GOVERNMENT OF INDIA
(MINISTRY OF RAILWAYS)
RESEARCH DESIGNS AND STANDARDS ORGANISATION
MANAK NAGAR, LUCKNOW-226 001

NO. EL/2.2.51 Dt.15th May' 2001

SPECIAL MAINTENANCE INSTRUCTIONS NO. ELRS/SMI/0224-2001(REV.'0')

1.0 TITLE

Reliability improvement measures for the operating coils (Solenoids) used in the equipments like Air Blast Circuit Breakers, Reversers / CTFs, Contactors (EP/EM) and Electrovalves of Electric Locomotives

2.0 BRIEF HISTORY

2.1 Failures of the operating coils of Electro-pneumatic Valves such as NC4/NC7, Electro-magnetic contactors and EFDJ/MTDJ have been adversely affecting the reliability of Electric Locomotives on Indian Railways. With a view to improve the reliability for better availability of locomotives, Railway Board vide their letter No.99 / Elec.(TRS) / 441 / 13 dated 30.07.1999 constituted a Committee to review the existing specification for theses operating coils, their approved suppliers, analysis of the nature of failures and maintenance practices including testing facilities in the electric loco sheds/work shops.

2.2 The Committee after detailed study and discussions finalised its recommendations as under, which have also been approved by Railway Board vide their letter No. 99/Elec(TRS)/441/13 dated 16.03.2001.

- Reliability Assurance Specification to form a part of the CLW Specification;
- During AOH / POH, all coils to be subjected to measurement of resistance, check on inter-turn short and surge comparison test.
- Sheds / shops to maintain make-wise and application-wise record of failed coils for failure analysis to determine reasons of the failures and adoption of remedial measures by coil manufacturers.
- MTDJ and EFDJ coils to be procured from OEM only and other coils for EP contactors, Reversers/CTFs etc. from RDSO's approved sources. The sources have been mentioned at Para 5.4 of this SMI after ensuring the availability of following minimum facilities and infrastructure with coil manufacturers for obtaining quality coils:-
  - Automatic coil winding machine with speed control device to achieve proper tension of the wire and avoid overlapping of inter-turns.
  - VPI plant.
  - Baking oven.
  - Proper storage facilities for raw material which normally have shelf life (insulating materials such as varnish, tapes etc.)

- Test bench for –
  - High voltage test
  - Surge comparison test &
  - Burn-in test etc.
- Necessary tools, jigs and fixtures as well as instruments for measurement of resistance should also be available with the firm.

3.0 APPLICATION

Solenoids (coils) of the equipments such as Electro-pneumatic valves, Electro-magnetic contactors and EFDJ/MTDJ coils etc fitted on electric locomotives.

4.0 OBJECT

4.1 Analysing the failure data collected from the user railways, it is observed that the failure of coils can be classified as –
- Open circuiting
- Complete burning
- Short circuiting &
- Breakage of terminals.

4.2 The majority of the failures of coils is, however, due to insulation failure between outer and inner lead / terminal with outermost / innermost layer of the coil.

4.3 With a view to arrest / minimise the coil failures as stated above, this SMI lays down the requirements of input materials and manufacturing facilities, maintenance practices to be followed by the sheds/shops, availability of testing facilities and the names of the Regular Approved Sources for the present for procurement of reliable operating coils.

5.0 **INSTRUCTIONS**

5.1 **Raw Materials and Manufacturing Procedure**

5.1.1 With the availability of new insulating materials having improved properties, the Railways and Production Units shall ensure that the coil manufacturers use the following raw materials and procedure for manufacture of coils.

5.1.1.1 Super enameled dual coated winding wires as per IS:13730 Pt.XIII i.e. H200 class for coils.

5.1.1.2 Glass filled Nylon 66 material as per IS:13464-92 for bobbins. (Tests as per IS-13360-92 Pt.1 to 6)

5.1.1.3 6KV (Proof Voltage), H-class silicon coated sleeves while taking out the inner lead on the top and over the outer lead also.

5.1.1.4 VPI of the coils to be done with Dr.Beck's H-71 or FT-2005/500EK, H-200 class impregnating resin.

5.1.1.5 Potting or incapsulation of the coil to be done with Dr.Beck's DOVEKOT 520F or equivalent compound.

5.2 **Testing Facilities in Sheds / Shops**

5.2.1 Sheds / Shops will carry out the following tests on all coils during AOH / POH and keep records for monitoring the condition of the coils. Facilities for these tests are available in most of the sheds as well as shops. However, those sheds / shops which do not have testing facilities for these tests, should organise them.

5.2.1.1 Measurement of coil resistance.

5.2.1.2 Check for inter-turn short and

5.2.1.3 Surge comparison test

Rejected / failed coils should be subjected to detailed examination jointly with the coil manufacturers.

5.3 **Maintenance Practices by Sheds / Shops**

5.3.1 The condition monitoring of the coils through tests as recommended in Para 5.2 above should be adopted by sheds / shops.

5.3.2 Analysis of the failures make-wise and application-wise to determine the reasons there of. Adoption of remedial measures should be jointly finalised with the coil manufacturers.

5.4 **Recommended Regular Approved Suppliers**

5.4.1 Keeping in view the criticality of coils in the electric locomotives and availability of infrastructure, machinery plants / testing facilities, the following **THREE sources are approved as Regular Sources** for the present for manufacture and supply of the coils:-

(I) **M/s. CIBIMAR & Co.**
7/F, Abinash Chandra Banerjee Lane,
Beliaghata, Calcutta-700 010

(ii) **M/s. Patron Industrial Corporation,**
Howrah Amta Road,
Baltikuri, Howrah-711 402

(III) **M/s. Inspros Engineers Pvt. Ltd.,**
126, Sector 'A', Industrial Area,
Mandideep, Bhopal-462 046

5.4.2 Considering the total reliability for MTDJ and EFDJ coils which are also being procured by Railways for their spare requirements, it is recommended that these coils should only be procured from the Original Equipment Manufacturer (OEM).

SMI/0224

5.5 **Reliability Assurance Specification for Coils**

5.5.1 CLW's existing specification for electromagnetic solenoids (i.e.coils) has been updated by CLW to include the recommendations contained in the **"Reliability Assurance Specification for Electro-magnetic Solenoids"** which forms a part of the RITES Reliability Report on the subject. This specification has since been up dated to include new insulating / raw materials now available and a copy of the same is enclosed. The revised Reliability Specification should form a part of the CLW procurement specification. All coil manufacturers should adopt the instructions contained in the revised Reliability Specification.

6.0 **INSTRUCTION DRAWING**

Reliability Assurance Specification (Annexure-1).

7.0 **AGENCY FOR IMPLEMENTATION**

Production Units, All Electric Loco Sheds, EMU car sheds, POH workshops and Coil Manufacturers.

8.0 **DISTRIBUTION**

As per list enclosed.

SMJ/0224

Shivaji Kumar Sinha
14.5.2001

(S.K.Sinha)
For Director General (Elect.)

ANNEXURE-1

RELIABILITY ASSURANCE SPECIFICATION FOR ELECTRO-MAGNET SOLENOIDS

1.0 INTRODUCTION

1.1 This specification describes certain features to be adopted in the design, manufacturing process and screening / testing procedures for electro-magnet solenoids used on electric rolling stock in order to improve their reliability.

1.2 The provisions of this specification are supplementary to those in the particular specification or drawing for the solenoid. The particular specification gives details of the application, size of the winding wire, the number of turns, the overall dimensions of the solenoid and its terminals.

1.3 This specification allows freedom to the manufacturer of the solenoid regarding choice of material. Wherever any specific material is mentioned in this specification, the manufacturer may use an alternative only if it can be shown that the mechanical, electrical and thermal properties of the proposed material are not worse than those of the specified material.

1.4 This specification also describes certain process elements and test procedures. These must always be complied with. In general, any deviation from this specification must have the prior approval of RDSO.

1.5 This specification gives in detail various features relating to design, manufacture and testing. Where necessary reasons for certain provisions are explained.

2.0 BOBBIN

2.1 The bobbin for the winding shall be made of Heat stabilized nylon 66 with 30 to 40 % glass filler conforming to the requirements of IS:134641992. The material shall be tested as per IS:13360 (Pt.1 to 6).

2.2 While test certificates from the bobbin manufacturers may be accepted, confirmatory tests shall be made on the bobbins by the solenoid manufacturer in regard to the dielectric strength to withstand 5 kV/mm, 50 Hz, RMS for 1 minute.

3.0 WINDING WIRE

3.1 The super enameled dual coated winding wire complying with the requirements of IS:13730 Pt.XIII i.e. H200 class shall be used. The enamel thickness shall be 'medium'.

3.2 The winding wire shall be of a make approved by RDSO. Test certificates from such manufacturer may be accepted. However, confirmatory tests shall be made by the solenoid manufacturer in regard to the flexibility, adhesion, heat shock and breakdown voltage tests, on samples drawn from each spool

SMI/0224

3.3 The manufacturer of the solenoid should maintain records of the above tests. These records should indicate the date of test, test results and name/signature of the person witnessing the test. This record may be inspected by the Inspecting Authority deputed by the Indian Railways.

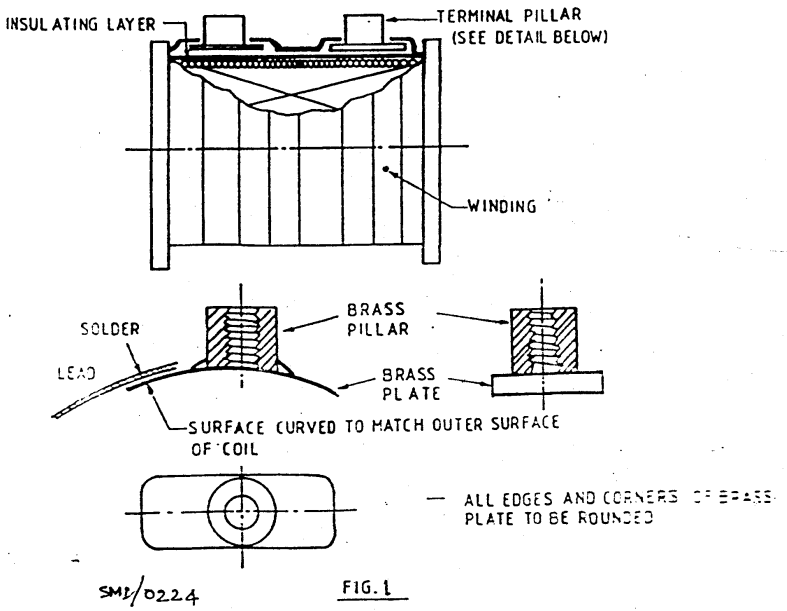
4.0 **INSULATING VARNISHES AND COMPOUNDS**

4.1 The varnishes and compounds used during manufacture shall be compatible with the enamel on the winding wire. Certificates regarding this compatibility should be obtained from the manufacturer of the winding wire.

4.2 Vacuum / Pressure impregnation of the coils should be done with Dr. Beck's H-71 or FT-2005/500 EK, H-200 class impregnating varnish with suitable hardener manufactured by Dr. Beck in accordance with their recommendations for the application. The tapes used in the process of coil winding shall be impregnated with the same resin.

5.0 **TERMINALS**

5.1 The terminals may be either moulded into the bobbin or fastened over the winding as shown in the figure-1.



SMI/0224

FIG. 1

5.3 The terminal pillars and the curved plates shall be made of brass or copper. The pillar shall be brazed to the curved plates with hard solder with melting point more than 500 deg. C. Soft solders shall not be used for this purpose.

5.4 The curvature of the brass plate shall match the outlet surface of the coil with its insulating cover tape.

5.4 The edges of the brass plate shall be carefully rounded and polished to prevent cutting into the tape.

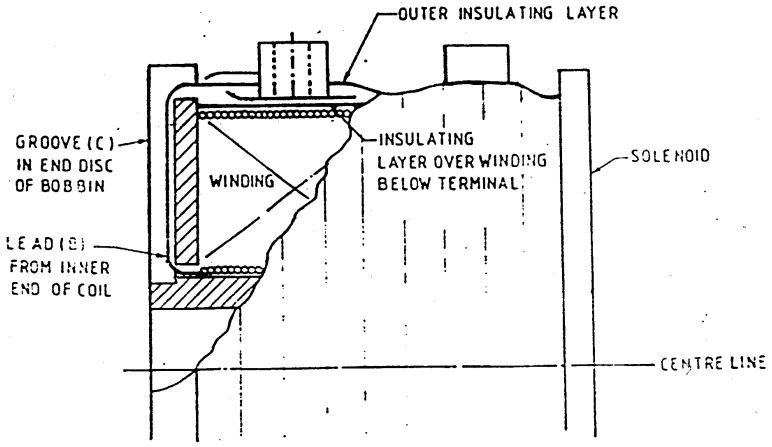
5.5 The terminal assembly shall be tinned with pure tin before assembly on the coil.

5.6 The minimum distance between the two terminal plates shall be not less than 25mm.

5.7 The brass plates shall be coated with one of the varnishes mentioned in Para 4.2 and placed on the semi-cured coil cover tape. They shall be held in place by cords tied tightly around the brass plates and knotted.

6.0 THE LEAD FROM THE INNER END OF THE WINDING

6.1 The lead from the inner end of the winding shall be brought to the top of the coil through an opening / groove outside the end disc of the bobbin as shown in the figure-2.



NOTE:- AIR GAPS BETWEEN TURNS AND BETWEEN LAYERS SHOWN FOR CLARITY. ACTUALLY THERE SHOULD BE NO AIR GAPS

SMI/0224 FIG-2

6.2 The groove shall be filled with araldite after ensuring that the lead is secured at the bottom of the groove. If necessary, in order to obtain the final dielectric strength, an insulating sheet of nomex impregnated in one of the varnishes mentioned in Para 4.2 with hardener may be pasted over the end-disc of the bobbin. The residual thickness of bobbin material below the lead shall be at least 1.5mm so as to obtain a dielectric strength of at least 5 Kv between the lead and the winding.

6.3 Care should be taken to seal the edges of the insulating layer at the point where the lead crosses the outer layer of the winding on its way to terminal post.

7.0 THE MAIN INSULATING LAYER OVER THE WINDING

7.1 This insulating layer has a very important function. The induced voltage across the winding when it is switched off, is of the order of 5 KV. The insulating layer must be capable of withstanding repeated surges with peak voltages of 5 KV or perhaps even higher occasionally. This requirement is important particularly when either terminal leads or terminal themselves are situated near the top layer of the winding.

7.2 It is recommended that this insulating layer be built up with 3 layers of glass-mica-glass tape 0.13mm thick and 20 mm wide, half-lap. This will give a total thickness of about 0.8 mm and develop a dielectric strength capable of withstanding 5 kV, 50 Hz for 1 minute. Any alternative material must comply with this last requirement.

7.3 The GMG tape should be impregnated with one of the varnishes mentioned in Para 4.2 + Hardener before winding over the coil. Before applying the first layer of the tape, the winding shall be given a liberal coat of recommended varnish (para 4.2).

7.4 This insulating layer shall be partly cured and then the terminal plates shall be fastened over it.

8.0 LEADS AND SOLDERED CONNECTION

8.1 The leads as also the portion of the terminal plates shall be thoroughly cleaned and soldered with 60:40 (tin + lead) solder. During soldering, a non-activated resin based flux shall be used. Activated resins may leave residues which can cause corrosion of fine copper wires. Excess flux and drops should be removed with methylated spirit.

8.2 The soldered joint should show clear evidence of proper wetting of the lead as also the terminal plate, in regard to the angle of the soldered surface at the end of the deposit as shown in Fig.3.

SMI/0224 GOOD SOLDERED JOINT POOR SOLDERED JOINT

FIG. 3

9.0 THE FINAL OR FINISHING COVER

9.1 A final protective layer of glass tape ½ lap impregnated in one of the varnishes mentioned in Para 4.2 + Hardener should be wound around the coil. Excess varnish should be squeezed out before wrapping the tape tightly over the winding.

9.2 Where the tape goes around the terminal pillars, it should be cut carefully at appropriate points so as to accommodate the terminal pillar. The brass plate should get fully covered but the pillars should project out of cuts in the tape layer.

9.3 After applying a final coat of varnish + Hardener, the completed solenoid should be cured for 4 hours at 120 deg. C

9.4 The combined strength of the adhesion between the terminal plates and the layer covers as also the cords tied around the plates tightly, should be adequate to prevent any movement or breakage of the adhesive bonds, when the terminal screws are fully tightened with a torque which is about 75% of the torque required to shear the screw.

10.0 WINDING PROCESS

10.1 The inner lead is to be formed first. Lay the enameled wire with multiple bends as shown in figure-4.

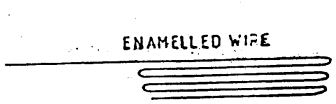


FIG. 4 (a)

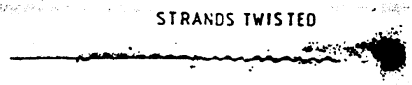


FIG. 4 (b)

Twist the strands together to form a lead. Solder the end of the lead with minimum quantity of 60:40 solder and resin based flux.

10.2 Apply a thin coat of recommended varnish + Hardener on the bobbin surfaces. Insert the lead and secure it with adhesive type. Wind the first layer of winding wire and apply a thin coat of recommended varnish + hardener.

10.3 During winding it should be ensured that the tension in the wire does not exceed 3 Kg per square mm of the wire section. Special care has to be taken when winding fine wires to see that the winding speed is not established suddenly by direct-on-line starting of the driving motor. The moment of inertia of the supply bobbin on which the winding wire supply is received is likely to produce high tensile forces on the wire when drawn by the winding mechanism if it is accelerated too quickly.

The most effective way of controlling this tension is to take the wire over a pulley support held by a spring leaf, the deflection of which will give visible indication of the winding tension. It will also cushion any sudden jerk. The winding speed and acceleration should be such as to ensure that the leaf spring does not ever bend excessively.

10.4 Wind second layer with slow speed and again apply a thin coat of varnish. Repeat the process at least upto ten layers.

10.5 Now increase the speed of winding machine gradually and complete the winding with the specified number of turns and layers. After completing the winding, hold the free end of the wire in place with an adhesive tape.

10.6 The total number of turns should be divided into an odd number of layers so that the end of the outermost layer appears at the side opposite to the side where the inner lead is attached.

10.7 Form the outer lead as explained per para 10.1.

10.8 Apply the main insulating layer as per para 7. Semi cure in an oven.

10.9 Fasten the terminal plates as described in para 5.

10.10 Solder the leads to the terminal plates, taking care to see that the inner lead is well insulated from the top layer.

10.11 Apply the final or finishing layer of glass tape as described in para 9.

10.12 Do the vacuum / pressure impregnation of the coil as per para 4.2 and complete the curing.

10.13 Do the potting or in-capsulation of the coil with Dr. Beck's DOVEKOT 520 or equivalent compound.

11.0 **ROUTINE TESTS**

11.1 Measure the resistance of the coil with an ohm meter of accuracy ± 0.5%.

11.2 Connect the solenoid (without iron core) to an alternating voltage, at 50 Hz, of such magnitude as to pass a current which is 10 per cent higher than the DC rated current at nominal voltage (=1.1 x nominal voltage / coil resistance at 20 deg.C), or 3 times nominal DC voltage whichever is less. In case of short time rated solenoid (e.g. EFDJ) or solenoids which normally operate with economy resistors in series, the nominal voltage shall be defined for a temperature rise of 50 deg.C. Maintain this current for 168 hours. Switch off and switch on the supply momentarily every 5 minutes.

11.3 At the end of the process in para 11.2, repeat the resistance measurement. If the resistance (corrected to 20 deg.C) differs by more than 2%, reject the solenoid.

11.4 Carry out a 5 KV surge comparison test with another sound solenoid. There should be no signs of discharge on the CRT trace at peak voltage.

11.5 Mark the resistance value at 20 deg.C (as made) on the outer surface of the solenoid.

11.6 This screening process is designed to weed out as far as possible solenoids which have stray or local weaknesses in the wire or joints. The screening will not cause any damage to good solenoids for the following reasons.

a) The solenoids are designed to operate in an ambient of 55 deg.C but the ambient during testing will be less than 40 deg.C. A 10% over current will not cause solenoid temperature to exceed the permissible limit.

b) Even when the applied voltage is three times the nominal voltage, the maximum inter-turn voltage will not exceed the strength of enamel insulation.

11.7 The advantage of screening with AC are :-

a) Incipient shorts are more likely to burn-out at higher inter turn voltage.

b) The facilities required are cheaper.

SMJ/0224