

1. This Specification governs the quality of continuously transposed Copper cable exactly similar to specification AA28129 except following modification /additional requirements. The cable shall not be manufactured earlier than 30 days from date of dispatch since it has a limited shelf life.  
In case on any conflict between AA28129 & TRE036, TRE036 shall prevail.
2. An extra coating of Semi cured ('B' stage) epoxy enamel shall be given over PVA enamel) on all the conductors. The coating shall be tack-free at room temperature and it shall be able to fully cure when heated at 130°C for 6 hours. The increase in dimension due to epoxy coating shall be  $0.06 \text{ mm} \pm 0.02 \text{ mm}$  and due to enamel coating increase in dimensions shall be  $0.085 \pm 0.025 \text{ mm}$ .
3. Nominal value of 0.1% proof stress of conductor shall be specified on order.
4. Tolerance on overall width and thickness (bare strip + PVA enamel + epoxy) of individual conductor shall be as per Annexure 2 of this document.
5. Paper used for outer coverings shall comply to AA 21111 or as specified in order.
6. Insulation test between strips as per Cl. 12.1 of AA 28129.
7. In order to check the bonding strength of epoxy powder coating , samples after curing should be subjected to "Radial bending test" as per enclosed Annexure-1.
8. Test certificate shall be issued indicating observed and specified values of dimension and test as per Cl. 13 of AA 28129 and Cl. 6 & 7 of TRE: 036. Packing and marking will be as per Cl. 14 of AA 28129. Packing shall be seaworthy and drums should be kept in a container/ Crate to avoid ingress of moisture in transit.

REV 08	DATE 08.9.18	ALT CHD	REV 07	DATE 05.9.18	ALT CHD.	-sd- -sd-	REV 04	NAME	SIGN	DATE
Annexure 1 & 2 updated.			Clause 5,6,7,8 of Annexure-2 revised.				PREP	S.K.MAHAJAN	-sd-	09.12.07
							APPD	J.S.KUNTIA	-sd-	09.12.07
DWI/TCB/TRE/010										

## ANNEXURE-1

### RADIAL BENDING STRENGTH TEST FOR EPOXY BONDED CTC CABLE

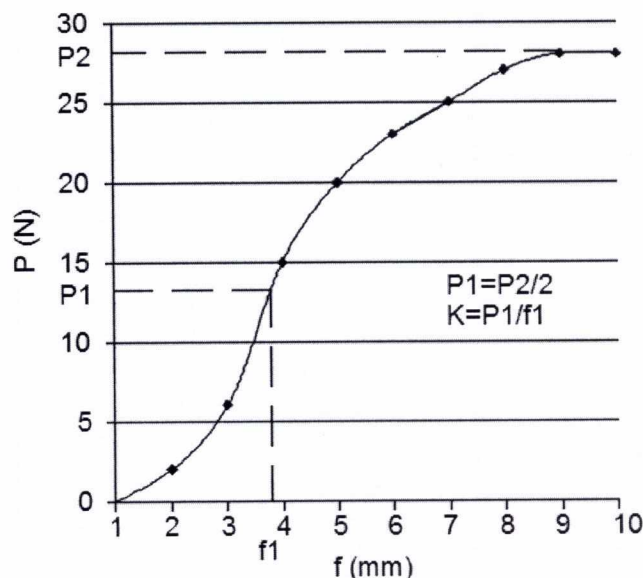
#### 1. Determination of bonding strength radial bending strength test

The bonding properly is the property of proper bonding of various strands of CTC after curing.

In order to establish the proper bonding the test method as per CI 4.0 shall be followed. From the tests a curve of "P" as function of "f" is obtained, where P is the force on the cable [N]  
f is the deflection or flexion [mm]

The curve gives:

- The value of the maximum load P2
- The ratio K corresponding to the ratio between the half of the maximum load and the corresponding deflection:  $K = P1/f1$



RADIAL BENDING STRENGTH

#### 2. Limitations & Assumptions

- The ratio between radial dimension RD of the bare CTC and axial dimension AW of the bare CTC is:  
 $< 5.0$  for CTC made with not bondable strands  
 $< 4.5$  for CTC made with bondable strands

$$RD/AW = \frac{((n+1)/2)(t+e+Ie)}{2(b+e+Ie)}$$

where,  $e+Ie$  = double-sided thickness of enamel and epoxy if any

- The radial strand dimension  $t \leq 3.2$  mm
- The axial strand dimension  $b \leq 12.5$  mm

#### 3. Calculation & Tables

The value of  $P2 = \epsilon \times b \times n^2 \times t^2 \times 9.81/d$  (N)

Where:

$\epsilon$  = coefficient taking into account the number of strands of the CTC as per Table-1

d = distance between the supports

= 150 mm for CTC up to 31 strands

= 300 mm for CTC with more than 31 strands

The average value of K shall be greater or equal to the value calculated as

$$K = \eta \times E \times b \times t^3 \times ((n-2)^3 + 2)/d^3 \text{ (N/mm)}$$



Where,

E is the Young modulus of the copper strand & its value is:

- For  $R_{p0.2\%} \leq 180$  MPa is considered equal to 80000 N/mm<sup>2</sup>
  - For  $R_{p0.2\%} > 180$  MPa and  $R_{p0.2\%} \leq 230$  MPa is considered equal to 100000 N/mm<sup>2</sup>
  - For  $R_{p0.2\%} > 230$  MPa is considered equal to 110 000 N/mm<sup>2</sup>
- $\eta$  is coefficient depending on the number of strands as per Table-2

**Table 1 (For  $\epsilon$ )**

Number of strands	$R_{p0.2\%} > 230$ MPa	$230 \text{ MPa} \geq R_{p0.2\%} > 180$ MPa	$R_{p0.2\%} \leq 180$ MPa
Up to 23	7.0	5.4	4.4
25	6.6	5.1	4.2
27	6.2	4.8	4.0
29	5.8	4.3	3.7
31	5.0	3.9	3.2
33 to 41	4.6	3.5	3.0
43 to 51	4.0	3.1	2.8
53 to 61	3.6	2.9	2.4
63 to 71	3.2	2.6	2.0
Over 73	2.9	2.2	1.8

**Table 2 (For  $\eta$ )**

Number of strands	$t < 2$ mm	$t \geq 2$ mm
Up to 15	0.90	0.90
17 to 23	0.90	0.70
25	0.75	0.50
27	0.60	0.45
29	0.55	0.40
31	0.35	0.25
33 to 41	0.40	0.24
43 to 51	0.24	0.22
53 to 61	0.19	0.17
63 to 71	0.17	0.14
Over 73	0.14	0.12

#### 4. Test Method

4.1 **Specimen** : 3 nos. CTC specimens as below shall be prepared for each supply.

Length = 450 mm for CTC with  $n < 33$

Length = 600 mm for CTC with  $n \geq 33$

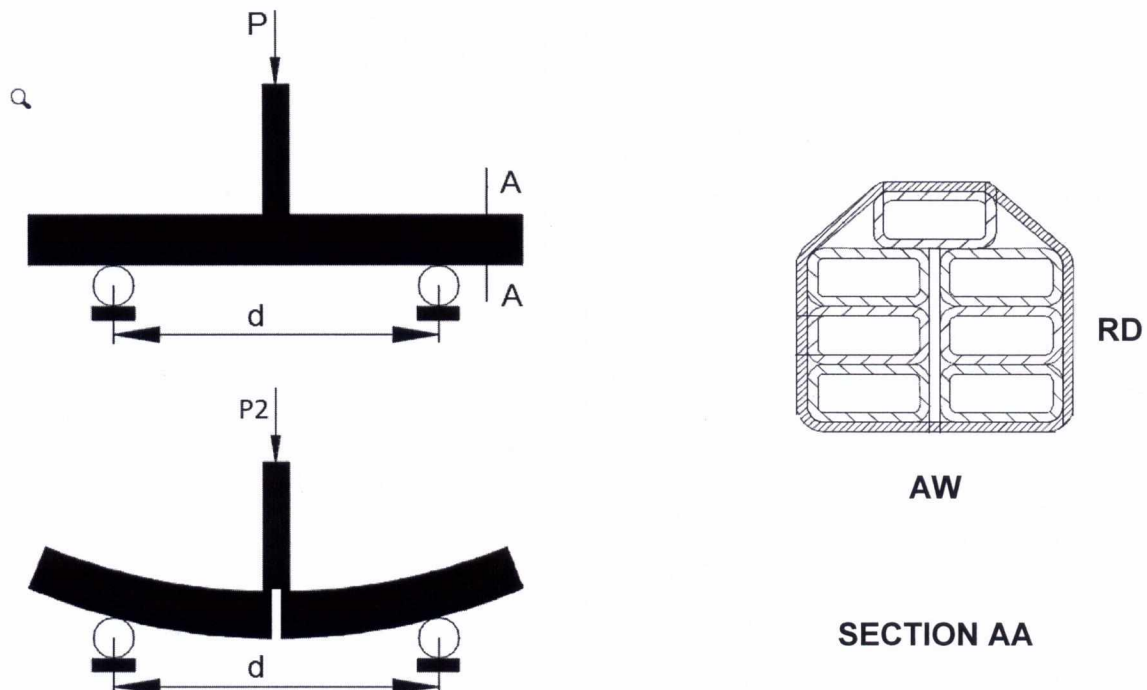
4.2 **Sampling** : Each specimen shall be cut from the original drum without bending the cable. Strands shall be locked in a suitable way.

4.3 **Thermal treatment** : The specimens shall by means of a device be shaped to a diameter of 1000 mm and axially loaded with side jaws. Treatment in an oven with air circulation at a temperature of  $120 \pm 5^\circ\text{C}$  for 24 hours or at  $110 \pm 5^\circ\text{C}$  for 48 hours. Cooling at room temperature for at least 6 hours.

#### 4.4 Test Method

Each sample shall be placed over the cylindrical supports of the flexion machine-with the concave part towards the top and the convex part towards the bottom of the flexion machine.

In case of CTC with ratio  $RD/AW > 3$ , it is convenient to take the specimen in the correct position using suitable side-roll supports, without applying any stress.



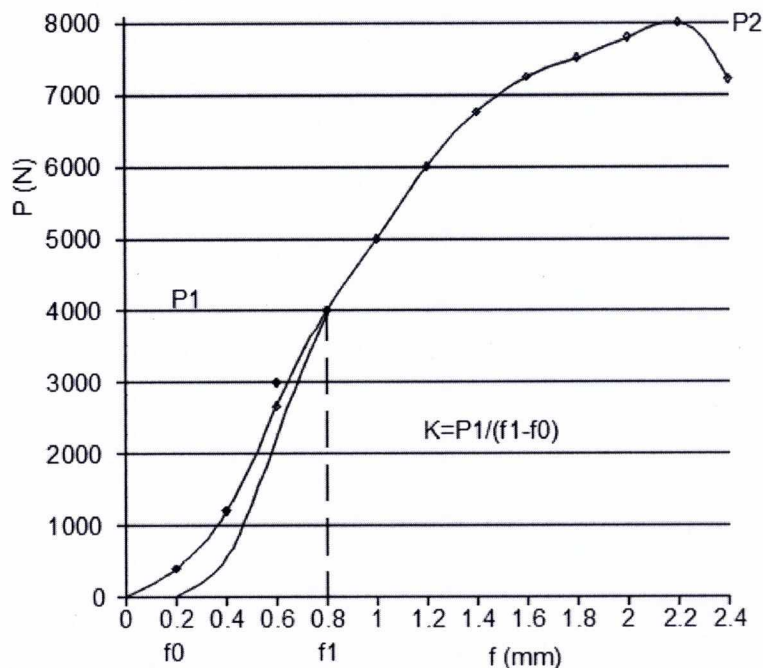
5.0 **Results** - The parameters P2 & K are calculated and average value shall be greater than the values required in Cl. 3.0.

#### 6.0 Detail of test set up:

Flexion machine is composed by a dynamometer, a support device and a plotter. Support device consists of two cylindrical supports at distance of 150 or 300 mm depending on the number of strands of the CTC.

- 150 mm for CTC with  $n < 33$
- 300 mm for CTC with  $\geq 33$

The dynamometer is used in compression with a jaw connected to a cylinder in order to apply the flexional load in the middle of the specimen. The plotter is used in order to plot the curve of load and flexion. The support device is placed at the bottom of the dynamometer and the arrow is measured with a strain gauge connected to a touch sensor to the bottom of the specimen. The touch sensor shall touch an area coincident with the width of the strand, when the spring of the touch sensor is put in tension. On the plotter the zeroing of the paper is done. The load is gradually applied to the specimen, plotting the diagram of load and arrows.



Example :  $K = P1/(f1-f0) = 4000/(0.8-0.2) = 6660 \text{ N/mm}$

In order to keep the measurement independent of settling of paper and transpositions, the following test procedure is prescribed:

- Make a dummy test with one of the specimens. This test gives a maximum P2 value where the bonding breaks.  $P1 = P2/2$  is calculated.
- On each of the other specimens the load shall be raised up to the theoretical value P1 and then decreased down to zero. Gives a remaining small flexion f0, which is the new, zero point for the flexion.

A load is then applied up to the break of the bonding properties of the specimen. This point is the P2 value for that specimen and is recognized in the diagram when the plotting mark is going towards the bottom showing a significant loss of bonding adhesion.

$P1 = P2/2$  is calculated.

- From the load/flexion curve, corresponding P1 and f1 values can be read. Calculate the ratio  $K = P1/(f1-f0)$



## ANNEXURE-2

### COVERED DIMENSIONS OF TRANSPOSED CABLES

1.	Transposing Factor (Tp)		$T_p = \pi \times ID / (n \times b)$
2.	Nominal Covered Axial Width (AW)		$AW = 2 \times (b + e + le) + P + l_{cp}$
3.	Tolerance on AW		+0.15 / -0.10
4.	Nominal Covered Radial Depth (RD)		$RD = (n+1)/2 \times (t + e + le) + P$
5.	Tolerance on RD		
	n	If $T_p \geq 7$ & $t < 2.00$ & $R_p \leq 170$ MPa	If $T_p \geq 5$ & $t \geq 2.00$ & $R_p > 170$ MPa
	$\leq 21$	+ 0.30 / -0.20	+ 0.50 / -0.15
	23 to 35	+ 0.40 / -0.25	+ 0.60 / -0.25
	37 to 55	+ 0.80 / -0.40	+ 1.30 / -0.40
	> 55	+ 1.10 / -0.60	+ 1.40 / -0.50
6.	Tolerance on dimension t or b		
	$\leq 3.15$		$\pm 0.030$
	3.16 to 6.30		$\pm 0.050$
	6.31 to 12.50		$\pm 0.070$
	12.51 to 16.00		$\pm 0.100$
7.	Overall covered dimension AW & RD shall be measured under pressure of 100 N/cm <sup>2</sup> .		
8.	Abbreviation		
	ID = Inner diameter of winding n = No. of single strands in transposed cable b = Nominal width of bare single strand t = Nominal thickness of bare single strand e = Nominal increase due to enamel le = Nominal increase due to epoxy P = Nominal thickness of paper (both side) lcp = Inter column paper, if specified (100 $\mu$ m) Rp= 0.1% proof stress value  <div>(All dimension are in mm, if not specified)</div>		