

	CORPORATE PURCHASING SPECIFICATION			AA 281 28											
				Rev. No. 06											
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PAPER COVERED RECTANGULAR COPPER CONDUCTOR (0.1% PROOF STRESS)															
1.0 GENERAL: This specification governs the quality requirements of high conductivity work hardened rectangular copper conductor covered with atleast three layers of paper and suitable for use in hot insulating oil. Paper shall conform to BHEL specification AA 21111. The material in oil shall have temperature index of atleast 105.															
2.0 APPLICATION: Used for windings of transformers.															
3.0 COMPLIANCE WITH NATIONAL STANDARDS: There is no National standard covering this type of material. However, assistance has been derived from IEC:60317-27-1990 : Specification for particular Type of Winding Wires-paper Covered Rectangular Copper Wires.															
4.0 DIMENSIONS:															
4.1 Conductor of any size within the following range shall be ordered. <table style="width: 100%; border: none;"> <tr> <td style="width: 60%;">Thickness</td> <td>: 1 to 6 mm</td> </tr> <tr> <td>Width</td> <td>: 3.2 to 18 mm</td> </tr> <tr> <td>Area</td> <td>: 5 to 90 mm²</td> </tr> <tr> <td>Width/Thickness</td> <td>: 1.3 to 8</td> </tr> <tr> <td>Radial insulation thickness on the conductor</td> <td>: 0.15 to 2.6 mm</td> </tr> </table> However paper insulated wire with radial insulation above 2.6 mm can also be ordered in special cases.						Thickness	: 1 to 6 mm	Width	: 3.2 to 18 mm	Area	: 5 to 90 mm ²	Width/Thickness	: 1.3 to 8	Radial insulation thickness on the conductor	: 0.15 to 2.6 mm
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4.2 Bunched wire (number of insulated conductors stacked axially or radially and then insulated overall) with maximum covered diagonal of 25 mm can also be ordered. Size range or individual bare strip shall be within the range indicated in Cl.4.1.															
4.3 Round edge (semi-circular edge) wire with the size limitation as per Cl.4.1 can also be ordered.															
Revisions : Cl: 33.5.28 of MOM of MRC-E			APPROVED : INTERPLANT MATERIAL RATIONALISATION COMMITTEE-MRC (E)												
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4.4 Conductor size, radial insulation thickness and covered dimensions shall be as stated on the order. Total weight of conductor, the length of wire per drum and total number of drums shall also be stated on the order. The length per drum is very important. It shall neither be less nor be more than the specified.

4.5 Weights indicated in an order are nominal and can vary within $\pm 2\%$ considering all allowed tolerances on dimensions and on corner radius.

Excess weights more than 2 percent shall not be admissible in any circumstances.

5.0 TEST SAMPLES:

5.1 Paper :

The supplier shall send test certificate for papers for all the tests as per BHEL specification AA 211 11 for approval. The test report shall be sent for each lot of paper and of different thicknesses received from the paper mill which are to be used in the manufacture of BHEL paper covered conductors.

In the absence of proper test certificate 20 sheets of size 300 X 300 mm of paper from each lot and of different thicknesses shall be supplied for our testing and inspection, with machine direction and cross machine direction marked on each sheet.

5.2 Finished Conductor:

5 metre long sample of covered conductor shall be supplied for testing and inspection.

6.0 TEST METHODS :

Unless otherwise specified, the test shall be conducted in accordance with relevant methods of IEC 60851.

7.0 CONDUCTOR :

7.1 Grade of Material :

The conductor shall be manufactured from ETP grade copper conforming to BHEL specification AA 12024. Except that it shall be work hardened and meet the requirements of 0.1% proof stress as per clause 7.4 and resistance as per clause 7.5.

NOTE: Manufacture of copper conductors from continuous cast copper bars is preferable provided all other acceptance parameters and conditions remains same.

7.2 Tolerances on Dimensions:

<u>Width or Thickness, mm</u>		Tolerances $\pm$ mm
Over	Upto and Incl.	
--	3.15	0.030
3.15	6.30	0.050
6.30	12.50	0.070
12.50	--	0.100



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7.3 Radius on corners:

<u>Thickness of Conductors, mm</u>		<u>Corner Radius, mm</u>	<u>Tolerance, %</u>
Over	Upto and Incl.		
--	1.00	Semicircular	± 25
1.00	1.60	0.50	
1.60	2.24	0.65	
2.24	3.55	0.80	
3.55	--	1.00	

NOTE: In case of round edge wire tolerance on radius shall be $\pm 25\%$.

7.4 0.1% Proof stress (IS: 1608):

The nominal value of proof stress shall be selected from the following and shall be as sated in the order.

7.4.1 Nominal value 0.1% proof stress:

115,125,135 and 145 MPa

7.4.2 Tolerance:

+ 15% and - 10%

Tests shall be carried out on one sample only taking 50 mm gauge length as per IS : 1608. However, any other value of proof stress can also be ordered.

7.5 Electrical Resistivity :

The resistivity at 20°C , when measured directly on the sample in “as received condition” shall not be grater than $0.01777 \text{ ohm-mm}^2/\text{metre}$ (Refer Appendix B of IS:613 for temperature correction factor).

7.6 Joint :

All Joints in the conductor shall be resistance welded and subsequently cold worked.

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8.0 PAPER :

8.1 Grade of paper:
Kraft paper shall conform to BHEL specification AA 21111.

8.2 Thickness:
The thickness of paper shall be within limits of 40 and 125 microns both inclusive and shall also comply with the requirements of clause 9.4.

9.0 APPLICATION OF PAPER :

9.1 General :
To prevent the inclusion of copper dust or other extraneous matter under the paper covering, the conductor shall be fully cleaned by felt pads or other suitable means immediately before entering the paper covering machine. Each layer or paper shall be continuous firmly applied and substantially free from creases. No bonding or adhesive material shall be used except to anchor the ends of paper. Any such bonding or adhesive material shall have no deleterious effect on transformer oil, insulating paper or the electric strength of the covering. When papers of different thicknesses are used, the outermost paper shall be the thickest. The thickness of the paper shall be progressively increased from the innermost to the outermost layers.

9.2 Width of paper:
For butt wound layers, the width of paper shall not exceed 1.5 times the sum of the width and the thickness of the conductor or 20 mm whichever is lower.

For overlap wound layer, the width of the paper shall be between 1.35 to 1.5 times the width of the paper for butt wound layers or 25 mm whichever is lower.

9.3 Overlap:
Paper tap wound with each turn overlapping the preceding turn by not less than 25 to 35 percent of the paper width, with a minimum of 3 mm overlap.

9.4 Minimum number of layers of paper covering:

The paper covering shall contain a minimum number of layers as indicated below. Total number of layers shall be same in all the drums of particular size of an order.

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Radial paper covering mm 1	Min. Number of paper covering 2	Max. thickness of paper for butt wound layers micron 3	Min. thickness of paper for overlap wound layers micron 4
0.15	3	45	45
0.20	4	45	45
0.25	4	55	55
0.30	5	65	65
0.35	6	65	65
0.40	7	65	65
0.45	7	65	65
0.50	8	65	65
0.55	9	65	65
0.60	9	65	65
0.65	10	65	65
0.70	10	65	65
0.75	11	65	65
0.80	12	65	65
0.85	13	65	65
0.90	13	65	65
0.95	14	65	65
1.00	14	65	75
1.05	15	65	75
1.10	15	75	75
1.15	16	75	75
1.20	16	75	75
1.30	17	75	75
1.40	18	75	75
1.50	20	75	75
1.60	21	75	75
1.70	23	75	75
1.80	24	75	75
1.90	25	75	75
2.00	27	75	75
2.10	28	75	75
2.20	29	75	75
2.30	31	75	75
2.40	32	75	75
2.50	33	75	75
2.60	34	75	75

Note: 1. Order shall indicate minimum number of paper layers when radial covering is more than 2.6 mm in exceptional cases.



2. Paper thickness indicated in column 3 and 4 are nominal thickness. 63 and 64 micron nominal thickness declared by a few manufactures shall be acceptable against 65 micron requirement of this table.

3. For radial paper thickness not specified in column 1 above, paper covering arrangement shall be as per the nearest lower radial insulation in the table. For example, for radial insulation of 0.33 mm radial insulation shall be followed.

9.5 Arrangement of layers:

All the layers shall be applied in the same direction, all except the outermost layer shall be butt wound and the outermost layer shall be overlap wound. Within each group of papers, the position of the butt joints of layer relative to the layer below shall be progressively displaced by approximately 30 percent of the paper width with a minimum of 3 mm. However, this displacement shall be about 50% of paper width when there are only two butt wound paper layers in a group.

9.6 Wax Coating:

When specified on order, a coating of paraffin wax confirming to IS:4654, of thickness not exceeding 0.02 mm shall be applied on the bottom flat sides of fully paper covered conductor. Wax shall be applied only on one side of covered width of the conductor.

10.0 INCREASE IN DIMENSIONS DUE TO COVERING :

10.1 Increase in Dimensions :

The increase in dimensions due to covering shall have tolerance as stated below:

<u>Increase due to the covering, mm</u>		Tolerance, percent
Over	Upto and Includ.	
0.25	0.5	+0 , -10
0.5	1.3	+0 , -7.5
1.3	-	+0 , -5

10.2 Measuring Equipment :

The measurement shall be made with a suitable ratchet micrometer. The spindle and anvil of the micrometer shall have a diameter of 5 to 8 mm.



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10.3 Measuring Method:

Overall thickness shall be measured at three positions not less than 100 mm apart. The measurements shall be made on completely straight parts of the conductor. The measurement shall include at least one overlap. The average of the three results shall be reported as the overall thickness. The covering shall be removed by any method which does not damage the conductor for three positions used for the measurement of the conductor for three positions used for the measurement of overall thickness and conductor thickness measured at these positions. The average of the three results shall be reported as conductor thickness.

The difference between the overall thickness and the conductor thickness shall be reported as the increase in dimensions due to covering.

10.4 Counter check :

The increase in dimensions due to covering shall also be counter checked by adding up the thickness of paper used in each layer. Radial build up due to the outermost 25 percent overlap wound layer shall be taken as 1.5 times the thickness of paper used. The thickness of paper shall be measured by ratchet micrometer by stacking the tapes of paper in different layer one above the other. However, the thickness of overlap layer shall be separately measured. Paper tape shall not be folded to form two or more tapes. Length of paper tapes shall not be less than 150 mm. Five measurements shall be made distributed over the stack. The paper thickness shall be computed by dividing by five the mean of the five readings.

- 10.5** Radial insulation so computed in CI 10.4 shall not be less than the minimum allowed (considering the appropriate tolerance) as per CI 10.1.

10.6 Maximum overall Dimension:

Overall dimension shall not exceed the sum of the maximum bare dimension and the maximum increase in dimension due to covering permitted.

11.0 SPECIFIC REQUIREMENTS FOR BUNCHED WIRE:

- 11.1** To facilitate proper bunching without any tearing of the paper, paraffin wax on mating surfaces of two or more strips (each covered with individual paper insulation) shall be applied by the manufacture. Total thickness of wax coating shall not exceed 0.02 mm. Extra built up to this extent, i.e. 0.02 mm over specified covered dimensions shall be allowed.

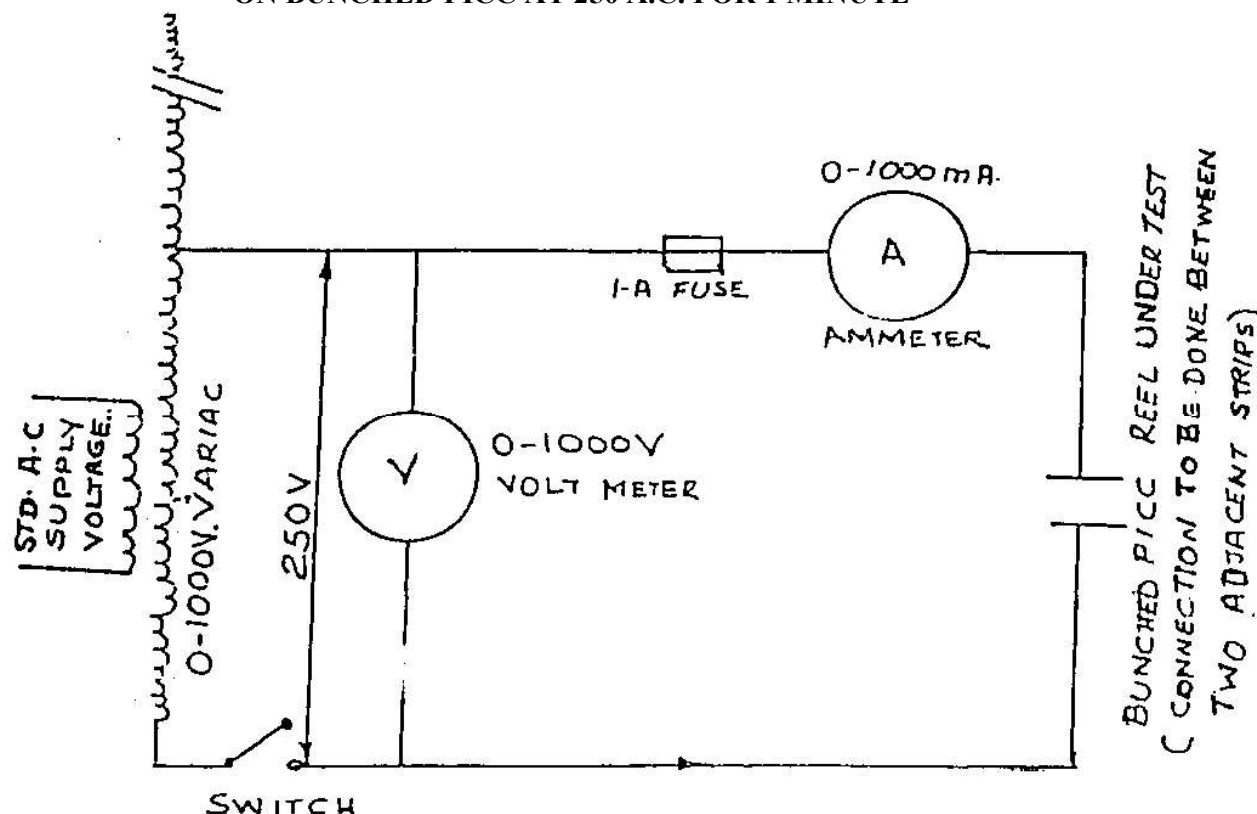
11.2 Insulation Test :

The insulation test at 250 V, AC for 1 minute shall be conducted on all drums, between conductors. A fuse wire of 1 ampere rating shall be connected in series with test specimen. The drum shall be considered to have passed the insulation test if charging current is less than 1 ampere i.e. fuse wire is not fused. An ammeter shall also be connected in the circuit to measure leakage current between adjacent strands of bunched wire.

The test setup shall be as given below :



**CIRCUIT DIAGRAM FOR INSULATION TEST
ON BUNCHED PICC AT 250 A.C. FOR 1 MINUTE**



- 11.3 The starting end of the bunched wire shall project outwards from all the drums. Individual strips be separated at this end during insulation test.

12.0 TEST CERTIFICATE:

Unless otherwise specified, three copies of test certificates shall be supplied alongwith each consignment .In addition, the supplier shall ensure to enclose one copy of the test certificate along with their despatch documents to facilitate quick clearance of the material.

The test certificate shall bear the following information:

AA 281 128 (Rev 06): Paper covered rectangular copper conductor (0.1% Proof stress).

BHEL Order No.

Manufacturer's / Supplier's Name

Trade mark, if any

Bare conductor size

Over all wire size

Increase in dimensions due to covering

No. of layers and thickness of paper of each layer

No. of drums / Net weight

Test values obtained for test on conductor and wire as per clauses 4.0 , 7.0, 9.0, 10.0 and 12.0.

**Test certificate for compliance of characteristics of paper to BHEL specification
AA 21111.**

**13.0 PACKING AND MARKING :**

The paper covered conductor shall be tightly and evenly wound, without twist, on drums in such a direction that when unrolled the exposed edge of the overlap of the outer layer of paper is towards the drum. The drums shall conform to IEC 60264 / IS:2069. Dimensions of drums will be subjected to charge to suit our requirement of paper covered conductor weight per drum. However, the construction of the two flanges of the drum shall be any one of the following 3 alternatives.

- a) Laminated plyboard construction flange thickness built up using 1 to 3 mm thick veneer plyboard bonded together using phenol/cresol formaldehyde resin.

(OR)

- b) Laminated timber core construction. Timber core will be made using buttons of width not less than 50 mm on both side; of timber core 3 to 4 mm thick laminated/single veneer plyboard will be bounded. Adhesive used in manufacturing timber core drum flanges will be phenol/cresol formaldehyde resin.

(OR)

- c) Manufactured from any other suitable alternative material like plastic, steel etc. subject to prior approval by BHEL.

The bunched wire shall be supplied only in drums of minimum barrel diameter of 560mm. Flange diameter and transverse of drum can be changed to suit the actual length and weight of bunched wire required against as per order.

Before winding the insulated conductor, a layer of polythene sheet shall be wrapped on empty drum. Polythene sheet shall be least 60 microns thick complying to IS:2508, Gr.:000. Then a layer of 75 or 100 micron thick Kraft paper or any other packing paper shall be put over the polythene sheet. After winding the conductor, the polythene sheet edges shall be folded over the conductor so that polythene sheet is on outer side for protection against water ingress. Thereafter a polythene strip shall be wound on outside.

Whenever bare cross section of paper insulated copper conductor is more than 40 mm², an interlayer of 50-60 micron thick Kraft paper shall be given to protect the conductor during winding at BHEL.

As a final protection, a layer of oiled canvas, or similar waterproof material shall be wrapped over the polythene sheet, ensuring that no part of the conductor is exposed.

Metal/non-metal strips used over the drum shall be stamped/sealed with the manufacturer's identification mark. Similarly, end of the conductor shall also be sealed/stamped.

The covered conductor on each drum shall be in on continuous length. There shall be a gap of atleast 25mm between fully packed conductors and drum flange diameter to facilitate handling and transportation of drums.

Direction of winding shall be indicated on the drum. For this suitable stamp of "Arrow" mark shall be made. This mark should be stamped on each drum flange indicating the winding direction.



Each drum shall be labeled clearly stating the following information. The label shall preferably be cemented into a recess with side of the flange of the drum.

AA 28128 : Paper covered Rectangular copper conductor (0.1% Proof stress).

BHEL Order No.

Manufacturer's / Supplier's Name

Dimensions of conductor

Size of conductor

Net weight / Gross weight

14.0 REFERRED STANDARDS (Latest Publications Including Amendments):

- 1) IS:613 2) IS: 1608 3) IS: 2069 4) IS:2508 5) IS: 4654
6) AA 12024 7) AA 21111 8) IEC 60317-27 9) IEC 60264 10) IEC 60851