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# भारत सरकार, रेल मंत्रालय

Government of India, Ministry of Railways

# INDIAN RAILWAY TECHNICAL BULLETIN

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# Cyber Security – Implementation in Traction SCADA System in Indian Railways


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**Abstract :** **Cyber Security is a critical aspect of protecting railway systems from emerging threats. As the trend of cyber-attacks continues to rise globally, railway networks face significant risks to public safety, operational disruptions, and data breaches. Indian Railways, being a vital part of the country's transportation infrastructure, relies heavily on the Supervisory Control and Data Acquisition (SCADA) system for smooth & efficient operation. Recently, the SCADA System of Indian Railways was designated as Critical Information Infrastructure by the National Security Council Secretariat, Govt. of India. To safeguard this critical infrastructure, robust cybersecurity measures are essential. These include network isolation, implementing DMZ (Demilitarized Zone), using unidirectional gateways, firewalls, intrusion prevention systems (IPS), intrusion detection systems (IDS), encrypted communication, strong alphanumeric passwords, asset management, and vulnerability assessments. Additionally, leveraging emerging technologies like Artificial Intelligence (AI) and machine learning can enhance active scanning of network traffic for detection of anomalies and vulnerabilities. Overall, staying vigilant and continuously learning about evolving cybersecurity threats is crucial in this ever-changing landscape.**

**सारांश :** रेलवे प्रणालियों को उभरते खतरों से बचाने के लिए साइबर सुरक्षा एक महत्वपूर्ण पहलू है। जैसे–जैसे वैश्विक स्तर पर साइबर हमलों का चलन बढ़ रहा है, रेलवे नेटवर्क को सार्वजनिक सुरक्षा, परिचालन संबंधी व्यवधान और डेटा उल्लंघनों के लिए महत्वपूर्ण जोखिमों का सामना करना पड़ रहा है। भारतीय रेलवे, देश के परिवहन बुनियादी ढांचे का एक महत्वपूर्ण हिस्सा होने के नाते, सुचारू और कुशल संचालन के लिए पर्यवेक्षी नियंत्रण और डेटा अधिग्रहण (एससीएडीए) प्रणाली पर बहुत अधिक निर्भर करता है। हाल ही में, भारतीय रेलवे की SCADA प्रणाली को राष्ट्रीय सुरक्षा परिषद सचिवालय, भारत सरकार द्वारा महत्वपूर्ण सूचना अवसंरचना के रूप में नामित किया गया था। भारत की इस महत्वपूर्ण बुनियादी ढांचे की सुरक्षा के लिए, मजबूत साइबर सुरक्षा उपाय आवश्यक हैं। इनमें नेटवर्क अलगाव, डीएमजेड (डिमिलिटराइज्ड जोन) को लागू करना, यूनिडायरेक्शनल गेटवे, फायरवॉल, घुसपैठ रोकथाम प्रणाली (आईपीएस), घुसपैठ का पता लगाने वाली प्रणाली (आईडीएस), एन्क्रिप्टेड संचार, मजबूत अल्फान्यूमेरिक पासवर्ड, परिसंपत्ति प्रबंधन और भेद्यता आकलन का उपयोग करना शामिल है। इसके अतिरिक्त, आर्टिफिशियल इंटेलिजेंस (एआई) और मशीन लर्निंग जैसी उभरती प्रौद्योगिकियों का लाभ उठाकर विसंगतियों और कमजोरियों का पता लगाने के लिए नेटवर्क ट्रैफिक की सक्रिय स्कैनिंग को बढ़ाया जा सकता है। कुल मिलाकर, इस बदलते परिदृश्य में सतर्क रहना और उभरते साइबर सुरक्षा खतरों के बारे में लगातार सीखना महत्वपूर्ण है।


## 1. Introduction

Cyber security is gaining popularity given the current Covid-19 scenario and the entire world becoming virtual. According to a research study by Deep Instinct, ransom ware increased by 435% in 2022 compared with 2021. These numbers show that this is likely to increase in 2023 and in the future. This shows how crucial it is to have cyber security. Recently, SCADA (Supervisory Control and Data Acquisition) has been declared as a Critical Information Infrastructure (CII). As per IT Act 2000, CII are those 'Computer Resources', the incapacitation or destruction of which, shall have debilitating impact on National Security, Economy, Public Health or Safety. Therefore, Cyber Security in SCADA System becomes more than ever important today.

## 2. SCADA: A brief Overview

SCADA which stands for Supervisory Control and Data Acquisition is a computer-based system for gathering and analyzing real-time data to monitor and control equipment that deals with the critical and time-sensitive materials or events. SCADA systems include hardware and software components. The hardware gathers and

feeds data into field controller systems, which forward the data to other systems that process and present it to a human-machine interface (HMI) in a timely manner. SCADA systems also record and log all events for reporting process status and issues. SCADA applications warn when conditions become hazardous by sounding alarms. In railways, data is acquired from the field devices like Circuit Breakers ON/ OFF status, relays, alarms etc. by the Remote Terminal Unit (RTU).

The RTU is an electronic device utilizing a microprocessor, which links objects in the physical world with an automation system. This is accomplished by transmitting telemetry data to the system and/or changing the physical state of connected objects based on control messages received from the automation system. Data from RTU is sent over to the SCADA present in the Remote Control Centre (RCC) via proper communication channels like RS 485 Cable or OFC Cable. The controlling of the field devices is done through command sent by SCADA via RTU to field devices.

The communication protocol for the communication between field devices and RTU is on IEC 60870-5-103, IEC 61850 or MODBUS and the communication between RTU and SCADA is on IEC 60870-5-104 protocol.

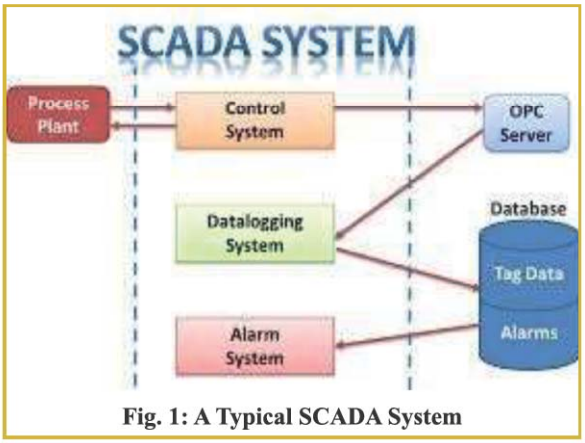


**Fig. 1: A Typical SCADA System**

## 3. What is Cyber Security?

Cyber security refers to protecting systems connected to the internet from threats in cyberspace, some of them business- critical. It involves protecting an organization's software, data, and hardware and helps prevent cyber criminals from gaining access to devices or their networks. It is the art of protecting our networks and devices from unauthorized access. Unauthorized access here refers to a small or big cyber-attack or a cyber-threat.

### 3.1 Various forms of Cyber Threats

There are various types of cyber-attacks that we can fall prey to, the most common ones being the following:

a) **Phishing:** It is the practice of sending fraudulent communications that appear to come from a reputable source. It is usually done through email. The goal is to steal sensitive data like credit card and login information, or to install malware on the victim's machine.

b) **Man in the middle attack:** This type of attack involves the cybercriminal intercepting conversations or data transmissions between multiple people. An example would be a cyber attack using an unsecured Wi-Fi network to intercept the data that the victim sends from their computer to the network.

c) **Malware Attack:** Malware attacks are any type of malicious software designed to cause harm or damage to a computer, server, client or computer network and infrastructure without any end- user knowledge. It is mostly used to steal personal, financial or business information.

d) **Ransomware:** Ransomware infects machines, encrypts files and holds the needed decryption key for ransom until the victim pays. Ransomware

attacks targeting enterprises and government entities are on the rise, recent attack being on AIIMS Public Healthcare Institute in which the critical files have been encrypted and an undisclosed amount has been sought in cryptocurrency for the decrypt key. Examples: Wanna Cry, Petya and loki etc.

e) **DDOS Attack:** Distributed denial of service attack involves multiple connected online devices, collectively botnet, which are used to overwhelm a target website with fake traffic.

f) **Password Attack:** These attacks are malicious ways hackers attempt to gain access to an account. Examples of password attacks are brute-force attack, credential stuffing and password spraying.

## 4. Why Cyber security is important for SCADA?

The importance of Cyber security comes down to the need and requirement to keep information, data and devices secure. In today's world, people store vast quantities of data on computers, servers and other connected devices. Much of this is sensitive and it can cause havoc if a cyber criminal gains access to it. They can share sensitive information, use passwords to steal funds, or even change data so that it benefits them. In case of SCADA without proper security from the Cyber threats, it can severely affect daily services of Railways causing a debilitating impact on national security, economy, public health and safety.

At any point, the CIA, which stands for Confidentiality, Integrity, and Availability are being implemented in any organization to ensure that the information is secure. There is a great demand for professionals like Ethical Hackers, CISOs, and many more cyber security experts who can implement Cyber Security and safeguard an organization's data.

There can be many intentions for cyber-attacks. Some of them are:

a) **Financial Gain:** Many phishing attacks are conducted by hackers to collect the bank details of individuals like card numbers, account login details, passwords, etc. This is then used by them to transfer money to their own account. They also use attacks like Ransomware on the entire organization for money.

b) **Recognition and Popularity:** In general, every human feels happy when everyone recognizes them. This kind of act is done by hacking social media accounts and increasing their followers or likes.

c) **Data exfiltration and Injection:** This includes stealing of sensitive data from an organization and tampering with it. They could sell those data or just submit incorrect data to a system without detection, causing trouble to the organization.

Another very common type of attack is the Hardware Attack. These are attacks that are launched on hardware which exposes its vulnerability. It is classified into 2 types: Invasive and Non-Invasive.

Invasive Hardware attacks are where the physical properties of the electronic chips in the hardware board are irreversibly modified. One of the most well-known invasive attacks is called Micro probing. In this attack, microscopic needles are attached to the internal wiring of the chips. The purpose of this attack can be to either read out internal secrets that are not intended to leave the chip, or it can be used for fault attacks. While the equipment required for Micro probing may sound expensive, the second-hand market makes all attack equipment available even for individuals.

This makes it important to research on low-cost protection mechanisms. For invasive attacks, it is vital to remove the upper packaging of the chip. This is done by the process of manual decapsulation which usually starts with milling a hole in the package and pouring nitric acid on it

so that it only affects the desired area above the chip die.

Non Invasive Hardware Attacks are any hardware attacks that happen on the system PCB hardware which does not damage any chip packages directly. The procedure for such attacks is:

- Attacker open the physical covering of the system.
- Attacker can either tap the wires to the device, or plug it into a test circuit for the analysis.
- No tamper evidence is left after they are applied.
- Once found, these attacks could be easily replicated and does not involve very much cost.

Mostly, attacks that happen on the FDUs are Non Invasive attacks.

To save them from these cyber threats, a person must follow some basic protocols:

- Never share their personal information like bank details, One Time Passwords (OTP), ATM pin, etc. with anyone.
- Do not open suspicious websites while surfing on the internet.
- Do not click on any links received on any social media by anonymous people.

## 5. Implementation of Cyber Security in SCADA

Cyber security is directly linked to the Cyber Physical System which consists of 2 types – IT and OT. IT or Information Technology are systems of hardware or software that can capture, process, exchange, store, and present information using electrical, magnetic, or electromagnetic energy. OT or Operation Technology collects information and causes changes in the physical world through the direct monitoring and control of physical devices. SCADA is an example of Operational Technology.

A few ways to implement cyber security in SCADA are:

a) **Defining clear boundaries and configuring the Demilitarized Zone (DMZ):** A demilitarized zone network, or DMZ, is a subnet that creates an extra layer of protection from external attack. It is a physical or logical subnetwork that contains and exposes an organization's external-facing services to an untrusted network, usually a larger network such as the Internet.

b) **Using network security control devices like Firewall:** A firewall is a network security system that monitors and controls incoming and outgoing network traffic based on predetermined security rules. A firewall typically establishes a barrier between a trusted internal network and untrusted external network, such as the Internet.

c) **Configuring IPS/IDS:** An intrusion prevention system (IPS) is a network security tool (which can be a hardware device or software) that continuously monitors a network for malicious activity and takes action to prevent it, including reporting, blocking, or dropping it, when it does occur.

d) **Using Unidirectional Security Gateway:** Unidirectional Security Gateways are a combination of hardware and software. The hardware permits data to flow from one network to another, but is physically unable to send any information at all back into the source network. In case of SCADA, since Energy Management Server (EMS) is connected to Web Server, therefore, unidirectional gateway will be between EMS and SCADA Network so as to allow the flow of data from SCADA network towards EMS only.

e) **Using communication protocol based on IEC 62443 and IEC 62351:** The IEC 62443 series of standards define requirements and processes for implementing and maintaining electronically secure industrial automation and control systems (IACS). These standards set best

practices for security and provide a way to assess the level of security performance.

IEC 62351 series also defines the cyber security requirements for implementing security technologies in the operational environment, including objects for network and system management (e.g. with SNMP), role-based access control (RBAC), cryptographic key management, and security event logging.

f) **Carrying out security testing:** Timely carrying out the Cyber security testing in the SCADA System will help address the vulnerabilities present in the system.

g) Periodical changing of passwords with alphanumeric combinations, white listing of authorized applications, encryption methods and using proper biometric identification.

## 6. Conclusion

Cyber security is a very important and complex topic for the protection of SCADA System. A properly secured system will save the system from various types of Cyber Threats and vulnerabilities and will make the system more reliant and efficient.

## 7. References


a) Research Designs & StandardsOrganization (RDSO), Indian Railways Specification no. TI/SPC/RCC/SCADA/0133.

b) IEC 62443 Standard: To secure industrial automation and control systems (IACS) throughout their lifecycle.

c) IEC 62351 Standard: For security in energy management systems and the exchange of energy-related data

d) PD CLC/ TS- 50701: 2021 : BIS Standard for Railway Applications - Cyber security

e) IEC60870-5-103Transmissionprotocols: Companion standard for the informative interface of the protecting equipment.

f) IEC 61850 Standard: Communication Protocol for intelligent Electronic Devices at Electrical Substation.


★★★

# Metallurgy Involved in Developing Train-18 Axles

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**Abstract : Till early 2022, railway wheels and axles were being imported for Train-18 (Vande Bharat). Russia-Ukraine war had disrupted the import schedule for forged wheels and axles in early 2022. Though 128 wheels from war-hit Ukraine through Romania were managed somehow but forged axles were still to be brought out.**
**The project of making Train-18 (Vande Bharat) Train-set was the dream Project of Gov of India. Railway Wheel factory, Bengaluru was asked to manufacture axles for Train-sets as per the European standard EN- 13261-EA1N-CAT2. This was a herculean task as the Bloom testing, forging, heat treatment and NDT parameters were not available in India. Within a span of three months, Metallurgical properties & NDT activities were standardized and successfully completed the manufacturing of high speed axles. The task was considered to be one of the best examples of MAKE IN POLICY.**

**सारांश : 2022 की शुरुआत तक ट्रेन–18 (वंदे भारत) के लिए रेलवे के पहिये और एक्सल का आयात किया जा रहा था। रूस–यूक्रेन युद्ध ने 2022 की शुरुआत में फोरज्ड पहियों और एक्सल के आयात कार्यक्रम को बाधित कर दिया था। हालांकि रोमानिया के माध्यम से युद्ध प्रभावित यूक्रेन से 128 पहियों को किसी तरह प्रबंधित किया गया था, लेकिन फोरज्ड एक्सल को बाहर से लाया जाना बाकी था।**
**ट्रेन–18 (वंदे भारत) ट्रेन–सेट बनाने की परियोजना भारत सरकार का उस समय का ड्रीम प्रोजेक्ट था। रेलवे व्हील फैक्ट्री, बेंगलुरु को यूरोपीय मानक EN–13261–EA1N–CAT2 के अनुसार ट्रेन–सेट के लिए एक्सल बनाने के लिए कहा गया था। यह एक कठिन कार्य था क्योंकि ब्लूम परीक्षण, फोर्जिंग, हीट ट्रीटमेंट और एनडीटी पैरामीटर भारत में उपलब्ध नहीं थे। तीन महीने की अवधि के भीतर, धातुकर्म गुणों और एनडीटी गतिविधियों को मानकीकृत किया गया और उच्च गति वाले एक्सल का निर्माण सफलतापूर्वक पूरा किया गया। इस कार्य को मेक इन पॉलिसी के सर्वोत्तम उदाहरणों में से एक माना गया।**

## Introduction

Till early 2022, railway wheels and axles were to be imported for Vande Bharat, Because of the Ukraine war, it was decided that axles would be made in Bengaluru at Railway Wheel Factory (RWF).

**Reason:** Ukraine war has disrupted the import schedule for forged wheels and axles in early 2022. Though 128 wheels from war-hit Ukraine through Romania were managed somehow but forged axles were still to be brought out.

**Urgency:** The project of making Vande Bharat Trainset was the dream Project of Gov of India. All efforts were required to expedite it. The Ukraine war has disrupted the import schedule.

**Grabbing the opportunities under MII policy:** Railway Wheel factory, Bengaluru was asked to manufacture axles for trainsets as per EN 13261. This was a herculean task as the Bloom testing, forging, and heat treatment parameters were not available in India. At the same time within a span of three months, NDT activities had to be standardized as per EN 13261.

The task was considered to be one of the best examples of MAKE IN POLICY. Though, RWF is being engaged in manufacturing the axles for railway purposes for a long but with different specifications viz: 1RS R-16 & IRS R-43. Getting the directives to make forged axles to EN 13261 required different strategies and planning as technical know-how was not available in India. Railway Wheel Factory in Yelahanka in Bengaluru grabbed this opportunity and standardized the manufacturing of Vande Bharat axles after continuous research. Axles were manufactured and sent to M/s Medha for making wheel sets & bogies.

**Planning & Action:** The first purchase order of forged axles was for 64 motor axles & 64 Trailer axles. These axles should conform to the specification EN-13261-EA1N-CAT2. Accordingly, Alloy Steel Plant, Durgapur was asked to manufacture Bloom through ingot technology with revised mechanical properties and ultrasonic acceptance criteria.

**Metallurgical Effort:** A comparative study was done for the Chemical & Physical properties of the axles to understand the feasibility of Train-18 axle manufacturing at RWF.

To meet the requirement of EN- 13261-EA1N-CAT2 a specification was framed by Metallurgical Wing of RWF incorporating acceptance standards for Ultrasonic Testing of Bloom and Axles.

**FORGED AXLES SPECIFICATION (Table - 1)**

**CHEMICAL COMPOSITION %**

| CHARACTERISTICS | IRS R-43/1992 | | IRS R-16/1995 | EN-13261-EA1N CAT2 |
|---|---|---|---|---|
| | Category A | Category B | Class B (Wagon) | EA1N |
| Carbon | 0.40 - 0.55 | 0.22 - 0.29 | 0.37 Max | ≤ 0.40 |
| Manganese | 0.60 - 0.90 | 0.60 - 0.90 | 1.12 Max | ≤ 1.20 |
| Silicon | 0.15 Min | 0.15 - 0.40 | 0.15 - 0.46 | ≤ 0.50 |
| Phosphorous | 0.045 Max | 0.035 Max | 0.04 Max | ≤0.020 |
| Sulphur | 0.05 Max | 0.04 Max | 0.04 Max | ≤ 0.015 |
| Chromium | - | 0.90 - 1.20 | 0.30 Max | ≤ 0.30 |
| Nickel | - | - | 0.30 Max | ≤ 0.30 |
| Copper | - | - | 0.30 Max | ≤ 0.30 |
| Molybdenum | - | - | 0.05 Max | ≤ 0.08 |
| Vanadium | - | - | 0.07 Max | ≤ 0.06 |
| Hydrogen ppm (Max) | 2 | 2 | 3 | 2.5 |
| Nitrogen % (Max) | 0.007 | 0.007 | 0.007 | -- |

| MECHANICAL & METALLOGRAPHIC PROPERTIES | | | | | | | |
|---|---|---|---|---|---|---|---|
| **CHARACTERISTICS** | **Wheel Seat** | **Wheel Seat** | **Normalized** | **N. Q. T** | **Train – 18, Normalised** | | |
| U.T.S Kg/mm$^2$ (MPa) | 570 - 685 | 650 -800 | 550 - 650 | 550 - 700 | 550 – 650 | | |
| Yield Strength (MPa) | Not less than 50% UTS | 400 Min | 320 Min | | 320 Min | | |
| Elongation % (Min) | 21-17 | 18 | 22 | | 22 % Min | | |
| Reduction in Area % Min | - | 60 | - | | -- | | |
| Grain Size (ASTM) | 6 - 8 | 6 - 8 | Greater than 5 | | 5 - 8 | | |
| Micro Structure | Fine Pearlite | Fine Pearlite | Fine Pearlite | | Fine Pearlite | | |
| Macroscopy | Shall not reveal any harmful defects | Shall not reveal any harmful defects | Must not reveal any discontinuities | | Must not reveal any discontinuities | | |
| Impact Strength in J/Sq.m at +20° C Min | Normalised = 20 J; Normalised & Tempered = 35 J | Normalised & Tempered = 40 J | 25 J | 40 J | Position | **MIN KU (J)** | **AVG KU (J)** |
| | | | | | Longitudinal | ≥ 21 | ≥ 30 |
| | | | | | Transverse | ≥ 14 | ≥ 20 |
| Sampling Size | 1 in each cast / heat | 1 in each cast / heat | 1 in each cast / heat or max. 100/batch | | 3 in each batch or heat | | |
| Sample Location | Extended portion of journal | Extended portion of journal | Extended portion of journal | | The test pieces shall be taken from three levels in the largest axle section/ wheel seat | | |
| * Ultrasonic Testing | 100% | 100% | 100% | | 100% | | |
| MPT | 100% | 100% | 100% | | 100% | | |
| **Category A** | **Motor-driven DSL, Electric Loco, EMU Coaches & Rail Cars** | | | | | | |
| **Category B** | **Shaft-Driven DSL, Hydraulic LOCO & Rail Cars** | | | | | | |
| **N. Q. T** | **Normalized, Quenched & Tempered** | | | | | | |

## Ultrasonic Testing Methodology:

| * Ultrasonic Test Methodology employed for testing Train - 18 Axles | | | | | |
|---|---|---|---|---|---|
| **S. NO.** | **Product** | **Ultrasonic parameters** | **RWF Bloom Specification for IRS R-16 axles** | **RWF Bloom Specification for IRS R-43 axles** | **RWF Bloom Specification for EN 13261:2020 (E) axles** |
| 1. | **Blooms** | **Acceptance Criteria** | Isolated flaw echo max. 25% when back echo adjusted to 100% of the full screen height acceptable and more than 25% is unacceptable for rolled blooms. In case of forged blooms 20% when back echo adjusted to 100% of the full screen heightis acceptable and more than 20% is unacceptable. | | Isolated flaw echo max. 10% whenback echo adjusted to 100% of the full screen height acceptable and more than 10% is unacceptable forboth rolled and forged blooms. |
| | **Forged Blooms ( Axles)** | | **IRS R- 16/95** | **IRS R- 43/92** | **EN 13261: 2020 (E) with ISO 5948** |

| | | | | | |
|---|---|---|---|---|---|
| 2. | Axle | **Permeability / Penetrability** | 3.2 mm FBH Block  | 3.2 mm FBH Block   | 1 mm FBH Block  Reference Standard Block prepared & certified by an external accredited agency for 1 mm FBH. |
| 3. | | **End-to-End Discontinuity Test** | 3.2 mm up to 381 mm, 6.4 mm 381 – 762, 9.5 mm 762 - 1143 (DAC) ZONE wise | | ZONE-wise DAC not applicable |
| 4. | | **Radial Scanning** | Rejection criteria as predefined using 3.2 mm hole reference block. | Rejection criteria as predefined using 3.2 mm hole reference block. | Rejection criteria as predefined using 3.0 mm hole reference block with different depths (DAC)  |

## Challenges faced while testing of Train – 18 axles at RWF:

1) Specification for ultrasonic testing of Bloom framed to meet the train–18 axles requirement.

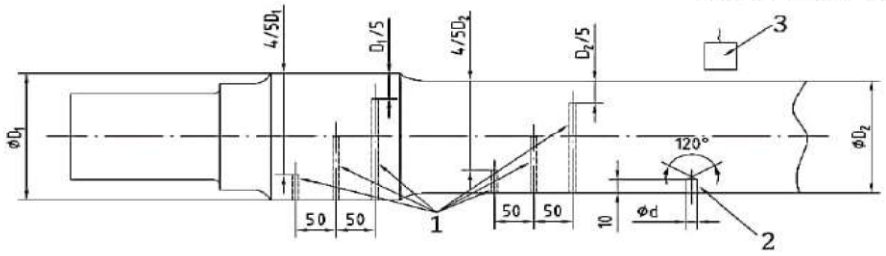
2) In order to meet ultrasonic testing acceptance Criteria for defect size 1 mm, Reference Standard Block of 1 mm defect size for Ultrasonic testing of train – 18 axles has to be prepared and get certified by external accredited agency.

3) 3 Nos. of test samples from each batch/heat from various location (as mentioned in table-1, sample location) required for mechanical testing whereas RWF sampling practice is only 1 No. of test sample from extended journal portion of axle.

## Reference blocks for discontinuity detection tests

ISO 5948:2018(E)

Dimensions in millimetres




**Key**

1 flat-bottomed hole
2 taper-bottomed hole
3 probe

NOTE The reference block design may vary depending on types of axles and testing techniques.

**Figure A.4 — Reference block for radial testing of solid axles by the DAC method and by evaluating the loss of back-wall echo**

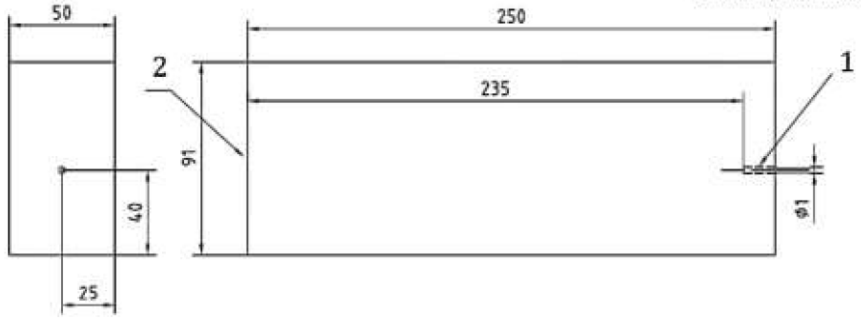
## Reference block for determining the ultrasonic permeability of axles

### B.1 Design of the reference block

An example of a reference block for determining the ultrasonic permeability of axles is shown in Figure B.1.

Tolerances and surface roughness of the reference block may refer to the applicable standard, or shall conform to the technical specification agreed upon at the time of enquiry and order.

Dimensions in millimetres




**Key**

1 flat-bottomed hole
2 scanning surface

**Figure B.1 — Typical reference block for determining the ultrasonic permeability of axles**

APPENDIX–A

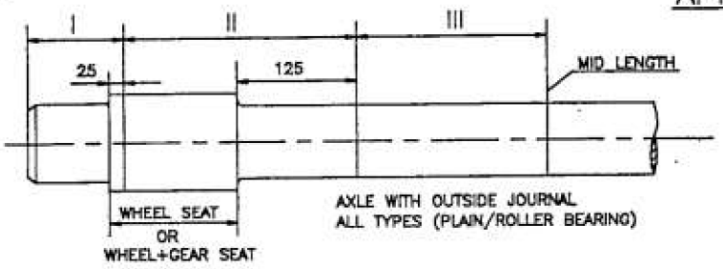



FIG. 1 (a)– ZONE DEMARCATION FOR ULTRASONIC TESTING OF ROUGH TURNED AXLES
(TO BE READ ALONGWITH THE RELEVANT AXLE DRAWING)

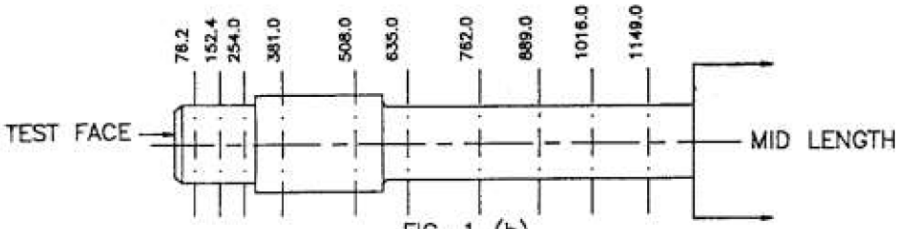



FIG. 1 (b)

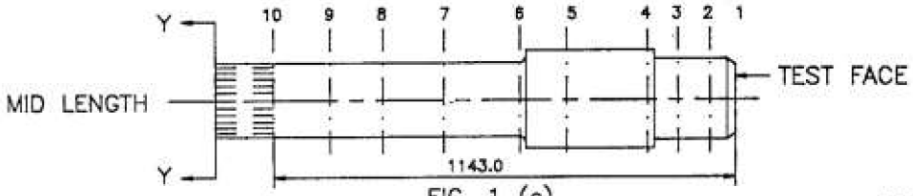
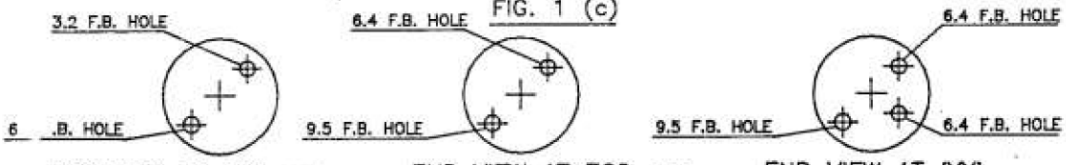



FIG. 1 (c)




END VIEW AT 381 mm  END VIEW AT 762 mm  END VIEW AT 'YY'

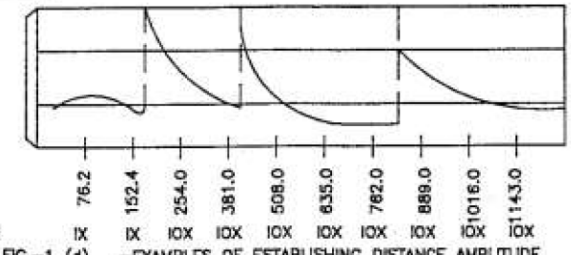



FIG.–1 (d) –EXAMPLES OF ESTABLISHING DISTANCE AMPLITUDE CURVE FOR A TYPICAL AXLE

TABLE FOR FIG.–1(b)

| FLAT BOTTOM HOLE (mm) | DISTANCE OF FLAT BOTTOM OF THE HOLES FROM THE TESTING FACE (mm) |
|---|---|
| 3.2 ø | 76.2, 152.4, 254.0 |
| 3.2 ø & 6.4 ø | 381.0 |
| 6.4 ø | 508.0, 635.0 |
| 6.4 ø & 9.5 ø | 762.0 |
| 9.5 ø | 889.0, 1016.0, 1143.0 |

NOTE:
FIG. 1 (c) INDICATES THE LOCATIONS 1 TO 10 WHERE THE REFERENCE AXLE WILL BE PROGRESSIVELY SLICED AND TESTED.

METHOD OF ULTRASONIC TESTING OF AXLES

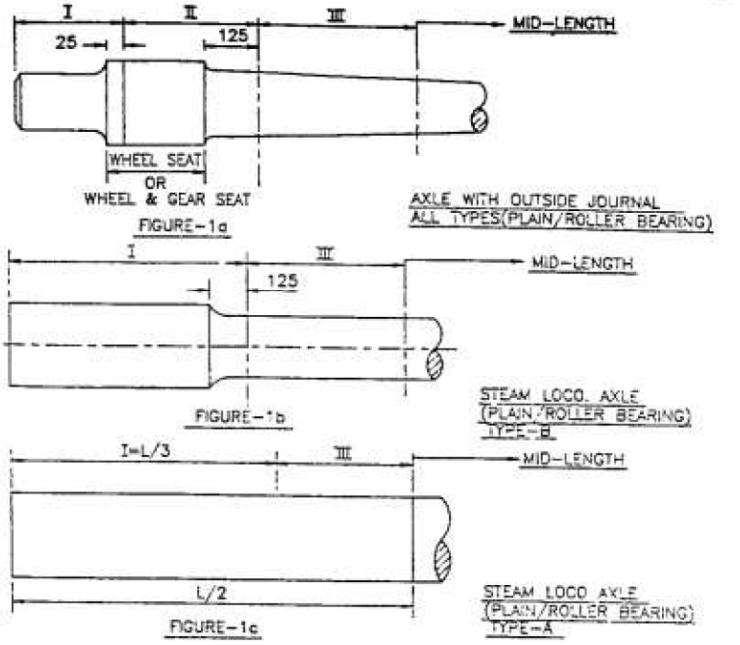



FIG. 1a, 1b & 1c:- ZONE DEMARCATION FOR ULTRASONIC TESTING OF ROUGH-TURNED PROCURED AXLES (TO BE READ ALONG WITH THE RELEVANT AXLE DRAWING)

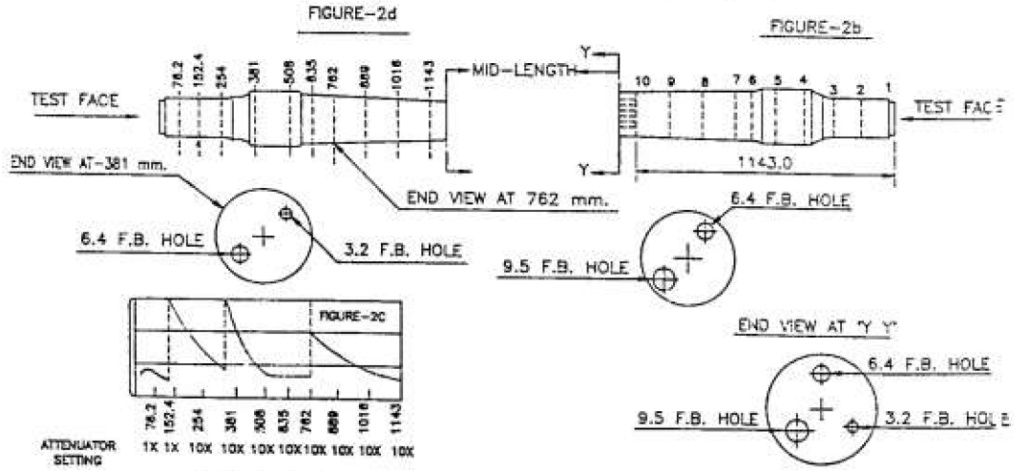



FIG. 2d, 2b, 2c EXAMPLE OF ESTABLISHING DISTANCE-AMPLITUDE CURVE FOR A TYPICAL AXLE

TABLE FOR FIG.2a

| FLAT BOTTOM HOLE (mm) | DISTANCE OF THE FLAT BOTTOM OF THE HOLES FROM THE TESTING FACE (mm) |
|---|---|
| ϕ3.2 | 76.2 , 152.4 , 254 |
| ϕ3.2 & 6.4 | 381 |
| ϕ6.4 | 508 , 635 |
| ϕ6.4 & 9.5 | 762 |
| ϕ9.5 | 889 , 1016 , 1143 |

NOTE:-

FIG.2b INDICATES THE LOCATIONS 1 TO 10 WHERE THE REFERENCE AXLE WILL BE PROGRESSIVELY SLICED AND TESTED.

(APPENDIX-A)

# Investigation to Check Safety and Passenger-Comfort Issues in Increased Speed Operations over 1 in 8.5 Turnouts Utilising Instrument Wheel Sets (IWS)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**Abstract :** **Presently, RDSO is conducting oscillation trial/Dynamic Performance Assessment of rolling stocks based on Third report of Standing Criteria Committee Rev. 1 (May 2013) with minor modifications from time to time. Basically, Straight / tangent track, station yard, curves up to 2 degree and long confirmatory runs (LCR) are considered as test stretch. Lateral and vertical forces are evaluated by indirect method with the help of load cells and spring deflection and ride indices are evaluated by measuring the acceleration under both lateral and vertical modes at car body level near bogie pivot. Evaluation of data is peak based.**

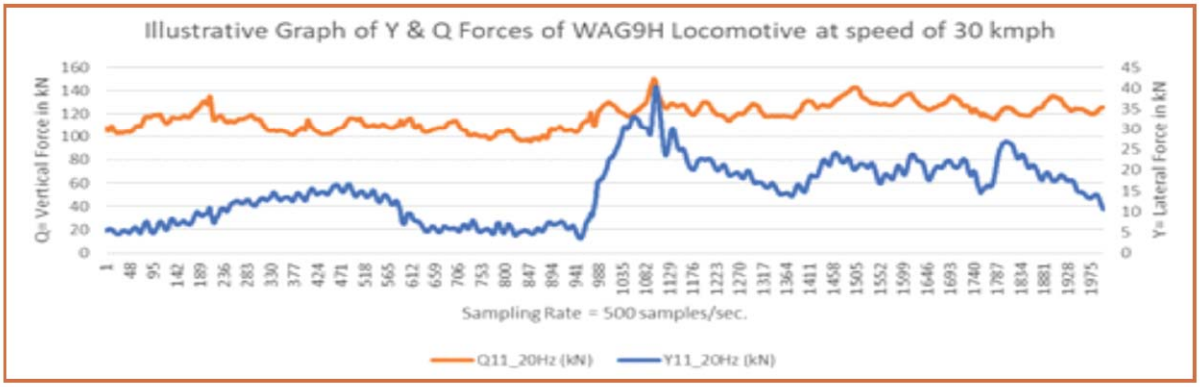
**Since, changing the technologies day by day and it needs to be accepted / adopted international norms of assessments of rolling stocks for its acceptance in Indian Railways Scenario. It will help to reduce the dispute for acceptance of rolling stocks.**

**Now, Indian Railways has decided switch over to international norms by conducting oscillation trials/ dynamic performance assessment of Railway vehicles based on international norms (European Standard) for dynamic performance assessment of rolling stocks. Lateral & vertical forces are measured by direct method at rail & wheels contact point for evaluation of safety parameters and track loadings. In this context Railway Board desired as per item No. 1335 of 87th TSC Dated Jan 2019 to increase the speed from 15 kmph 30kmph, to conduct study trials on 1 in 8.5 cross overs and turnouts with instrumented measuring wheel of WAG9H locomotive & BOXNS wagon of 25T axle load for measurement of forces at rail wheel level at Katepurna Yard of Bhusawal Division over Central Railway.**

**सारांश :** वर्तमान में आरडीएसओ समय समय पर मामूली संशोधनों के साथ स्थायी मानदंड समिति संशोधन (1 मई 2013) की तीसरी रिपोर्ट के आधार पर रोलिंग स्टॉक का दोलन परीक्षण/गतिशील प्रदर्शन मूल्यांकन कर रहा है। मूल रूप से सीधे/स्पर्शरेखा ट्रैक स्टेशन यार्ड 2 डिग्री तक के कर्व और लॉन्ग कन्फर्मेटरी रन (एलसीआर) को टेस्ट स्ट्रेच माना जाता है। लेटरल और वर्टिकल फोर्स का मूल्यांकन लोड सेल्स की मदद से अप्रत्यक्ष विधि द्वारा किया जाता है और बोगी पिवट के पास कार बॉडी लेवल पर लेटरल और वर्टिकल दोनों मोड के तहत एक्सेलेरेशन को मापकर स्प्रिंग डिफ्लेक्शन और राइड इंडेक्स का मूल्यांकन किया जाता है। डेटा का मूल्यांकन शिखर आधारित है।

चूंकि प्रौद्योगिकियों को दिन–ब–दिन बदलना और भारतीय रेलवे परिदृश्य में इसकी स्वीकृति के लिए रोलिंग स्टॉक के आकलन के अंतरराष्ट्रीय मानदंडों को स्वीकार/अपनाया जाना आवश्यक है। यह रोलिंग स्टॉक की स्वीकृति के लिए विवाद को कम करने में मदद करेगा।

अब भारतीय रेलवे ने रोलिंग स्टॉक के गतिशील प्रदर्शन मूल्यांकन के लिए अंतरराष्ट्रीय मानदंडों (यूरोपीय मानक) के आधार पर रेलवे वाहनों के दोलन परीक्षण/गतिशील प्रदर्शन मूल्यांकन का संचालन करके अंतरराष्ट्रीय मानदंडों पर स्विच करने का निर्णय लिया है। सुरक्षा मापदंडों और ट्रैक लोडिंग के मूल्यांकन के लिए रेल और पहियों के संपर्क बिंदु पर सीधे विधि द्वारा पार्श्व और ऊर्ध्वाधर बलों को मापा जाता है। रेलवे बोर्ड के आइटम संख्या 1335 के 87वीं टीएससी दिनांक जनवरी 2019 क्रॉस ओवर और टर्न आउट्स पर गति 15 किमी/घंटा से 30किमी/घंटा करने के संदर्भ में मध्य रेलवे पर भुसावल डिवीजन के काटेपूर्णा यार्ड में रेल और पहियों के संपर्क बिंदु पर बलों की माप के लिए WAG9H लोकोमोटिव और 25T एक्सल लोड के BOXNS वैगन के यंत्रीकृत माप पहिया के साथ 1 in 8.5 टर्नआउट पर अध्ययन परीक्षण आयोजित किया गया।

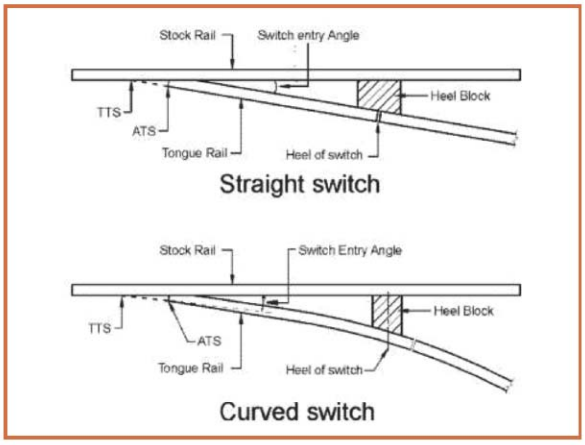



## 1. Brief Introduction

Over the past few years, despite huge investments in Track infrastructure, leading to opening of several 130 kmph/ 160 kmph fit sections, the overall throughput/ average speeds, even in these sections has at best shown only a limited improvement. One of the prime reasons, for the above is the continued speed restrictions on track layout features such as curves or turnouts.

Speed restrictions over turnouts, is one of the most significant factors affecting mobility & section throughput. A turnout is a very critical track assembly owing to (a) Abrupt change in direction due to entry angle of switch (b) Absence of a transition curve leading to (i) high Lateral accelerations (ii) High Lateral guiding forces on the rail, during the traversing of the turnout.

Owing to several unavoidable reasons (track geometry, topography, limits of land, multiple tracks, SOD related factors) ensuring transition




curves is in several instances not practically possible. Thus, for safety the MPS on the turnouts is restricted:

As a matter of policy & as part of infrastructure upgradation, the older 1 in 8-1/2 turnouts have been progressively replaced with 1in 12 curved switch turnouts. However, despite the above, the present population of the 1 in 8-1/2 curved switch turnout (which has the most restrictive mps of 15 kmph) is still significant, as enumerated below:

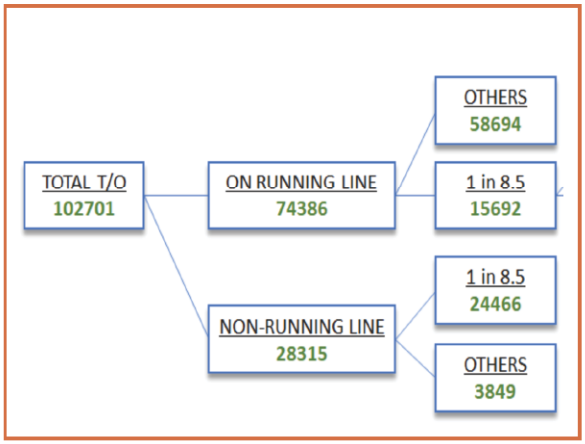
IRPWM: 408 (4) a) i)

(i) *Turnouts* – Speed, in excess of 15 Kmph, should be permitted on turnouts laid on PSC sleepers only. All turnouts on the running loops shall be laid with curved switches, with minimum rail section being 52 kg/m. All rail joints on these turnouts should also be welded to the extent possible.

For different type of curved switches permissible speed are as under –

| Sl. No. | Type of Turnout | Permissible speed |
|---|---|---|
| 1. | 1 in 8½ curved switch | 15 Kmph |
| 2. | 1 in 8½ symmetrical split with curved switches | 30 Kmph |
| 3. | 1 in 12 curved switch | 30 Kmph |

*Note: The permissible speed for 1 in 12 TWS is 50 Kmph*




Owing to the above, tackling speed restriction on the 1 in 8-1/2 turnout, has always been amongst the agenda/ directions of Railway Board & the Track Standards committee. Some of the recent directions on increasing the speeds on 1 in 8-1/2 turnouts are briefly encapsulated below:

Item 696, 51st TSC, MARCH 1975

**Committee's Recommendations**

1.
(i) The maximum permissible speed on 1 in 8½ and 1 in 12 BG turnouts with curved switches to existing RDSO drawings should be as follows:

| Turnouts | Maximum permissible speed in km/h. |
|---|---|
| 1 in 8½ | 25 |
| 1 in 12 | 40 |

The track structure of the turn-in curves should be the same as that of the main line track. In addition, an extra shoulder width of ballast of 150 mm, should be provided on the outside of the turn-in curves as recommended under Item No. 616 of the 44th Track Standards Committee and accepted by the Board. The inspection of turn-in curves should be done to the same schedule as that of the main line. The track structure on the loop lines should be suitably strengthened to match the increased permissible speeds on these turnouts.
(ii) The introduction of these turnouts should be done on a programmed basis to cover all passenger running lines on an engine run so as to derive the full benefit of the increased permissible speed.

Item 1335, 87th TSC, JAN 2019

**Theoretical Speed Potential of 1 in 8.5 T/O**

- Cant Deficiency Criteria ~35.5 kmph
- Absence of Transition Curve Criteria
  - Martin's Formula ~45 kmph
  - IRPWM Formula ~34 kmph
- Lateral force criteria (Blondel Formula)
  - ~25 kmph with Turn in curve
  - ~30 kmph without Turn in curve

**Board's Orders**: RDSO to conduct the field study to measure the lateral force and vertical force on turnouts after procurement of instrumented measuring wheel.

## 2. The Project (Brief Details)

In consideration with the above, Railway Board's orders on recommendations of 87th meeting of Track Standards Committee (TSC- for item no. 1335) have been communicated vide Railway Board letter no. 2017/CE-II/TSC/1 dated 04.07.2019. Track Design Directorate vide note No. CT/PTX/TO/Speed dated 20.01.2024, 20.01.2024 & 23.01.2024 has requested to conduct field trials to measure the lateral & vertical force on 1 in 8.5 turnouts for increasing speed potential on 1 in 8.5 turnout to 35 kmph.

In order to objectively evaluate the impact of any increase in speed over the 8-1/2 turnout on actual lateral forces, it was essential that actual assessment through field trials on select rolling

stock was undertaken. Accordingly, as requested by Track Directorate (vide note No. CT/PTX/TO/Speed dated 20.01.2024, 20.01.2024 & 23.01.2024) trials, were planned, to assess lateral & vertical forces on 25T axle load wagon-BOXNS & WAG9H locomotive, while traversing selected 1 in 8-1/2 turnout at increased speeds with max test speed of 35 kmph.

The technical requirement of the track dte, through these trials, could not have possibly been met using the standard test methodology & data collection + analysis as per the standard 3rd criterion methodology followed by RDSO for Rolling stock assessment, since the 3rd criterion methodology incorporates assessment of lateral force using an axle-box mounted load cell & the vertical force, in an indirect manner through the measure of spring deflection. The recorded data (of indirect force or even of Lateral force using load cell) could not be expected to show any marked distinction given the small increase in the speed over the 8-1/2 turnout (20 kmph from the present mps of 15 kmph).

Based on further discussions with Track Dte, it was decided to utilise the Instrumented Measuring Wheel (IMW) to accurately access the lateral, vertical forces alongwith other ride-affecting parameters, detailed in EN-14363, for these crucial trials.

Although, the utilisation of the IMW, would enable recording forces at the rail-wheel interface points, accurately, the data analysis was not possible, in line with the requirements/ methodology of EN-14363, since the data was to be collected at just a few speeds, over much smaller test section (span of the Turnout), than that stipulated in EN-14363. Based on further technical deliberations, a customised data analysis methodology was developed by Testing, in consultation with Wagon, Elect. Loco & Track Design Dte's of RDSO. The data analysis, methodology, adopted the limited test stretch + speeds while also inculcating the statistical approach as per EN 14363. The parameters to be calculated & the max acceptable limits of these parameters were also deliberated & jointly decided.

Apart from the above, owing to both Loco (WAG9H) & 25T axle load wagon-BOXNS being chosen for trials as representative of the heaviest RS that may traverse the turnout, it was decided to utilise IMW in both the Loco & the Wagon + also conduct trials in (i) Leading & Trailing directions of IMW (ii) Empty And Loaded mode of the 25T axle load BOXNS.

## 3. Main Contents, Study/Analysis & the Inputs given in the Project

### (A) The Project had the following peculiarities:

(a) Railway Board had been regularly flagging the issue of increase of speed over the 8-1/2 turnout. It was thus, now incumbent, for RDSO to address the issue, urgently, since the implications of higher permissible speeds on 8-1/2 turnout, on mobility of rolling stock was immense.

(b) The issue was deliberated, at the highest level (incl CRB, MI, MTRS) during a specific review by Rly Board on 20 Jan'24, wherein RLY Bd stressed on the positive impact of permitting higher speeds on the 1 in 8-1/2 turnout on the mobility + sectional throughput pan IR.

(c) As explained earlier (Point 1 & 2), permitting higher speeds on turn outs, in effect meant, increased lateral force both on the rail & as experienced by travelling passengers. Either of the above, could not be permitted on the basis of just empirical mathematical calculations. Actual running trials & assessment of the forces + the ride quality parameters was an essentiality, in order to practically & confidently permit higher speed operations on curves.

(d) To ensure that an accurate objective assessment of forces at the Rail wheel interface, is recorded, the trials were decided to employ IMW's. Since RDSO had decided to use set of IMW both for BOXNS wagon & WAG9H loco, the trials comprising of different modes + operating configurations had to be planned & conducted. Each trial was hence preceded by the set-up operation of installing the IMW by lifting the wagon/ Loco, dismantling the bogie, fitment of IMW by replacing the wheel set, verification of working of IMW, after wheel-up. This set-up was parallelly taken up in Electric Loco shed, BSL (for WAG9H Loco) & Wagon ROH depot, BSL (For BOXNS wagon)

(e) Since the trials were to be undertaken at higher than permitted speeds over turn-outs, co-ordination including steps such as withholding ALL running traffic in the opposite line as well, during the trial runs had to be planned & executed during actual trial.

(f) The data analysis was also custom-designed to ensure utilisation of the collected data, while not being able to strictly follow the data analysis methodology of EN-14363.

(g) The implications of the trials were serious since the increase in speed was to be affected pan-IR & had serious impact over mobility while be mindful of the safety & comfort of passengers. The trials, were, in effect, the field check/ manifestation of what the theory underlined as feasible or do-able. Any safety related doubts had to be thoroughly & professionally ruled-out or else the restricted-speed operations would need to be continued, adversely affecting system throughput.

**(B) Adopted Way-Forward:**

With the above peculiarities, in consultation with Track & Wagon & Electric Loco dte, the Testing team chalked-out the way-forward for the multiple trials to be undertaken:

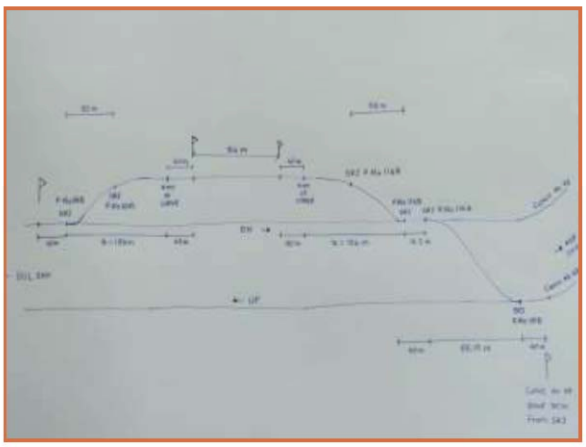
- Using IWS, Vertical & Lateral Forces were to be measured at the Rail-Wheel interface directly unlike the conventionally used Load cell at the axle box level.
- The IWS set-up has a sampling rate of 500 Hz (500 samples per sec) compared to the conventional Load Cell system sampling rate of 100 Hz (100 samples per sec). This would enable capturing a bigger-data-set over the small sampling time range (approx. 0.5 sec) when the vehicle passed over the curves.
- Paramcters to bc mcasurcd/ rccordcd:

| PARAMETER | LOCATION | TRANSDUCERS/ MEASURING SET-UP |
|---|---|---|
| Vertical & Lateral Acceleration | Floor level near bogie centre pivot. | Accelerometer (Range ±4g) |
| Lateral & Vertical force | Rail Wheel contact points | Instrumented measuring wheelsets |
| Speed | RDSO oscillograph car | 5 Hz GPS/ Optical speed sensor |

- Based on the above data recording, the following parameters & the decided-upon max limits were decided to be evaluated:

| Instrumented Bogie Leading (Loco-WAG9H) | | | | | |
|---|---|---|---|---|---|
| | Lateral force (kN) | Derailment Coefficient | Vertical Load (kN) | Lateral Acceleration | Vertical Acceleration |
| | ∑Ymax | (Y/Q) max | Q max | Max 'g' | Max 'g' |
| LIMIT VALUE | 69.65 kN | *< 0.8 | 191 kN | 0.35g | 0.35g |

| Instrumented Bogie Leading/ Trailing BOXNS Wagon in Empty Condition | | | | | |
|---|---|---|---|---|---|
| | Lateral force (kN) | Derailment Coefficient | Vertical Load (kN) | Lateral Acceleration | Vertical Acceleration |
| | ∑Ymax | (Y/Q) max | Q max | Max 'g' | Max 'g' |
| LIMIT VALUE | 22.38 kN | *< 0.8 | Min. of ((Q0 +90):200kN) = 114.5 kN | - | - |
| **Instrumented Bogie Leading/ Trailing BOXNS Wagon in Loaded Condition** | | | | | |
| | Lateral force (kN) | Derailment Coefficient | Vertical Load (kN) | Lateral Acceleration | Vertical Acceleration |
| | ∑Ymax | (Y/Q) max | Q max | Max 'g' | Max 'g' |
| LIMIT VALUE | 77.99 kN | *< 0.8 | 186 kN | - | - |



- The Trials were to be done both in Loaded & Empty Condition of the BOXNS wagon.
- Owing to the typical turnout geometry trial runs were conducted at Katepurna yard of Central Railway. Trial locations consisted of the following two track configurations:

  a) Cross over on PSC layout having 1 in 8.5 turnouts at both ends.

  b) 1 in 8.5 Turnout having turn in curve.

**(C) Result Assimilation:**

The Next Major Challenge was Analysis & interpretation of data in a coherent, transparent manner & also focussed on answering the key-focus area of Ride characteristics, safety aspects of increased speed if permitted over 8-1/2 turn-out. Accordingly, a detailed methodology for Data analysis was custom-developed:

**A. Methodology for Calculations as 3rd Report of SCC (Rev-1)**

The test data was acquired with help of Data Acquisition System on LAB VIEW software at sampling rate 100 samples per second with low pass filter 10 Hz as per 3rd criteria. After acquisition, data was processed with Butterworth 2nd order band pass filter of 0.4 to 10 Hz.

**A.1 Accelerations - Max 'g'** for lateral and vertical acceleration is evaluated from the above processed data.

**A.2 Guiding Forces /Lateral Force (Σ Ymax )& Derailment Coefficient (Y/Q)**

Guiding Forces / Lateral Forces (Σ Ymax ) and Derailment Coefficients (Y/Q) are evaluated based on per 3rd report of Standing Criteria Committee (Rev -1 )

**B. Methodology for Calculations as per EN14363:2016**

The test data was recorded with the help of Instrumented wheel set (IWS) using Dewesoft software at sampling rate 500 samples per second with low pass filter 20 Hz.

**B.1 Guiding Forces / Lateral Forces (Σ Ymax ) and Derailment Coefficient (Y/Q)-**

Guiding Forces / Lateral Forces (Σ Ymax) and Derailment Coefficients (Y/Q) were evaluated based on Table 5 (under evaluation filter column – sliding mean method with window length 2.0 m step length 0.5 m) of EN 14363:2016 (page no. 60) over nominated test stretch.

The limit value of Guiding forces/ Lateral forces (Σ Ymax) i.e Prud Homme's limit is calculated as follows:

Prud Homme's limit is defined as:

Y2m>= 0.85(10+P/3), P is the axle load in KN.

Prud Homme's limit is calculated for:

Empty condition & Loaded condition for each RS variant.

The adopted methodology was well-documented & transparently shared in the formal report issued by Testing Dte.


**Instrumentation of BOXNS Wagon**


**Instrumentation of WAG9H Loco**

**(D) The Results**

Following the result-targeted methodology, the ride characteristics & the lateral/ vertical forces specifically over the nominated 8-1/2 turnouts were recorded & analysed for both the WAG9H loco & BOXNS wagon both in Loaded & Empty condition and in Leading + Trailing direction.

The detailed results/ findings following the separate Trials (One loco + BOXNS) are contained in the respective Testing Report issued following the Trials. It however, suffices to mention, that

(i) The WAG9H loco & the BOXNS wagon exhibited satisfactory riding and stability characteristics behaviour during trials over

8-1/2 turnout under empty as well as in loaded conditions.

(ii) The WAG9H loco & the BOXNS wagon exhibited max lateral & vertical forces including its calculated parameters well within the Max. permissible respective values for the same.

## 4. Impact of Project on Railway Operations & Safety

The Project, for the first time **quantitively provided evidence** of ride characteristics & comprehensively addressed any doubts/ misgivings on safety issues in permitting higher speeds on existing 8-1/2 turnouts.

The following can be considered as major Impact factors of the Project:

(a) Quantitative measure of Ride Characteristics over 8-1/2 turnout.

(b) Practical-Application of the Strength of IWS- Force assessment at the Rail-Wheel Interface.

(c) Valuable Inputs/ Feedback on actual forces (compared to the theoretical forces) at the Wheel-Track interface especially in 1 in 8-1/2 turnout.

(d) Inputs + firm basis of upward Speed Revision on 1 in 8-1/2 turnout, thus positively impacting mobility across IR.

## 5. Significant Contribution of RDSO

In this subject project, wherein, following multiple inputs, constraints of speed restrictions over 1 in 8-1/2 turnout across ZR, had been identified as a significant reason affecting mobility & it had become incumbent on RDSO to firmly check + establish whether there were any safety implications/ comfort implications before permitting higher speeds on 1 in 8-1/2 turnouts. There was no other means (simulation) or agency- other than RDSO, which could have addressed the issue TECHNICALLY & FIRMLY to identify issues, if any or alternatively establish (beyond reasonable doubt) that there were no safety implications in the increased speed operations over 1 in 8-1/2 turnouts.

Through the deployment of IWS, along with the adaptation of data assessment so as to address the core problem, enabled RDSO to **quantitatively prove** that there were NO safety or comfort Related issues.

As had been experienced even in the project, had the trials been undertaken, only with the conventional Load-Cell instrumentation, the results would not have been so explicitly elaborate & conclusive. Also, it would have persisted the doubts of ZR of actual forces (at Rail-Wheel interface) being, in real-life, more than the indirectly measured forces at Axle box level using the Load-cell.

The Project has enabled RDSO to

(a) Specifically point-out to ZR- the criticality of maintenance of track geometry & other parameters of 1 in 8-1/2 turnouts where high Lateral forces or Low Vertical forces or a Combo of the above is being experienced in actual higher speed operations.

(b) Quantitatively prove to Track Dte, Elect Loco Dte, Wagon Dte, ZR & Rly Bd that there were no Safety-Related or Comfort-Related issues with permitting higher speeds on 1 in 8-1/2 turnouts.

(c) Provide Quantitative inputs regarding actual forces being encountered in Empty/ Loaded operations of BOXNS wagon & WAG9H Loco over 1 in 8-1/2 turnout at the max. permissible speeds.

(d) Positively contribute & address a ZR

referred issue that had direct implications with Safe Operations with positive impact on Mobility over the entire IR.

(e) Effectively deploy & utilise the available IWS + related Data acquisition + Analysis to quantitatively resolve/ provide insights to a real-life practical field issue, other than its core purpose of being utilised for RS dynamic behaviour assessment.

(f) **RDSO has recommended to Railway Board to increase the speed on Crossover with 1 in 8.5 turnouts on both ends & 1 in 8.5 turnouts with turn in curves up to 25kmph.**

## 6. References


(a) Third Report of Standing Criteria Committee Rev-1 May-2013.

(b) EN 14363:2016.

(c) RDSO Report No. MT- 2096/F.

(d) RDSO letter No. CT/PTX/TO/Speed Dt. 04.03.2024.




# Selection of Conductors in Low Voltage Installations

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**Abstract : Selection of appropriate size and type of Conductor/cable for low voltage installation is very important part of designing of protection system. There are various factors, which affect the current carrying capacity of conductor/cable. This article describes about major factors affecting the current-carrying capacity of a conductor/cable. Selection of protective conductor size is also included in this article. All these concepts are based on Indian Standards IS 732-2019 "Code of Practice for Electrical Wiring Installations".**

**सारांश : कम वोल्टेज स्थापना के लिए कंडक्टर/केबल के उपयुक्त आकार और प्रकार का चयन सुरक्षा प्रणाली के डिजाइन का बहुत महत्वपूर्ण हिस्सा है। ऐसे कई कारक हैं, जो कंडक्टर/केबल की करेंट वहन क्षमता को प्रभावित करते हैं। यह आलेख कंडक्टर/केबल की करेंट–वहन क्षमता को प्रभावित करने वाले प्रमुख कारकों के बारे में बताता है। इस आलेख में प्रोटेक्टिव कंडक्टर आकार का चयन भी शामिल है। ये सभी अवधारणाएँ भारतीय मानक IS 732–2019 "विद्युत तारों की स्थापना के लिए अभ्यास संहिता" पर आधारित हैं।**

## 1. Factors Affecting Size of Conductor In Low Voltage Installtions

### Introduction

During the designing of any protective low voltage installation, selection of proper size & type of conductor/cable is important part. It is generally believed that the current-carrying capacity of a conductor/cable depends on size/type of core & insulation only. Other factor is not important.

The current-carrying capacity of a conductor/cable depends upon the different parameters like Size/type of core/type of insulation.

| | | | |
|---|---|---|---|
| Size | 4 core 10 sq.mm PVC insulated cable | 4 core 16 sq.mm PVC insulated cable | Current carrying capacity shall be different |
| Core | 4 core 16 sq.mm PVC insulated cable | 2 core 10 sq.mm PVC insulated cable | Current carrying capacity shall be different |
| Type of insulation | 4 core 10 sq.mm PVC insulated cable | 4 core 10 sq.mm XLPE insulated cable | Current carrying capacity shall be different |

Further, it also depends upon other factors given below:

i. The method of installation of Conductor

ii. The ambient temperature

iii. Group containing more than one circuit

iv. Harmonic disturbances

v. Voltage drop due to length of conductor

## 1.1 The Method of Installation of Conductor

*(Ref: Para 4.1.3.6 & 5.2.7 of IS 732:2019)*

Wiring/cabling is done in 73 different installation methods. These methods of installation has been further classified under 10 groups (A1, A2, B1, B2, C, D1, D2, E, F & G) given in Table-19 & Annexure-S of IS732:2019 for obtaining current carrying capacity of different installations.

Based on above methods the current carrying capacity of different size/core/ PVC&XLPE insulation type of conductors are given in table21 to table 24, table 29 to table 32 of IS 732:2019. Annex-T of IS 732:2019 is a simplified version of above tables as shown below with reference ambient temperatures.

a) For insulated conductors and cables in air, irrespective of the method of installation: 30 °C; and

b) For buried cables, either directly in the soil or in ducts in the ground: 20 °C.

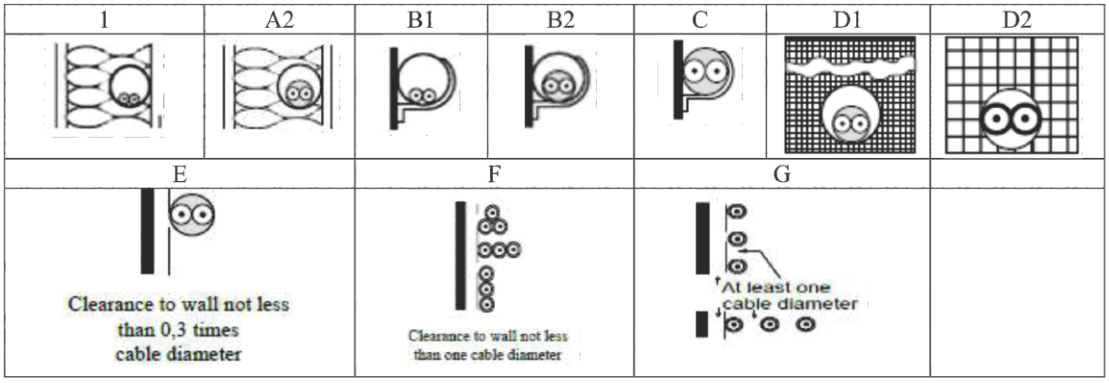



**Figure 11: Type of Installations**

## 1.2 The Ambient Temperature

*(Ref: Para 5.2.5.1 of IS 732:2019)*

The ambient temperature is the temperature of the surrounding medium when the cable(s) or insulated conductor(s) under consideration are not loaded. Current carrying capacity of conductor also depends on the ambient temperature.

While selecting the type of insulation of the conductor for a particular location, it should be ensured that the ambient temperature in that area under normal operation and fault conditions should not exceed the limiting temperature of the insulation, which is given in Table 8 of IS 732: 2019.

Where the ambient temperature in the intended location of the insulated conductors or cables differs from the reference ambient temperature (30 °C for Air & 20 °C for buried in ground), the appropriate correction factor given in Table 33 & 34 of IS732:2019 shall be applied to the values of current-carrying capacity set out in Annex-T of IS 732:2019.

Note: Ambient temperature for conductor or cables should be taken for particular location of the installation not the ambient temperature of the environment.

## 1.3 Group containing more than One Circuit

*(Ref: Para 5.2.6.5 of IS 732:2019)*

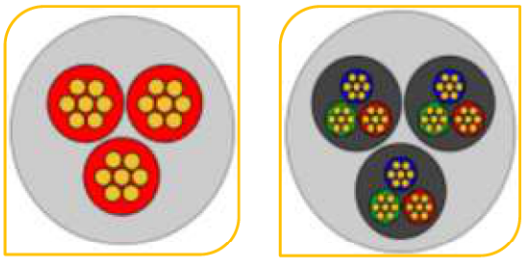
The group reduction factors (Table 36 to 40 of IS732:2019), are applicable to groups of insulated conductors or cables having the same maximum operating temperature i.e. 70°C

The current-carrying capacities given in Annex-T of IS 732:2019 related to single circuits for single phase/three phase PVC/XLPE conductor in different installation (A1, A2, B1, B2, C, D1, D2, E & F). Where more insulated conductors or cables, other than bare mineral insulated cables not exposed to touch, are installed in the same

group, the group reduction factors specified in Table 36 to 38 of IS732:2019 shall be applied.

Similarly, the current-carrying capacities given in Annex-T of IS 732:2019 also related to single circuits for single phase/three phase conductor in different installation (E & F). Where more insulated conductors or cables are installed in the same group, the group reduction factors specified in Table 39 to 40 of IS732:2019 shall be applied.

**Three conductors inside conduit**



**Single Conductor Cables Multi Conductor Cables**

For groups containing cables or insulated conductors having different maximum operating temperatures, the current-carrying capacity of all the cables or insulated conductors in the group shall be based on the lowest maximum operating temperature of any cable in the group, together with the appropriate group reduction factor.

If, due to known operating conditions, a cable or insulated conductor is expected to carry a current not greater than 30 percent of its grouped current carrying capacity, it may be ignored for the purpose of obtaining the reduction factor for the rest of the

## 1.4 Harmonic disturbances

In an Installation due to presence of electronic equipment and AC/ DC conversions the harmonic currents are generated in the system. These can be measured by using power quality analyser. The equipment likely to cause harmonic current are fluorescent luminaries, LED luminaries, computers, VVVF drives, inverter technology based electrical gadgets etc.

### 1.4.1 Reduction factors for harmonic currents in four-core and five-core cables with four cores carrying

In balanced three-phase circuits, neutral currents due to the line currents, having a harmonic content does not get cancelled and under such circumstances, reduction factors shall be applied. If only two of the three phases are loaded, the neutral conductor will carry the harmonic currents in addition to the unbalanced current. Such a situation can lead to overloading of the neutral conductor.

If harmonic content is significant, that is, more than 15 percent, for example, 9th, 12th, etc. are expected then lower reduction factors are applicable. Where there is an unbalance between phases of more than 50 percent then lower reduction factors may be applicable.

The tabulated reduction factors, when applied to the current-carrying capacity of a cable with three loaded conductors, will give the current-carrying capacity of a cable with four loaded conductors where the current in the fourth conductor is due to harmonics. The reduction factors also take the heating effect of the harmonic current in the line conductors into account.

**Table 1: Reduction factors for Harmonic Currents in Four-Core and Five-Core Cables**

| Third Harmonic Content of Line Current% | Reduction Factor | |
|---|---|---|
| | Size Selection is Based Line on Current | Size Selection is Based on Neutral Current |
| 0-15 | 1 | - |
| 15–33 | 0.86 | - |
| 33-45 | - | 0.86 |
| 45 | - | 1 |

**NOTES:**

1. The third harmonic content of the line current is the ratio of the third harmonic and the fundamental (first harmonic), expressed in percent.

2. The reduction factors only apply to cables where the neutral conductor is within a four-core or five-core cable and is of the same material and cross-sectional area as the line conductors. These reduction factors have been calculated based on third harmonic currents.

### 1.5 Voltage Drop due to Length of Conductor

Voltage in an installation should be as per the standard supply voltage with permissible tolerance. To ensure this, it is important to check that the cumulative voltage drop from the source upto any point in the installation does not exceed the tolerance permitted. Due to increase length of wire, if value of Voltage drop exceeds the specified value in the wiring system, then cross-section of the conductors must be increased.

### 1.5.1 Permissible Voltage Drop in Consumer's Installations

*(Ref: Annex Y of IS 732:2019)*

The percentage voltage drop with respect to the value of the nominal voltage from the source up to any point in the installation are given in Annexure Y of IS 732:2019.It shall not exceed:-

1. 3% for lighting & 5% for other use (in case of Low voltage installations supplied directly from a public low voltage distribution system)
2. 6% for lighting & 8% for other use (in case of Low voltage installation supplied from private LV supply)

### 1.5.2. Calculation of Voltage Drop

*(Ref: Para 6.2.3.10 of IS 732:2019)*

After selecting the size of wire voltage drop to be checked for particular length. It shall not exceed the value given in table shown in previous slide. Voltage drop chart are generally given by a manufactures in their manuals. As per company catalogue Voltage drop has been given

**Table 4: Estimated Voltage Drops in PVC/ XLPE Aluminium Cables for A.C. System**

| Nominal area of conductor (sq. mm) | (Voltage drop – Volts/ Km/ Amps) | | | |
|---|---|---|---|---|
| | P.V.C. Cable | | XLPE Cable | |
| | Single phase | Three phase | Single phase | Three system |
| 1.5 | 43.44 | 37.62 | 46.34 | 40.13 |
| 2.5 | 29.04 | 25.15 | 30.98 | 26.83 |
| 4 | 17.78 | 15.40 | 18.98 | 16.44 |
| 6 | 11.06 | 9.58 | 11.80 | 10.22 |
| 10 | 7.40 | 6.41 | 7.88 | 6.82 |
| 16 | 4.58 | 3.97 | 4.90 | 4.24 |
| 25 | 2.89 | 2.50 | 3.08 | 2.67 |
| 35 | 2.10 | 1.80 | 2.23 | 1.94 |
| 50 | 1.55 | 1.30 | 1.65 | 1.44 |
| 70 | 1.10 | 0.94 | 1.15 | 1.00 |
| 95 | 0.79 | 0.68 | 0.83 | 0.70 |
| 120 | 0.63 | 0.55 | 0.66 | 0.56 |
| 150 | 0.52 | 0.46 | 0.55 | 0.48 |
| 185 | 0.42 | 0.37 | 0.44 | 0.40 |
| 240 | 0.34 | 0.30 | 0.35 | 0.30 |
| 300 | 0.28 | 0.26 | 0.30 | 0.26 |
| 400 | 0.24 | 0.22 | 0.24 | 0.22 |
| 500 | 0.23 | 0.20 | 0.23 | 0.20 |
| 630 | 0.20 | 0.18 | 0.21 | 0.18 |
| 800 | 0.19 | -- | 0.20 | -- |
| 1000 | 0.18 | -- | 0.18 | -- |

## 2. Selection of Size Of Phase Cable For Final Circuit

*(Ref: Para 4.1.3.6 & 5.2.7 of IS 732:2019)*

### 2.1 Coordination between rating of MCB & Size of cable

*(Ref: Para 4.4.4.1 & Annex-E of IS 732:2019)*

After deriving the capacity of MCB the selection of adequate size of the conductor is very important. The operating characteristics of a device protecting a cable/wire against overload shall satisfy the two following conditions:

$IB \leq In \leq IZ$ (Equation 1)

$I2 \leq 1.45x\ IZ$ (Equation 2)

Where;

| | |
|---|---|
| $I_B$ | The design current for that circuit |
| $I_Z$ | The continuous current-carrying capacity of the cable/ wire |
| $I_n$ | The rated current of Protective device (NOTE: For adjustable protective devices, the rated current $I_n$ is the current setting selected. |

| | |
|---|---|
| $I_2$ | The current ensuring effective operation in the conventional time of the protective device i.e. 1.45x $I_B$ |
| | **Conventional time: -**The conventional time is 1 h for circuit-breakers of rated current up to and including 63 A, and 2 h for circuit-breakers of rated current above 63 A. |

Note: Protection in accordance with this clause may not ensure protection in certain cases, for example where sustained over currents less than I2 occur. In such cases, consideration should be given to selecting a cable with a larger cross-sectional area.

These equations can be also explain as per given diagram

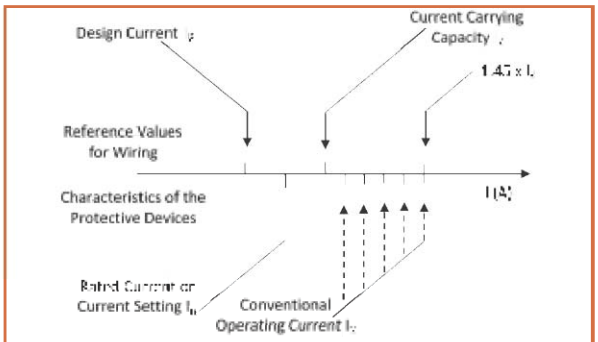



**Figure 2: Illustration of equations 1 & 2 for Selection of Cable**

## 2.2 Procedure for Selection of Size of Cable

After selecting, the rating of MCB/MCCB size of the cable/wire may be selected through following procedure. This can be explain with help of two example

Example-1: Selection of wire connected to MCB (Final Circuit)

10A MCB is installed for an installation. The outgoing two core PVC insulated wire is to be to be laid in conduit in masonry of building. 2 No. additional circuits with this circuit are also laid in same conduit. . Ambient temperature 40°C is considered

Case (A):- This MCB is connected to fixed load like lighting load.

Case (B):- This MCB is connected to sustain overload

**Table 5: Procedure for Selection of Size of Cable**

| S.N. | Procedure/ Step | Example | | Remarks |
|---|---|---|---|---|
| 1. | Identify the Method of Installation of conductor | B1 Installation | | (S.N.59 of table-19 of IS: 732 2019) in which Insulated conductors or single-core cables to be laid in conduit in masonry of building |
| 2. | Decide type of Insulation of conductor PVC / XLPE/ | PVC | | Type of insulation |
| 3. | Decide type of Core | 2 Core | | Type of core |
| 4. | Check the rating of MCB ($I_n$) | 10 Amp. | | |
| | | **Case A** | **Case B** | |
| 5. | Minimum Current carrying capacity of wire | 10 Amp. ($I_n \leq I_z$) | 10x1.45= 14.5 Amp. | ($I_n \leq I_z$) for fixed load (for Case A).Considering requirement of overload protection factor for sustain overload (Multiply overload factor of MCB (1.45) to rated current (for Case B) |
| | Apply ambient temperature reduction factor(by current carrying capacity divided by reduction factor) from table 33 to 34 of IS 732:2019, | 10/0.94 | 14.5/ 0.94 | Ambient temperature 35°C to be considered., Reduction factor 0.94 from table 33 of IS 732:2019 |

| S.N. | Procedure/ Step | Example | | Remarks |
|---|---|---|---|---|
| | Apply reduction factor (by current carrying capacity divided by reduction factor) depending on the number of circuits (grouping) from table-36 to 40 of IS 732:2019. | 10/ (0.94 x 0.70) | 14.5/ (0.94 x 0.70) | 2 No. additional circuits with this circuit (total 3 circuit) are also laid in same conduit. As per table-36 of IS 732:2019, reduction factor 0.70 will be applicable |
| | Deriving the final current | 15.20 Amp. | 22.04 Amp. | (Calculating from S.N.7) |
| | Checking of size of wire for particular size/ core/ insulation/ installation from Annex-T of IS 732:2019, which has minimum Current carrying capacity. | 2 core 1.5 Sq.mm PVC insulated copper wire | 2 core 2.5 Sq.mm PVC insulated copper wire | Checked from Table 41 of Annex-T as current carrying capacity is<br>23 Amp:-2 core 2.5 Sq.mm 17 Amp.:-2 core 1.5 Sq.mm |
| | Apply reduction factor (by current carrying capacity divided by reduction factor) depending on the number of circuits (grouping) from table-36 to 40 of IS 732:2019. | 10/ok (0.94 x 0.70) | 14.5/ (0.94 x 0.70) | 2 No. additional circuits with this circuit (total 3 circuit) are also laid in same conduit. As per table-36 of IS 732:2019, reduction factor 0.70 will be applicable |
| | Deriving the final current | 15.20 Amp. | 22.04 Amp. | (Calculating from S.N.7) |
| | Checking of size of wire for particular size/ core/ insulation/ installation from Annex-T of IS 732:2019, which has minimum Current carrying capacity. | 2 core 1.5 Sq.mm PVC insulated copper wire | 2 core 2.5 Sq.mm PVC insulated copper wire | Checked from Table 41 of Annex-T as current carrying capacity is<br>23 Amp:-2 core 2.5 Sq.mm 17 Amp.:-2 core 1.5 Sq.mm |

### 2.2.1 Minimum Nominal Cross-Sectional Area of Cable for Standard Circuits

The minimum cross section area of Line, Neutral & Earth Conductor for Standard Circuits in non residential buildings are as below.

**Table 6:Minimum Nominal Cross-Sectional Area of Cable for Standard Circuits in non-residential buildings (Ref: Table-6 of Section-9 Part-1 of NEC:2023).**

| S.N. | Type of Circuit | Connected Load/No. of board/socket | Minimum Size of Line, Neutral &Protective Earth Copper Conductor |
|---|---|---|---|
| 1 | Lighting circuits | Maximum 2 boards may be looped, subject to load < 1 kW or Maximum 24 points on two boards | 1.5 Sq.mm |
| 2 | 5/6A Socket | Maximum 4 Nos. sockets, subject to total load < 1 kW | 1.5 Sq.mm |
| | | Maximum 8 Nos. sockets, subject to total load < 2 kW | 2.5 Sq.mm |
| 3 | 16A Socket | Maximum 2 Nos. sockets, subject to total load < 2 kW | 2.5 Sq.mm |
| 4 | Appliance < 2kW | 1 No., subject to total load < 2 kW | 2.5 Sq.mm |
| 5 | Appliance < 3kW | 1 No., subject to total load < 3 kW | 4 Sq.mm |
| 6 | Appliance < 6kW | 1 No, subject to total load < 6 kW | 6 Sq.mm |

**Table7: Recommended Minimum Nominal Cross-sectional Areas of Conductor for Residential Building (Ref: Table-1 of Section 1, Part-3 of NEC:2023).**

| Use | Minimum Size of Line, Neutral & Protective Earth Copper Conductor |
|---|---|
| Point wiring for light/ fan/ bell/ independent plug 6A | 1.5 mm2 |
| Branch circuit (DB to switch board) limited to total 10 points/800W | 1.5 mm2 |
| Branch circuit (DB to 6/16A power outlets 2 Nos.) for general use or 1 No. independent point for Water heater/Microwave /OTG/Induction, total max. load 3 kW/circuit | 2.5 mm2 |
| Branch circuit (DB to 16/25A power point 1 No.) e.g. A.C. 2TR/3TR total max. load 5kW/circuit. | 4.0 mm2 |
| Mains/sub-mains for total connected load up to 5 kW | 4 mm2 |
| Mains/sub-mains for total connected load > 5 kW and < 7 kW | 6 mm2 |
| Mains/sub-mains for total connected load > 7 kW and < 10 kW | 10 mm2/4 mm2 or 6 mm2 (4 + E)* |
| * For 3-ph supply and load un-balance within 10 percent use 4 mm2, if load un-balance likely to exceed, use 6 mm2 (4+E) | |

### 3. Selection of Size of Neutral Cable

*(Ref: Para 5.2.7.2) of IS732:2019)*

Generally in Railway installation size of neutral cable is same as per phase cable.

1. The cross - sectional area of the neutral conductor/cable shall be at least equal to the cross-sectional area of the phase conductors in following condition:
   a) Single-phase circuits with two conductors, whatever be the cross-sectional area of conductors;
   b) Multi-phase circuits where the cross-sectional area of the line conductors is less than or equal to 16 sq.mm copper or 25 sq.mm aluminium;
   c) Three-phase circuits likely to carry third harmonic currents and odd multiples of third harmonic currents and the total harmonic distortion is between 15 percent and 33 percent.
2. Where the third harmonic and odd multiples of third harmonic currents is higher than 33 percent, total harmonic distortion, it may be necessary to increase the cross-sectional area of the neutral conductor. These levels of harmonic current are found in circuits dedicated to IT applications.

**Note:** Single-core cables armoured with steel wire or tape shall not be used for ac circuits. Conductors of ac circuits installed in ferromagnetic enclosure shall be arranged so that the conductors of all phases and the neutral conductor (if any) and the appropriate protective conductor of each circuit are contained in the same enclosure.

### 4. Selection of Size of Protective Earth Cable

*(Ref: Para 5.4.3 of IS732:2019)*

Protective Conductor — A conductor used for some measures of protection against electric shock and intended for connecting together any of the following parts:

a) Exposed conductive parts,
b) Extraneous conductive parts,
c) The main earthing terminal, and
d) The earthed point of the source, or an artificial neutral.

Cross sectional area of protective conductor shall not be less than the appropriate value shown in table 42.

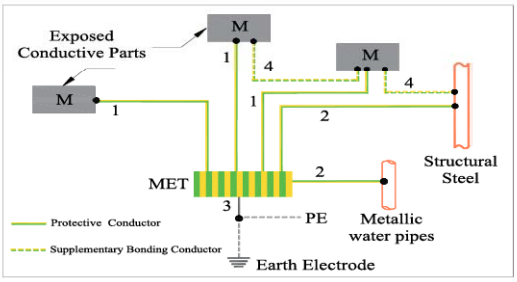



**Figure 3: Equipotential Bonding with all Exposed/ Extraneous Conductive Parts**

**Table 8: Detail of Protective Conductor**

| | |
|---|---|
| **Structural steel (extraneous-conductive-part)** | |
| Metallic water pipe (extraneous-conductive-part) | |
| Earth electrode (TT and IT system) | |
| PE (TN systems) | |
| 1 | Circuit protective conductor |
| 2 | Main protective bonding conductor |
| 3 | Earthing conductor |
| 4 | Supplementary protective bonding conductor (if required) |
| 1,2,3,4 | Protective conductors |

**Table 92: Cross Sectional Area of Protective Conductor**

(Ref: para 5.4.3.1 of IS 732: 2019)

| S.N. | Cross-sectional Area of Line Conductor, S ($mm^2$ Cu) | Minimum Cross Section Area of Protective Conductor $mm^2$ | |
|---|---|---|---|
| | | If the protective conductor is of the same material as the line conductor | If the protective conductor is not of the same material as the line conductor |
| **1** | S≤16 | S | $(K_1/K_2)$x S |
| **2** | 16<S≤35 | 16[1] | $(K_1/K_2)$x16 |
| **3** | S>35 | S[1]/2 | $(K_1/K_2)$ x (S/2) |

Where

K1 = is the value of k for the line conductor selected from Tables 60 of Annexure-7

K2 = is the value of k for the protective conductor, selected from Tables 61 to Table 65 of Annexure-7

1) For a PEN conductor, the reduction of the cross-sectional area is permitted only in accordance with the rules for sizing of the neutral conductor

Note: In TT systems, where the earth electrodes of the supply system and of the exposed conductive parts are electrically independent, the cross-sectional area of protective conductors need not exceed:

– 25 mm2 copper,

– 35 mm2 aluminium.

## Conclusion

The current-carrying capacity of a conductor/cable also depends upon other factors given below

i. The method of installation of Conductor
ii. The ambient temperature
iii. Group containing more than one circuit
iv. Harmonic disturbances
v. Voltage drop due to length of conductor

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# Study on Vertical Clearance between Axle Box and Bogie Frame for WAG9 HC Locomotive

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**Abstract :** **Indian Railways has done TOT agreement with ABB for 6000 hp three phase electric locomotives. The WAG-9 &9H is a high-speed main line locomotive for hauling Freight trains. The three axles, three motor Co-Co bogie assemblies, is one of the major parts of the locomotive. Two bogie assemblies support the entire weight of the locomotive and provide a means for transmission of the tractive effort to the rails.**

**The bogies are designed to withstand the stresses and vibrations resulting from normal rolling stock applications. An important function of the bogie is to absorb and isolate shock caused by variations in the track bed. Isolation and absorption of shock loads and vibration is performed by the primary and secondary suspension. Movement between the car body and bogie is smoothly controlled by the primary and secondary suspension. Although the springs permit free movement in any direction, lateral buffers and dampers limit the amount and rate of lateral movement. Rebound limit chains and vertical dampers limit the amount and rate of the vertical rebound of the locomotive car body.**

**The issue of primary vertical clearance between axle box and bogie frame of WAG-9HC three phase electric locomotive is being raised by all Zonal Railways/PUs time to time and it is being reported that measured values are not in line with issued guideline as per RDSO technical circular no. ELRS/TC/0082(Rev.1), dtd. 17.09.2015.**

**In this context, a study on impact on bogie clearance due to change in spring arrangement has been done for exploring possible solution to attain bogie clearance as per specified limit of RDSO technical circular no. ELRS/TC/0082(Rev.1), dtd. 17.09.2015.**

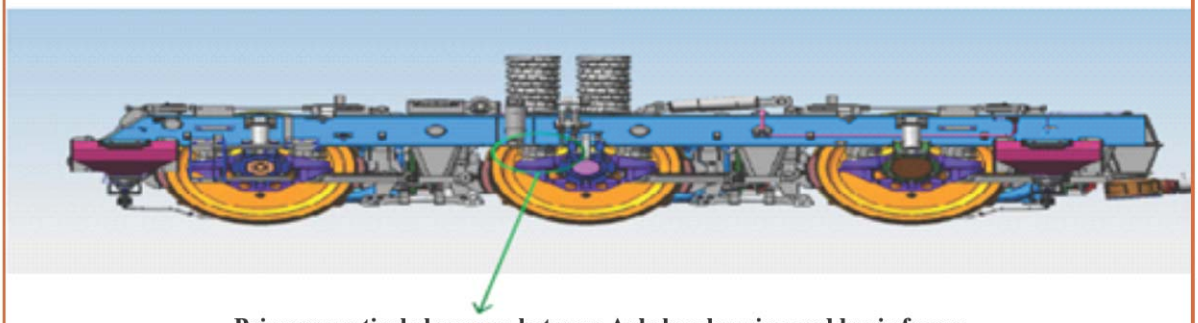
**सारांश :** भारतीय रेलवे ने 6000 एचपी के तीन फेज इलेक्ट्रिक इंजनों के लिए ABB के साथ टीओटी समझौता किया है। WAG-9 & 9H मालगाड़ियों को खींचने के लिए एक उच्च गति वाली मुख्य लाइन लोकोमोटिव है। तीन एक्सल, तीन मोटर CO-CO बोगी असेंबली, लोकोमोटिव के प्रमुख भागों में से एक है। दो बोगी असेंबलियां लोकोमोटिव के पूरे भार को सहन करती हैं और पटरियों पर कर्षण एफर्ट के संचरण के लिए एक साधन प्रदान करती हैं।

बोगियों को सामान्य रोलिंग स्टॉक अनुप्रयोगों के परिणामस्वरूप होने वाले तनाव और कंपन का सामना करने के लिए डिजाइन किया गया है। बोगी का एक महत्वपूर्ण कार्य ट्रैक बेड में भिन्नता के कारण होने वाले झटके को अवशोषित करना और अलग करना है।

शॉक लोड और कंपन का अलगाव और अवशोषण प्राथमिक और सेकेंडरी सस्पेंशन द्वारा किया जाता है। कार की बॉडी और बोगी के बीच की गति को प्राइमरी और सेकेंडरी सस्पेंशन द्वारा सुचारू रूप से नियंत्रित किया जाता है। यद्यपि स्प्रिंग्स किसी भी दिशा में मुक्त गति की अनुमति देते हैं, लेकिन पार्श्व बफर्स और डैम्पर्स पार्श्व गति की मात्रा और दर को सीमित करते हैं। रिबाउंड लिमिट चेन और वर्टिकल डैम्पर्स लोकोमोटिव कार बॉडी के वर्टिकल रिबाउंड की मात्रा और दर को सीमित करते हैं। WAG-9HC तीन फेज इलेक्ट्रिक लोकोमोटिव के एक्सल बॉक्स और बोगी फ्रेम के बीच प्राथमिक बोगी क्लीयरेंस का मुद्दा सभी क्षेत्रीय रेलवे/पीयू द्वारा समय–समय पर उठाया जा रहा है और यह बताया जा रहा है कि मापा गया मान आरडीएसओ तकनीकी परिपत्र संख्या ईएलआरएस/टीसी/0082(रेव.1), दिनांक 17.09.2015 के अनुसार जारी दिशानिर्देश के अनुरूप नहीं है।

इस संदर्भ में, आरडीएसओ तकनीकी परिपत्र संख्या ईएलआरएस/टीसी/0082(रेव.1), दिनांक 17.09.2015 की निर्दिष्ट सीमा के अनुसार बोगी क्लीयरेंस प्राप्त करने के लिए संभावित समाधान की खोज के लिए स्प्रिंग संयोजन के संयोजन में परिवर्तन के कारण बोगी क्लीयरेंस पर प्रभाव पर अध्ययन किया गया है।

**Pictorial view of Primary vertical clearance**



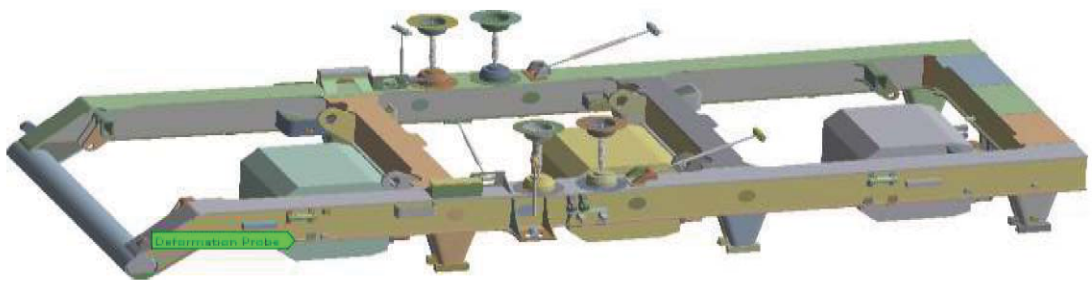
**Primary vertical clearance between Axle box housing and bogie frame**

## Brief Technical Details on Study

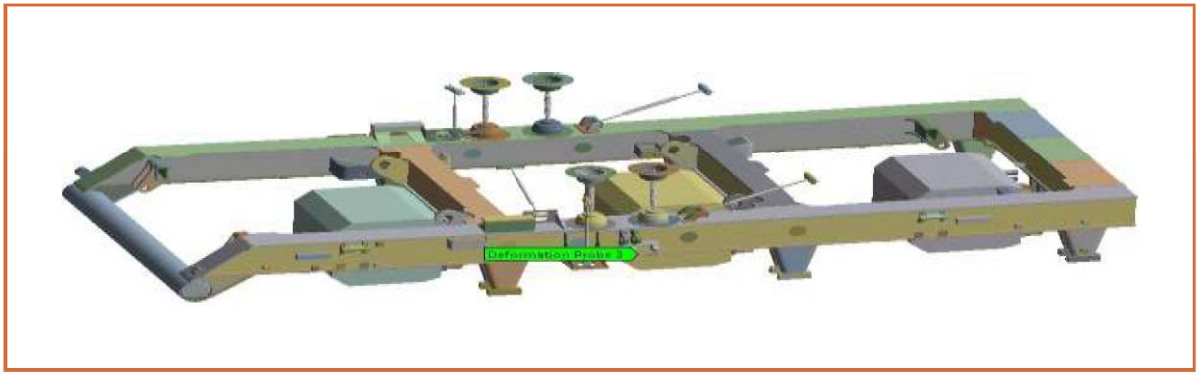
The study has been done with help of Finite element analysis with different combination of stiffness values of primary helical springs and its effect on primary vertical clearance between axle box and bogie frame. Out of various combination tried following two combination yield results of primary vertical clearance within limit as tabulated below:

| Proposed Helical Springs Combination for WAG-9HC | Loaded Height (in mm) | Nominal values of Loaded Height (in mm) | Vertical Clearance (Axle Box & Bogie Frame (in mm) | Reference Value of primary vertical clearance (in mm) |
|---|---|---|---|---|
| Only primary outer helical springs at End Axles and middle axles having both primary outer & inner helical same as in existing WAG-9HC | 189.22 | 192 mm | 32.22 | 30-35 |
| | 187.57 | | 30.57 | |
| | 191.03 | | 34.03 | |
| Reduced stiffness of all primary outer helical springs to 825 N/mm keeping same primary inner helical springs at all axles as in existing WAG-9HC | 190.37 | | 33.37 | |
| | 188.51 | | 31.51 | |
| | 191.99 | | 34.99 | |

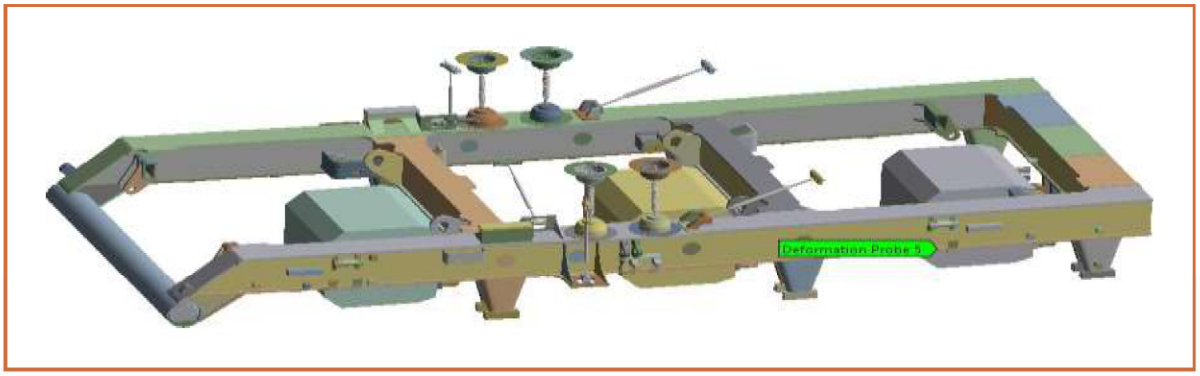
**Simulation results for combination of spring arrangement End axles without primary inner helical springs and middle axles with both primary outer and inner helical springs same as being used in existing WAG-9HC locomotives.**



| |
|---|
| Loaded height (self-weight) = Free height of spring – deformation Probe<br>= 238.8 – 49.58 = 189.22mm |
| Vertical Clearance = (Loaded height) - dist. to top of Axle Housing - BF cam dist.<br>=189.22 - 148 - 9 = 32.22mm |

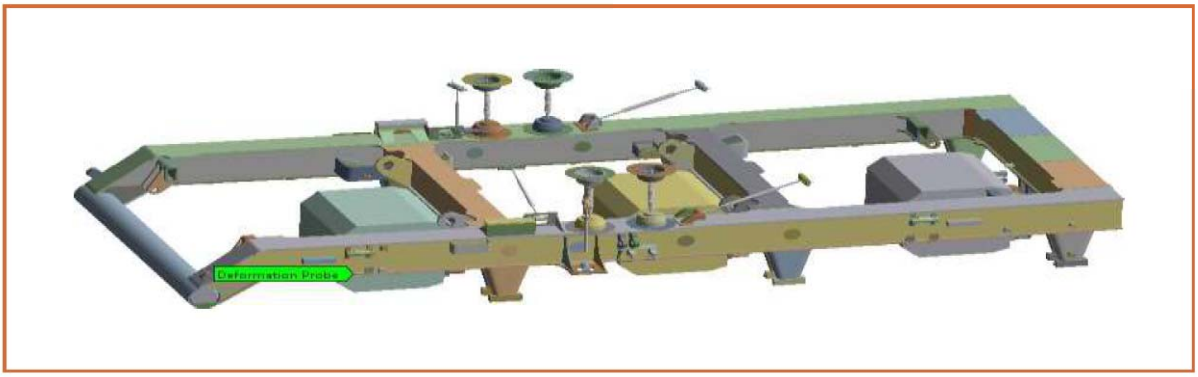



| |
|---|
| Loaded height (self-weight) = Free height of spring – deformation Probe<br>= 238.8 – 51.23 = 187.57mm |
| Vertical Clearance = (Loaded height) - dist. to top of Axle Housing - BF cam dist.<br>=187.57 - 148 - 9 = 30.57mm |

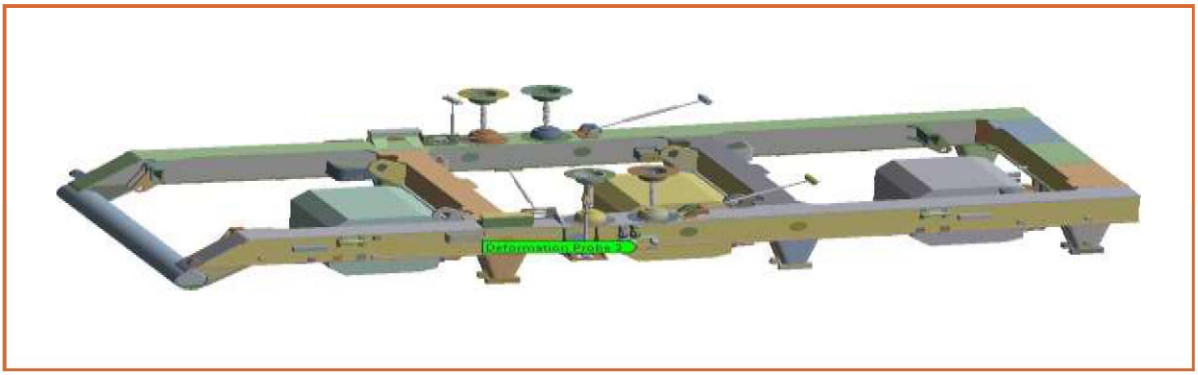



| |
|---|
| Loaded height (self-weight) = Free height of spring – deformation Probe<br>= 238.8 – 47.77 = 191.03mm |
| Vertical Clearance = (Loaded height) - dist. to top of Axle Housing - BF cam dist.<br>=191.03 - 148 - 9 = 34.03mm |

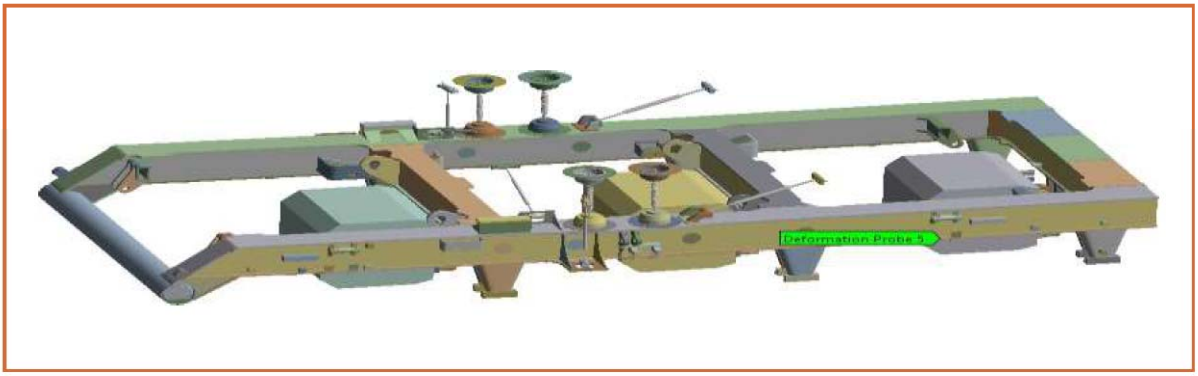
**Simulation results for combination of spring arrangement with all primary outer helical springs having reduced stiffness to 825N/mm as nominal values and primary inner helical springs at all axles same as that of existing WAG-9HC locomotives.**




| |
|---|
| Loaded height (self-weight) = Free height of spring – deformation Probe<br>= 238.8 – 48.43 = 190.37mm |
| Vertical Clearance = (Loaded height) - dist. to top of Axle Housing - BF cam dist.<br>=190.37 - 148 - 9= 33.37mm |




| |
|---|
| Loaded height (self-weight) = Free height of spring – deformation Probe<br>= 238.8 – 50.29 = 188.51mm |
| Vertical Clearance = (Loaded height) - dist. to top of Axle Housing - BF cam dist.<br>=188.51 - 148 - 9= 31.51mm |



| |
|---|
| Loaded height (self-weight) = Free height of spring – deformation Probe<br>= 238.8 – 46.81= 191.99mm |
| Vertical Clearance = (Loaded height) - dist. to top of Axle Housing - BF cam dist.<br>= 191.99 - 148 - 9= 34.99mm |

## Conclusion

With above detailed study in order to validate further static and dynamic trials of the locos with above spring arrangement combination of primary suspension springs may be conducted to resolve the issue of primary vertical clearance between axle box and bogie frame of WAG-9HC three phase electric locomotive raised by all Zonal Railways/PUs time to time and it is being reported that measured values are not in line with issued guideline as per RDSO technical circular no. ELRS/TC/0082(Rev.1), dtd. 17.09.2015.

# A Paradigm Shift to Automatic Seat Cover Lift of Western Style Lavatory Seat in Coach Toilets to Improve Hygienic

**Kuldeep Raghuvanshi**
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**Abstract : The image of Indian Railways greatly depends on the perception of traveling public. While travelling in a mail express a passenger remain at Railway coaches remain in a coach for a time ranging from one hour to forty-eight hours or so. Maintaining a clean and hygienic environment in coaches is imperative for Indian Railway since an average of 1.4 crore passengers travel in the trains every day all over the country. Toilets in trains are a basic necessity, every endeavour is made to keep the toilet hygiene maintained by proliferation of user-friendly approach to provide good experience to all users. Hygiene and health are crucial for individuals. Mumbai Division of Central Railway have developed an indigenous method to enhance hygiene in western style toilets by providing a spring loaded lid on commode replacing conventional lid.**

**सारांश : भारतीय रेलवे की छवि काफी हद तक यात्रा करने वाले लोगों की धारणा पर निर्भर करती है। मेल एक्सप्रेस में यात्रा करते समय एक यात्री रेलवे कोच में एक घंटे से लेकर अड़तालीस घंटे तक रुकता है। भारतीय रेलवे के लिए डिब्बों में साफ–सुथरा और स्वच्छ वातावरण बनाए रखना बेहद जरूरी है क्योंकि पूरे देश में हर दिन औसतन 1.4 करोड़ यात्री ट्रेनों में यात्रा करते हैं। ट्रेनों में शौचालय एक बुनियादी आवश्यकता है, सभी उपयोगकर्ताओं को अच्छा अनुभव प्रदान करने के लिए उपयोगकर्ता–अनुकूल दृष्टिकोण के प्रसार द्वारा शौचालय की स्वच्छता बनाए रखने के लिए हर संभव प्रयास किया जाता है। स्वच्छता और स्वास्थ्य व्यक्तियों के लिए महत्वपूर्ण हैं। मध्य रेलवे के मुंबई मंडल ने पश्चिमी शैली के शौचालयों में स्वच्छता बढ़ाने के लिए पारंपरिक ढक्कन की जगह कमोड पर स्प्रिंग लोडेड ढक्कन प्रदान करके एक स्वदेशी विधि विकसित की है।**

## Introduction

The image of Indian Railways greatly depends on the perception of traveling public. While travelling in a mail express a passenger remain at Railway coaches remain in a coach for a time ranging from one hour to forty-eight hours or so. Maintaining a clean and hygienic environment in coaches is imperative for Indian Railway since an average of 1.4 crore passengers travel in the trains every day all over the country.

Toilets in trains are a basic necessity, every endeavour is made to keep the toilet hygiene maintained by proliferation of user-friendly approach to provide good experience to all users. Hygiene and health are crucial for individuals.

Mumbai Division of Central Railway have developed an indigenous method to enhance hygiene in western style toilets by providing a spring loaded lid on commode replacing conventional lid.

## Problem with conventional lid over Western style commode in train toilets:

IR coaches have at least one toilet having western style commode. Seat covers are provided over the commode seat for preserving hygiene. These lids were of conventional design and requires manual lift while one go to use the toilet. At public toilets where western commode seats exist, most of the people do not lift the seat cover before urinating, which makes it unhygienic for other people to use it and it poses a threat of turning seat to unhygienic for subsequent user.

Now the passenger using toilet will not have use their hands to raise the seat of Western style toilet Mumbai Division has developed an indigenous method to keep the facility in "lift up" position.

## Introduction of the Innovation

The aforementioned problem has been overcome by simple modification using a pair of springs for auto lift up, aluminium base plate for mount and pair of bolts. This spring action keeps the seat cover always in its 'lift up position'. When a person wants to use the toilet, he can easily push it down when it has to be used for the toilet purpose only. It will remain in the down position, as long as a person is using it, otherwise it will lift up automatically to its upward and normal position back.

## Innovative Cost-Saving & Time Saving Idea

This kind of innovation is almost cost effective and easy to install in toilet seats and works on mechanical principle. Motorised Sensor Controlled Fully Automatic Toilet Seat Cover were not feasible to fit as it requires power supply also not cost effective for IR coaches. There is no major capital investment involved and yet it revolutionizes the upkeep of hygiene and enhanced passenger satisfaction.

Automatic Lift Up arrangement has been made with the help of specially designed spring. The spring has been fitted in seat cover in such a way that the spring action keeps the Seat Cover always in it's 'Lift Up Position.

Approximate cost of this innovation was rupees one hundred fifty (₹ 150/-) per toilet which is negligible when compared to its advantage of easy and quick implementation.

## Steps to be followed to carry out Modification

1. The bottom part of existing commode cover needs to be cut to accommodate the spring.
2. Insert a spindle of 6 mm into commode cover to accommodate the spring in it.
3. After fitting the spring into spindle, mount the end of the spindle into the other end of commode cover.
4. Fix the looped ends of the springs into the fixing bolts of commode cover. Now the commode cover is ready for fitment
5. Fix the nut from bottom, the commode cover is ready to open automatically with the help of spring force.

## Conclusion

Initially the modification was done in coaches of train No. 22221/22222 Rajdhani Express and passenger feedback were obtained. The innovation was appreciated by the passengers. On getting passenger feedback, all western style toilet seat cover of Central Railway are modified to enhance and another step of excellent customer service has thus been taken by the Mumbai Division of Central Railway. This innovation has been done to promote hygiene as a part of Indian government's Swaccha Bharat Abhiyan.

★★★

# Instructions for the guidance for contribution to the Indian Railway Technical Bulletin published by RDSO

Articles are invited from the serving and retired Railway personnel of the Zonal Railways, Railway Institutes and Production Units for publication in Indian Railway Technical Bulletin (IRTB) on:

(i) Technical articles relevant to railway working.

(ii) Reference to Railway-relevant good articles from reputed magazines.

(iii) Short notes on handy gadgets or practical hints on care, maintenance and operation of equipment used in railway working.

## About the article:

- Article should normally not exceed 3000 words. Article should begin with a synopsis, both in English & Hindi not exceeding 100 words. Reference should be quoted numerically in a bibliography at the end. Standard or well recognized notations should be used. Personal reference and lengthy quotations should be avoided.

  In case of reference to articles (item ii above), whereabouts of the article (name of magazine, publication month, article's name, author's name), and 2-3 lines about what the article is about and how it is so good - should be sent.

- Author's full name, designation and photograph should be sent.

- The authors should certify that the articles sent for publication in the Indian Railway Technical Bulletin have not been sent elsewhere for publication.

- The entire content (article, photograph, certification etc.) should be sent in hard copy to Executive Director / Administration, Research Designs and Standards Organisation, Manak Nagar, Lucknow-226011 as well as in soft copy (editable e.g. .doc as well as non-editable, e.g. .pdf formats) to e-mail: publicationrdso@gmail.com, aliordso@gmail.com.

Articles from officials of RDSO should be routed through, and approved by, the concerned Executive Director. In case of articles from outside RDSO, they should be duly forwarded by department head (SA Grade and above). Retired Railway personnel may send their article directly.

Decision of Executive Director /Administration regarding selection of article for publication in IRTB shall be final.

Comments and criticism in the form of 'Letters to the Editor' on articles which have appeared in earlier issues of the bulletin are welcome. Suggestions about improving the IRTB are also welcome.

★★★

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