RDSO SPECN. No.ELRS/SPEC/TM/ 0012

(Rev. 01)

SPECIFICATION OF POLYIMIDE COVERED COPPER CONDUCTOR FOR D.C TRACTION MOTOR

1. SCOPE

This specification covers polyimide covered high conductivity copper conductors of rectangular section for manufacture of armature coils and equalizer coils for D.C traction motors.

2. STANDARD SPECIFICATION:

This specification is prepared taking assistance from various National and International Standards for copper conductors and Covered Copper Conductors for electrical Machines. In particular, assistance has been derived from the following :

S. N.	Specification No.	Description
1.	4 TMS.092.063 Alt-7	CLW specification for Kapton covered conductor for class 'H' traction motor.
2.	BS:6017 – 1981	Specification for copper refinery shapes.
3.	IS:6160-1971	Specification for Rectangular conductor for Electrical Machines.
4.	IS 2069 – 1991, Revision-II	Specification for drums for covered winding wires and strips for electrical purposes.
5	IS 3855 (Part-II) 1979	Specification for rectangular & square enamelled copper conductors- Methods of tests.
6.	IS 613-1984, Rev. - II	Copper rods and bars for electrical purposes.

Certain additional requirements have also been stipulated in this specification to meet the end uses of the product.

3. CONDUCTOR :

3.1 Material:

The copper conductor shall be manufactured from oxygen controlled copper and before covering the conductor shall comply with the requirements of **BS 6017**, Gr.Cu.OF with oxygen content less than 140 PPM. The conductor shall have a smooth surface and radiused corners and shall be free from sharp, rough and projecting edges.

3.2 .1 Dimensions:

The dimensions of the Polyimide Covered Rectangular Copper for TAO-659 & HS 15250A/HS1050Er Traction Motors are furnished below :

(All dimensions in mm)

S.No.	DESCRIPTION	TRACTION MOTOR	
		TAO-659	HS 1050 Er/HS15250A
1	Armature Coil - Bare - Covered	 8.0 x 2.8 8.225 x 3.025	 7.0 x 3.4 7.15x 3.55

3.2.2 Tolerances on Dimensions:

The tolerances on nominal dimensions are as per Clause 3.1.3.1 (Table 2) of **IS:6160 1971** appended below:

S. No.	**Nominal dimensions** (Width or Thickness)		**Tolerances (+ mm)**
	Over (mm)	Up to and including (mm)	
1	-	3.15	0.03
2	3.15	6.30	0.05
3	6.30	12.50	0.07
4	12.50	16.00	0.10

3.2.3 Radius on Corners:

The Conductor shall have radiused corners and the radius of curvature shall be in accordance with clause 3.1.3.3 (Table-3) of **IS 6160 -1971** appended below:

S. No.	**Nominal Thickness of Conductors**		**Corner Radius(mm)**
	Over (mm)	Up to and including (mm)	
1	-	1.00	**Semi Circular**
2	1.00	1.60	0.50 (may be semi-circular)

3	1.60	2.24	0.65 (may be 0.80 mm)
4	2.24	3.55	0.80
5.	3.55		1.00

4. COVERING INSULATION :

1.1 Material:

The conductor shall be covered with one layer of Heat sealable Polyimide film type ``KAPTON 150 FN 019" of DuPont make of suitable width, 1.5 mil thick comprising a 1 mil 'H' tape with 0.5 mil layer of Fluorinated Ethylene Propylene (FEP) adhesive on one side. Alternatively, heat sealable polyimide film of Grade 150 AF-019 of M/s Kaneka Corporation, USA/Japan may be used. The tenderer shall indicate width of tape proposed to be used by the manufacturer.

4.2 Before covering, the surfaces of the copper conductor shall be completely free from copper dust, extraneous matter, black spots and bends etc. Cleanliness of copper is extremely important to achieve optimum adhesion.

4.3 The tape shall be lapped on the conductor tightly, evenly and free from creases or wrinkles, with the adhesive on the inside. The covered conductor shall have smooth surface free from embedded particles of dust and other deleterious materials.

The surface shall be free from any abrasion, tears edge lifting. The number of defects of all types per 100 m length shall not exceed three. The purchaser, however, at their sole discretion may accept the material with defects marginally more than the stipulated value by deducting weight of 1.6 m length of conductor per defect from the total quantity of the lot. The number of defects will be worked out based on the average number of defects per reel out of the sample reels inspected.

4.4 The tape shall be applied 2/3 overlap (67% to 70%) or as specified in tender enquiry/contract.

4.5 After lapping, the tape shall be heat sealed by suitable means to form an adherent and continuous sheath.

4.6 The tape joints shall be made in such a way that the higher dimensions over the joint shall be limited only over a length of 20 mm. (Max.).

4.7 The tenderer shall indicate clearly in their offer the detailed scheme of insulation and manufacturer's technical data of the insulating material used.

4.8 The tenderer should submit proof of import of heat sealable polyimide film.

5. INSPECTION & TESTING:

5.1 The inspection of the material shall be done at the manufacturer's premises. All the tests as indicated below shall be conducted on each lot and the results evaluated.

TEST SCHEDULE FOR POLYIMIDE COVERED COPPER CONDUCTOR

TEST DESCRIPTION	Clause Specification No.
i). Resistance to alternate bends	6.1
ii). Springiness Test	6.2
iii). Elongation Test	6.3
iv). Electrical Resistivity	6.4
v) HardnessTest	6.5
vi). Flexibility & Adherence of covering insulation Test	6.6
a. Mandrel Winding Test	6.6.1
b. Heat Shock Test	6.6.2
c. Adherence Test	6.6.3
d. Twist Test	6.6.4
e. Peel off Test	6.6.5
vii). Dielectric strength Test	6.7
a. Dielectric strength test On Straight Samples	6.7.1
b. Dielectric strength test On bent Samples	6.7.2
viii).. Pin Hole Test	6.8
ix). Heat Ageing Test	6.9
a. D.E. Test on heat aged Samples.	6.9.1

5.2 10% of the Reels shall be re-reeled for checking the visual defects, if any, and samples from each of these reels to be taken for checking and judging the quality requirements stipulated in this standard. If these Reels meet the specification, the lot represented would be accepted.

5.3 Purchaser reserves the right to carry out stage inspection also at firm's premises particularly with reference to manufacturing process, quality control and compliance with various clauses of the specification.

6. TEST DETAILS:

6.1 RESISTANCE TO ALTERNATE BENDS:

Conductor shall withstand the following alternate bends through 180^0 without fracture or cracks.

Thickness of conductor (mm)		Radius of bends (mm)	Minimum No. of alternate bends to withstand fracture/crack
Over	Upto and including		
-	1.2	5	12
1.2	1.6	5	9
1.6	2.8	10	15
2.8		20	15

The test specimen shall be firmly held on its flat surface as shown in Figure 1A in a suitable fixture and shall be bent through 90º to its longitudinal axis as shown in figure 1B over a pin of specified radius. The specimen shall then be bent through 180º over another pin of same specified radius and brought to position 3 as shown in figure 1C, passing the test specimen through its position 1 and thus subjecting it to one alternate bend.

The procedure shall be repeated until the specimen is subjected to the minimum specified number of alternate bends. The specimen shall then be removed and examined for any cracks /fractures etc.

The supplier shall manufacture a suitable bending fixture to carryout the test as above.

6.2 SPRINGINESS TEST:

The spring back angle shall not exceed 5º when tested as per **Clause 4.5 of IS:3855 (Part-II) 1979,** "Specification for Rectangular and Square Enamelled copper conductors – Methods of tests".

6.3 ELONGATION TEST:

The minimum elongation at rupture for the conductors with a gauge length of 250 mm shall be as follows:

Area of cross-section of the conductor	% Elongation (minimum)
a. Up-to 5 mm^2	36%
b. Above 5 mm^2 up-to 30 mm^2	38%
c. Above 30 mm^2	40%

6.3.1 METHOD OF TEST OF ELONGATION AT BREAK:

APPARATUS:

A tensile testing machine, power driven, equipped with a continuous load indicating device and steel seals with indicator so that the breaking load and the distance between the jaws respectively at the moment of break may be determined.

TEST SPECIMEN

Three test specimens of sufficient length to give an initial test length of 250 mm plus gripping lengths are removed from the reel by pulling tangentially.

PROCEDURE

The test specimen shall be placed in the testing apparatus in the grips spaced 250 mm apart. Two (2) dot marks having an interval of 100 mm between them are to be given on the central position of the specimen as shown in figure 2. Then the load is applied evenly and the grips separated steadily at a rate between 1 and 5 mm/second until the conductor fractures.

The maximum load is recorded. The elongation is determined by the increase in the distance between the jaws at the moment of break.

It is necessary to take care to ensure that during the test, the specimen does not slip in the jaws of the testing machine. The measured value shall be discarded if the break occurs at a place other than the central portion of 100 mm. In such case, the same number of new specimen shall be added for tests instead of discarded specimen.

RESULTS :

The distance between the jaws is measured by joining together the broken parts of the tests specimen carefully on machine itself, so that the centre lines of the parts lie in a straight line . In case the same is not possible on a machine, then the broken pieces to be taken out from jaw and the elongated length measured separately, in which case, however, initial marks of 250 mm gauge length on copper are necessary.

The elongation percentage shall be obtained from the following formula:-

$$\text{Elongation(\%)} = \frac{\text{Distance between jaws when broken parts are joined together (mm).} - \text{Original distance between the jaws at the start of the test (mm).}}{\text{Original distance between the jaws at the start of the test (mm)}} \times 100$$

6.4 ELECTRICAL RESISTIVITY :

The electrical resistivity of the conductor when measured directly on the sample in "as received" condition shall not be greater than 0.01724 ohm mm^2/m at 20^0 C (Refer **Appendix B of IS:613** for temperature correction factor).

6.5 HARDNESS TEST WITH 5 KG LOAD :

When checked on width of the conductor after the removal of Polyimide film as per the method given in Clause 6.5.1, the Hardness with 5 Kg load shall be within 50-55 HV.

6.5.1 Method of removal of Polyimide Film :

The Polyimide film shall be removed by either alkaline or acidic method, as given below :

(a) Preparation of Sample :

Take a sample of polyimide film covered copper conductor 200-300 mm long, as required. Make a cut on polyimide film covering by knife on both sides of conductor, thickness-wise.

(i) Alkaline Method :

Prepare the alkaline solutions as follows :

- KOH/NaOH : 20 gms.
- Industrial Methylated spirit : 20 cc
- Water : 100 cc

Keep the sample in the alkaline solution for 12-16 hrs. at room temperature.

(ii) Acidic Method :

Keep the sample in concentrated Sulphuric Acid (Specific gravity 1.84 approx.) for 4 – 5 hrs. at room temperature.

(b) Removal of Polyimide film :

Remove the sample from Alkaline/Acidic Solution and wash in fresh water to remove all traces of solution.

Remove the Polyimide film while sample in wet from the conductor surface using soft material, without applying any mechanical force.

6.6 FLEXIBILITY AND ADHERENCE OF COVERING INSULATION TESTS:

6.6.1 Mandrel Winding Test:

Samples of polyimide covered conductor in as received condition shall be bent through 180º round a mandrel having a diameter 4 times the bare width of the conductor when bent on the edge or 4 times the bare thickness when it is on the flat. Separate samples from different reels shall be bent on the edge and on flat and when so tested the covering shall not open to expose bare conductor. There shall be no loosening of the insulation. There shall be no cracks, edge lifting, wrinkles, de-lamination of the insulation etc.

6.6.2 Heat Shock Test:

Samples having already undergone Mandrel winding Test as per Clause 6.6.1 shall be heated for 1 hour in an oven at a temperature of 245-255º C and then allowed to cool to room temperature. The samples shall show no opening, cracks or de-lamination. There shall be no appreciable wrinkles and edge lifting, edge curling, etc. on the insulation.

6.6.3 Adherence Test :

The insulation covering on samples of 250 mm gauge length from different reels shall be cut through circumferentially at a point approximately half way along with measured length. The samples are then stretched in tensile strength testing machine for an elongation of 20%. The covering shall not become detached for a distance exceeding the following:

i) For conductors of thickness of 2 mm or more – Thickness of conductor.
ii) For conductors of thickness less than 2 mm – Width of conductor.

6.6.4 Twist Test :

Samples of 300 mm length shall be twisted by 4 complete turns along longitudinal axis of the insulation wire, keeping one end clamped. There shall be no cracks, or any other damage or loosening on the insulation. There shall be no appreciable de-lamination, edge lifting or wrinkles on the insulation.

6.6.5 Peel off Test :

A test specimen of about 300 mm length shall be taken and reasonably flattened. The insulation at the corners of the conductor should be removed/cut using a sharp knife. The insulation over the width shall be cut and lifted at the correct end of the conductor as shown in Figure 3.

The polyimide film layer shall be carefully peeled for about 25-50 mm. The specimen shall then be clamped and a pan attached/clipped to the lifted end of the insulation layer as shown in Figure 4.

Standard weights shall be added in the pan until the layer starts peeling off. The insulation shall not peel off at a weight less than 100 g/mm width of insulation at a rate of 300 mm per minutes.

The manufacturers are advised to equip themselves with a suitable apparatus by which the insulation layer may be peeled off at a constant rate of 300 mm/minute and the corresponding peel load may be recorded/observed for future reference/modification of the specification of RDSO.

6.7 DIELECTRIC STRENGTH TEST:

6.7.1 Dielectric Strength test on straight sample:

The test is a routine proof dielectric test followed by a routine puncture dielectric test.

Five test specimens of 300 mm length each shall be placed one over the other on width and bound tightly over a distance of 200 mm (Approx.) along the central portion with un-impregnated glass fibre tape. The ends of the conductor shall be bent outward in such a manner as to prevent flash over during D.E. Test. The

covering shall be removed from one end of each conductor for the application of the test voltage. The assembly shall then be placed in a well ventilated air circulation oven and heated for about 6 hours at 180º C and allowed to cool down to room temperature.

Test voltage AC 50 Hz shall be applied between pairs of adjacent conductors and gradually increased to 7000 volts on 2/3 lap conductor and maintained for 2 minutes. There shall be no break down of insulation during this period.

On completion of proof test on all the adjacent conductors the following routine puncture test is to be carried out on the same bunch of conductors.

The test voltage shall then be gradually increased further until break down occurs. The minimum break down voltage shall be 10000 volts on 2/3-lap conductor on two thicknesses.

6.7.2 DIELECTRIC TEST ON BENT SAMPLES:

This test is a routine puncture dielectric test .

The test specimens as bent flat-wise and edge –wise as in para 6.6.1 from as received conductor shall be placed in a well ventilated air circulating oven and heated for 6 hours at 180º C and then tested for dielectric strength by keeping them in a suitable trough, filled with lead balls of 1 mm diameter, the ends of the specimen projecting sufficiently outside the trough. The total length of the specimen immersed in the lead balls shall be about 90 mm; the specimen shall be surrounded at least 5 mm all round by the lead balls.

The test voltage AC 50 Hz sinusoidal shall be applied between the conductor and lead balls. The voltage shall be gradually increased till break down occurs.

The minimum acceptable break down voltage is **8500 volts** on 2/3 lap conductor.

6.8 PIN HOLE TESTING :

The covered conductors shall be checked be checked for continuity of covering, i.e. for presence of pin poles in the coverings, continuously during final stage of manufacture through an IN-PROCESS apparatus. The conductor shall be passed through the Pin Hole Testing apparatus after taping and just prior to wind up on the reel. The Pin Hole Tests shall be capable of detecting minute insulation defects like tears, cuts etc. The operation of the detector shall be at 1500V, 3000 Hz, AC.

The number of faults shall not exceed 2 per 100 meter length of the conductor. The fault locations shall be marked with coloured plastic adhesive tape for easy identification.

Complete record of In Process Pin Holes Testing shall be maintained and produced for inspection by the manufacturer.

6.9 HEAT AGEING TEST :

Straight samples of 300 mm length and bent samples edgewise and flatwise as prepared in 6.6.1 shall be heated for 20 hrs. in an oven at a temperature of 245-255º C and then allowed to cool to room temperature . The samples shall show no appreciable cracks, opening, delamination of covering, edge lifting and edge curling.

6.9.1 Dielectric Strength test on heat aged samples:

The samples heat aged as in Clause 6.9 shall be tested for dielectric strength as in 6.7.1 and 6.7.2. The minimum acceptable break down voltage is 9000 volts on 2/3 lap conductor on two thickness of insulation and that on bent samples is 7000 volts on 2/3 lap conductor on single thickness of insulation.

7.0 CRITERIA FOR CONFORMITY AND INTERPRETATION OF THE TEST RESULTS:

The supplies offered for inspection shall be considered to be satisfactory and acceptable, if all the test results presented by the manufacturer and these obtained by the inspector on the samples selected by him are within the specified limits and statistically satisfactory.

If the results of any of the tests is not within the specified limit or statistically not satisfactory, the test shall be repeated on twice the number of samples.

If the results of the repeat tests are not within the specified limits, the entire supplies shall be rejected. The purchaser shall have however the right to reject the supplies in full or in part. If the results of the repeat tests are within the specified limit, the supplies shall be considered to be acceptable.

8.0 PACKING :

8.1 The conductor shall be delivered in continuous lengths. Each reel or drum shall contain not more than two lengths of wire. If the reel or drum contains two lengths this shall be indicated on the label. If the contents of the reel consists of two lengths a slip of paper shall be inserted between the layers to indicate the commencement of the second

length. The net weight of the conductor per drum shall be 80 ± 20 Kgs. Cut pieces of minimum weight of 20 kgs each will be accepted subject to 10 % of the ordered quantity.

8.2 The covered conductor shall be wound evenly and compactly on reels with a band of suitable number of layers of thick paper to protect the conductor from external damages. The construction of the drum shall generally conform to **IS-2069-1991** 'Specification for drums for covered winding wires and strips for electrical purposes'.

8.3 Each drum shall be labelled at a distinct location easily visible on the drum indicating
the following information:

(a) Name and address of the manufacturer.
(b) Purchase Order reference and date.
(c) Description and nomination dimension of the conductor.
(d) Date of manufacture of the conductor.
(e) Date of inspection of the lot and lot size.
(f) Gross weight of the drum; tare weight of the drum.
(g) Net weight of the conductor and number of lengths.
(h) Special precautions, if any, for storage .
(i) Number of faults noticed on continuity of covering test.

9. GUARANTEE :

The supplier shall guarantee the material supplied against any manufacturing, material and/or workmanship defects for a period of 18 months from the date of supply. The guarantee will cover replacement free of cost including transport and other incidental charges of such materials found to be defective within the warranty period subject to such replacement are also covered by fresh warranty.

10. INFORMATION TO BE FURNISHED BY THE TENDERER

While submitting the offer the tenderer shall furnish the following information :

i) Full details of the material used in the construction viz.-

(a) Type with full technical details, size and source of supply of polyimide film used for covering.
(b) Details of copper conductor.
(c) Details of manufacturing process.

(ii) 'Quality Assurance Plan' for manufacture of polyimide heat sealed copper conductors duly approved by RDSO Lucknow.

(iii) Copy of ISO-9000 certification.

(iv) Name of the electrical equipment manufacturers to whom such/similar conductors have already been supplied and also the quantities supplied with references.

(v) Service experience/feed back information obtained on such suppliers as at (ii) above.

(vi) A list of deviation, if any, from this specification. Even if tenderer has no particular deviation in their offer, a 'NIL' statement shall be submitted.

(vii) The offer shall be accompanied by a sample of at least 6 meters of Polyimide covered conductor developed/supplied by them for other customers.

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