GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

TECHNICAL AUDIT OF MAINTENANCE PRACTICES OF PANTOGRAPH FOR ELECTRIC LOCOMOTIVES

Report No: RDSO/2016/EL/TAR/0006, Rev. '0'

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Approved by
Signature

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1.0 Introduction:

Line failure of pantographs leading to entanglement with OHE severely disrupts the traffic leading to detention of trains. Thus even a single case of pantograph entanglement must be viewed seriously and proper failure analysis to be carried out to establish the root cause of failure for preventing the recurrence of entanglement cases.

Vide their letter No. 2016/Elect(TRS)/155/1 dated 03.03.2016 Railway Board sent a list of 19 cases of pantograph entanglement affecting punctuality of mail express trains during 2015-16 (up to Feb 2016). Detailed analysis of each failure has been carried out. Some of the failures like plunger box pin missing, crack in longitudinal tubes of upper arm assembly etc. point out toward lacunae in maintenance practices. Therefore, a need was felt to conduct audit of pantograph maintenance in various sheds of Zonal Railways. In this connection various sheds namely ELS/CNB, ELS/TKD, ELS/GZB, ELS/KYN and ELS/BSL were audited. Remedial measures have been suggested vide RDSO letter no. EL/2.2.1 dated 15.07.2011. Over the period, additional maintenance practices have been included for reliable working of pantograph. These have been taken into account in this audit report.

2.0 Failure Details:

2.1 Analysis of 19 cases of failures reveals followings:

(i) Cases of entanglement caused due to breakage of longitudinal tubes – 07 cases
(ii) Out of 07 cases, 05 cases were due to old flaws or cracks in tubes.
(iii) Plunger box pin missing – 05 cases.
(iv) Servo mechanism assembly insulator failures – 03 cases.
(v) Defective plunger box – 01 case.
(vi) Missing bolt of anti-balancing tube – 01 case.

Details are attached as annexure II of the report.

2.2 Analysis of pantograph entanglement cases:

(i) The date of manufacture of failed pantograph commonly were not available in records. Most of the zonal railways did not have data of service period of component or sub component of a particular pantograph. Non availability of this information prevents Railways in following predictive maintenance practices for components which are prone to ageing related failures like longitudinal tubes or Servo mechanism assembly insulators. It is better to appreciate the theoretical basis of pantograph entanglement cases.
(ii) The pantograph is subjected to shock and vibration which are transferred to it because of movement. The factors which contribute to these shocks and vibrations on these pantographs are:

(a) Interaction between the rail and the wheel  
(b) Interaction between loco body and bogie.  
(c) Interaction between OHE and pantograph  
(d) Pantograph is also subjected to air drag on the bow assembly.

(iii) The pantograph is designed to cater to shocks and the vibrations. To reduce the shocks and vibrations so transferred by loco on pantograph, the main raising system, dampers and pan suspension have been provided on pantographs as shown in Fig1, 2 & 3 of different types of pantograph.

![Diagram of AM-12 Type Pantograph](image)

Figure1: Parts of AM-12 Type Pantograph (slow speed)
Figure 2: AM-92 Type Pantograph without Panto Pan (high speed)
Figure 3: Pantograph type IR-03H of M/s. Contransys (high speed)

(iv) In above three systems the pan suspension play more important role in reducing transfer of shocks and vibration. These suspensions have been provided on the pantograph by two ways

(a) Plunger box in case of AM-12, AM-92, IR-01, IR-03H, PAN-01 and EL-0

(b) Leaf spring in case of WBL-85.

Failure or problem in this suspension results in disturbing the horizontality of pantograph pan leading to breakage of plunger box and consequently pantograph entanglement.

(v) The analysis of failures indicates that majority of entanglements have taken place due to breakage of upper articulation tube. Old cracks in various pantograph parts have caused pantograph failures. This is cause of serious concern.
Next major cause of failure as envisaged above is the failure of plunger box assembly. Defective plunger box restrict free movement of pan assembly causing disturbance in static balancing of pantograph which lead to pantograph pan instability causing entanglement.

3.0 Maintenance practices of sheds:

3.1 Practices during Trip Inspection:
During inspection of various trip sheds at GZB, CNB and MGS observations noted are as under:

(i) Visual examination of the entire head structure of the pantograph including bow assembly, horn, wear strips and support assembly for crack. Photograph of some of the cracks/breakages noticed during trip inspection are given in figure 4 and 5.

(ii) Checking for any bent or bowed pans, leakage in operating cylinder & proper functioning of dampers and pan springs.

(iii) Intactness of pan head locking pins and spring. Free movement of the head on its mounting pins attached to the apex frame.

(iv) The tightness of the shunt connecting screws and its frayed strands is being checked. All shunt having frayed strands beyond 25% are replaced.

(v) Raising and lowering time is observed on the basis of visual experience only.

(vi) Cleaning of foot mounting insulators is not carried out in most of the trip sheds.

Recommendations:

(i) Usage of stopwatch for recording pantograph raising and lowering time.

(ii) Super check randomly at supervisor level.

(iii) It is worth mentioning that trip shed Manmad has prevented a potential pantograph entanglement case by identifying the longitudinal tube breakage case of loco 22616 of ELS GZB during trip inspection itself. Thus there is a greater need of carrying out
stringent trip inspection and maintenance of pantograph to prevent any pantograph entanglement case.

Figure 4: Breakage of AM-92 pantograph near the welding joint at pantograph end

Figure 5: Upper Frame Broken on 18.04.2016 of PT-2 of loco No. 22616(GZB)
3.2 Observations during Inspection Schedule (IA):

During inspection schedule IA various assemblies and sub assemblies of pantograph are inspected and checked by loco sheds. Assemblies wise practices observed are as follows:

(i) Flexible connection/shunt

All flexible connection/shunts are checked for damaged braid or loose connection. All metallic contacts are found to be applied with conducting grease. All the sheds are carrying out this activity diligently and not a single case of any braid cut was found during audit of the sheds.

![Breakage of copper braid of pantograph shunt](image)

Figure 6: Breakage of copper braid of shunt in AM-12 pantograph

**Recommendation:**

If any braid is found to be cut or damaged, it is required to be changed and loose Screws are tighten properly. While replacing shunts, care should be taken that the bi-metal plate Aluminum touches the Aluminum Alloy part and Copper side touches the shunt. Contact surface of Aluminum alloy must be rubbed clean with metallic brush and then covered with conducting grease. It is a must change item in POH schedule. The photographs of shunts are shown in figure 6 & 7.
(ii) **Pantograph pan**

Pan is inspected for any groove, wear, bend or abnormality on the surface or breakage. However at various instances M Seal was found to be applied and was not properly leveled with metalized carbon strip. Measurement of thickness of metalized carbon strip is being carried out by Vernier Calipers. This is shown in figure 8.

![Proper fitment of pantograph shunt](image1)

**Figure 7**: Proper fitment of pantograph shunt

![Rough surface left after filling gap between Horn and metallized carbon strip end with M-Seal](image2)

**Figure 8**: Rough surface left after filling gap between Horn and metalized carbon strip end with M-Seal (not recommended).
Recommendations:

Rough surfaces near strip region must be prevented at any cost. Leveling of M Seal joint can be done by rubbing with sand paper. Rounding off edges should be done with file as shown in figure 9.

![Properly dressed panto pan after filling gap between Horn and metalized carbon strip](image)

Figure 9: Properly dressed panto pan after filling gap with M-seal between Horn and metalized carbon strip (recommended).

(iii) Insulators

Panto insulators are to be checked for cracks and flash marks. Cleaning of foot insulators and operating rod insulator is carried out with detergent and wiping by dry cloth which is in order. But it was found those flashed insulators were put into service by applying the Bectol Red on flashed area which is not acceptable.

Recommendations:

Flashed insulators should be identified and changed at first opportunity. A properly cleaned insulator of pantograph is shown in figure 10.
Figure 10: Proper cleaning of the panto mounting Insulator however one insulator is flashed and Bectol red is applied on it.

(iv) **Main springs**

Visual checking of main springs is carried out for cracks or breakage.

(v) **Roof Bar**

Roof Bar is checked for breakage, loose connection, flash mark etc. special care must be taken with Aluminum bars.

**Recommendations:**

All joints in Roof Bar should be applied with conducting grease for prevention of rusting or overheating of joints. Zonal Railways must modify roof bar as per Modification sheet No. RDSO/2015/EL/MS/0446(Rev.0) in loco roof bars and fittings on conventional locomotives similar to three phase locomotives as per RDSO letter No. El/2.2.21 dated 07.12.2015.
(vi) **Plunger operations**

Plunger box was checked for the plunger/support rod cylinder operations. They were generally found to be free sliding while pressing. However in few cases of jamming, loosening of sleeves/bushes was noticed. In these cases, plunger box was found to be dirty. All the sheds were using a weight of 10kg or combination of 7kg and 3 kg for measuring the displacement of plunger.

![Plunger operations](image)

Figure 11: The above method of measuring displacement is improper. Weight should not be suspended at plunger support rod (not recommended).

**Recommendations:**

All sheds should diligently check the plunger/support rod cylinder operations in both plunger boxes. It should slide freely on pressing. In case of jamming, loosen the sleeves/bushes fix in the spring boxes, turn it around their vertical axis until jamming is removed. If required, lubricate the plunger boxes. Displacement of plunger box should be measured by a weight of 10kg above each support rod and the deflection should not be more than 25mm. The weight of 10kg should be applied on the top of the plunger box assembly. The correct method is shown in figure 12.
Figure 12: Weight installed above each support rod for measuring displacement.

(vii) **Lubrication**

Some sheds were using non standard and readily available lubricant like SP150 oil for lubrication.

**Recommendations:**

List of lubricants recommended by manufacturer is attached as annexure I. Sheds/Shops should ensure use of these lubricants only.

(viii) **Raising and Lowering**

Most of the sheds are not using stopwatch or timers for checking of Pantograph raising (6s to 10s) and lowering (below 10s) time.
Recommendations:

Sheds must adopt the practice of using timer or stopwatch for measuring pantograph raising and lowering time.

3.3 Practices during Inspection schedule (IB)

The works carried out in monthly inspection schedule (IA) are repeated in this schedule. In addition, the following works are found to be carried out:

(i) Pantograph Pan/Bow

Sheds are checking the pantograph pan horizontality visually which is not proper.

Recommendations:

Sheds should check the pan horizontality with a spirit Level. ELS BSL is using spirit level for checking horizontality of panto pan as shown in figure 13.

Figure 13: Horizontality of pantograph pan with spirit level (recommended)
(ii) **Load on stops (Housing Force)**

Most of the sheds are not checking the load on stop which is desirable to ascertain the acceptable level of vibrations in pantograph during working. Higher level vibrations may lead to crack or flaw in upper and middle articulation assembly.

**Recommendations:**

Check the load on stop. Lift the pantograph with spring balance fixing its hook with upper distance piece of panto pan assembly. Measure the load at 5mm above the stop. The force to lift the Pan off the rubber stop should be 15 kg (minimum). If housing force is less than specified value, it may lead to vibration of pantograph in locked down condition (non-working pantograph) and may cause damage.

### 3.4 Practices during Inspection schedule (IC)

The works carried out in monthly inspection schedule (IB) are repeated in this schedule. In addition, the following works are found to be carried out:

(i) **Mechanical parts and articulated system**

All the sheds are carrying out checks for all the mechanical parts including all hinged joints of articulated system for identification of any distorted or cracked parts showing signs of shock by the use of RDPT.

**Recommendations:**

Special care should be taken by sheds while inspecting the mechanical parts and articulated systems of AM-92 pantograph of SIL make. Figures 14 & 15 shows the critical locations for carrying out RDPT for detection of cracks.
Figure 14: Some critical locations where RDPT to be carried out on AM-92 type pantograph for detection of cracks
Figure 15: Some critical location where RDPT to be carried out on AM-92 type pantograph Upper frame assembly.
(ii) **Throttle valve operation**

All the sheds are verifying the operation of throttle valve.

**Recommendations:**

Sheds should verify the operations of throttle valve and if it is found outside of limits, throttle valve should be opened and the moving parts should be cleaned with kerosene along with replacement of all the rubber components.

(iii) **Contact Pressure**

All the sheds are measuring the thrust exerted upwards by the Pantograph on the Contact Wire by putting the weight of 7 kg on the head.

**Recommendations:**

The thrust exerted upwards by the Pantograph on the Contact Wire must be checked, by putting the weight of 7 kg on the head. Adjust the static contact pressure by static adjustment of counter balancing in case of variation of static force.

(iv) **Transverse Flexibility of the pantograph-Articulated system**

All sheds are carrying out Transverse flexibility measurement by pulling of pantograph sideways manually and checks the deviation on the basis of experience. This method of measurement is though easy but very subjective in which results can erroneous.

**Recommendations:**

Raise the pantograph to its maximum working height, arrange to pull the Panto pan/ upper articulation transversely at the upper distance piece with a force of 30 kg weight as checked by a spring Balance or by a system of weight 30 kg suspended on a rope passing over a pulley. The displacement of the bow should be 30
mm maximum. Sheds can develop the mechanism on the basis of figure indicated in figure no. 16.

Figure 16: Indicative sketch of mechanism for measuring Transverse flexibility in position on locomotives.

However pantograph manufacturer are asked to develop the fixture to carry out transverse flexibility during IC. Only Stone India Limited has submitted scheme of fixture as shown in figure no. 17.

Figure 17: Indicative sketch submitted by manufacturer.
(v) **Panto pan Swivel angle**

Swivel angle is not being measured by most of the sheds.

**Recommendations:**

Panto pan Swivel angle should be checked with Protector. Place a flat metal sheet above both metallized carbon strips and put protector on it, rotate the pantograph pan front and back and measure the swivel angle, it should be $7^0 \pm 1^0$ each side.

3.5 **Maintenance work carried out in shed during Overhauling schedules (TOH, IOH):**

(i) **General upkeep**

Some sheds are keeping Pantographs in vertical position without protection leading to rusting of tubes and pantograph frames.

![Improper storage of Pantograph in sheds](image)

Figure 18: Improper storage of Pantograph in sheds
Recommendations:

Pantograph should be kept in horizontal position on fixtures. Pantographs should not be kept for long duration. Pantographs should be kept in neat & clean area.

(ii) Bearing

After dismantle, all ball bearing are checked for wear of cage, balls etc. Bearing of one pantograph was dismantled and the condition was found to be very bad. Bearing cage and balls were found to be rusted.

![Figure 19: Condition of the ball bearing and stud found during overhaul.](image)

Recommendations:

Sheds should dismantle and replace the bearing on condition basis.

(iii) Mechanical parts:

Overhauling of upper and lower articulation tubes are carried out by dismantling. The same are repaired/replaced if found bent or deformed. The middle articulation shaft, the Base Frame and Brackets etc. are being checked thoroughly for cracks and damages. Old split pins, locking plates, self-locking nuts etc.
should be replaced with new ones and old ones should be scrapped.

4.0 General Recommendations:

On the basis of failure analysis of entangled pantographs and shortcoming noticed in maintenance practices, it is recommended that following measures must be taken to improve the reliability of pantographs:

(i) Due to introduction of metalized carbon strip, total weight of pantograph has increased by 2.5 kg. To compensate additional weight of metalized carbon strip, RDSO vide Modification sheet no. ELRS/MS/0333, Rev. ‘0’ dated 28.12.2004 has already advised to increase the spring stiffness from 0.35 kg/mm to 0.5 ± 5% kg/mm to take care of additional weight of metalized carbon strip of AM-12 or similar design of Pantograph.

(ii) Plunger box spring is to be replaced by new one with stiffness of 0.5 ± 5% kg/mm, if not replaced earlier during every AOH as stipulated in Technical circular No. RDSO/2007/EL/TC/0094.

(iii) Deflection of plunger support rod should less than 25 mm with 10 Kg weight.

(iv) All the split pins and fasteners may be procured from RDSO approved sources as stipulated in Technical circular No. RDSO/2007/EL/TC/0094 (Rev. ‘0’) on subject “To change the component of AM-12 and similar pantographs during AOH / IOH & POH”.

(v) Split pins should not be re-used.

(vi) Centre swing link and bushes of plunger box are to be replaced in every IOH.

(vii) While fixing longitudinal tube on centre swing link it is necessary to maintain a draw of 2 mm between tube and centre swing link. It will ensure proper fitment & tightness of longitudinal tube with swing link. Similarly draw of 2 mm is required to be maintained between longitudinal tube and top mounting fittings.

(viii) Railways reported that existing spring catcher was not able to prevent the spring to come in contact with loco roof in case of breakage. RDSO vide Modification sheet No. 0389 recommended for provision of additional spring catcher which will not allow the broken portion of spring to fly off. The same may be implemented
and MS plate welded on lower arm if any (local modification done by few sheds) may be removed as it may affect total up thrust force on pantograph pan.

(ix) To ensure implementation of various modifications sheets, SMIs& TCs issued by RDSO from time to time as summarized below:

<table>
<thead>
<tr>
<th>S No.</th>
<th>Modification Sheet/ SMI/TC No.</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ELRS/MS/WAG5/242</td>
<td>Provision of a rubber bush inside the open end of the longitudinal tube to prevent seepage of water entry into the tube resulting in rusting and consequent breakage.</td>
</tr>
<tr>
<td>2</td>
<td>ELRS/MS/0333, Rev. ‘0’ with Amendment- 1</td>
<td>Standardization of Panto Pan Assembly of AM-12 or similar Pantograph for Electric Locomotive and EMUs” to restrict swivel/ measurement of degree of freedom of collector head of the Panto Pan and standardize the horn and support rod. Moreover, due to increase in weight of Panto Pan with Metallised Carbon strips, the plunger springs have to be compensated by increasing the stiffness.</td>
</tr>
<tr>
<td>3</td>
<td>RDSO/ELRS/SMI/75</td>
<td>Ensuring proper raising and lowering of pantograph type AM12, to ensure lowering of Pantograph without jerk by providing damping towards the end of the motion while the pantograph is being lowered.</td>
</tr>
<tr>
<td>4</td>
<td>RDSO/ELRS/SMI/192</td>
<td>Periodic maintenance / checks for pantograph AM-12 type and similar design to balance and correct horizontality of the pantograph during every IC.</td>
</tr>
<tr>
<td>5</td>
<td>RDSO/ELRS/SMI/198</td>
<td>Lubrication schedule for improving reliability of pantograph AM-12 and similar design to avoid breakage / cracks of moving parts due to inadequate lubrication of moving parts.</td>
</tr>
<tr>
<td></td>
<td>RDSO/2007/EL/TC/0094 (Rev. ‘0’)</td>
<td>To change the component of AM-12 and similar pantographs during AOH / IOH &amp; POH, to avoid fatigue failures of components</td>
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<td>7</td>
<td>RDSO/ELRS/EL/MS/0389</td>
<td>Provision of additional spring catcher to prevent the main raising spring to fly off in case of breakage of spring of AM-12 or similar design pantographs used on electric locomotives and EMU/ MEMU.”</td>
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</tbody>
</table>

(x) RDSO has advised Railways to procure spare component as AOH/IOH/POH kits only from RDSO’s approved sources. Maintenance Instruction needs to be issued on summarizing the good maintenance practices being followed by Railways and maintenance proposed by the firms in their maintenance manual.

(xi) The Codal life of the pantograph is 12 years as per Railways Board’s letter No. 2002/AC-II/10 dated 24.05.2006. Necessary material planning must be carried out by Zonal Railways for their replacement.

(xii) Amendment no. 2 has been issued vide RDSO letter No. 2.2.1/1 dated 16.5.2016 wherein upper arm assembly of pantographs has been made a must change item during POH schedule. Zonal railways/workshops may please note and plan replacement accordingly.
## NEW LUBRICATION CHART OF PANTOGRAPH

<table>
<thead>
<tr>
<th>SI. NO.</th>
<th>PARTS TO BE LUBRICATED</th>
<th>RECOMMENDED LUBRICATION</th>
<th>SUBSTITUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BALL BEARINGS, PIN JOINT &amp; PLUNGER</td>
<td>MP3 (BAMEROL)</td>
<td>MOBILUS-EP2</td>
</tr>
<tr>
<td>2</td>
<td>SERVO MOTOR PISTON PACKING</td>
<td>LIPLEXT2 (BAMEROL)</td>
<td>SILICON VALVE &amp; PACKING GREASE (OKS 1110)</td>
</tr>
<tr>
<td>3</td>
<td>THROTTLE VALVE</td>
<td>METROARK SILICON 17 COMPOUND (WAKER SILICONES)</td>
<td>MALYKOTE - 111</td>
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<td></td>
<td>SILICON VALVE &amp; PACKING GREASE (OKS 1110)</td>
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Causes of failures of pantographs as noted in pantograph entanglement cases

<table>
<thead>
<tr>
<th>SN</th>
<th>Entanglement due to PT part</th>
<th>No. of cases</th>
<th>Cause of failure</th>
<th>Pantograph Type/Make</th>
</tr>
</thead>
</table>
| 1. | Upper Articulation Tube    | 07          | Breakage of tube (old crack in 5 cases) | AM-92 (SIL) – 5 case  
 IR01(CPL) – 2 case |
| 2. | Plunger Box Pin            | 05          | Plunger Box Pin Missing | AM-12(SIL) – 3 case  
 AM-92(SIL) – 1 case  
 IR-03H(CPL) – 1 case |
| 3. | Servomotor Mechanism       | 03          | Insulator Breakage | AM-92/SIL – 1 case  
 IR-03H/CPL – 2 case |
| 4. | Plunger Box                | 1           | Defective Plunger box | AM-12/SIL – 1 case |
| 5. | Anti Balancing tube bolt   | 1           | Bolt missing       | AM-92/SIL – 1 case |
| 6. | Caused by OHE              | 2           | Dropper open, OHE steady arm displaced | Pertains to OHE |