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| | | PREFACE SHEET |

# POLYESTERIMIDE ENAMELLED AND POLYESTERIMIDE VARNISH BONDED DOUBLE GLASS LAPPED RECTANGULAR COPPER CONDUCTORS (TEMPERATURE INDEX 180)

**FOR INTERNAL USE ONLY**
**REMOVE THIS PREFACE BEFORE ISSUE TO SUPPLIERS**

## Comparable Standards:

IS:13730 Pt.31–1997 / Î

IEC 317-31 -1990 (R 2002) Î

## Suggested/Probable suppliers and grades:

1. Refer plant vendors list

## User Plant References:

1. BHOPAL : PS 31248
2. HARDWAR : PS 31248



| Revisions : Cl: 34.1.12 of MOM of MRC-E | | | APPROVED : INTERPLANT MATERIAL RATIONALISATION COMMITTEE -MRC (E) | | |
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# POLYESTERIMIDE ENAMELLED AND POLYESTERIMIDE VARNISH BONDED DOUBLE GLASS LAPPED RECTANGULAR COPPER CONDUCTORS (TEMPERATURE INDEX 180)

## 1.0 GENERAL:

This specification covers the quality requirements of rectangular copper conductors, insulated with polyesterimide based enamel (of temperature index 180) and a double glass lapped covering bonded to the conductor with a polyesterimide varnish having a temperature index of at least 180.

## 2.0 APPLICATION:

For used in winding of electrical machines.

## 3.0 COMPLIANCE WITH NATIONAL STANDARDS:

There is no National / International standard covering this type of material . However assistance has been taken from the following standard.

IS:13730 Pt.31–1997 / IEC 317- 31 -1990 (R 2002) Specifications for particular types of winding wires Part 31 Glass – fibre wound, Polyesterimide Varnish-treated, Bare or Enamelled :

## 4.0 DIMENSIONS AND TOLERANCES :

### 4.1 Dimensions :

### 4.1.1 Sizes And Grades :

The conductor shall be supplied to the size and grade as specified in BHEL order. The sizes shall preferably be selected from table 1 of IS: 6160.

### 4.1.2 Radius on Corners :

Bare conductors shall have rounded corners, the radius of curvature being within the range given below. The arc shall merge smoothly in to the flat and the conductor shall be free from sharp, rough and projected edges.

| Nominal Thickness, mm | | Radius on Corner, mm |
|---|---|---|
| Over | Upto & incld. | |
| -- | 1.00 | Semicircular |
| 1.00 | 1.60 | 0.50 - 0.75 |
| 1.60 | 2.25 | 0.65 - 0.95 |
| 2.25 | 3.55 | 0.80 - 1.20 |
| 3.55 | and above | 1.00 - 1.50 |

4.1.3 **Increase In Dimensions Due To Covering :**

The increase in dimensions due to the enamel covering, glass covering and combined insulation, when determined by the method described in Appendix A of IS:6181 shall conform to the values given below, except under the conditions stated in clause 4.1.4 when the maximum may be exceeded.

| | Enamel mm | Glass Lapping mm | Combined Insulation mm |
|---|---|---|---|
| Minimum | 0.06 | 0.18 | 0.24 |
| Maximum | 0.11 | 0.23 | 0.34 |

**4.1.4 Maximum Dimensions:**

The maximum dimensions due to individual covering of enamel /glass braiding may exceed provided the overall dimensions of the insulated conductor does not exceed the maximum increase due to the combined insulation given in the above table. The overall dimensions of the conductor shall not exceed the nominal value permitted for the bare conductor plus the appropriate maximum enamel and glass covering thickness as applicable.

4.1.5 **Increase In Dimensions Due To Repaired Covering:**

The increase in dimensions due to covering at the repair shall not exceed 2 times the maximum value specified for the glass covering mentioned in clause 4.1.3.

**4.2 Tolerances :**

**4.2.1 On Nominal Dimensions:**

Tolerances on nominal dimensions of bare conductors shall be as follows:

| Width or Thickness, mm | | Tolerance, ± mm |
|---|---|---|
| Over | Upto and incld. | |
| -- | 3.15 | 0.03 |
| 3.15 | 6.30 | 0.05 |
| 6.30 | 12.50 | 0.07 |
| 12.50 | 16.00 | 0.10 |

**5.0 MANUFACTURE:**

**5.1 Conductor:**

The conductor shall be manufactured from high conductivity, annealed copper of ETP grade to IS:191-part 5.

**5.2 Joints:**

No joint shall be made in the copper conductor after it is drawn. Any joint made during the drawing process shall be resistance welded only.

## 6.0 TEST SAMPLES:

Six metres of enameled conductor shall be supplied with each consignment for testing purposes. The sample shall be cut off cold and shall receive no further treatment before testing. Î

## 7.0 CHEMICAL COMPOSITION:

The composition of copper used for conductor, when analysed in accordance with IS:440, shall be as follows.

| Element | Percent min | Percent max |
|---|---|---|
| Copper and Silver | 99.90 | - |
| Bismuth* | - | 0.001 |
| Lead * | - | 0.005 |
| Total of all impurities excluding silver and oxygen | - | 0.030 |

* These elements need not be determined when the material supplied conforms with mechanical and electrical properties specified in this specification. However, the supplier shall ensure that the composition of the material lies within the limits specified above.

## 8.0 PROPERTIES:

Unless otherwise specified, the testing shall be conducted as per relevant parts of IS:13778/ IEC 60851 series. Î

### 8.1 Properties of Bare Conductors:

### 8.1.1 Tensile strength:

A sample of 200-250 mm long conductor after removal of insulation is fixed between the grips of a tensile testing machine and shall be steadily elongated at a rate of 50 – 100 mm per minute until the conductor fractures.

| Property | For thickness, mm: Upto & incld. 2.5 | For thickness, mm: Above 2.5 and upto & incld. 10.0 |
|---|---|---|
| Tensile strength, N/mm2, max | 265 | 255 |
| Elongation, % min | 30 | 35 |

### 8.1.2 Hardness (Vickers):

When tested as per the test method given below, the hardness shall not exceed 60 HV.

**TEST METHOD**

One piece of conductor about 300 mm length is dipped in 10% hydrochloric acid for 3-4 hours with at least 250 mm length submersed.

Conductor should be washed with tap water and then wiped out with cloth gently. After complete removal of insulation, it shall be thoroughly washed for complete removal of acid content from the sample surface.

Vicker's hardness shall be measured at three places at least 50 mm apart. The test load shall be 5 kg.

### 8.1.3 Electrical Resistivity:

The electrical resistivity of the conductor when measured directly on the sample in 'as received' condition at $20^0$C shall not be greater than 0.01739 ohm/$mm^2$/m (Ref. Appendix B of IS:613 for temperature correction factor.)

## 9.0 ENAMEL COVERING :

The conductor shall be completely and uniformly covered with a durable, flexible, synthetic polyesterimide enamel whose temperature index shall be at least 180. The enameled conductor shall have a smooth surface, free from embedded particles of dust and other deleterious material.

## 10.0 Properties of enamel/enamelled conductors (Relevant parts of IS:13778 / IEC 60851) Î

### 10.1 Flexibility And Adherence:

#### 10.1.1 Flexibility Mandrel Winding Test:

Samples of enameled conductor in as received condition shall be bent through $180^0$ round a polished metal mandrel, two on the flat (or width) and two on the edge (or thickness) in two directions to form an elongated **'S'** shape. The straight portion between the two **U** shaped bends shall be approximately 150mm. The diameter of the mandrel shall be as given below, according to whether the samples are bent on the flat or the edge respectively . Care should be taken to ensure that the sample neither buckler nor departs from uniform bend.

| | Size, mm | | Mandrel diameter |
|---|---|---|---|
| | Over | up to and incl. | |
| Flat or width | - | 10 | 4 x Thickness |
| | 10 | - | 5 x Thickness |
| Edge or thickness | All sizes | | 4 x Width |

After bending, the specimen shall show no cracks when examined under a magnification of 6 to 10 times.

**10.1.2 Adherence Test**

A specimen shall be selected for elongation with a free measuring length between 200 –250 mm. The enamel film shall be cut circumfrerentially at a point of approximately half way along the measured length. Specimen shall be elongated up to 15% of length at a rate of 50-100 mm/min. The maximum distance over which the cut edges have traced or over which the enamel has lifted from the conductor either side of the cut is reported as distance of cross of adhesion shall be less than the width of conductor.

**10.1.3 Solvent Test:**

The enamel shall not get removed from the test specimen with a pencil of hardness –H.

**10.1.4 Cure test:**

A sample of enamelled wire not less than 100mm length, which has been conditioned at $130\pm2^0$ C for ten minutes, shall be immersed without bending, in a boiling mixture initially containing 30% commercial grade toluol and 70% denatured ethyl alcohol by volume for a period of 5 minutes. On removal from the liquid, the enamel film on the immersed portion of the sample shall not show any visible swelling or blistering. Any effect on the film within a distance of 10mm from the immersed end of the sample shall be disregarded.

**10.1.5 Heat shock:**

Samples of the enameled wire shall be bent through $180^0$ round a polished metal mandrel two on the flat and two on the edge. The diameter on the mandrel shall be 6 times the thickness or width according to whether they are bent flatwise or edgewise respectively. The samples shall be placed in an electrically heated forced air circulated oven maintained at a temperature of 200 to $205^0$ C for 30 minutes. After removal from the oven, the samples shall be allowed to cool to room temperature. When examined under a magnification of 6 to 10 times, the samples shall show no cracks.

**11.0 GLASS COVERING:**

**11.1 Application Of Glass Covering:**

The enamelled conductor shall be lapped firmly, evenly, closely and continuously with two layers of glass fibre yarn which shall then be bonded to the enamelled conductor with the approved polyesterimide varnish of temperature index 180.

**11.2 Repairs To Insulation:**

When, for manufacturing reasons, it is necessary to apply a hand lapped covering of glass yarn or untreated glass tape over an interruption in the braiding, it will be permitted, but the length of any such hand lapping shall not exceed 100 mm and that this length shall be subsequently varnished. The number of hand lapped spots shall be not more than one per 100 metre length.

**12.0 PROPERTIES OF GLASS C OVERED VARNISH BONDED CONDUCTOR:**

**12.1 Flexibility (As Received):**

Samples of glass braided conductor in as received condition shall be bent through $180^0$ round a polished mandrel having a diameter 6 times, the bare width of conductor when it is bent on edge or 6 times the bare thickness when it is bent on flat. Separate samples shall be bent two on the edge and two on the flat and when so tested the covering shall not open sufficiently to expose the bare conductor to view, when examined under diffused light by normal eye sight. There shall be no appreciable loosening of insulation or no cracks shall be seen in the insulation.

**12.2 Flexibility After Heat Ageing:**

Bent samples prepared as per clause12.1 above shall be placed in an electrically heated, forced air circulating oven, at a temperature of $200\pm5^0$ C for 48 1 hours, removed from the oven and allowed to cool to room temperature. Sample shall pass the test as detailed in clause 12.1 above.

**12.3 Adherence:**

A sample of approximately 250 to 300 mm long shall be straightened limiting the elongation upto a maximum of 1% . The covering shall be removed retaining the covering on the central 100 mm length of the wire. The specimen shall be elongated in an elongation tester or a tensile testing machine. The free measuring length shall be between 200 and 250 mm. The wire shall be elongated at a rate of 50 to 100 mm per minute.

The covering shall not loose adhesion after an elongation for the appropriate width/thickness ratio as given below. Loss of adhesion of the covering is shown by its being able to slide along the conductor as a whole or being detached in part.

| **Width/Thickness ratio** Over upto & incld. | **Elongation percent** |
|---|---|
| - 2 :1 | 5 |
| 2 :1 and above | 10 |

**12.4 Cure Test:**

Two strips of each 200mm long shall be laid flat to flat and bound tightly with polyester fibre tape. The specimen shall then be placed in a hot air circulating oven at $180^0\pm3^0$ C and left for $30 \pm 2$ minutes. It shall then be removed and after removing the binding tape , it shall be possible to separate the strips without damaging the covering.

**12.5 Break Down Voltage Test:**

**A)Test Specimen:**

Five samples of glass lapped conductor shall be bent flatwise through $180^0$ round a mandrel Having a diameter of 6 times bare thickness of the conductor. The ends of the specimens are brought out to a distance of 75 to 100mm and insulation stripped off at the ends for electrical connections.

**B) Test Method at Room Temperature:**

The specimen prepared as above shall be placed in a metallic vessel filled with metallic balls of diameter 2.0 mm maximum and vessel solidly connected to earth. A sinusoidal a.c. voltage of 50 Hz is applied and increased from zero at an uniform rate of 100 volts per second Î until breakdown occurs.

**C) Test Method at Elevated Temperature:**

The specimen prepared as per above along with steel balls are inserted into a heating chamber maintained at the specified temperature and are allowed to remain there until the specimen attain the rated temperature (usually 15 minutes). They are then tested within 15 minutes after the specimens reach the rated temperature. The total time in chamber shall not exceed 30 minutes.

When tested as per the test methods given above, (at room temperature and at the rated temperature of $180^0 \pm 5^0$C) four out of five samples shall not breakdown at the following values and the value of fifth specimen shall show a minimum of 50% of the specified value.

| Temperature, $^0$C | Break Down Voltage, kV, minimum |
|---|---|
| RT | 2.0 |
| $180^0 +5^0$ C | 1.6 |

**13.0 TEST CERTIFICATE:**

Unless otherwise stated, 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 dispatch documents to facilitate quick clearance of the material.

The test certificate shall bear the following information:

AA 281 11 (Rev 04): Polyesterimide enameled and Polyesterimide varnish bonded double glass braided, rectangular copper conductors (Temperature index 180).

BHEL Order No.
Manufacturer's/Suppliers Name
Batch / Lot No.
Size and quantity supplied
Test values obtained for clauses 4, 7, 8, 10 and 12.

**Note:** On first consignment for establishment of the material the supplier shall indicate the type and make of glass yarn, enamel and varnish used for the conductors, with its life time characteristics of enamel and varnish for BHEL's approval. The approved glass yarn and varnish / enamel as identified by IR spectroscope or any other suitable instrumental method. shall only be used.

On subsequent orders, the supplier shall furnish a certificate that the approved glass yarn, enamel and varnish has been used.

Also the supplier shall ensure that the number of repairs undertaken lies within the specified limits.

For easy identification of the repairing parts, contrast coloured adhesive tapes are to be pasted on the repaired parts.

## 14.0 PACKING AND MARKING :

Unless otherwise specified, the braided conductor shall be wound on drum No. 4520 (Dia of flange: 450 mm and approximate capacity 55 kg) to IS:2069.

The Wires shall be protected against possible damage from the inner faces of flanges of the drum by lining each flange with thick paper or card board.

Each package shall be legibly marked or labeled with the following information :

AA 281 11 : Polyesterimide enameled and Polyesterimide varnish bonded double glass braided, rectangular copper conductors (Temperature index 180).

BHEL Order No.
Manufacturer's/Suppliers Name
Batch / Lot No.
Size and quantity supplied
Date of manufacture

## 15.0 REFERRED STANDARDS (Latest Publications Including Amendments):

| | | | |
|---|---|---|---|
| 1) IS:191, part 5 | 2) IS: 440 | 3) IS:613 | 4) IS:2069 |
| 5) IEC:60317-0-4 | 6) IS: 6181 | 7) IS: 13778 | 8) IEC:60851 |