators to permit parallel winding of 2 or more lengths.

ORDERING

When ordering PPE Continuously Transposed Conductors, the following information are requested:

- number of strands and their nominal dimensions
- type of copper and type of enamelled wires (with or without bondable epoxy varnish)
- minimum winding diameter
- total paper thickness and paper type
- interleaving paper and its thickness
- required length and type of drum

Please use our card for Contract Review that is available by PPE Sales Dept. or use the e-mail esmaltados@ppefios.com.br

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