



ज्ञान ज्योति से मार्गदर्शन
To Beam As A Beacon of Knowledge

MONOGRAPH ON BO- BO FLEXI COIL FABRICATED BOGIE (WAP5 LOCOMOTIVE)

June 2017

**Indian Railways Institute of Civil Engineering
Pune 411001**

Addendum-1, Date 12-03-2019

Changes (in Bold and Green Highlighted Fonts) carried out in chapter Nos. 3,4,5 & 11 as necessitated by introduction of new accident proforma wide Rly.Board's Letter No 2018/Safety/(A & R)/1/8 Dated 25/01/2018.

FOREWORD

It has been endeavour of IRICEN to bring out publications which are useful to field staff. The book published by IRICEN on the subject of “Investigation of Derailment” is hugely popular amongst field staff of various disciplines. IRICEN is now issuing series of Monographs for various Rolling Stock commonly used for Coaching, Freight and Loco operations for the guidance of field staff. 3 Monographs in this series viz. for ICF All - Coil Coach, CASNUB Bogie & FIAT Bogie (LHB Coaches) have already been published. The fourth monograph now being brought out is on Bo Bo Flexi Coil Bogie (WAP5 Locomotive).

The purpose behind bringing out these Monographs is to educate the field staff and to increase their awareness level as present day Accident Proforma of Accident Manual do not have adequate measurements for various Rolling stock components which may be required to determine the cause of accident. I hope that the Railwaymen from various disciplines would find this publication useful.

Pune,
June 2017

N. C. Sharda
Director
IRICEN, PUNE

PREFACE

With the view to educate field officials and increase their awareness, it is proposed to issue series of Monographs for Rolling stock commonly used in Coaching, Freight and Loco operations.

Fourth Monograph in this series is on Bo Bo Flexi Coil Fabricated Bogie(WAP5 Locomotive) which is the main stay of premium passenger train hauling Locomotive on Indian Railways. The contents in the Monograph are mainly from existing "Maintenance & Repair Manual for WAP5 Locomotive and text book on the subject of "Investigation of Derailment" published by IRICEN. For more detailed knowledge on the subject, readers are advised to refer Maintenance Manual for WAP5 Locomotive.

I am grateful to Shri N. C. Sharda, Director, IRICEN for giving me the opportunity for preparation of this Monograph and also for his encouragement and guidance from time to time for bringing out this publication. Thanks are also due to Shri Gautam Birhade, Professor Works, IRICEN, for checking the drafts and for giving his valuable suggestions. I am thankful to faculty and staff of IRICEN who have contributed immensely for this publication. Efforts taken by Shri R. A. Sayyad, Senior Instructor in correcting the draft and scrutinizing the manuscript are also appreciated. Suggestions from readers to improve the contents are welcome and can be sent to mail@iricen.gov.in which will be taken into account while bringing future editions.

Pune
June 2017

Niraj Kumar Mishra
Associate Professor(Track-1)

MONOGRAPHS PUBLISHED

1. ICF All-Coil Coach
2. CASNUB Bogie
3. FIAT Bogie (LHB Coach)
4. WAP5 (Bo-Bo Flexi-coil Fabricated Bogie)

FORTHCOMING MONOGRAPHS

5. WDM3A (Co-Co Tri-Mount Bogie, similar to WAG5)
6. WDG3A (High Adhesion Bogie, similar to WAG7,WDM3D)
7. WDP4 (HTSC Bogie, similar to WDG4)
8. WAP7 (Co-Co Flexi-coil Fabricated Bogie, similar to WAG9)

CONTENTS

1	Introduction	1-5
2	Bogie Frame	6-9
3	Wheel Set	10-18
4	Wheel Inspection & Measurement	19-27
5	Primary Suspension	28-31
6	Secondary Suspension	32-36
7	Hydraulic Dampers	37-43
8	Transfer of Tractive Effort	44-49
9	Draft Gears	50-53
10	Buffing Gears	54-55
11	Common Defects	56-57
12	Clearance Table	58
13	References	59

1. Introduction

(i) Bo-Bo Flexi-coil Fabricated Bogie

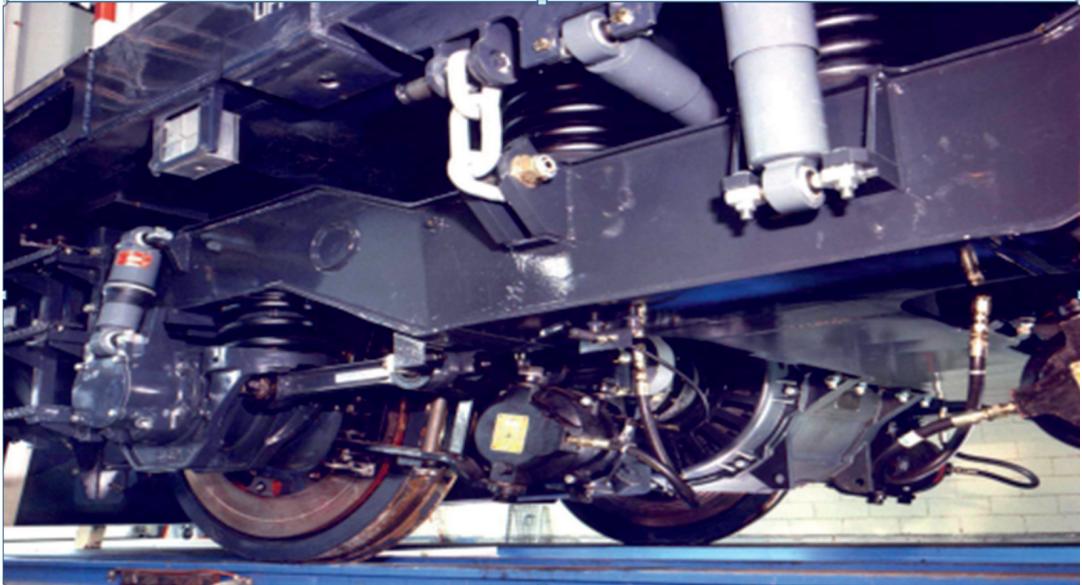


Fig1 : Photo showing part view of Bo-Bo Bogie

Bo-Bo is the UIC (International Union of Railways) indication of wheel arrangement for Railway locomotives. A locomotive, which has two bogies each having two axles and both are independently driving axles then such a configuration is called as Bo Bo configuration. The Bo Bo configuration is allowed for higher cornering speeds due to smaller wheel base. In high speed passenger (Coaching) services this configuration is used where requirement of speed is more than higher torque value.

The bogies are fabricated and lateral guidance between bogie and loco body is provided by flexi coil action of secondary suspension springs hence these bogies are called as Flexi-coil bogies. Similarly flexi coil action of Primary springs permit lateral movement of Axle with respect to bogie frame.

Such Bo-Bo Flexi-coil Fabricated Bogies are used on WAP 5 locomotives. WAP5 is Broad gauge Electric Locomotive used for Passenger service on Indian Railways which is the 5th model in passenger loco segment.

(ii) Parameters of WAP5 Locomotive

First 10 locomotives of this class were imported from ABB (Asean Brown Boveri) now Bombardier of Switzerland in 1995. Chittaranjan Locomotive Works (CLW) started production in 2000 under transfer of technology. It was designed to haul 18 coach passenger trains at 200 kmph. It is the first 3 phase locomotive in India. On 3rd July 2014, a WAP5 set a record on Indian Railways by hauling a train from Delhi to Agra within 90 minutes at a speed of 160 km/h. A 24 coach (1430t) passenger rake can be accelerated to 110 km/h in 312 seconds (over 6 Km), to 120 km/h in 402sec (6.9km); and to 130km/h in 556 sec (14.2km) by a WAP5.

Table1: Parameters of locomotive

Max Traction Motor (TM) speed	3174 RPM
Continuous TM speed	1585 RPM
Max permissible speed	160 kmph
Axle load	19.5 t
Gear ratio	3.941
Max tested speed	184 kmph
Wheel configuration	Bo Bo with quill drive which enables locos to negotiate sharper curves at high speeds
TM configuration	Fully suspended
Bogies	Bo-Bo Henschel flexifloat
Loco Wheel base	13000 mm
Bogie wheel base	2800 mm
Tractive effort	26.3 t
Length over buffers	18162 mm

Other notable features of this locomotive is Hotel Electric Power (HEP). HEP is electricly generated & used for ew purpose other than propulsion. The electrical load generated by the system known on hotel load. pantry load, flexible coupling and wheel mounted disc brakes. Braking systems include 160 kN loco disc brakes, automatic train air brakes and a charged spring parking brake.

(iii) Salient features of WAPs Locomotive

Design features of Bogie

- Two axle boltsterless bogie with two stage suspension of helical coil springs at both the stages.
- Loco body rests directly on the secondary springs. Anti-vibration rubber pads are provided below and above the springs.
- Lateral guidance between bogie and loco body by flexi-coil action of secondary springs.
- A pair of springs on each axle box forms the bogie frame primary support.
- Damping is provided in both Primary and secondary stages. Four Primary Vertical dampers one on each axle box and two vertical, two lateral and two longitudinal dampers in secondary stage.
- One lateral damper is provided with each traction motor.
- Traction rod with rubber pads between bogie and under frame to cushion the thrust and for transmission of traction and braking forces.
- Wheel mounted disc brakes.
- Guide links between axle boxes and bogie frame for guidance of wheel sets and transmission of traction and braking forces.
- Wheel set guidance in lateral mode is provided by lateral stiffness of primary springs.
- Less un-sprung weight as Traction motors are fully suspended in bogie frame. A crowned gear coupling between traction motor and gear box for transmission of torque.
- Secondary spring guides, lateral and longitudinal damper brackets, vertical and lateral bump stop brackets are welded to the top plate of long beams.
- Vertical damper brackets and lifting chain brackets are welded to the plates of long beams.
- Traction motor mounting brackets and disk brake mounting brackets are welded to the transoms.
- Traction bar bracket is welded to the bottom of end transom.

(iv) Special features

- WAP5 loco bogie is provided with fully suspended traction motors i.e. motor is supported in bogie frame and connected to gear box through a crowned gear coupling HZK 100-280 supplied by ZF HURTH, Germany.

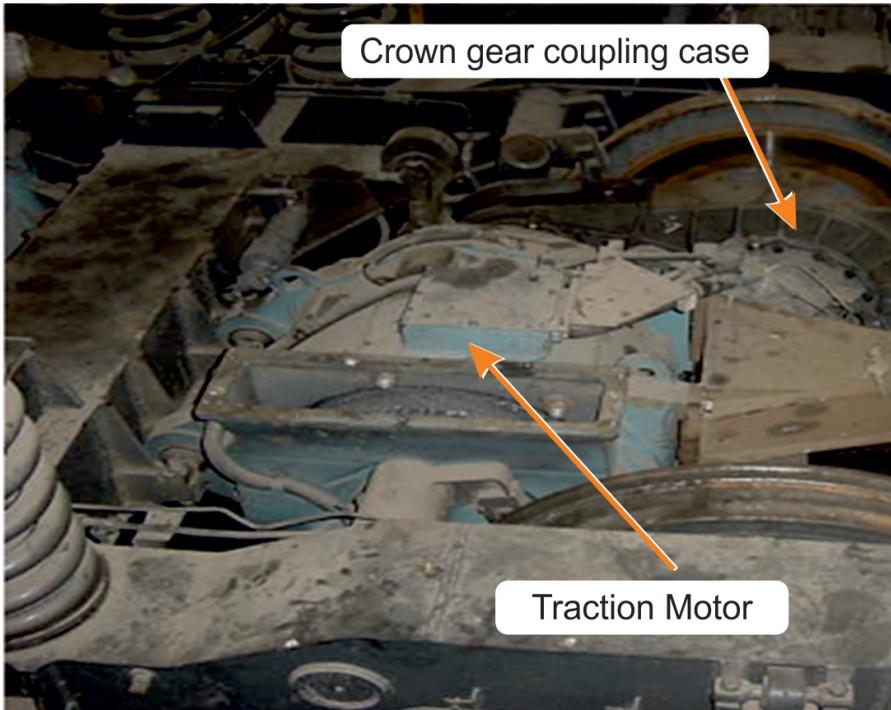


Fig 2 : Fully suspended traction motor

- Gear box is connected on the driving axle. The motor torque is transmitted to gear box through this gear coupling.
- The coupling is designed to take radial, axial and angular shaft misalignment and mainly consists of coupling sleeve assembly, coupling star assembly, cover, O-ring, locking ring, sealing ring etc.
- Inner toothed coupling sleeves are mounted rigidly on motor and transmission shaft.
- Coupling star installed in motor and transmission are bolted together.
- Coupling is equipped with separate closed lubricant chambers in each

coupling half. The lubricant chambers remain closed when removing or installing the motor or transmission.

- Maintenance is limited to a visual check for oil leaks or damage and oil change during major schedule inspections.
- The coupling is designed for a maximum motor torque of 10000 NM (Newton meter) and maximum speed of 3600 rpm.



2. Bogie Frame

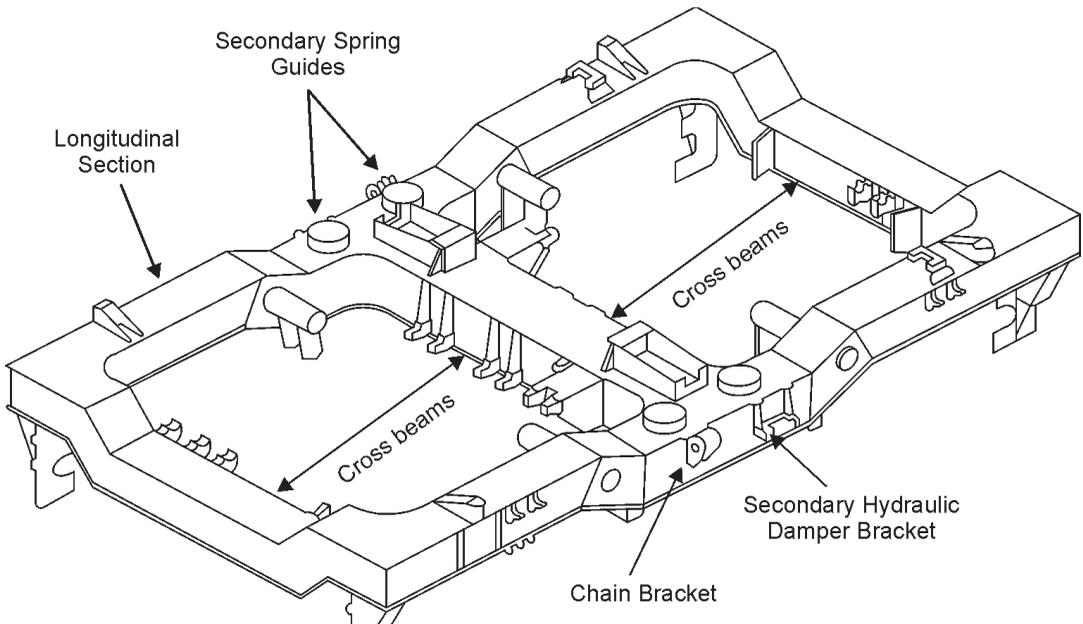


Fig 3 : Bogie frame with location of different parts

Bogie frame is a fabricated steel structure. It consists of two longitudinal sections, which form the side members and three lateral box sections which form the cross members. The cross members are positioned and welded to the side members forming a rectangular frame. All structural welds on the bogie are ultrasonically tested during manufacture for penetration.

The axle guide rod support brackets are of cast steel and are welded to the bottom flange of the side members. The axle spring guides and primary suspension spring pads are welded to the bottom flange of the side members as are the mounting brackets for the sanding outlet pipe, wheel flange lubrication and tread conditioners. Secondary suspension spring guides, longitudinal (yaw) damper brackets and vertical bump stops are all welded to the top flange of the side members.

Brackets for the vertical dampers and pivot brackets for the rebound limiting chains are welded to the outer webs of the side members

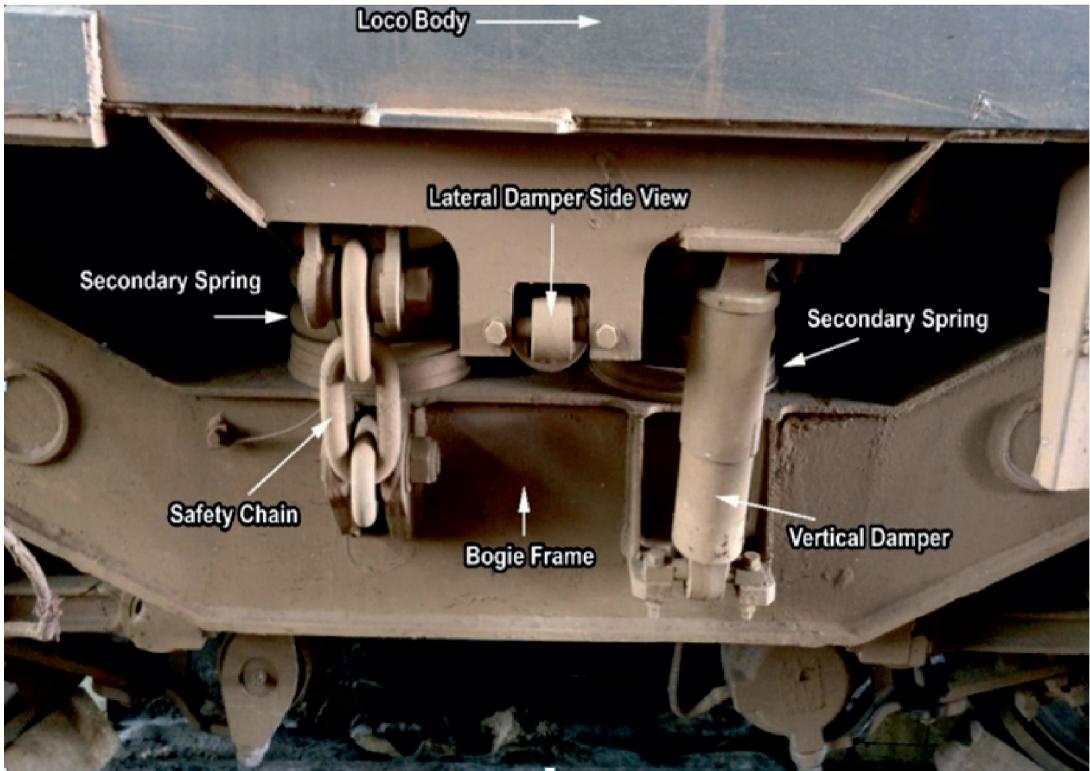


Fig 4 : Bogie & Loco connection

Lateral damper and bump stop brackets are welded to the top flange of the center cross member. Brackets for mounting the traction motors and transmission are welded to the centre cross member, another mounting bracket for the traction motor is located on the end cross member.

To ensure full protection against corrosion, all box sections are sealed against the entry of moisture and the frame is coated with a two pack polyurethane paint over an epoxy primer.

Table 2: Bogie dimensions

Length (nominal)	4640 mm
Width (nominal)	2580 mm
Weight (nominal)	2060 kg

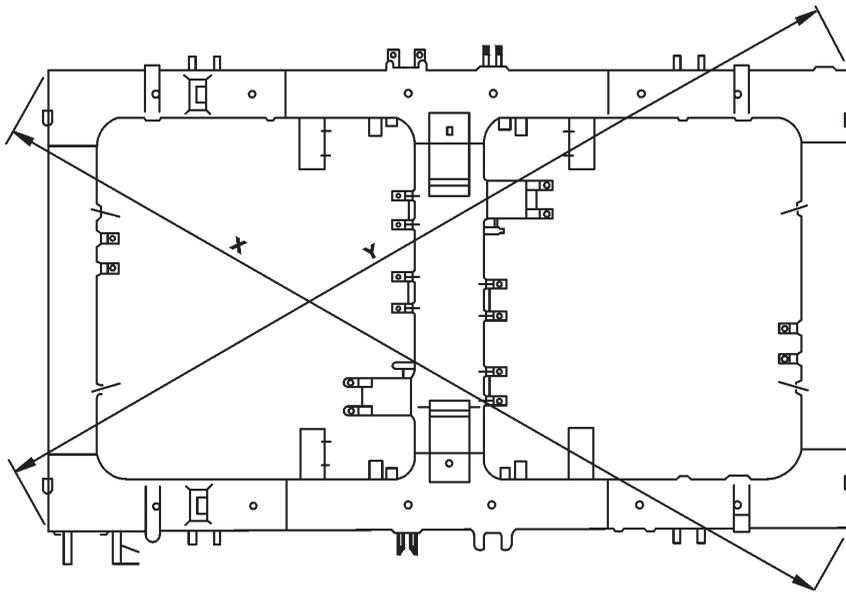


Fig 5: Bogie frame alignment/twist check

Checking of frame twist/ out of square- With the bogie frame located in a suitable fixture, dimensions(X) and (Y) between outermost corners of the bogie are measured. **Allowable difference between dimensions (X) and (Y) is 5 mm.**

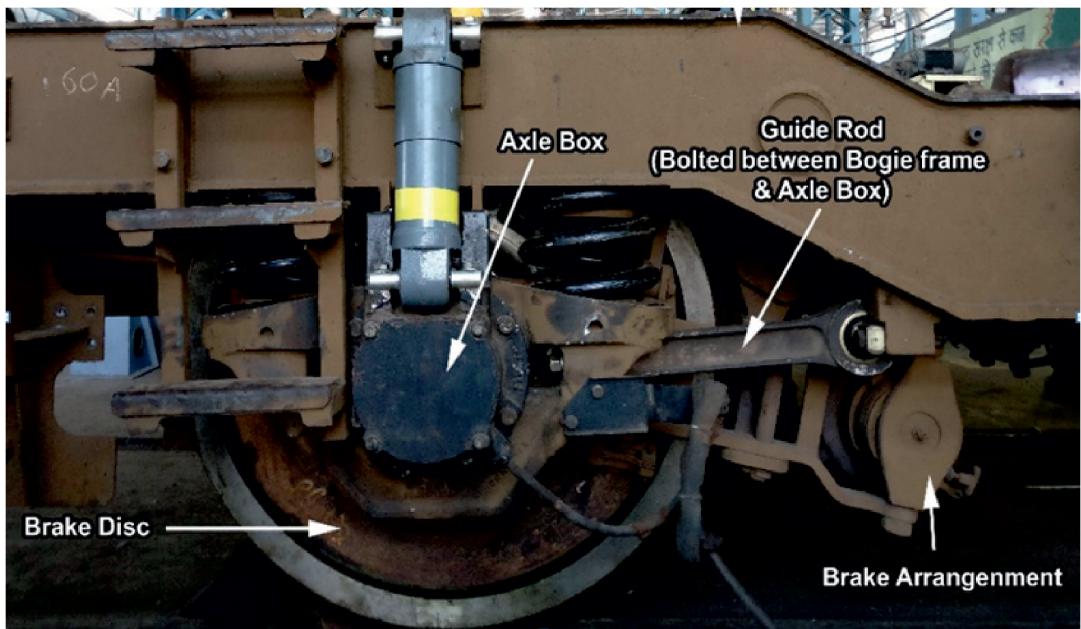


Fig 6 : Bogie view at primary suspension

Table 3: Items to be checked

Item	To be checked for	How to check	Repercussion
Bogie frame- welds & joints in the frame	a) Cracks, fatigue, High Wear signs, Damages at critical locations and for loose connections, breakage & dropping of fasteners b) Check alignment and twist in bogie frame	a) Visually, DPT b) By measuring X & Y diagonal	a) Loss of integrity and functionality of affected component b) Angular run of wheels can cause unsafe condition
Longitudinal beams, Cross beam(Transom)- Brackets & supports for various items			
Mounting locations of Brake equipment, dampers, traction Motors, gear boxes, safety chains, guide rods, sanding equipment, wheel flange lubrication equipment,			
Bushings and holes			
Bump stops			
Spring seat areas			
Link rod pivot on end transom			



3. Wheel Set

The wheels are a one piece monoblock design. They are machined from a single casting and manufactured to comply with IRS R 34-81. The tread is IRS thick Profile type CSL 3040.

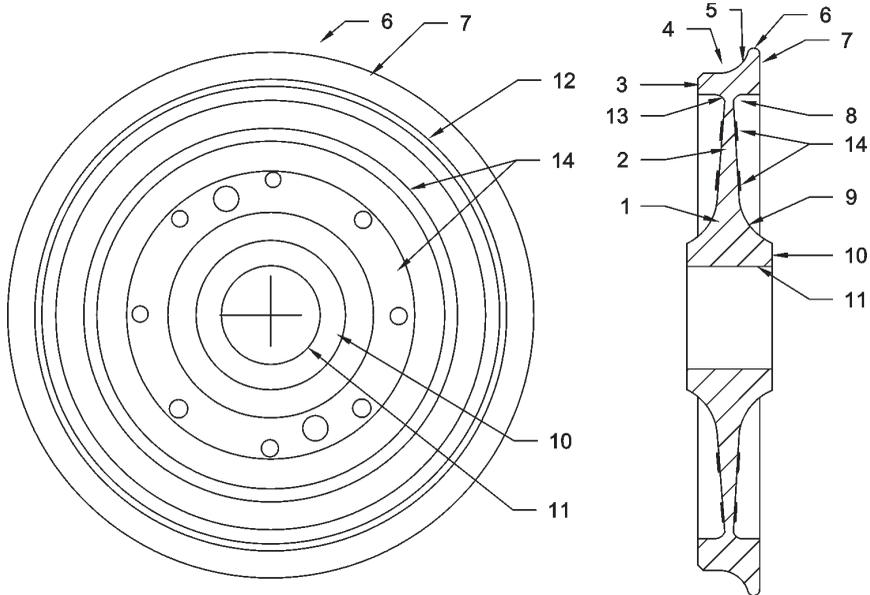


Fig 7: Wheel sketch indicating profile & contours

Table 4 : Description & location of wheel profile & contours

1	Front hub fillet	8	Back rim fillet
2	Web plate	9	Back hub fillet
3	Front rim face	10	Hub
4	Tread	11	Wheel hub bore
5	Root (gauge line)	12	Condemning line
6	Flange	13	Front rim fillet
7	Back rim face	14	Brake disc mounting blocks

Each wheel is balanced to UIC 812-3 standards and the value of the residual imbalance is stamped on the hub.

Wheel hub (10) and bore (11); Tread profile (4) and brake disc mounting blocks (14) on the web plate (2) are machined to precision tolerances. A groove, the condemning line (12) on the back rim face (7) provides a reference line for measuring the tread depth. Wheel treads and flanges are hardened during manufacture for increased durability. As the wheel wears during locomotive operation, work hardening occurs and consolidates the tread and flange. Consolidated material is more resistant to wear than the softer material beneath the surface. Thus, work hardening hardens the wheel treads and flanges as they wear. As a guide, the work hardening usually extends 3-5mm below the surface, after the wheel has travelled approx. 3,000 kms.

Wheel sets comprise an axle shaft, a main gear, two labyrinth rings, the axle end caps and two single piece monobloc wheels with a brake disc on each side.

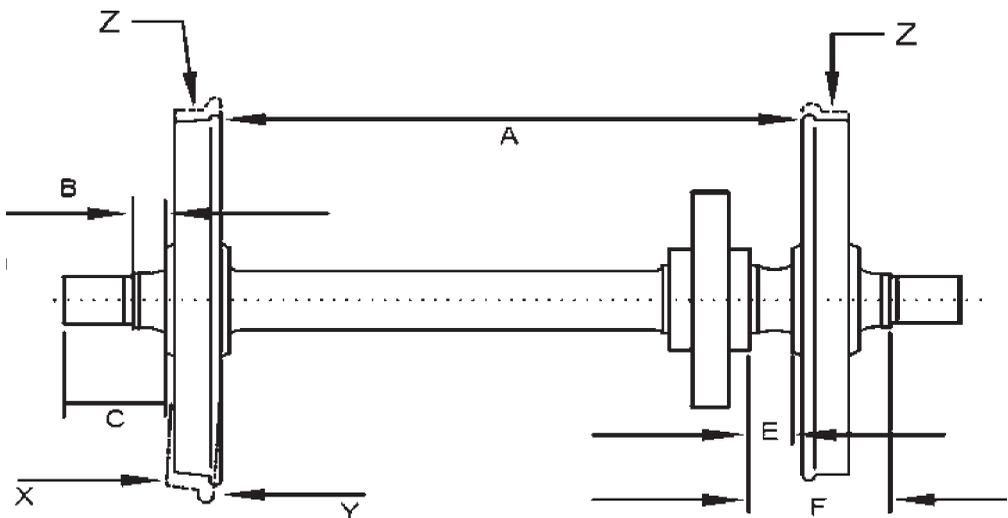


Fig 8 : Wheel assembly indicating manufacturing tolerances

Table 5 : Manufacturing tolerances for wheel

Distance 'A' Wheel gauge	1595.5– 1596.5mm
Distance 'B' Distance between Bearing journal & disc hub face	79.9 – 80.1 mm
Distance 'C' Distance between disc hub face to end face of journal	289.5 – 290.5 mm
Distance 'E' Distance between disc hub face(Inner)to bull gear hub face	114.9 – 115.1 mm

Distance 'F' Distance between Bull gear hub face to Bearing journal	374.5 – 375.5 mm
Run out rim front face 'X' Max	0.5 mm
Run out rim front face 'Y' Max.	0.5 mm
Run out tread 'Z' Max	0.1 mm

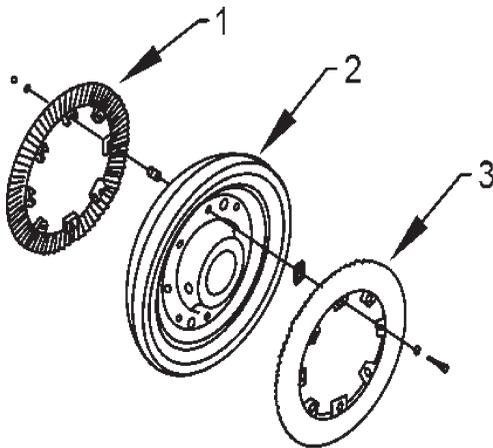
Table 6 : Wheel and axle loads

Axle load (nominal)	19,306 - 20, 094 kg
Maximum difference in wheel loads	770-800 kg

*-difference in wheel loads must be less than 4% of the measured axle loads.



Fig 9 : Wheel assembly showing fitment of brake disc



Vented brake discs are bolted to the front and back of the web plate (2). Vented brake discs are mounted on each side on the wheel plate (2). The brake discs (1) are screwed together through the wheel disc (2).

Fig 10: Expanded view of wheel and brake disc

Main Gear-

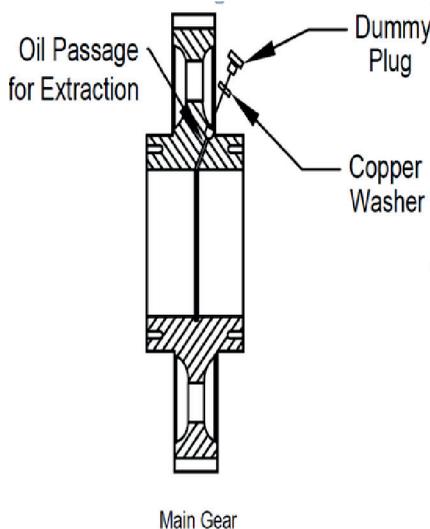
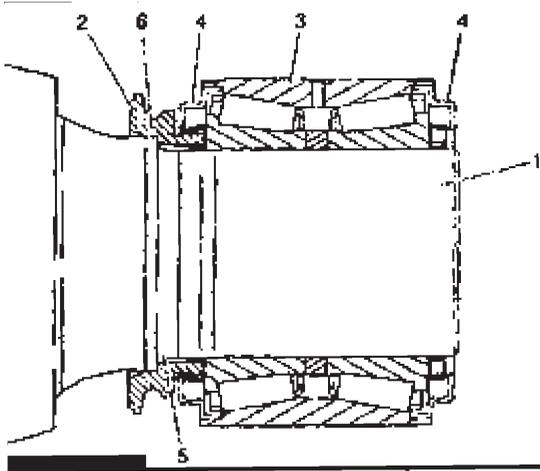


Fig 11 : Main gear X-sect

Fig 12 : Main gear photo

The main gear is forged from Chromium nickel molybdenum steel, then machined and ground to precision tolerances. After machining, each gear is ultrasonically tested for flaws. The gear teeth are ground then hardened to a depth of 1.4 mm.

Labyrinth Ring-



The labyrinth ring (2) is used to locate the inner edge of the tapered bearing unit (3) in relation to the axle shaft (1). The axle end cap locates the outer end. The labyrinth ring is an interference fit into a shoulder (6) at the inside end of the bearing journal fillet (5). When the tapered bearing (3) is installed, the labyrinth ring (2) lip seats within the bearing seal. The labyrinth ring (2) is manufactured to precision tolerances and hardened against wear. All mating areas are ground to a 3.2 micron surface finish.

Fig 13 : Labyrinth ring fitment on axle

Axle End Cap-

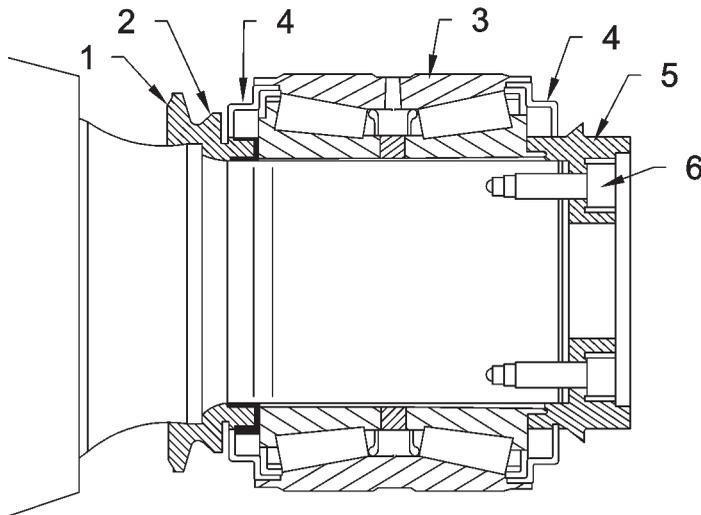


Fig 14 : Axle end cap fitment on axle

The axle End cap (5) is used to locate the outer edge of the tapered bearing unit (3) on the axle shaft (1). The labyrinth ring (2) locates the inner end. The cap (5) is secured to the axle shaft (1) by means of four bolts. When installed, a lip from the cap (2) seats within the bearing seal (4). The axle end cap is manufactured to precision tolerances. Mating areas are ground to a 3.2 micron surface finish.

Axle Box Housing

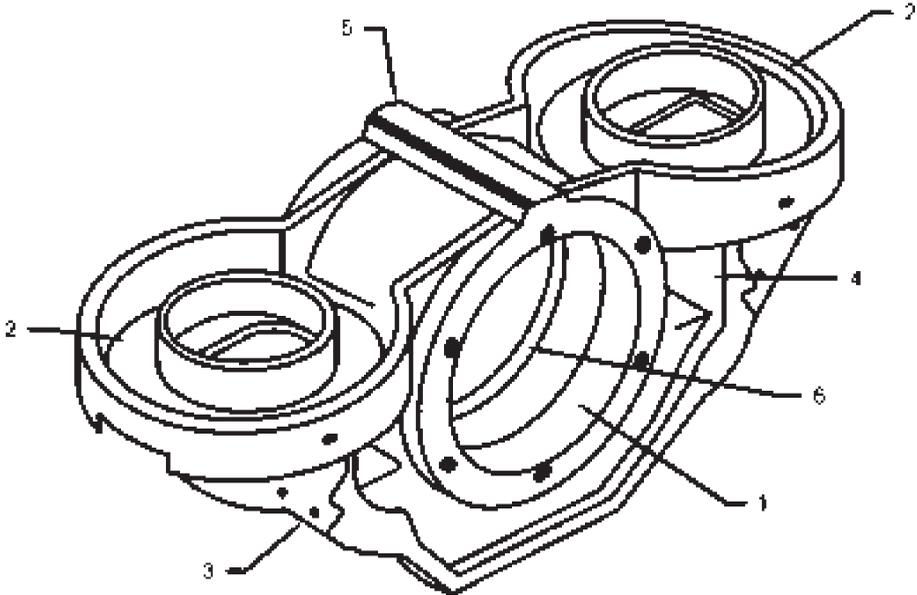


Fig 15 : Axle bearing housing indicating spring seat, bump stop land,



Fig 16 : Axle bearing housing photo graph

Axle boxes provide a housing for the tapered roller bearings and seats (2) for the primary suspension springs. The boxes also provide a connection (3) for the guide rods between the wheel set and the bogie frame for the transmission of tractive and braking effort. Webbing (4) between the bearing housing (1) and the spring seats (2) forms a rigid structure and mounting points for the axle guide rods. A land (5), cast as part of the axle box, provides a vertical limit stop for the primary suspension. The axle boxes are manufactured from cast aluminium alloy, machined to precision tolerances then x-ray tested for flaws.

Tapered Roller Bearing-

WAP-5 Bo Bo locomotives use tapered roller bearings (3) on the axle shafts(1). The bearing units fit within a precision machined bore in the axle boxes (1). The location of the bearing unit on the axle is maintained by the axle end cap(5) and labyrinth ring (2).

Axle boxes are capped on the outside by the front cover (9) to protect the tapered roller bearing units (3) from contamination with dust and debris.

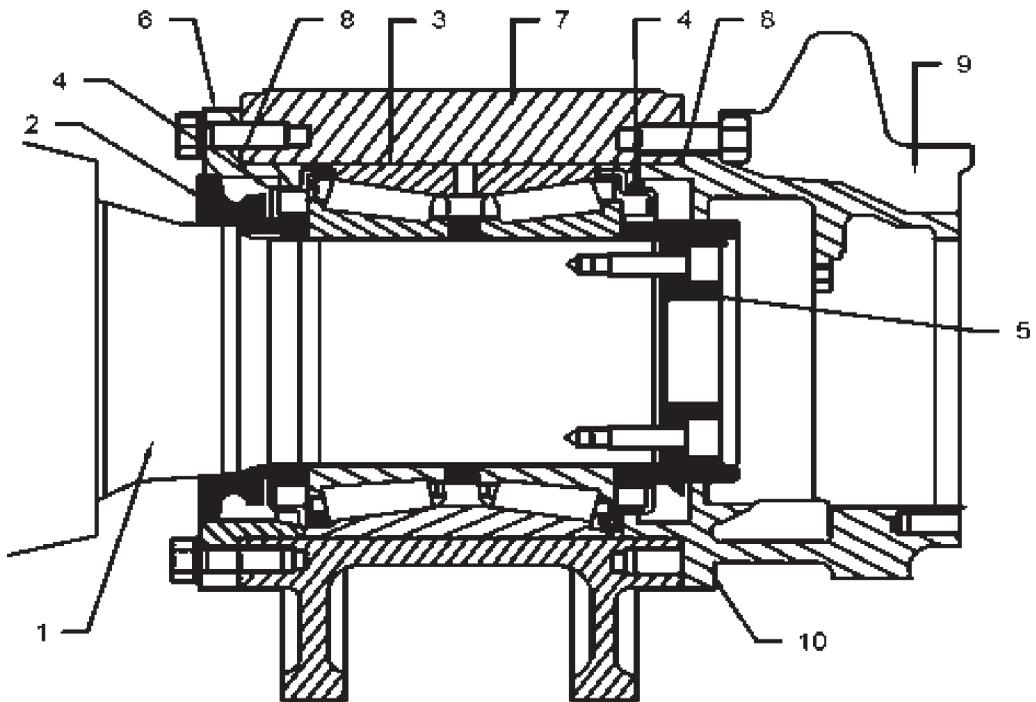


Fig17 : Assembled axle box

Table 7 : Parts of axle box

1	Axle shaft	6	Split ring
2	Labyrinth ring	7	Axle box
3	Tapered bearing unit	8	O-ring
4	Oil seal	9	Axle box front cover
5	Axle end cap	10	Breather hole

The axle bearing are self-contained, preassembled, pre-lubricated taper roller cartridge type bearings



Fig 18 : Photo graph of cartridge tapered roller bearings

Assembled wheel with coupling, Axle box:-



Fig 19 : Photo of assembled wheel showing hurth coupling gear case, Axle box and brake disc

Table 8: Items to be checked

Item	To be checked for	How to check	Repercussion
Brake Disks	Mounting bolts loose, missing etc., crack, wear in disc faces beyond limit	Visually, DPT	Loss of integrity and functiona-lity of affected Component
Axle Boxes	Grease leakage, burning smell, tell tale signs of high bearing temperature or seizure, Wear/ damage on Bump stop face, Spring seat areas, Guide rod spheribloc	Visually	
CTRB	Overheating, End plate bolt breakage Excessive wear in cup & cone	Visually	
Bump	To check for bump marks	Visually	
Spring	To check for damage	Visually	
Link rod pivot on end	Availability of all fasteners in place & in tight condition, Welding of Pivots with Bogie & Loco chasis	Visually	



4. Wheel Inspection & Measurement

As the locomotive traverses through corners and bends, the wheel flange, root and tread do wear. Predominate wear on the flanges is usually identified into the flange at the gauge line. Measuring of wheel profile is shown below,

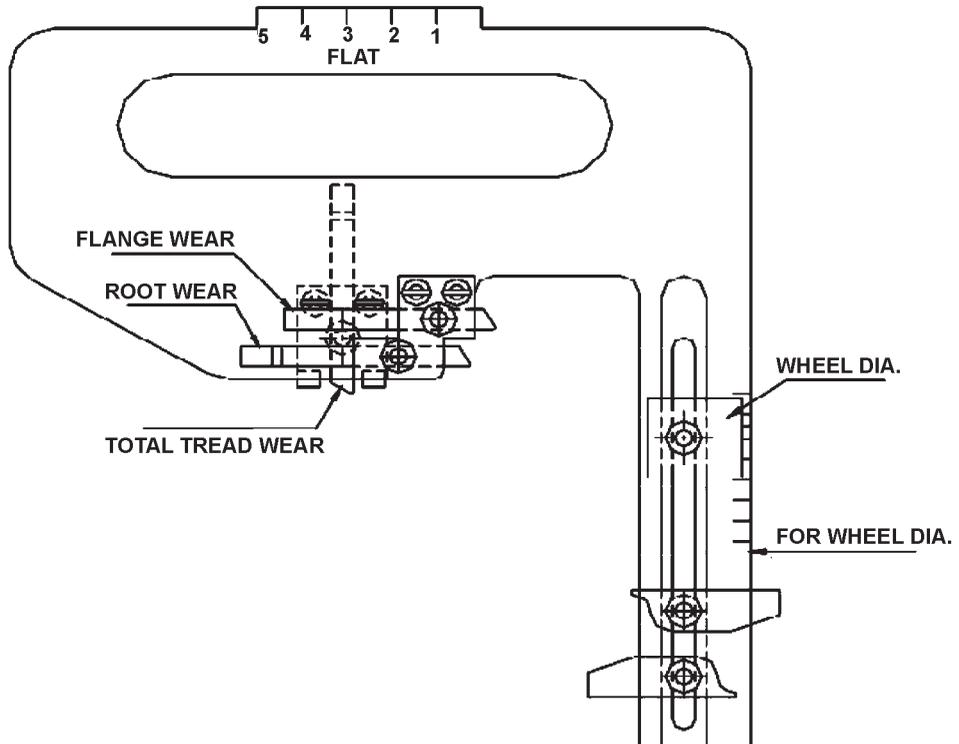


Fig 20 : Wheel profile gauge to RDSO Drg no. SKDL-4446 & SKDL-4447
(Drg. No. SKDL-4446 & SKDL-4447 to be used instead of SKDL-3592 Alt-5 on WAP5 locomotive as per Rly. Board's Letter No 2018/Safety/(A & R)/1/8 Dated 25/01/2018.)
For other locomotives RDSO Drg. No SKDL-3592 Alt-5 to be used.

Wheels are subjected to wear at three places, viz. i. On flange, ii. On root radius, iii. On tread. The wear taking place is seldom uniform, therefore diameter of 2 wheel discs on same axle also differs during service. For safe running of the rolling stock, the limit of service tolerances are fixed which are below the safety limits. Following paras will explain the procedure for checking of the above mentioned wears.

Placement of profile gauge for checking wheel wear.

(A) Procedure for checking wheel flange wear



Fig 21 : Procedure for checking wheel flange wear

Profile gauge to be placed as shown above. The stylus at top which is positioned at 13 mm from wheel flange tip needs to be slid to touch the flange. The reading value will give us wear at flange. The limit for this Loco is 2.5 mm

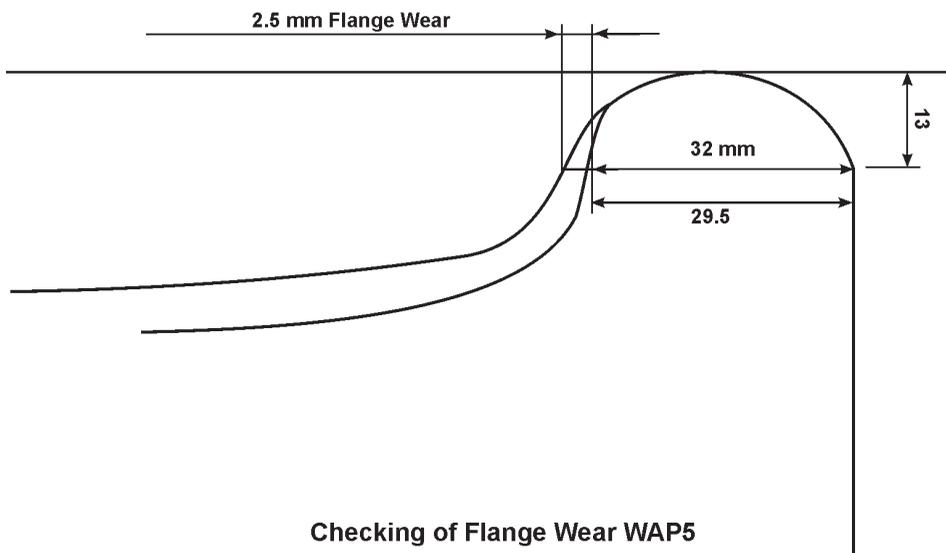


Fig 22 : Procedure for checking flange wear

B) Procedure for checking of root wear:-



Fig 23 : Procedure for checking wheel root wear

Profile gauge to be placed as mentioned above. The stylus at bottom which is positioned at 22 mm from wheel flange tip needs to be slid to touch the root radius. The reading value will give us wear at root radius. The limit for this Loco is 4.0 mm

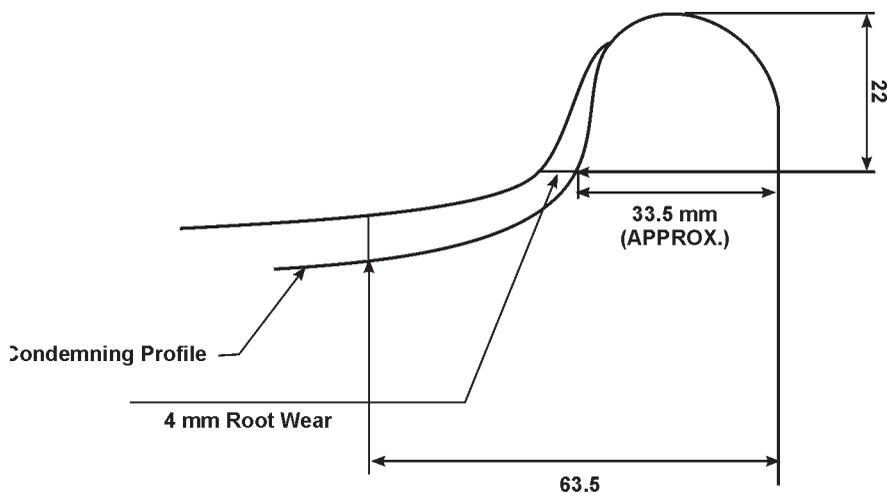


Fig 24 : Procedure for checking root wear

C) Procedure for checking of tread wear:-



Fig 25 : Procedure for checking wheel tread wear

Profile gauge to be placed as mentioned above. The stylus in the middle & backside of the profile gauge is positioned at 63.5 mm from wheel flange face needs to be slid to touch the tread. The reading value will give us wear at tread. The limit for this Loco is 6.5 mm

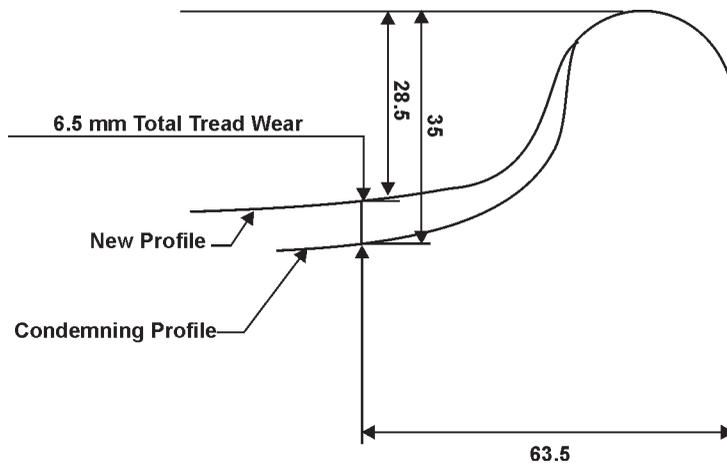


Fig 26 : Procedure for checking tread wear

WAP5 Locomotive profile with new & condemning contour

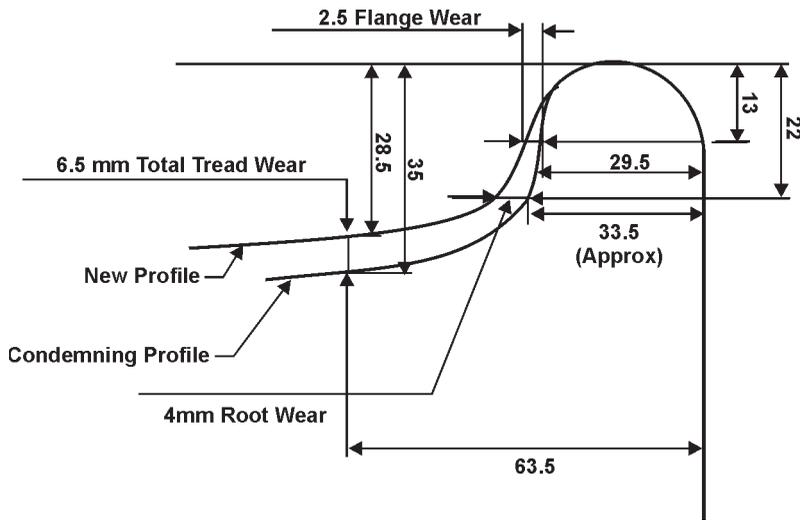


Fig 27 : Profile of wheel in new & condemned limits

Wheel Diameter Measurement :- Wheel diameter of loco wheels are measured on wheel profile machine. All major Loco sheds are having Under floor or pit wheel lathe. On these machines, wheel profiling is carried out 'in situ' i.e. wheels are not required to be removed out from locomotives like surface wheel lathes. Wheel whose diameter needs to be measured is rotated for 10 revolutions and average of 10 rounds is shown which is accurate up to 0.01 mm. The limits for this loco is tighter than other locos since this is a high speed coaching loco. The limits are shown below.

Table 9: Operational differences in Wheel dia. & profile sizes

Same axle	1.0 mm
Same bogie	4.0 mm
Same locomotive	20.0 mm
The condemning limit of tyre thickness is	27 mm
Minimum allowable flange width is	29.5 mm
Condemning limit of tread diameter is	1,016 mm
Maximum allowable wear on root thickness is	4 mm.

Apart from normal wear of wheel profile, other defects such as

i. Slide tread:-



Fig 28 : Slide tread

A slide flat spot on the tread occurs when the wheel drags on the track, even for a short distance. Wheels with flat spots of more than 50 mm length or width, or where two or more adjoining spots of greater than 40 mm length should be inspected for sub surface defects & overheating.

ii. Shattered rim:-



Fig 29 : Shattered rim

Shattered rim occurs when a piece of material flakes off from the tread or rim as a result of sub-surface defect. Usually sub-surface defect become apparent during wheel turning operations. Voids, delamination or flakes of material may split off from the wheel due to a localized underlying defect in the wheel during turning. If re profiling below 2 mm of underlying defect, tread is noticed without further defects then wheel can be kept in service else condemned. Localized pitting or flaking without presence of any other rejectable condition.

iii. Spread rim:-

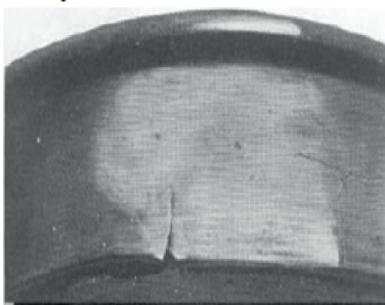


Fig 30 : Spread rim

Internal defects in the wheel can cause the front face of the rim to widen out for a short distance. Spreading rim is usually accompanied by a flattening of the tread and cracks or shelling may also be evident and is often associated with shattered rim. Spread rim condition is usually less than 300 mm long and should not be confused with uniform burning of the wheel rim caused by tread or even wear. Wheels with spread rims are condemned.

iv. Shelled tread:-

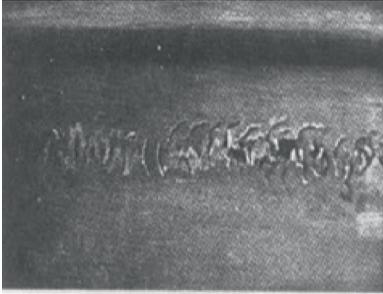


Fig 31 : Shelled tread

Shelled tread occurs when pieces of metal break out of the tread in several places almost continuously around the wheel. Excessive shelling is often the result of excessive load or speed, poor track condition or a continuous sub surface defect in the wheel tread. If reprofiling does not remove the defect, wheel is condemned.

v. Thermal cracks:-



Fig: 32 Thermal crack on tread

Thermal cracks appear on a wheel due to intense heating of the wheel arising out of severe brake binding. Such cracks occur on the tread and generally progress across the tread in a transverse & radial direction. Whenever such a crack becomes visible on the outer face of the rim or a tread crack has reached the outer edge (non-gauge face) of the rim; the wheel should be withdrawn from service. If a crack becomes visible on the outer flange face the wheel should be withdrawn from service.

vi. Built up tread:-

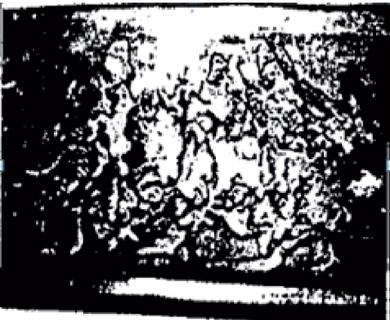


Fig 33 : Built up tread

Tread build-up is caused by metal from the wheel tread being heated to a plastic state, then being dragged around the tread. Built up tread is often associated with the siding or spinning of the wheel under braking or acceleration, respectively. If reprofiling does not remove the defect, wheel is condemned.

vii. Cracked or broken flange:-

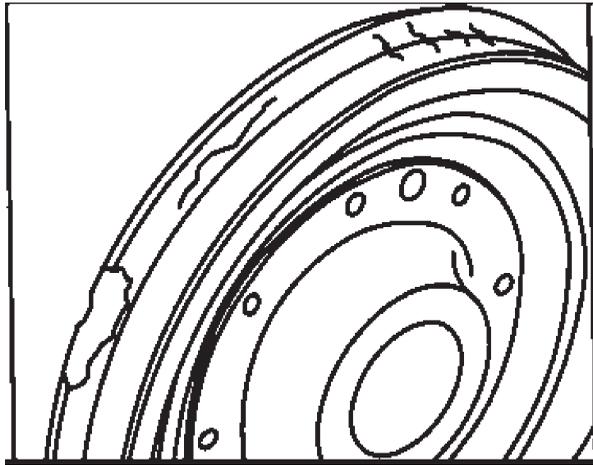


Fig 34 : Cracked or broken flange

Cracked or broken flanges often occur as a result of a severe impact shock. Locomotive that have been involved in a collision or severe derailment can have these defects. Wheels with cracked or broken flanges cannot be used & must be condemned.

viii. Cracked or broken rim:-

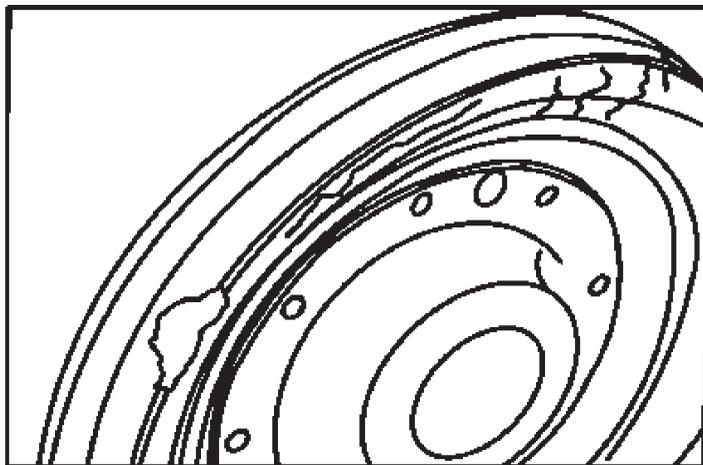
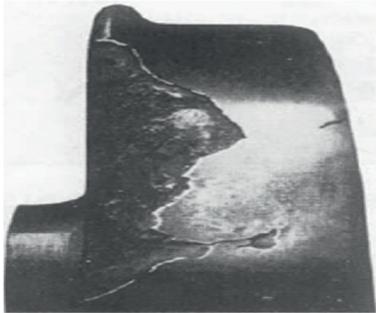


Fig 35 : Cracked or broken rim

ix. Burnt wheel:-



Defects such as broken rim, Broken or cracked plate, loose wheel, Out of gauge, burnt flange or tread etc. can also lead to unsafe conditions during run.

Fig 36 : Burnt flange & tread

Table 10: Items to be checked:

Item	To be checked for	How to check	Repercussion
Wheel profile	Difference in Dia, Flange, Root, Tread Wear & flatness on profile, gauge between wheel disc faces	Dia on wheel lathe machine, wear by profile gauge, wheel gauge Micro meter	Angular run, increased lateral play, strain on elastic couplings,
Wheel defects other than wear	Cracks, Deformation like Slide tread, Shattered rim, Spread rim, Shelled tread, Thermal cracks, Built up tread, Cracked thermal effects, broken flange or rim	Visually, DPT	Damage to rail profile, may cause weld failure, rail fracture, broken flange will cause jumping of wheel over track



5. Primary Suspension

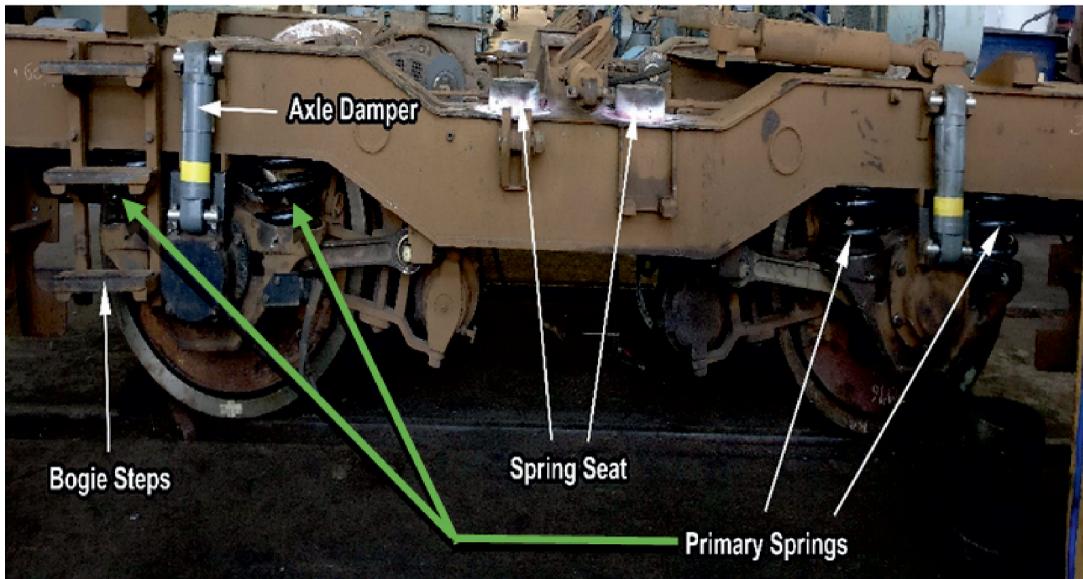


Fig 37 : Bogie assembly showing primary suspension

Primary Suspension comprises of twin coil spring and a hydraulic damper on each axle box. All springs vary slightly due to the manufacturing process. In smaller springs this difference is generally negligible, but on larger springs such as used on the WAP5 suspension, small variations can have a marked impact on performance. WAP-5 locomotive springs are manufactured to exacting standards, but variations between batches do occur. Springs are marked with one or two aluminium bands (1) during manufacture to identify the spring's tolerance range. Group one springs have one band, while group two springs have two bands. All springs on the bogie must be within the same tolerance range.

During use, springs soften slightly, giving a reduced spring height. The variations that occur in spring production and softening over time is offset by compensating plates (shims). These plates are available in 1, 2, 3 and 4 mm thicknesses. The compensating plates are positioned between the spring and insulating base.

The wheel and axle load is determined by the suspension system. Incorrect packing of either the primary or secondary suspension springs results in improper wheel loads. Incorrect loads increase wheel wear and reduce ride quality.

Correct adjustment of the wheel and axle loads is critical to the longevity of the wheels.

Longitudinal control of the axle and transfer of longitudinal forces is done by Guide Rods connected between axle box and bogie frame. Flexi-coil action of primary springs permits lateral movement to axle with respect to bogie frame. The system is similar to WAG9 locomotive.

Table 11A : Details of flexi coil primary springs

Parameter	Value
Material	51 CrMoV4
Bar Dia	37 mm
Active coils	2.5
Total coils	4
Weight	20 kg
Mean spring diameter	212 mm
Free height (max.)	231.0 mm (group-1)
Free height (min.)	228.2 mm (group-2)
Nominal Loaded height	175 mm



Fig 38 : Spring deflection testing machine

Table 11B: Primary spring height at specified loading

Spring (min–max) condition	Deflection (mm)	SpringHeight (mm)	Load (kN)
Unloaded	0	228.2–231.0	0
Static load	53.2	175.0–177.8	41.1
Load at stop	83.2	145.0–147.8	64.3
Load at solid length	95.0	133.2–136.0	73.4

Bump Stop Clearances at Primary Stage

The running clearance between the Bump stops at primary stage of all axles is measured to ensure serviceability of components and their proper assembly. Any deformity in frame, axle box or spring will affect bump stop clearance. Even if the readings are within serviceable limits, major difference on same axle may cause unequal distribution of loads and cause unfavourable condition on high speeds. Fig. 39 indicates the places where these clearances are to be checked and paragraph below shows the limits

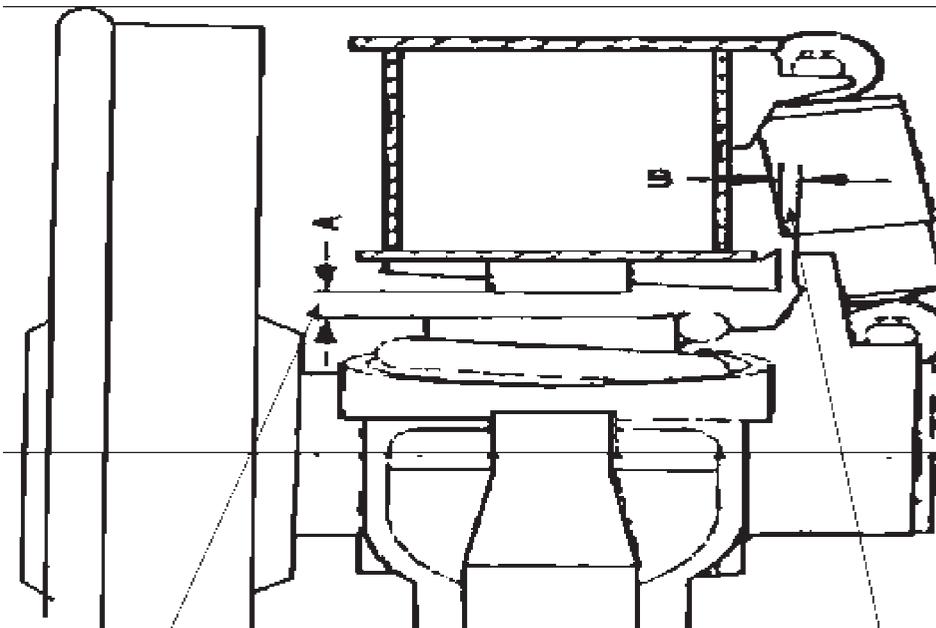


Fig 39 : Checking of Primary Bump stop clearance

For limits of Vertical Bump stop clearance 'A' Lateral Bump stop clearance 'B' see table 12.

Vertical and lateral movement between wheel set and bogie frame are limited by vertical and lateral bump stop clearances

Table 12 : Bump Stop Clearances at primary stage

Type of clearance	Limits
Vertical Bump stop clearance 'A'	27 to 35 mm
Lateral Bump stop clearance 'B'	15 to 20 mm

Table 13: Items to be checked:

Item	To be checked for	How to check	Repercussion
Spring	Damage, cracks and breakage	Visually,	Improper loading on axle boxes, Ineffective equalising, offloading on track cross level difference
	Permanent set	Change in bump stop clearance, Testing of spring for free height	
	Load deflection characteristics	Testing as per specification	
Rubber disc & bump stop for primary suspension	Damage, cracks and breakage	Visually,	Excessive vertical movement, offloading.
Spring	Paint colour, bands	Visually, match with the group colour	Improper loading on axle boxes, Not suitable, chance of offloading



6. Secondary Suspension

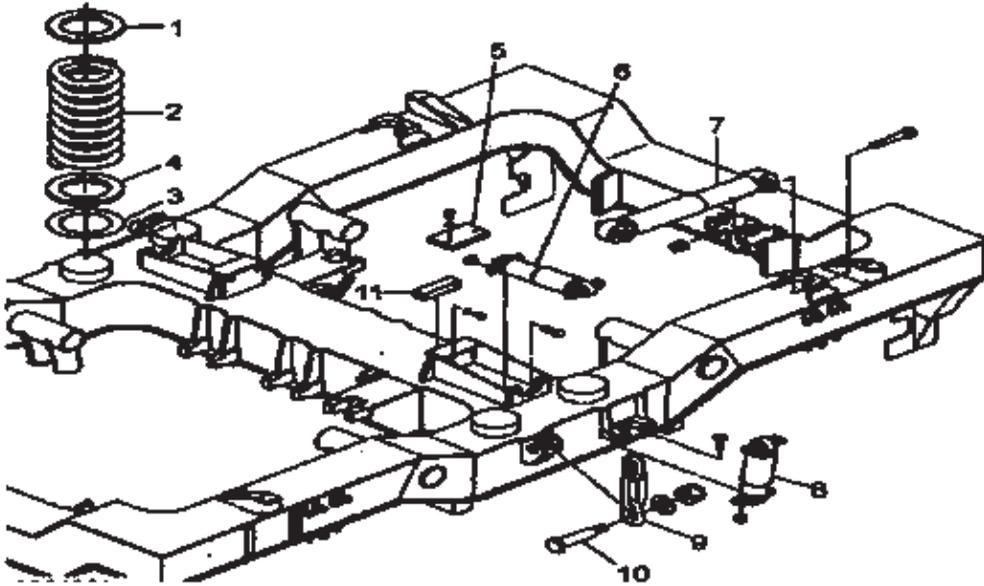


Fig 40 : Secondary suspension component details

Table14: Secondary suspension component names

SN	Name of the part	SN	Name of the part
1	Insulating base stop	2	Coil spring
3	Compensating plate	4	Insulating base bottom
5	Vertical bump stop	6	Lateral hydraulic damper
7	Yaw hydraulic damper	8	Vertical hydraulic damper
9	Safety chain	10	Pin
11	Lateral bump stop		

The primary and Secondary Suspension absorb and isolate shock loads, due to track deformities and other variations. The Secondary Suspension consists of coils prings and vertical, lateral and yaw dampers located between the bogie

frame and the locomotive underframe on each side of the bogie. The springs support the weight of the locomotive car body and allow free movement between the car body and the bogie. This flexi Float arrangement of the Secondary suspension arrangement allows the locomotive car body to move both laterally and vertically within certain limits relative to the bogies.

Although the springs allow movement in any direction, lateral buffers and dampers limit the amount and rate of the lateral movement. Rebound limit chains and vertical dampers limit the amount and rate of the vertical rebound of the locomotive car body. Longitudinal (Yaw) dampers are provided to dampen the rate of the pitch of the car body. Traction links connected between the bogie and locomotive underframe, control the fore and aft movement between the bogies and the locomotive and transmit tractive and braking effort from the bogie to the locomotive.

Insulating bases and compensating plates are installed between each spring and the bogie frame. Compensating plates may be added or subtracted to establish the correct axle load levels.



Fig 41 : Secondary springs

Table 15: Technical data of secondary suspension springs

Material	51 CrMoV4
Bar Dia	44 mm
Active coils	7.5
Total coils	9
Weight	78 kg
Mean spring diameter	245 mm
Free height (max.)	669.5 mm (group-1)
Free height (max.)	664.5 mm (group-2)
Loaded height	480 mm

Table 16: Secondary spring height at specified loading

Spring condition	Deflection (mm)	Spring Height (mm)	Load (kN)
Unloaded (nominal)	0	664.5	0
Static load Group1* (min-max)	184.5	480-490	61.5
Static load Group2* (min-max)	184.5	470-480	61.5
Load at stop (nominal)	219.5	445	73.2
Load at solid length	286.1	378.4	95.4

*Group1—one band, Group 2 – two band

Bump Stop Clearances at Secondary Stage

The running clearance between the Bump stops at Secondary stage of all four sides is measured to ensure serviceability of components and their proper assembly. Any deformity in Locomotive carbody, Bogie frame, or secondary springs will affect bump stop clearance. Even if the readings are within serviceable limits, major difference on same Bogie may cause unequal distribution of loads and

cause unfavourable condition on high speeds. Fig. 42 indicates the places where these clearances are to be checked and paragraph below shows the limits

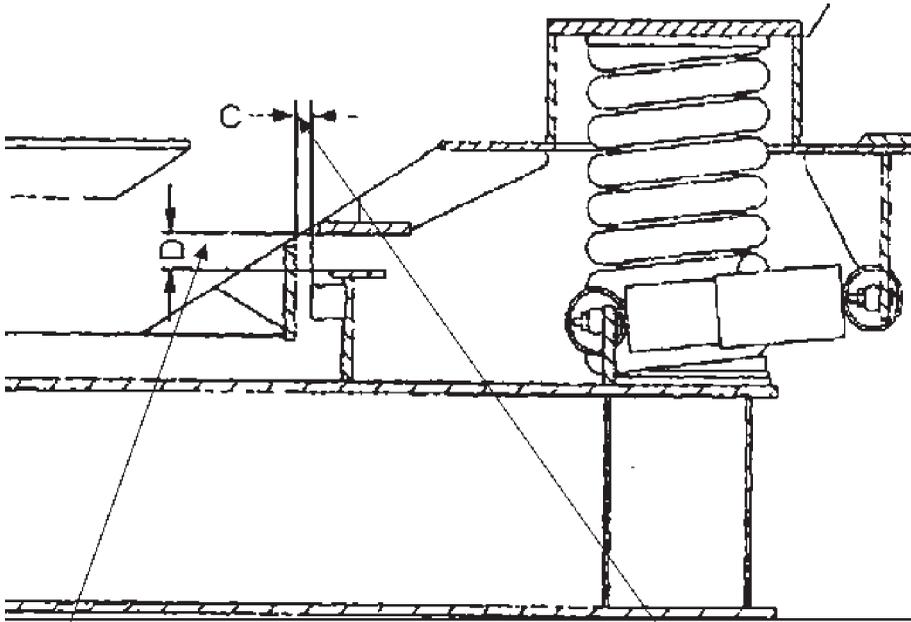


Fig 42 : Checking of secondary bump stop clearance

Fig 42 shows vertical bump stop clearance 'D' and lateral bump stop clearance 'C'

Vertical and lateral movement between locomotive body and bogie frame are limited by buffer and chain arrangement.

Table 17: Secondary bump stop clearance

Type of clearance	Limits
Vertical bump stop clearance 'D'	30 to 40 mm
Lateral bump stop clearance 'C'	20 to 40 mm

Table 18 :Items to be checked:

Item	To be checked for	How to check	Repercussion
Steel Coil Spring	Damage, cracks or breakage	Visually	Improper loading, Ineffective equalising, offloading on track cross level difference, Ineffective suspension effect, poor riding quality
	Permanent set	Change in bump stop clearance, Testing of spring for free height	
	Load deflection characteristics	Testing as per specification on testing machine	
Compensating plate	Thickness	Visually	
Insulating plate	Thickness	Visually	
Safety chain	Crack, damage or breakage	Visually	
Lateral Bump stop Pad		Visually	
Vertical Bump stop Pad		Visually	



7. Hydraulic Dampers

In hydraulic damping system, the resistance of the liquid flowing through valves and restrictions generates the damping force. The damper has a double function: damping force is generated for both inward and outward movement. In nearly all cases, the bump and rebound forces are basically equal. In other words Symmetrical.



Fig 43 : Hydraulic damper used to damp all vibrations

- i. Primary Vertical Dampers-** These dampers control the vertical movements between axle box and bogie frame, in particular the motion of bogie bouncing on the axle boxes and more important, pitching of the bogie frame in relation to the axles. The later is induced by irregularities in the track, rail joints and crossing. This causes the one end of the bogie frame to move down while the other moves upwards. Unless this motion is controlled, it can result in a serious wheel unloading with danger of derailment.
- ii. Secondary Vertical Dampers** - These dampers Control the vertical movements between car body and bogie frame, such as pitching. Correct damping is essential in relation to body mass and spring stiffness. Secondary vertical dampers, if widely spaced, will assist secondary springs to control rolling oscillations of the car body.
- iii. Lateral Dampers** - These dampers are used to control lateral movements of the car body. It is essential to ensure correct lateral damping. It is very important to carefully select the lateral damper rates in relation to the vertical and lateral suspension stiffnesses.
- iv. Yaw Dampers** - Yaw dampers are special dampers designed to control small amplitude sinusoidal rotation movements. Without this damping the rotation of the bogie around the centre pivot of the bogie may become excessive. These hunting movements result in discomfort for the passengers and in case of high-speed trains in risk of derailment. Yaw dampers are usually positioned longitudinally to control rotation of the bogie without influencing lateral damping. The damping rate must be carefully chosen. Excessive damping would result in too much resistance to bogie rotation with consequential risk of derailment, excessive wheel wear

During the day today working of locomotives, hydraulic dampers need to be checked for achieving desired performance from them. Visual observation and possible causes are shown below-

Dirt



Normal contamination caused by the operating environment of the dampers is harmless.

If a damper has a damp film over the whole body (including the dust cover), it is very probable that this is the result of an outside source of oil or dirt. In this case the damper can remain in service.

Fig 44 : Damper attracts dust when has a damp film

Sweating



For a long service life, it is necessary for the rod oil seal to remain lubricated. The continuous inward and outward movement of the piston rod may cause oil “sweat” from the rod oil seal.

This loss of oil can be recognized by the outside of the damper being slightly moist and dirty. However, no droplets of oil clinging to the damper.

A slight oil sweating will not affect the damping force and this damper may remain in service.

Fig 45 : Damper sweats due to continuous inward & outward movement

Oil drops



A strong oil leakage becomes apparent by a damp surface, which usually covers a large part of the reservoir tube.

Isolated oil drop formation is possible.

When wiping the absorber with a paper cloth, clear oil stains are visible. Check for crack, leakage may cause ineffective damping

Fig 46 : Damper which starts to leak oil

It is important to visually check the condition of all rubber attachments. **Worn or deteriorated bushings may affect the damper's performance and cause internal damage to the damper.** Bushings should be replaced when the rubber develops a cut or a split. If the bushing has only developed small cracks on the surface of the rubber, no action is necessary.



Fig 47 : Worn bush



Fig 48 : Torn bush

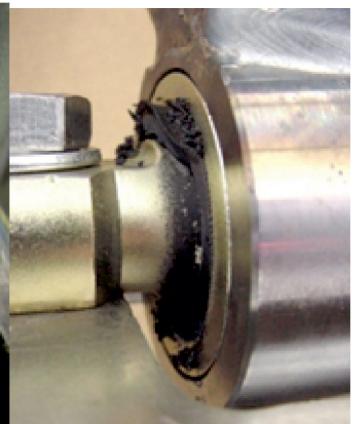


Fig 49 : Shifted bush

If the bushing is deteriorated or the pin is loose in the bushing, the damper must be removed and the bushing replaced.

While inspecting the bushings, it is a good idea to examine any welds between the bushing eye and the damper body. The welds should show no evidence of cracking or deterioration.

Testing machine



Fig 50 : Hydraulic damper testing machine

In principle dampers can be tested on any machine that allows the two fixing points of the dampers to move relative to each other. The forces generated by the damper can be measured mechanically, electronically or hydraulically. A force stroke diagram can be produced by recording the force and the displacement simultaneously. Care is required when adjusting the machine to the movement of the damper in order to prevent serious damage to machine or damper.

The performance graph should be made on the testing machine after the damper

has made 5 numbers of revolutions in order to prevent interference of adhesion of seals.

Diagram analysis

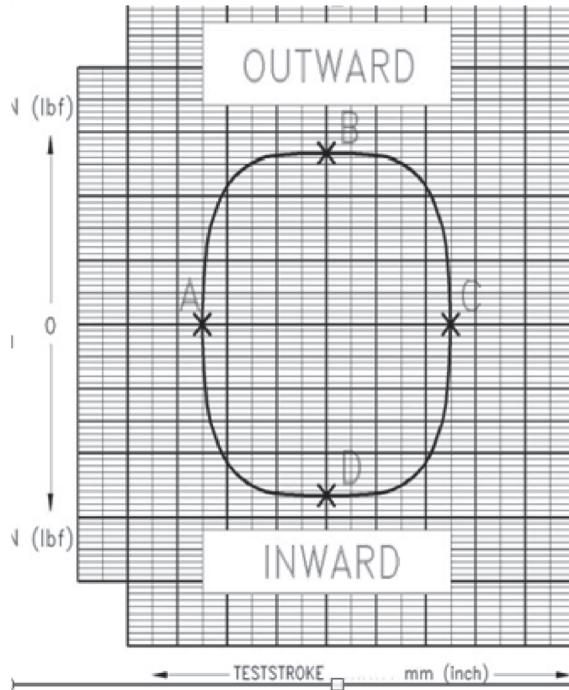


Fig 51 : Force stroke diagram

The testing machine produces a force-stroke diagram (clockwise) (Figure 51). The displacement is written on the horizontal axis of the diagram, while at the same time the damping force is registered along the vertical axis. The outward damping forces can be found above the zero level, the inward damping forces below. Point A in the diagram is the starting point of the outward movement.

At point B the piston of Hyd. Damper reached its maximum speed: here the outward damping force must be measured. Then the outward speed decreases again to zero at point C. Here the inward movement starts so that at point D the maximum inward speed is reached.

Table 19 :Items to be checked:

Item	To be checked for	How to check	Repercussion
Dampers	Deformations, damage, cracks and oil leaks, Aging	Visually, Testing during Schedule I & II, Replacement during Shop Sch. III (6 years)-mandatory	Weak, Ineffective damping, Large and persistent vibrations.
Fixings/ fasteners & rubber elements	Loose, Missing , Cracks, ageing, Detachments	Visually	Excessive play, damping will be ineffective.



8. Transfer of Tractive Effort

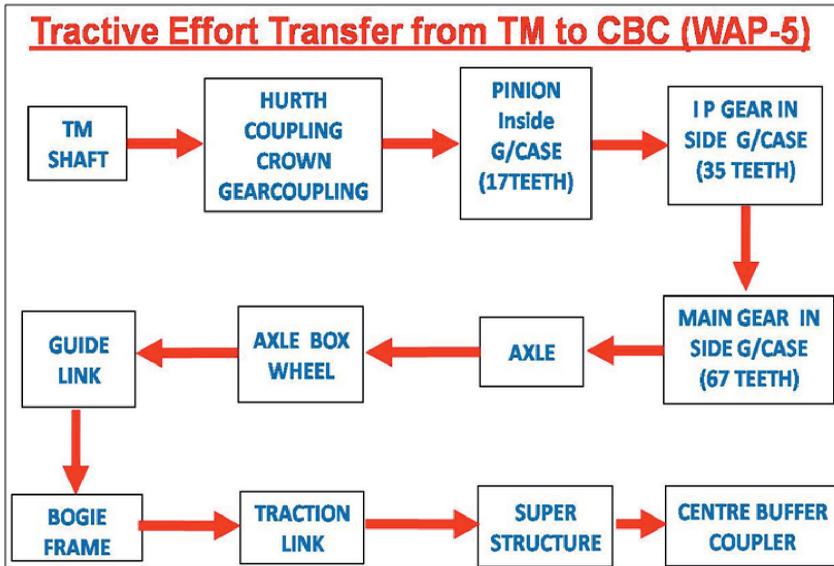


Fig 52 : Tractive effort transfer from traction motor to CBC

i. Traction motor and Hurth coupling crown gear coupling

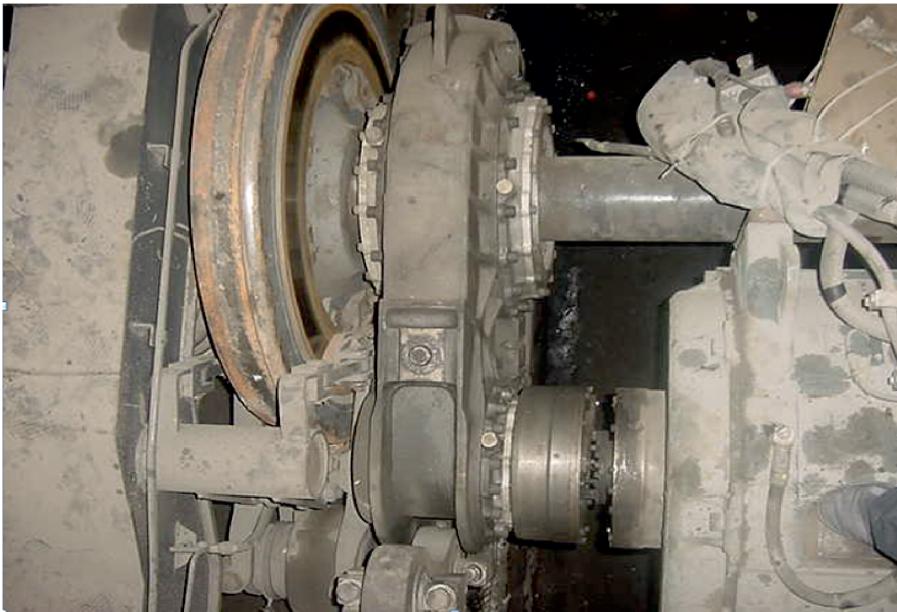


Fig 53 : Gear case & Hurth coupling arrangement

ii. Axle box & frame guide link

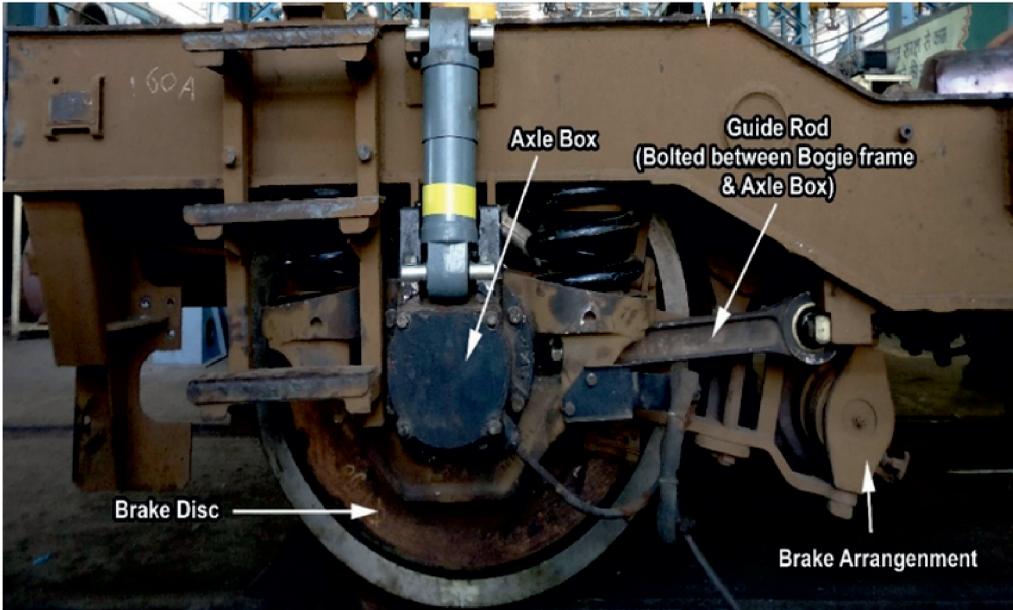


Fig 54 : Front view of bogie frame showing axle box & guide rod

iii. Guide rod

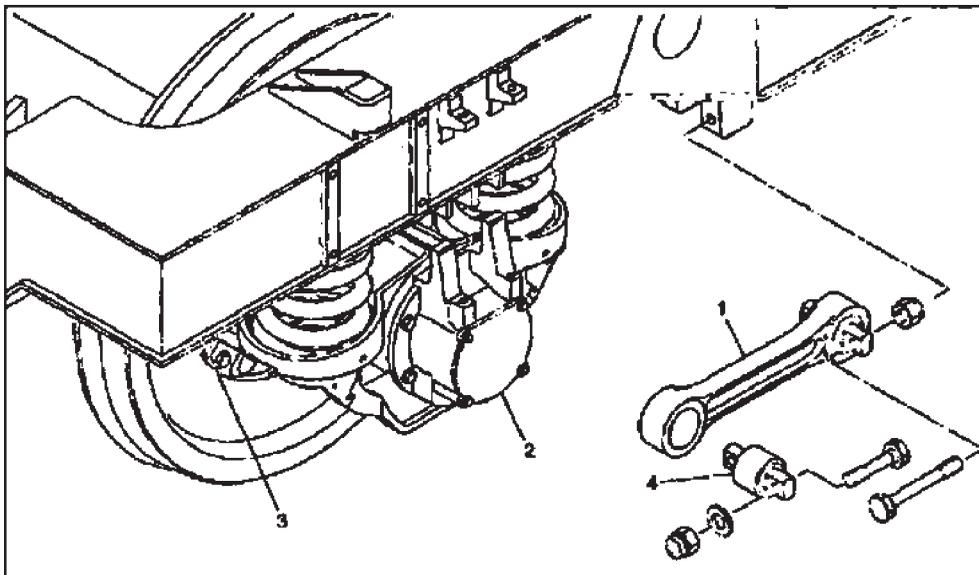
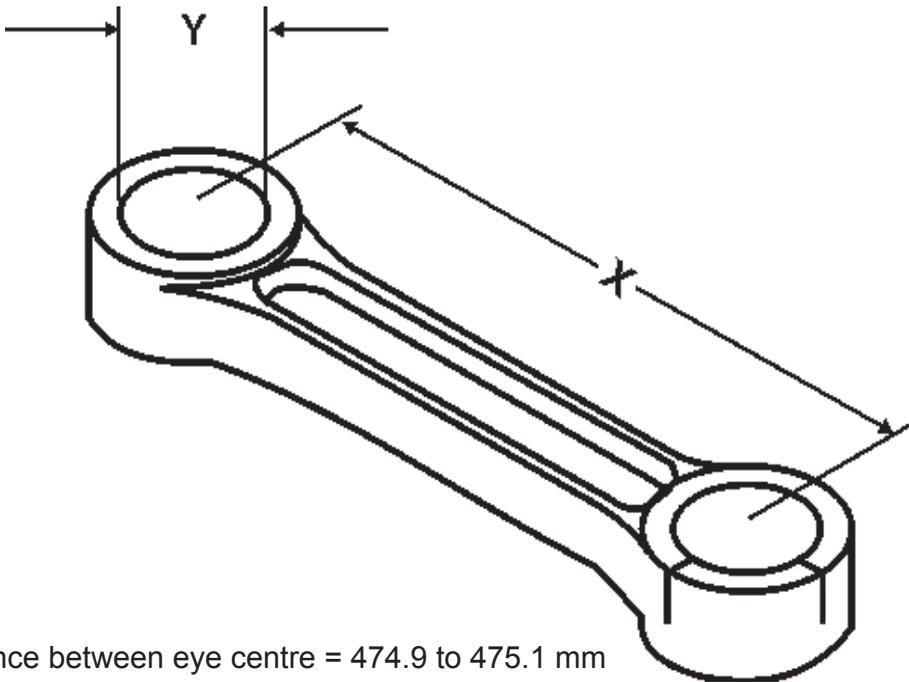


Fig 55 : Exploded view of guide rod, spheribloc & fasteners

The guide rod(1), bolted between the axle box(2) housing and bogie frame(3), provides a longitudinal guide for the axle box(2) and therefore axle.



Distance between eye centre = 474.9 to 475.1 mm
eye inside diameter = 90.000 - 90.046 mm

Fig 56 : Guide rod

Tractive and braking effort is transmitted through the guide rods (1) to the bogie frame (3). There are four guide rods (1) on each bogie. The guide rod is fitted with spherical rubber joints, Spheriblocs(4) at each end which provide positive longitudinal guidance while allowing some lateral movement. Lateral limit stops on the axle box front covers prevent excessive lateral movement of the axle.



Fig 57 : Photo of Guide rod with spheriblocs

The Spheriblocs in the axle guide rods are critical to maintaining wheel alignment. No damage or wear such as crack on periphery(1), wear/permanent set on radial part(2), peel off rubber pieces from front side(3) is permissible on either the metal or the rubber parts. Fig : 58 shows Unserviceable spheriblocs. Where one defect of spheribloc on bogie is deemed unfit for service, it is good engineering practice to thoroughly inspect all Spheriblocs on the bogie.

iv. Traction link

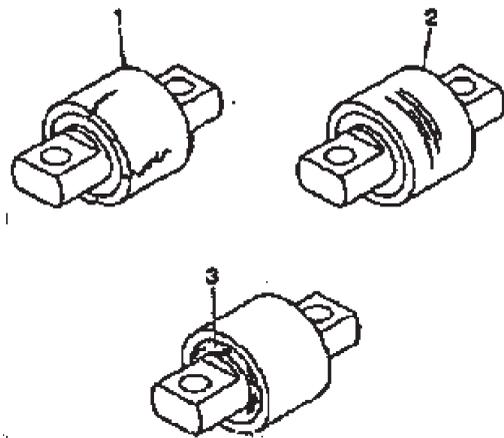


Fig 58 : Unserviceable spheriblocs

The traction link transmits traction and braking forces from the bogie to the locomotive superstructure(underframe). Although the traction link maintains the relative longitudinal position of the bogie to the locomotive underframe, it permits lateral movement between the two structures. The link rod is situated between two pivot points, one on the locomotive underframe, the other on the end transom of the bogie, permitting lateral movement but restraining longitudinal movement. Under normal conditions the rod is inclined at a 1:10 slope towards the centre of the loco underframe.

The rod is symmetrical end to end and the pivot heads are identical and interchangeable between the bogie and underframe.



Fig 59 : Traction link connection at loco pivot point.



Fig 60 : Locomotive Pivot points for connections of both bogie traction links.

Table 20 :Items to be checked:

Item	To be checked for	How to check	Repercussion
Hurth coupling	All fasteners, support bolts & rubber bushes, Oil leakage	Visually	will affect transmission of tractive force, safe movement of locomotive
Guide rods	Condition of spheriblocs, condition of fasteners at both ends	Visually, DPT	
Traction Links	Welding condition in bogie & loco chasis, Condition of ring in pivot head	Visually, DPT	



9. Draft Gears

CBC is a combined unit of Draw and Buffing Gear, located at the centre of Body Head Stock which

- i. Transmits both draft & buffing load between vehicles and to/ from under-frame
- ii. Absorb high frequency forces during impact
- iii. Multi functional units - Draft+Buffing



Fig: 61

Main parts of CBC

1.	Coupler body, Knuckle, Lock	5.	Striker casting
2.	Knuckle thrower	6.	Draft Gear
3.	Lock lifter assly	7.	Uncoupling device
4.	Yoke, Yoke pin, Yoke pin support	8.	Back stop.

Train parting can also lead unsafe running condition including derailment.

Train parting takes place in train due to following defects (see table 21) out of improper maintenance of rolling stock.

Table 21 :Items to be checked:

Item	To be checked for	How to check	Repercussion
CBC	Excessive wear of knuckle nose	Play on closing	Chances of CBC opening on run & train parting will increase, Drooping of CBC due to wear of bottom liner will cause hindrance in free movement & can cause problem in curve negotiation
	Excessive CBC drooping.	Visually	
	Cracks on Coupler Body.	Visually	
	Cracked knuckle, Improper/ Partial locking of knuckles	Visually	
	Dropping of Yoke pin support plate.	Visually	
	Deficiency of lock lifting components	Visually	
	Breakage/ Perished rubber pads in draft gear.	Yoke pin support plate will bend	

Yoke Draft gear

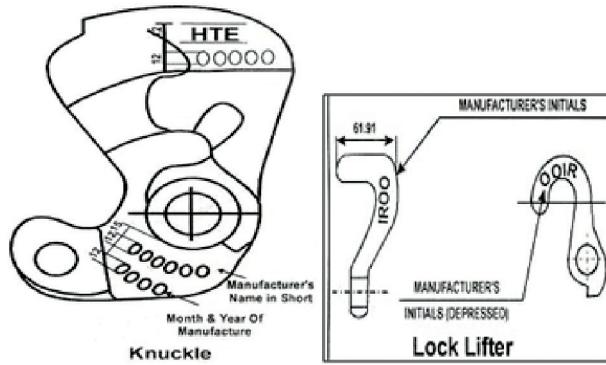
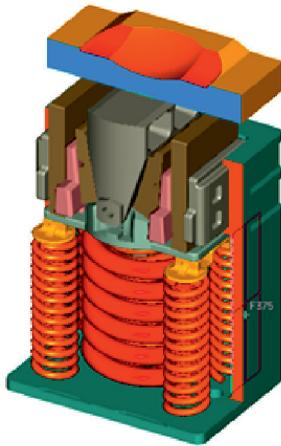


Fig 62 : Components of CBC



10. Buffing Gear

Two numbers of buffers are provided on body head stock to absorb the longitudinal impacts occurred during run on both ends, at a distance of 1956 mm. The role of buffers is also to transmit push impact to its trailing end stock. The main components of Buffing Gear are as under:-

1.	Buffer Plunger	6.	Recoil rubber Washer
2.	Buffer Socket with securing bolt	7.	Washer
3.	Buffer Spindle & Plug	8.	Nut
4.	Buffing Pad	9.	Cotter
5.	Destruction Tube		

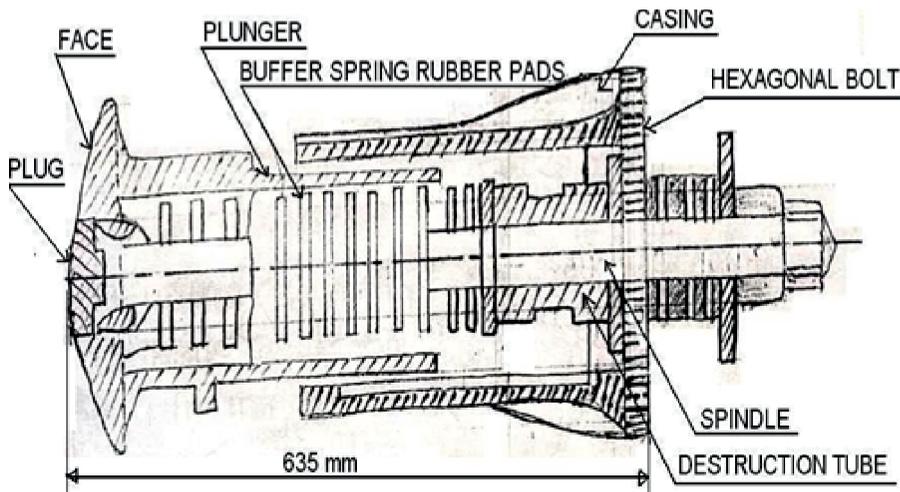


Fig 63: Buffer sectional view

Mainly Buffers are of two types:-

Long Case Buffer – Length from head stock – 635 mm

Short Case Buffer – Length from head stock – 458 mm

Other Parameter of Buffing Gear (Table - 22)

Max. Height	1105 mm
Min. Height	1030 mm
Allowed variation in height at same end	64 mm
Allowed variation with adjacent vehicle	75 mm
Max. Plunger Travel	127 mm
Min. Plunger Travel	51 mm
Number of Buffing Pads in each Buffer	14 to 16 Nos.
Capacity of Buffing Pads	1030 kgm (New Type)



Fig 64 : New type of buffer



11. Common Defects

Table 23 : Items to be checked, Conditions to be recorded:

Item	To be checked for	How to check	Repercussion
Frame	<ol style="list-style-type: none"> 1. Crack, 2. Missing of any component which can fall on track, 3. Uncoupling of fasteners holding any major components such as T/Motor, Drive coupling support, Guide rod & Traction link , Hydraulic dampers, 4. Condition of Bump stop items and Bump Stop clearances. 	<p>- Visually</p> <p>- Visually</p> <p>- Visually</p> <p>Visually & Feeler gauge & Vernier caliper</p>	<p>Any of these defects can lead to unsafe working conditions hence. After finding out, they have to be co related.</p>
Wheels	<ol style="list-style-type: none"> 1. Wear on profile 2. Any symptom of Axle bearing seizure 3. Other wheel defects than normal wear listed In wheel chapter 	<p>Profile gauge to RDSO Drg No.SKDL -4446 & 4447.</p> <p>Visually</p> <p>Visually</p>	
Springs	<ol style="list-style-type: none"> 1. Breakage of any spring from primary or secondary suspension, 2. Twisting of any spring/damage to compensating plate, 3. Fitment of mismatch group spring 4. (a) Condition of Suspension springs i.e. Normal/ Broken, Fresh/ Old Fracture or deformities occurred after derailment due to sudden impact. <p>(b) Deflected height of coil Spring after rereiling on Level, Uncanted Track.</p>	<p>Visually</p> <p>Visually</p> <p>Visually</p> <p>Visually</p> <p>Scale</p>	
Hydraulic dampers	<p>Condition to be recorded for :</p> <ol style="list-style-type: none"> 1. Oil leakage, 2. External damage, 3. On run working history from LP's log book 	<p>Visually</p> <p>Visually</p> <p>Reading</p>	

Item	To be checked for	How to check	Repercussion
Guide rod / Traction Rod	<ol style="list-style-type: none"> 1. Any physical damage, 2. Condition of Spheriblocs 	<ul style="list-style-type: none"> - Visually - Visually 	
Traction links including Connections	<ol style="list-style-type: none"> 1. If caused train parting, then check for all department factors, 2. Obstructed free movement due to wear of front box bottom liner 	<ul style="list-style-type: none"> - Visually - Visually 	
CBC	<ol style="list-style-type: none"> 1. If caused train parting, then check for all department factors, 2. Obstructed free movement due to wear of front box bottom liner 	<p>As mentioned in item 12</p> <p>Visually</p>	
Buffer	<ol style="list-style-type: none"> 1. Any physical damage, 2. Any of the buffer going dead/inactive causing unequal buffing forces, 3. Buffer height to check to confirm whether buffers are defective or defect in wheel, suspension system etc. 4. Measure buffer length to check possibility of buffer entanglement. 	<p>Visually</p> <p>Visually</p> <p>By buffer height gauge</p> <p>By Measuring Scale</p>	
Loco Body Underframe	<ol style="list-style-type: none"> 1. Condition of Lateral Stop components between Bogie and Loco Body Underframe. 2. Measure Secondary Bump Stop Clearances. 	<p>Visually</p> <p>Feeler gauge & Vernier caliper</p>	



12. Clearances

Loco	New wheel diameter	Wear limits		Axle Box Clearances				Difference in Wheel diameter			
		Root	Flange	Tread	Measurement	New condition		Location	Diff. in Dia.		
						Min	Max.			Service limit	
					Report No. MT-60 September 96 & drawing no.1 A011-00140 Sheet2				No.SD.WA1dt.01.09.02		
WAP5 (+5/-0)	1092	4	2.5	6.5	Vertical Clearance between Axle Box & Bogie Frame	27	35	--	Same axle	0.5	2.5
					Lateral Clearance between Axle Box & Bogie Frame	15	20	--	Same Bogie	2.0	4.0
					Vertical Clearance between Bogie Frame & Under Frame	30	40	--	Same Loco	15.0	20.0
					Lateral Clearance between Bogie Frame & Under frame	20	40	--			

13. References

1. Indian Railways WAP5 Maintenance & Repair Manual
2. CAMTECH /GWL's Pamphlet on Important Bogie clearances on Electric Locomotives(CAMTECH/E/2012-13/Bogie Clearances May 2012,
3. Product catalogue of Koni Dampers

