



भारत सरकार  
रेल मंत्रालय  
GOVERNMENT OF INDIA  
MINISTRY OF RAILWAYS

डीजल इलेक्ट्रिक लोको  
के  
कर्षण मोटरों में प्रयुक्त लपट प्रतिरोधी 200°C फ्लुरोइलास्टोमर कुचालित  
मेन लीड एवं ब्रशगियर केबिलों  
के लिए तकनीकी विशिष्टि

**TECHNICAL SPECIFICATION  
FOR  
FLAME RETARDANT 200°C FLUOROELASTOMER INSULATED  
MAIN LEAD & BRUSH GEAR CABLES USED IN TRACTION MOTORS  
OF  
DIESEL ELECTRIC LOCOMOTIVES**

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मार्च, २००८  
SPECIFICATION NO. MP. 0. 52.00.08 (REV.- 03)  
MARCH, 2008

अनुसंधान अभिकल्प एवं मानक संगठन  
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# **TECHNICAL SPECIFICATION FOR FLAME RETARDANT 200°C FLUOROELASTOMER INSULATED MAIN LEAD & BRUSH GEAR CONNECTOR CABLES USED IN TRACTION MOTORS OF DIESEL ELECTRIC LOCOMOTIVES**

## **1.0 SCOPE**

- 1.1 This specification covers the performance and test requirements for 200°C Fluoro-Elastomeric 1500V grade flame-retardant (equivalent to 1500V flame-retardant FLUONLEX insulated wire-WFM2 of M/s Hitachi Cables Ltd.) flexible Traction Motor Lead Cables & Brush Gear Connector Cables for use on Diesel Electric Locomotives. The cables shall be oil and grease resistant and resistant to moisture.
- 1.2 The cable is expected to have a minimum useful life of 25 years when applied at an appropriate duty cycle and environment.

## **2.0 CONDUCTORS**

- 2.1 The copper conductor shall be multi-stranded. The strands of the conductor shall consist of tinned, annealed, high conductivity circular copper wire conforming to JIS C 3152.
- 2.2 The direction of the lay should preferably be uni-directional (unilay) such that a compact conductor is obtained with smooth outside surface. The direction of the lay for all bunches shall be left hand.
- 2.3 Only brazed or welded joints of individual strands are permitted.

## **3.0 SEPARATOR**

A suitable separator between conductor and insulation is required, the same shall be offered giving the details of this separator.

## **4.0 INSULATION**

- 4.1 The insulation shall be an extruded layer of black modified ETFE (copolymer of tetrafluoroethylene and olefine) compound.
- 4.2 The cable shall be suitable for operation at 200°C. The manufacturer shall establish the Infra Red Spectrograph of the material and furnish the same to RDSO before type test and it should match with the Infra Red Spectrograph given at **Annexure - 1**.
- 4.3 The covering of the conductor shall be uniform over the entire length of the cable. The average thickness of the covering shall not be less than 90% and the minimum thickness at any point shall not be less than 80% of the value given in **Table-1**.
- 4.4 The insulation shall be so applied by extrusion that it fits closely with conductor and it can be strip off the conductor.

## **5.0 CONSTRUCTION**

The conductor formation (cross sectional area, diameter of wires in conductor, number of wires, diameter of conductor, thickness of covering, overall dimension of the cable and maximum resistance of conductor at 20°C) of fluoroelastomeric cables to be used on diesel electric locomotives for Indian Railways are as per **Table – 1**. If the manufacturer proposes different conductor formation, which equals or excels **Table – 1**, RDSO's approval shall be obtained before adoption.



## 6.0 COLOUR

Unless specifically indicated the colour of the insulation shall be black.

## 7.0 TEST METHOD & REQUIREMENTS

Tests on cables shall be carried out as per Table – 2 of this specification.

### 7.1 The tests at Table – 2 are classified as:

- Type Tests
- Acceptance Tests

### 7.2 Type Tests

- The manufacturer shall submit internal test results as per all the tests specified in **Table – 2** along with Infra Red Spectrograph of the polymer. If the results of internal test found satisfactory, the manufacturer shall be called for type test of the cable. And as a part of type test, the manufacturer shall also be asked to supply cables with end fittings for twelve traction motors for fitment trials at DLW / DMW / BHEL. The manufacturer shall notify in advance about readiness of the cable for type testing.
- The type test schedule shall be constituted of all the tests specified in **Table - 2**. Successful completion of type test is mandatory for final approval of fluoroelastomeric cables for application on diesel-electric locomotives. RDSO representatives at the cost and premises of the manufacturer shall witness type test. Type tests shall be repeated every three years as a part of quality audit. In case of any change in the material or design of the cable complete type tests shall be repeated.
- If the testing facilities for any test are not available at the manufacturer's premises, the manufacturer shall make necessary arrangements for carrying out that test at outside laboratories, either reputed or government approved.

### 7.3 Acceptance Tests

- These tests are to be carried out on samples selected randomly from a lot ready for despatch, for the purpose of acceptance of the lot by the purchaser or any other inspecting agency nominated by the purchaser as per the tests marked as Acceptance Tests in **Table–2**. Acceptance tests shall not be carried out on a particular size from the lot on which type tests have already been conducted. The acceptance test schedule shall be constituted of all those tests marked as Acceptance Tests in **Table–2**.
- If any of the test results does not meet the requirements, the whole tests shall be repeated on other samples selected again.
- If the results of the repeated tests are not found within acceptable limits, the entire offered lot shall be rejected.
- If the results of the repeated tests are found within acceptable limits, the offered lots shall be considered to be acceptable.

## 8.0 IDENTIFICATION

The following details shall be printed on the covering of the cable in contrasting colour within 1000mm:

- Manufacturer's Name / Trade Mark
- Rated voltage
- Year of manufacture
- Indication of Type of cable and Thermal Index.
- Cross Sectional area of the conductor.

## **9.0 PACKING & MARKING**

- All cables shall have their ends sealed with non-hygroscopic sealing materials.
- The cables shall be supplied on reels / drums and labelled. Standard length per reel / drum =  $100 \pm 5$  meters in one piece.
- The label/stencilling on the drum shall contain the following information:
  - Reference specification number
  - Manufacturer's name, brand name or trade mark
  - Types of cables and voltage grade
  - Number of cores
  - Nominal cross-sectional area of the conductor
  - Length of the cable on the drum / reel
  - Number of lengths of the reel / drum (if more than one)
  - Direction of rotation of drum (by means of arrow)
  - Approx. gross weight
  - Year of manufacture
  - Purchase Order Number



TABLE - 1

Conductor			Thick. of	Dia. of	Tolerance	Conductor	AC Test	Min.	Min.
Nom. Sectional Area (mm <sup>2</sup> )	Construction No. (Typical Value) / Dia. of Wire (max.) (mm)	Dia of conductor or (mm)	Insulation (mm)	finished cable (mm)	of overall dia. (mm)	Resistance At 20°C Max (Ω/Km)	Voltage (V/1 min.)	Insulation Resistance at 20°C (MΩ/Km)	Surface Leakage Resistance (MΩ)
250	61/77/0.26	22.6	3.0	28.8	+1.2	0.0804	5,400	900	50
200	37/102/0.26	20.2	3.0	26.4	+1.1	0.0991	5,400	1,000	60
150	37/76/0.26	17.5	2.5	22.7	+1.0	0.133	5,400	900	70
100	37/51/0.26	14.4	2.5	19.6	+0.9	0.198	5,400	1,000	80
80	19/79/0.26	12.7	2.5	17.9	+0.9	0.249	5,400	1,000	90
50	19/50/0.26	10.2	2.5	15.4	+0.8	0.394	5,400	1,000	100

**APPENDIX -1****COMPOSITION OF CONDUCTOR**

Tin-plating of the wires shall be visually examined. There should be no blistering or colour change of the wires. All wires must be of the same nominal diameter. The diameter of the wires must not differ from the nominal diameter beyond the tolerance  $\pm 0.01$  mm.

The diameter of the wire shall be measured by means of a ratchet micrometer or a dial micrometer, between smooth faces circular in shape and with a diameter of at least 5 mm. The average of the readings of the two measurements taken at right angles to each other shall be accepted as the value of the diameter.

**APPENDIX - 2****SLIPPAGE TEST**

A sample of length approximately 350 mm is taken and bent to a radius of 100 mm. The relative displacement of the conductor with insulation shall not be more than 5 mm for cables up to 25 mm dia. and 10 mm for cables over 25 mm dia. from each end of the cable.

**APPENDIX - 3****ABRASION RESISTANCE****Applicable Cable Size - 150 mm<sup>2</sup>**

The test shall be conducted as per UL Standard 719 (non-metallic sheathed cables) or TDE 76/P/16.

As per **UL Standard 719** (non-metallic sheathed cables) :-

Abrasion resistance shall be 2500 cycles (averages of 3 tests). The abrading blade shall be General Electric carbolloy tool blanks – Blank order no. 1330, Group II-370.

Three wire specimens shall be cut from unaged samples each having a length of approximately 14 inches. The test specimens are laid flat and parallel on a horizontal reciprocating table positioned beneath steel plungers. Each plunger is provided with three abrading blades of the type described above. The pressure applied to each plunger shall be according to 8 pounds and the motion of the table shall be 30 cycles per minute.

**APPENDIX - 4****FLEXIBILITY****TABLE - A**

S. No.	Conductor Size (mm <sup>2</sup> )	Dia. of mandrel (in.)	Maximum Weight (pounds)
1.0	100	3	17
2.0	150	4	24
3.0	200	4-1/2	26
4.0	250	5	35

At a temperature maintained between 20 and 25° C, one end of a 45 inch test specimen shall be secured to the mandrel and the other end to the load weight specified in TABLE - A. The



mandrel shall be mounted in a fixture so that the weighted end of the test specimen is freely suspended. The mandrel shall be rotated at 2 RPM until at least 3 full turns of the test specimen have been wrapped around the mandrel. The flexibility of the cable shall be such as to permit these turns to fit tightly against the mandrel. Any specimen exhibiting a continuous separation of adjacent turns for more than 90° when measured around the periphery from a point where the gap starts and to the point where the gap ends i.e. cable comes in contact again with the adjacent turns after exhibiting the separation or if it does not come in contact at all with the adjacent turn exhibiting a continuous separation, then it shall not meet the test requirement. (1<sup>st</sup> turn after clamping point may be ignored)

## **APPENDIX – 5**

### **CRUSH RESISTANCE**

When tested at a temperature not less than 70°F, the finished cable shall exhibit a resistance of crushing greater than 4000lbs (average of 10 tests) when tested according to UL Standard 719, as described in paragraphs 18.2 to 18.5 with the following exceptions: sample size shall be 100 mm<sup>2</sup>, 150 mm<sup>2</sup>, 200 mm<sup>2</sup> & 250 mm<sup>2</sup> and the cable to be tested will be crushed between a flat horizontal surface and the surface of a rigid steel rod having a diameter of ¾ inch.

## **APPENDIX – 6**

### **VOLTAGE WITHSTAND (DIELECTRIC TEST) & INSULATION RESISTANT TEST**

**TABLE - B**

<b>SI No.</b>	<b>Conductor Size (mm<sup>2</sup>)</b>	<b>AC test voltage (KV)</b>	<b>DC test voltage (KV)</b>	<b>Insulation resistance (MΩ/Km)</b>
1.0	100	5.4	24.0	1000
2.0	150	5.4	28.5	900
3.0	200	5.4	28.5	1000
4.0	250	5.4	31.5	900

#### **A) Voltage Withstand (dielectric test)**

The insulated conductors shall withstand AC voltages for 1 minute and DC voltages for 5 minutes as given in TABLE - B and ICEA S-66-524 after a 6-hour immersion in water. The water bath temperature shall not exceed 30°C.

#### **B) Insulation Resistance**

The manufacturer shall guarantee that any 25 foot sample, chosen at random from production, shall pass the **dielectric test** given as above and shall have an insulation resistance in excess of 900 – 1000 MΩ/Km when tested as given below:

Finished cable shall be immersed in tap water at a bath temperature less than 30°C for a period of 6 hours. Following this conditioning period, the insulation resistance shall be measured per paragraph 6.25 of ICEA S-19-81 and the results calculated in MΩ/Km.



## **APPENDIX-7**

### ***CURRENT CARRYING CAPACITY***

Take suitable length of cable fitted with lugs at both ends. Pass the cable through the current transformer of capacity of more than 2000 Amps. Make a loop of the cable by bolting the lugs and place it in draft free room at ambient temperature. Support the cable with wooden block so as to lift it in air in horizontal position. Insert thermocouple between the insulation and conductor and wrap tightly the area with glass tape to make good contact of the thermocouple with the conductor. Increase the current of the transformer intermittently allowing the conductor to attain the maximum temperature at each setting and continue until the rated temperature i.e. 200°C of the conductor is attained at a steady state and keep the cable at  $200 \pm 10^\circ\text{C}$  for min. 480 hours. Measure the current by inserting the probes around the cable. From the reading of the probes, current carrying capacity of the cable can be determined. After the conditioning period i.e. min. 480 hours, stop the current supply, unbolt the lugs and immediately wrap the cable in hot condition (within / around 1 min.), minimum three loops around the mandrel having a diameter equal to two times the overall diameter of the cable being tested. There shall be no cracks or splits in the cable covering (s) after bending and the sample shall also pass the dielectric test as per Appendix-6.

This method will give the current carrying capacity of the cable in free air at ambient temperature.



TABLE – 2

S.No	TESTS	Type Test	Accept- ance Test	REQUIREMENTS	TEST METHODS
<b>CONSTRUCTION &amp; DIMENSIONS</b>					
1.	(a) Composition of conductor	✓	✓	(a) Table – 1 of this specification,	Appendix – 1 For thickness of insulation : IEC-60811-1-1 For resistance: JIS C 3005
	(b) Tin Plating of copper wire	✓		(b) No blistering, no colour change	For tin plating: UIC 895 OR cl. 5.1.3
2.	a) Persulphate test(for Cu)	✓		a) 6.1.1 of IS: 8130:1984	a) Part 4 of IS: 10810:1984
	b) Annealing test (for Cu)	✓		b) 6.1.2 of IS: 8130:1984	b) Part 1 of IS: 10810:1984
<b>MECHANICAL PROPERTIES</b>					
3.	Mechanical Properties of Insulation: ➤ Tensile Strength as received ➤ Elongation at break as received ➤ Retention of tensile strength & elongation at break after heat ageing for 96 hrs. at 250°C	✓ ✓ ✓	✓ ✓ ✓	≥ 1.0 Kg /mm <sup>2</sup> ≥ 250% ≥ 80% of the value before ageing	JIS C 3005, cl. 18  JIS C 3005, cl. 19
4.	Slippage test	✓	✓	The relevant displacement of the conductor with Insulation shall not be more than 5mm for cables up to 25mm dia and 10mm for cables more than 25mm dia.	Appendix - 2
5.	Abrasion Resistance	✓	✓	The finished wire shall show a resistance to abrasion of no less than 2500 cycles (5000 strokes) when tested according to Appendix – 3	Appendix – 3 OR TDE76/P/16
6.	Impact at - 40±2 °C (for Power Cable)	✓		No cracks, no break down when tested as Sl. No. 13 of this table.	IEC-811-1-4, cl. 8.5 Test specimen as received & after ageing in air oven for 10days at 250°C



**TABLE - 2**

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S.No	TESTS	Type Test	Accept- ance Test	REQUIREMENTS	TEST METHODS
7.	Windability - bending at -40±2 °C	✓		No cracks, no breakdown when tested according to Sl. No. 13 of this Table.	IEC-811-1-4, cl. 8.1
8.	Windability after ageing (bending)	✓		250°C, 10 days, No cracks, no break down when tested according to Sl.No. 13 of this Table.	UIC 895 OR cl. 5.3.2
9.	Cross-linking degree test by Gel Fraction method	✓		Gel Fraction 85% min.  For uniformity, cut covering from the cross-section of a cable & cut 4 samples at 90° each from the cut cross section & do the test. Average of 4 pieces must meet ≥ 85%	JIS C 3005, cl. 27
10.	Flexibility	✓	✓	Any specimen exhibiting a continuous separation of adjacent turns for more than 90° shall not meet the test requirement.	Appendix - 4
11.	Crush Resistance	✓	✓	At room temperature, the finished cable shall exhibit a resistance of crushing of greater than <b>4000 lbs</b> (average of 10 tests).	Appendix - 5
12.	Tests for identification of polymers	✓	✓	Infra Red Spectrograph results of polymer should match the spectrograph attached with this specification.	ASTM - D - 3677 - 83
<b>ELECTRICAL PROPERTIES</b>					
13.	Voltage (dielectric test) & Insulation Resistance test	✓	✓	The insulated conductors shall withstand the r.m.s & DC voltages as given in Appendix - 6.	Appendix - 6 OR JIS C 3005, cl. 8 (1) & 9.1
14.	Current Carrying capacity	✓		At 200°C, rated current shall pass through the cable for 480 hrs and there should be no crack, no breakdown when tested according to Sl. No. 13 of this Table.	Appendix - 7
15.	Surface leakage resistance	✓		Not less than the value given in the Table-1	JIS C 3005, cl. 16



TABLE – 2

S.No	TESTS	Type Test	Acceptance Test	REQUIREMENTS	TEST METHODS
16.	<p>➤ Thermal Test &amp; Endurance of duration of usability.</p> <p>➤ Elongation at break absolute.</p>	✓		Arrhenious Plot	IEC-216
17.	Flame Retardance	✓	✓	<p>≥ 50% after 20,000 h at 200°C</p> <p>To be naturally extinguished within 30 seconds.</p>	JIS C 3005, cl. 28 (by Horizontal method) OR, IEC-332-Part-1
18.	Hot set test	✓		<p>200°C, 20 N/ Cm<sup>2</sup> : Max. elongation:</p> <ul style="list-style-type: none"> <li>• under load ≤ 100%</li> <li>• after cooling ≤ 25%</li> </ul>	IEC 811-2-1, cl. 9
19.	Oil resistance test	✓	✓	<p>➤ <b>Hot oil resistance test I</b> : No cracks or other deterioration in the covering. No break down when tested according to SI. No. 13 of this Table. The cable dia. increase shall not exceed 40 %.</p> <p>OR</p> <p>➤ <b>Hot oil resistance test II</b> : Minimum values for Tensile Strength &amp; Elongation measured shall be as follows:</p> <ul style="list-style-type: none"> <li>• % of original tensile strength : 60</li> <li>• % of original elongation : 60</li> </ul>	<p><b>Hot oil resistance test I</b> : The central 1 foot section of a 2 ft. sample should be immersed in a U-shape in ASTM No. 1, 2 &amp; 3 oil for 100 hrs. at 150 ± 2° C.</p> <p>OR</p> <p><b>Hot oil resistance test II</b> : As per JIS C 3005, clause 20 and class C of Table 6.</p>
		✓		<p>➤ <b>Fuel Oil test</b> : Cable dia. increase shall not exceed the value specified below:</p> <p style="text-align: right;">Dia. increase 20%</p> <p>High Speed Diesel oil</p>	<p><b>Fuel Oil test</b> : The central 1 foot section of a 2 ft. sample should be immersed for 100 hrs. at 25± 5°C in High Speed Diesel oil.</p>
20.	Ozone resistance test	✓		<p>275 ± 25 ppm, 96h at room temp.. No cracks in Insulation. No breakdown when tested according to S. NO. 13 of this table.</p>	IS: 10810, Part - 13
21.	Moisture Absorption	✓		<p>According to IEC 60811-1-3 § 9.2 After 168 hrs at 70° C in water Max. weight increase ≤ 8 mg/inch<sup>2</sup> (1.24 mg/cm<sup>2</sup>)</p>	IEC 60811-1-3 § 9.2

## INFRARED SPECTROGRAPH OF MODIFIED ETFE

