AA 281 46 : POLYESTERIMIDE ENAMELLED ROUND COPPER CONDUCTORS (TEMPERATURE INDEX 180)

1 Preface sheet:

"Equivalent/Comparable standards" to be replaced by "Comparable standards"

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Cl.6.3 : "Electrical Resistivity" to be replaced by the following:

6.3 Electrical Resistance/Resistivity:

a) Upto and including 1.0 mm dia.

"The resistance of the conductors in "as received" condition at 20°C shall be as per IS:4800, Part 1.

Contd...2.

b) Over 1.0 mm dia.
"The resistivity of the conductors in "as received" condition shall not be greater than 0.01739 ohm/mm^2/m.

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Add the following new clause as Cl.11 at the end.
Cl.11 REFERRED STANDARDS (Latest publications incl. amndts.
1) IS : 335

POLYESTERIMIDE ENAMELLED ROUND COPPER CONDUCTORS
(Temperature Index 180)

1. **GENERAL:**

This specification governs the quality of round copper conductors, covered with polyesterimide enamel of temperature index atleast 180.

2. **APPLICATION:**

Used in the winding of electrical machines.

3. **COMPLIANCE WITH NATIONAL STANDARDS:**

This specification is generally based on B.S:4665 Part 1 1971. Also this specification conforms to IS 4800 Pt. V, 1968 with alternative/additional requirements laid in clauses 5, 6.3, 6.4, 8.4, 8.5, 8.6, 8.8 & 8.10.

4. **SIZES:**

4.1 The conductor shall be supplied to the size specified on our order.

4.2 The sizes shall preferably be selected from column I of Table-I and overall diameter of the conductor shall also be stated on the order.

5. **JOINTS:**

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

6. **CONDUCTOR:**

6.1 **Conductor Material:**

The conductor shall be manufactured from ETP grade high conductivity copper conforming to IS: 191 - Part V.

6.2 **Tolerance on Nominal Diameter:**

The nominal diameter of conductor shall be neither more nor less than the maximum and minimum value specified in table I.

6.3 **Electrical resistivity:**

The resistance at 20°C of a conductor of one metre in length and an uniform cross-sectional area of 1 mm^2 in annealed condition shall not be greater than 0.01739 Ohms.

Revisions:
Covering of Grade 1&3 are included.
Brought upto date.

Approved:
INTERPLANT MATERIAL RATIONALISATION COMMITTEE-MRC (E)

Rev. No.	Rev. Date	Revised:	Prepared	Issued	Date
01	FEB. 89	BHOPAL	HARDWAR	CORP. R&D	MAR '80

6.4 Elongation:

The elongation at fracture shall not be less than the values given in column 10 of table-I.

7. OVERALL DIAMETER AND INCREASE IN DIAMETER:

The maximum overall diameter of the covered conductor and the increase in diameter due to covering of enamel shall not be less than that given in table-I.

Contd....3.

Table-1

Conductor diameter mm			Grade 1		Grade 2		Grade 3		Elongation % Min.
			Overall dia.mm	Increase in dia.mm	Overall dia.mm	Increase in dia.mm	Overall dia.mm	Increase in dia.mm	
Nom.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	
1	2	3	4	5	6	7	8	9	10
0.0200			0.025	0.002	0.027	0.003			6
0.0224			0.028	0.002	0.030	0.003			6
0.025			0.031	0.003	0.034	0.004			7
0.028			0.035	0.003	0.038	0.005			7
0.030			0.038	0.003	0.041	0.005			7
0.032			0.040	0.004	0.043	0.006			8
0.036			0.045	0.004	0.049	0.007			8
0.040			0.050	0.004	0.054	0.008			9
0.045			0.056	0.005	0.061	0.009			9
0.050			0.062	0.005	0.068	0.010			10
0.056			0.070	0.006	0.076	0.012			11
0.060			0.075	0.006	0.081	0.012			11
0.063			0.078	0.007	0.085	0.013			12
0.071	0.074	0.068	0.088	0.008	0.095	0.015			13
0.080	0.083	0.077	0.098	0.009	0.105	0.016	0.116	0.024	14
0.090	0.093	0.087	0.110	0.010	0.117	0.017	0.128	0.026	15
0.100	0.103	0.097	0.121	0.011	0.129	0.019	0.141	0.028	16
0.112	0.115	0.109	0.134	0.012	0.143	0.020	0.155	0.029	17
0.125	0.128	0.122	0.149	0.013	0.159	0.022	0.171	0.032	17
0.132	0.135	0.129	0.157	0.014	0.167	0.023	0.180	0.033	17
0.140	0.143	0.137	0.166	0.015	0.176	0.024	0.189	0.034	18
0.150	0.153	0.147	0.177	0.015	0.188	0.024	0.201	0.035	18
0.160	0.163	0.157	0.187	0.016	0.199	0.025	0.213	0.037	19
0.170	0.173	0.167	0.198	0.016	0.211	0.026	0.225	0.038	19
0.180	0.183	0.177	0.209	0.017	0.222	0.027	0.237	0.040	20
0.190	0.193	0.187	0.220	0.017	0.234	0.027	0.249	0.041	20
0.200	0.203	0.197	0.230	0.018	0.245	0.028	0.261	0.043	21
0.212	0.215	0.209	0.243	0.018	0.258	0.029	0.275	0.044	21
0.224	0.227	0.221	0.256	0.019	0.272	0.030	0.290	0.046	21
0.236	0.240	0.232	0.269	0.019	0.285	0.030	0.304	0.047	21
0.250	0.254	0.246	0.284	0.020	0.301	0.031	0.320	0.048	22
0.265	0.269	0.261	0.300	0.020	0.317	0.031	0.336	0.049	22
0.280	0.284	0.276	0.315	0.021	0.334	0.032	0.353	0.051	22
0.300	0.304	0.296	0.337	0.021	0.355	0.033	0.375	0.052	22
0.315	0.319	0.311	0.352	0.022	0.371	0.034	0.391	0.053	23
0.335	0.339	0.331	0.374	0.023	0.393	0.035	0.413	0.054	23
0.355	0.359	0.351	0.395	0.024	0.414	0.036	0.435	0.056	23
0.375	0.380	0.370	0.417	0.024	0.436	0.037	0.456	0.057	23
0.400	0.405	0.395	0.442	0.025	0.462	0.038	0.483	0.058	24
0.425	0.430	0.420	0.469	0.026	0.489	0.039	0.511	0.060	24
0.450	0.455	0.445	0.495	0.027	0.516	0.041	0.538	0.062	25
0.475	0.480	0.470	0.522	0.028	0.543	0.042	0.565	0.063	25
0.500	0.505	0.495	0.548	0.029	0.569	0.044	0.591	0.065	25
0.530	0.536	0.524	0.579	0.029	0.601	0.045	0.624	0.066	25
0.560	0.566	0.554	0.611	0.030	0.632	0.046	0.656	0.067	26
0.600	0.606	0.594	0.653	0.031	0.675	0.047	0.699	0.069	26
0.630	0.636	0.624	0.684	0.032	0.706	0.049	0.730	0.071	27
0.670	0.677	0.663	0.726	0.033	0.749	0.050	0.773	0.072	27
0.710	0.717	0.703	0.767	0.034	0.790	0.051	0.815	0.074	28
0.750	0.758	0.742	0.809	0.035	0.832	0.052	0.858	0.075	28
0.800	0.808	0.792	0.861	0.036	0.885	0.054	0.911	0.078	28
0.850	0.859	0.841	0.913	0.037	0.937	0.055	0.964	0.079	28
0.900	0.909	0.891	0.965	0.038	0.990	0.057	1.017	0.081	29
0.950	0.960	0.940	1.017	0.039	1.041	0.058	1.070	0.082	29
1.000	1.010	0.990	1.068	0.039	1.093	0.059	1.123	0.084	30
1.060	1.071	1.049	1.130	0.040	1.155	0.060	1.184	0.085	30
1.120	1.131	1.109	1.192	0.041	1.217	0.061	1.246	0.087	30
1.180	1.192	1.168	1.254	0.042	1.279	0.062	1.308	0.088	31
1.260	1.263	1.237	1.325	0.042	1.351	0.063	1.381	0.089	31
1.320	1.333	1.307	1.397	0.043	1.423	0.064	1.453	0.091	32
1.400	1.414	1.386	1.479	0.044	1.506	0.066	1.535	0.093	32

Conductor diameter mm			Grade 1		Grade 2		Grade 3		Elongation % Min.
			Overall dia.mm	Increase in dia.mm	Overall dia.mm	Increase in dia.mm	Overall dia.mm	Increase in dia.mm	
Nom.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	
1	2	3	4	5	6	7	8	9	10
1.500	1.515	1.485	1.581	0.045	1.608	0.067	1.638	0.094	32
1.600	1.616	1.584	1.683	0.046	1.711	0.068	1.741	0.096	32
1.700	1.717	1.683	1.785	0.047	1.813	0.069	1.844	0.097	32
1.800	1.818	1.782	1.888	0.048	1.916	0.071	1.947	0.099	32
1.900	1.919	1.881	1.990	0.049	2.018	0.072	2.049	0.100	32
2.000	2.020	1.980	2.092	0.049	2.120	0.073	2.152	0.101	33
2.120	2.141	2.099			2.243	0.074	2.275	0.103	33
2.240	2.262	2.218			2.366	0.075	2.398	0.104	33
2.360	2.384	2.336			2.488	0.076	2.522	0.105	33
2.500	2.525	2.475			2.631	0.077	2.665	0.107	33
2.650	2.677	2.623			2.784	0.078	2.819	0.108	34
2.800	2.828	2.772			2.938	0.080	2.972	0.110	34
3.000	3.030	2.970			3.142	0.081	3.176	0.112	34
3.150	3.182	3.118			3.294	0.082	3.330	0.113	34
3.350	3.384	3.316			3.498	0.083	3.534	0.115	34
3.550	3.586	3.514			3.702	0.085	3.738	0.117	35
3.750	3.788	3.712			3.905	0.086	3.942	0.118	35
4.000	4.040	3.960			4.160	0.087	4.196	0.120	35
4.250	4.293	4.207			4.414	0.088	4.451	0.122	35
4.500	4.545	4.455			4.668	0.090	4.705	0.124	36
4.750	4.798	4.702			4.923	0.091	4.961	0.126	36
5.000	5.050	4.950			5.177	0.092	5.215	0.128	36

8. ENAMEL COVERING:

8.1 General:

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

8.2 Flexibility And Adherence Of Enamel:

8.2.1 Mandrel Winding Test:

After winding ten contiguous turns on a polished mandrel, the diameter of which is in accordance with the values given below in table - 2, the covering of the sample shall show no cracks when examined under a magnification of 10 to 15 times.

Nominal conductor diameter		Mandrel diameter (d = nominal diameter of conductor in mm)
Over	Up to and including	
mm	mm	
-	0.040	0.150 mm*
0.040	0.250	3d*
0.250	2.000	d
2.000	5.000	2d

*The wire is stretched 20% or to the breaking point of the point of the copper, whichever is less, before winding on the mandrel.

The mandrel shall be rotated at between 1 and 3 turns per second, the tension of the wire being just sufficient to keep it in contact with the mandrel. Care shall be taken to avoid elongation or twisting of the wire. Three tests shall be made.

8.2.2 **Jerk Test:**

This test is applicable to conductors of diameter upto and including 1 mm. When the specimen is suddenly stretched to the breaking point or to the elongation as specified point or to the elongation as specified in column-10 of table-I, the covering of sample show no cracks or loss of adhesion when examined under a magnification of 10 to 15 times.

8.2.3 **Peel Test:**

This test is applicable to conductors of diameter over 1 mm. The enamel shall show flexibility and it shall not be possible to remove the enamel without difficulty from the wire (i.e. with thumb nail), when the wire twisted in the rotating device to the extent that the product of the bare nominal diameter and the number ofrevolutions is 110.

8.3 **Abrasion Test:**

This test is applicable to conductors of diameter from 0.25 mm upto and including 2.5 mm. When tested in accordance with clause 5.6 of IS: 4800 Pt. III, under the appropriate load mentioned below in table-3 the average number of strokes shall not be less than 40 and no individual value shall be less than 16.

TABLE 3 LOADS FOR ABRASION TEST

Nominal conductor diameter	load			Nominal conductor diameter	load		
	Grade 1	Grade 2	Grade 3		Grade 1	Grade 2	Grade 3
mm	N	N	N	mm	N	N	N
0.250	1.6	2.0	2.6	1.060	4.7	5.9	7.2
0.280	1.7	2.2	2.8	1.120	4.9	6.1	7.5
0.315	1.9	2.4	3.0	1.180	5.1	6.3	7.7
0.355	2.1	2.7	3.3	1.250	5.3	6.6	8.0
0.400	2.3	2.9	3.6	1.320	5.5	6.8	8.3
0.450	2.6	3.2	3.9	1.400	5.7	7.1	8.6
0.500	2.7	3.4	4.2	1.500	6.0	7.4	9.0
0.560	3.0	3.7	4.6	1.600	6.2	7.7	9.4
0.630	3.2	4.0	4.9	1.700	6.5	8.0	9.8
0.710	3.5	4.4	5.4	1.800	6.8	8.3	10.1
0.750	3.7	4.7	5.7	1.900	6.8	8.3	10.1
0.800	3.8	4.9	6.0	2.000	6.8	8.3	10.1
0.850	4.0	5.1	6.2	2.120	-	8.3	10.1
0.900	4.2	5.3	6.5	2.240	-	8.3	10.1
0.950	4.4	5.5	6.7	2.360	-	8.3	10.1
1.000	4.5	5.7	7.0	2.500	-	8.3	10.1

NOTE For intermediate sizes, the appropriate load is that given for the next finer size.

8.4 Cut-through Test:

When tested in accordance with clause 5.8 of IS: 4800 Pt. III, specimen shall show no break-down within 2 minutes at 265°C.

8.5 Springness Test:

This test is applicable to conductors of diameter from 0.05 mm, upto and including 1.6 mm. When tested in accordance with clause 5.4 of IS: 4800 Pt. III, the wires shall not give a spring back value in excess of that as given in table-4 below on a mandrel and under a tension specified therein.

TABLE 4 SPRINGINESS TEST

Nominal conductor diameter	Mandrel diameter	Tension	Maximum springback*		
			Grade 1	Grade 2	Grade 3
mm	mm	N			
0.050	3	0.1	72	87	-
0.063	3	0.1	68	82	-
0.071	3	0.1	65	77	-
0.080	5	0.25	70	80	100
0.090	5	0.25	67	77	94
0.100	5	0.25	64	73	90
0.112	7	0.50	64	73	88
0.125	7	0.50	62	70	84
0.140	7	0.50	59	67	79
0.160	10	1.0	59	67	78
0.180	10	1.0	57	65	75
0.200	10	1.0	54	62	72
0.224	12.5	2.0	51	59	68
0.250	12.5	2.0	49	56	65
0.280	12.5	2.0	47	53	61
0.315	19	4.0	50	55	62
0.355	19	4.0	48	53	59
0.400	19	4.0	45	50	55
0.450	25	8.0	44	48	53
0.500	25	8.0	43	47	51
0.560	25	8.0	41	44	48
0.630	37.5	12.0	46	50	53
0.710	37.5	12.0	44	47	50
0.750	37.5	12.0	43	45	48
0.800	37.5	12.0	41	43	46
0.850	50	15.0	47	49	52
0.900	50	15.0	45	48	51
0.950	50	15.0	44	46	49
1.000	50	15.0	42	45	47
1.060	50	15.0	41	43	45
1.120	50	15.0	39	41	43
1.180	50	15.0	37	39	41
1.250	50	15.0	35	37	39
1.320	50	15.0	34	36	38
1.400	50	15.0	32	34	36
1.500	50	15.0	30	32	34
1.600	50	15.0	28	30	32

NOTE The maximum springback for intermediate sizes will be the maximum specified for the next smaller size in the table.

8.6 Heat Shock Test:

Three test specimens shall be prepared as prescribed in clause 8.2.1 above but using mandrel diameters given below and kept for 30 minutes in a forced air circulating oven at a temperature of 200-205°C. After removal from the oven, the specimen shall be allowed to cool to room temperature and shall be examined under a magnification of 10-15 times. Each specimen shall be free from cracks.

Nominal diameter (mm)		Mandrel diameter(mm)
Over	Upto & including	
-	0.04	0.150 mm
0.04	0.16	3 d
0.16	0.25	4 d
0.25	1.00	2 d
1.00	5.00	3 d

8.7 Solvent Test:

When tested in accordance with clause 5.10 of IS: 4800 Pt. III, the enamel of the conductor shall not be removed down to the conductor in any one of the three tests with a pencil of hardness 'H'.

8.8 Resistance Of Enamel To Oil:

When tested in accordance with the method mentioned below the enamel shall be such that it shall not be removed down to the conductor by scraping with thumb nail.

8.8.1 Test Method:

The enamelled wire shall be wound in contiguous turns on a polished metal mandrel 2.5 cm. in diameter for about 10 mm length on the mandrel. The mandrel with the wire shall then be immersed in insulating oil to IS: 335 for 6 hours at 135 ± 2°C, taken out and allowed to cool to room temperature. The specimen shall then be scrapped with the thumb nail.

8.9 Breakdown Voltage:

8.9.1 Breakdown Voltage At Room Temperature:

8.9.1.1 Conductor Sizes Upto & Including 0.040 mm:

When tested in accordance with clauses 5.11.3 of IS: 4800 Pt. III, at least four of five samples shall not breakdown at voltages less than those given below in table-5.

TABLE 5 BREAKDOWN VOLTAGES
(FOR CONDUCTORS UP TO AND INCLUDING 0.040 mm DIAMETER)

Nominal conductor diameter	Minimum breakdown voltage (r.m.s.)	
	Grade 1	Grade 2
mm	V	V
0.020	40	115
0.0224	40	115
0.025	60	140
0.028	60	140
0.030	60	140
0.032	70	175
0.036	70	175
0.040	100	230

8.9.1.2 Conductor Sizes Over 0.040 mm Upto And Including 2.5 mm:

When tested in accordance with clause 5.11.3 of IS: 4800, Pt. III the breakdown voltage shall be higher than the value given below in table-6. If however, of the five samples tested one has a lower value than that mentioned below in table-6 the test shall be repeated with a second series of samples and no failure shall occur.

TABLE-6 BREAKDOWN VOLTAGES (FOR CONDUCTORS OVER 0.040 mm DIAMETER UP TO AND INCLUDING 2.500 mm DIAMETER)

Nominal conductor diameter		Minimum breakdown voltage (r.m.s)		
		Grade 1	Grade 2	Grade 3
mm		V	V	V
0.045		350	700	-
0.050		350	700	-
0.056		375	750	-
0.060		375	750	-
0.063		400	800	-
Over	Up to and including			
mm	mm			
0.063	0.080	500	950	1400
0.080	0.100	600	1200	1600
0.100	0.125	700	1300	1800
0.125	0.160	800	1500	2200
0.160	0.200	900	1700	2500
0.200	0.250	1000	2000	3000
0.250	0.315	1200	2200	3300
0.315	0.400	1400	2400	3700
0.400	0.500	1600	2800	4000
0.500	0.710	1800	3100	4400
0.710	0.850	1900	3500	4700
0.850	0.950	2000	3700	5100
0.950	1.120	2100	3800	5300
1.120	1.320	2200	3900	5600
1.320	1.600	2300	4000	5900
1.600	1.900	2400	4300	6100
1.900	2.500	2500	4400	6300

8.9.1.3 **Conductor Sizes Over 2.5 mm:**

When tested in accordance with clause 5.11.4 of IS: 4800 Pt. III at least four of five samples shall not breakdown at voltages less than 1000, 1600 and 2400 Volts respectively for Grade 1, 2 and 3 of covering.

8.9.2 **Breakdown Voltage At Higher Temperature:**

75 percent minimum of the appropriate values given above in Cl 8.9.1 when tested at 180°C.

8.10 **Continuity Of Covering:**

This is applicable to conductors of diameter upto and including 0.5mm. When tested in accordance with clause 5.12 of IS: 4800 Pt. III the number of faults per 30 metre of wire shall not exceed the values given below:

TABLE-7

Nominal conductor diameter		Maximum number of faults per 30 m		
Over	Up to and including	Grade 1	Grade 2	Grade 3
mm	mm			
-	0.040	30	12	-
0.040	0.500	15	6	4

9. **TEST CERTIFICATE:**

Three copies of test certificate shall be supplied which shall give the following information:-

AA 281 46 : Polyesterimide Enamel Round Copper Conductors
(Rev. 01) : (Temperature Index 180).

BHEL'S Order No.
Manufacturer's/Supplier's Name:
Batch/Lot No:
Test Results of clauses 6 to 8.

On first consignment for establishment of material, supplier shall indicate the type and make of enamel with life time characteristics alongwith the sample of enamel for infra-red spectograph for our approval on subsequent orders. Certificate that the supplier has used the approved enamel shall be furnished.

10. **PACKING AND MARKING:**

The conductors shall be wound on reels, and packed, wrapped and labelled in accordance with IS: 482-1968 'Specification for Reels for covered, solid, round electrical winding wires'.

Flange diameters of reels shall conform to table-I of above IS, but wires between 0.914 mm and 0.315 mm shall be wound only on reels conforming to column 2 or 3 of table-III of the above IS. Each reel shall be marked with the following:

AA 281 46 : Polyesterimide Enamelled Round Copper Conductors (Temperature Index 180).

BHEL's Order No.
Manufacturer's/Supplier's Name.
Batch/Lot No.
Size & grade of conductor.
Quantity Supplied.