Corrosion Repairs in C&W

Introductory topics

- Corrosion Prone areas in ICF Coaches & BOXN Wagons
- Factors affecting Corrosion
- Preventive actions

Basic Objectives

- Corrective measure i.e. Corrosion Repairs
  - Inspection
  - Corrosion diagram in rolling stocks
  - Repair procedures
    - Cutting by oxygen & combustible gas flames/Electric Arc & air plasma
    - Surface/Edge preparation
    - Welding/fabrication {Coated arc/Bare electrodes}
    - Finishing/surface grinding
  - Corrosion Repair shop management
  - Wagon body rehabilitation / BOXNR conversion

Corrosion Repairs in Rolling Stocks : {C&W} – Sequences.

- Inspection of carriage & wagon for corrosion {diagrams} ?
- Whether it is excessive ? Refer RDSO pamphlets !
  - If yes for corrective action {corrosion repairs} in the affected stock
    - then gas/plasma arc cut corroded sections & dress the kerfs !
    - next renew/refit new properly surface treated sections by arc welding with edge preparations if reqd. !
    - finishing fabrications/welded joints by angular grinding !
  - Else
    - scrap the rust & repaint !
    - again think of preventive action wherever possible !

Galvanic Corrosion cells : ICF coaches -

- Concentration cells

  Solebar, Trough floors, Turnunders & body pillars in vulnerable regions, roof ventilators & water wriggles
- Stress cells

  Headstocks & Trough floors {in other non vulnerable regions} where there is cold press bending sans any heat treatment / non stress relieved weldings
- Dissimilar material contact cells

  MS Crossbars supporting SS Trough floors & MS lavatory U channels {2mm thick} supporting SS lavatory inlays

Coaching Corrosion Repair pamphlets & technical guidelines -

- For ICF BG coach

  RDSO pamphlet C 7602 Rev. 01, Dec.1992
- For BEML BG coach

  RDSO pamphlet C 75003
- Technical instructions of ICF MG coach Corrosion repairs : RDSO CMI K-302
- Corrosion repair procedures of Carriage Headstock assemblies issued by RDSO dtd. 21/12/2010

ICF & BEML coach corrosions : a very brief history -

Before 1977 in ICF & BEML coaches

1. No window sealing in non AC coaches
2. 5 mm thick Turn Under with drain holes
3. 1st corrosion repair in coaches is 6 yr.s following mfg.

After 1977 in ICF & BEML coaches

1. Window sealing in non AC coaches
2. 2 mm thick lower body wall sheet
3. 1st corrosion repairs in ICF & BEML coaches are 9 yr.s & 7 yr.s following mfg.

ICF coach underframe modifications

- In 1974, solebar stiffening by 6mm/3.15 mm thick boxing was done in ICF BG coaches from the inner headstock end to body bolster end following RDSO Sketch nos. 75080, 76011 + 76012 to prevent the lavatory region solebars from corrosion
- But the boxings stored electrolytic lavatory seepage water thereby getting corroded

ICF coach underframe modifications

- In 1989, MgOCl {Decolite} flooring in coaches is replaced by 2mm thick light waterproof PVC sheets preventing water soaking & further seepage in underframe
- This saved tare weight & further prevented corrosion in the modified carriages

ICF coach underframe modifications

- 19 mm diameter zigzag drain holes are provided in the 2 mm thick MS trough floors {these trough floors are designed for absorbing about 70% of buffing loads}
- 217 mm X 127 mm edge chamfered elliptical drain holes are provided in the 5 mm thick turnunders preventing water accumulation in corrosion vulnerable spots

ICF coach underframe modifications

- From 1999 onwards in all new ICF coaches, tubular structures beneath lavatories gave way to 1.7 mm thick AISI 301 Trough floors & the MS trough floor was replaced by SS Trough floor
- 2 mm thick AISI 304 one piece lavatory inlay was also adopted preventing water seepage beneath lavatories

Corrosion inspection : ICF -

- Body Panel cutting upto a height of 450mm/500mm in nonvulnerable/vulnerable locations for Corrosion inspection if suspected
- Trough Floor 300mm X 300mm square area cut for inspection of crossbars if corrosion is suspected

ICF Shell:

S.No.	Major Assemblies	Steels used
1.	Side wall, End wall and Roof structure	IRS M-41 (Corten Steel)
2.	Roof sheet and Trough floor	IRS M-41 (Corten Steel) Austenitic Steel (SS 301) (for 1.7mm Trough floor)
3.	Under frame	IRS M-41 (Corten Steel) IS : 2062 E-250 & IS:1239 Pt.I Tab.3

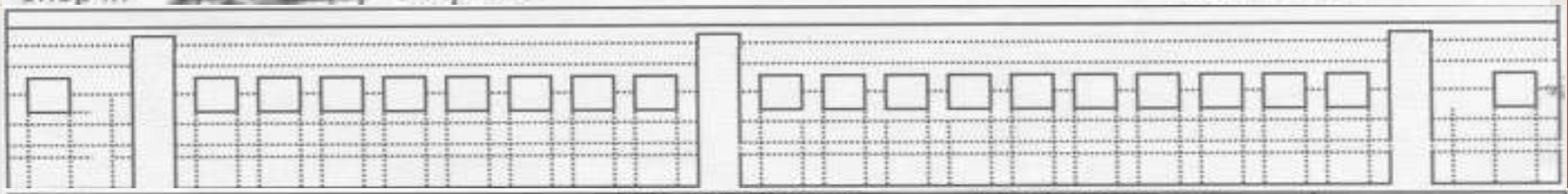
S.No.	ITEM	SPECIFICATION No.
1	***Steel sheets for manufacture of***	
1.1	Trough floor	2mm for IRS: M-41-97 Gr. I, 1.7 mm for Austenitic stainless steel.
1.2	Pillars, sidewall sheet, light rail, waist rail and end wall sheet.	2 mm for IRS: M-41-97 Gr. I
1.3	Carline	2 mm for IRS: M-41-97 Gr. I
1.4	Roof sheet and longitudinal stiffener	1.6 mm for IRS: M-41-97 Gr. I
1.5	Cant rail and Ribs	3.15 mm for IRS: M-41-97 Gr. I
1.6	Other structural members	IRS: M-41-97 Gr. I
2	**Steel plates for manufacture of**	
2.1	Sole bars and turn under	5 mm for IRS: M-41-97 Gr. I
2.2	Cross bearers above and below trough floor, end wall stanchions	4 mm for IRS: M-41-97 Gr. I
2.3	Headstock	5,6,8,12 mm for IRS:M-41-97 Gr.I
2.4	Other structural members like sole bar stiffeners	IRS: M-41-97 Gr. I
3	Tubes for tubular frame below lavatory	IS: 1239-90 Pt. 1, Tab. 3
4	**Non-Structural members**	
4.1	Sheets like skirting plate for reservoirs and floor side moulding	IRS: M-41-97 Gr.1
4.2	Plates	IRS: M-41-97 Gr.1
5	Red Oxide zinc chromate primer paint	IS:2074-92 or IRS: P-31-71
6	Bituminous anti-corrosive paint, solution type brushing quality	IRS: P-29-68
7	Bituminous emulsion paint	IRS: P-30-96, IS:158-81

CHECK LIST FOR JOINT INSPECTION & RECORD OF COACH CORROSION REPAIR

Rly. [redacted] Coach No. [redacted] Code/Type [redacted] Last POH M/Hrs.

POH Shop [redacted] Bay [redacted] Last POH Shop

Shop In [redacted] Shop Out Last POH Dt.



Sl. NO.	Corrosion Repair Items	Qty. as marked above nominated after inspection	Qty.of corrosion repair actually done	Remarks
1	Outer Head Stock			
2	Composite Head Stock			
3	Sole Bar			
4	Sole Bar Sagging			
5	Sole Bar Bend			
6	Cross Bar (under T/ Floor)			
7	Trough Floor			
8	Yoke			
9	Bottom Panel Width of 1.5 Ft.			
10	Bottom Panel Width of 2 Ft			
11	Bottom Panel Width of 3 Ft			
12	Body Bottom Part Pillar			
13	Turn Under			
14	Piller Bkt. Guard			
15	Window Profile			
16	Buffer Tube			
17	Body Bolster			
18	Tubular Pipe			
19	T/ Pipe Cross Bar			
20				

Total M-Hrs.

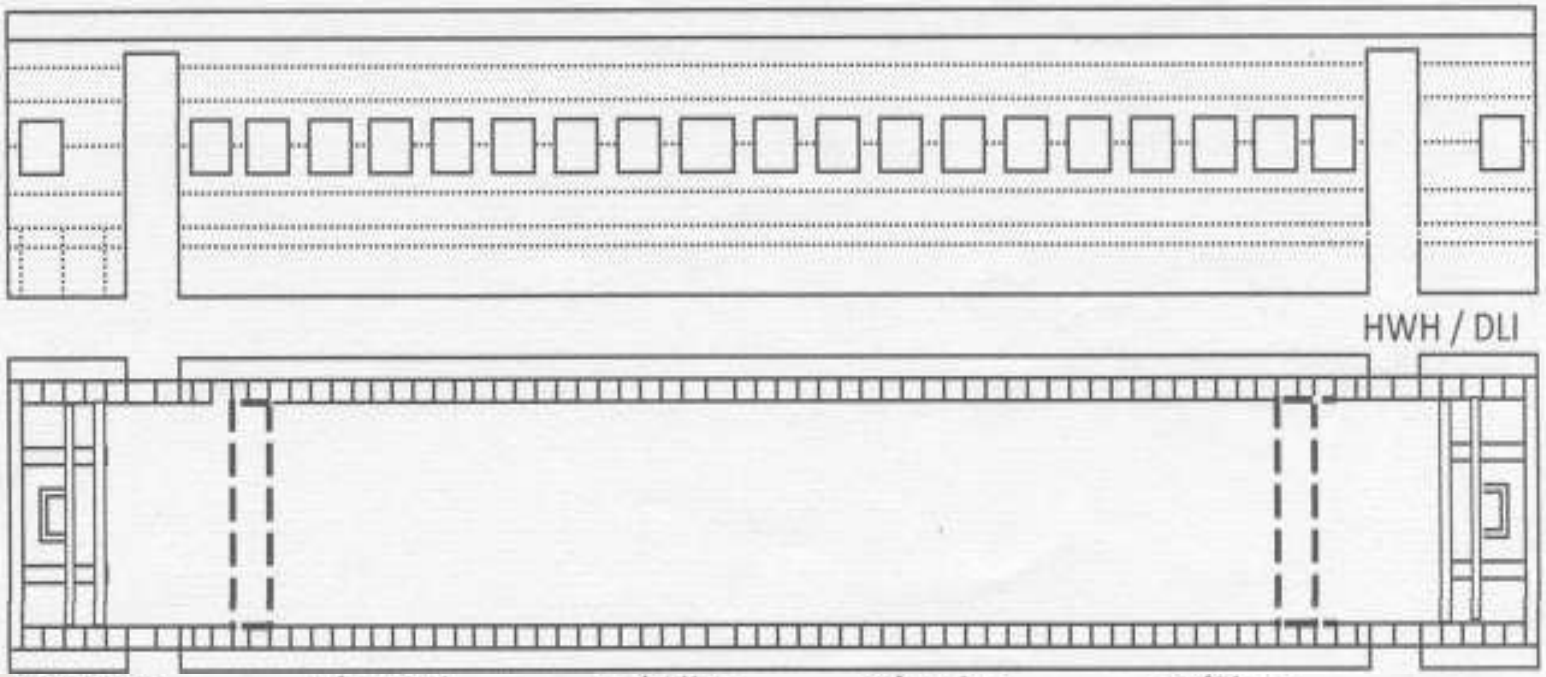
CARRIAGE & WAGON WORKSHOP
EASTERN RAILWAY - LILUAH

INSP / CORR / 07 / 02
(Rev..- 01)

COACH CORROSION REPAIR DIAGRAM

RLY..... Coach no..... Code..... Type..... Shop/ Bay.....

Shop In Dt.....Shop Out Dt..... M-Hrs..... DIVN.....



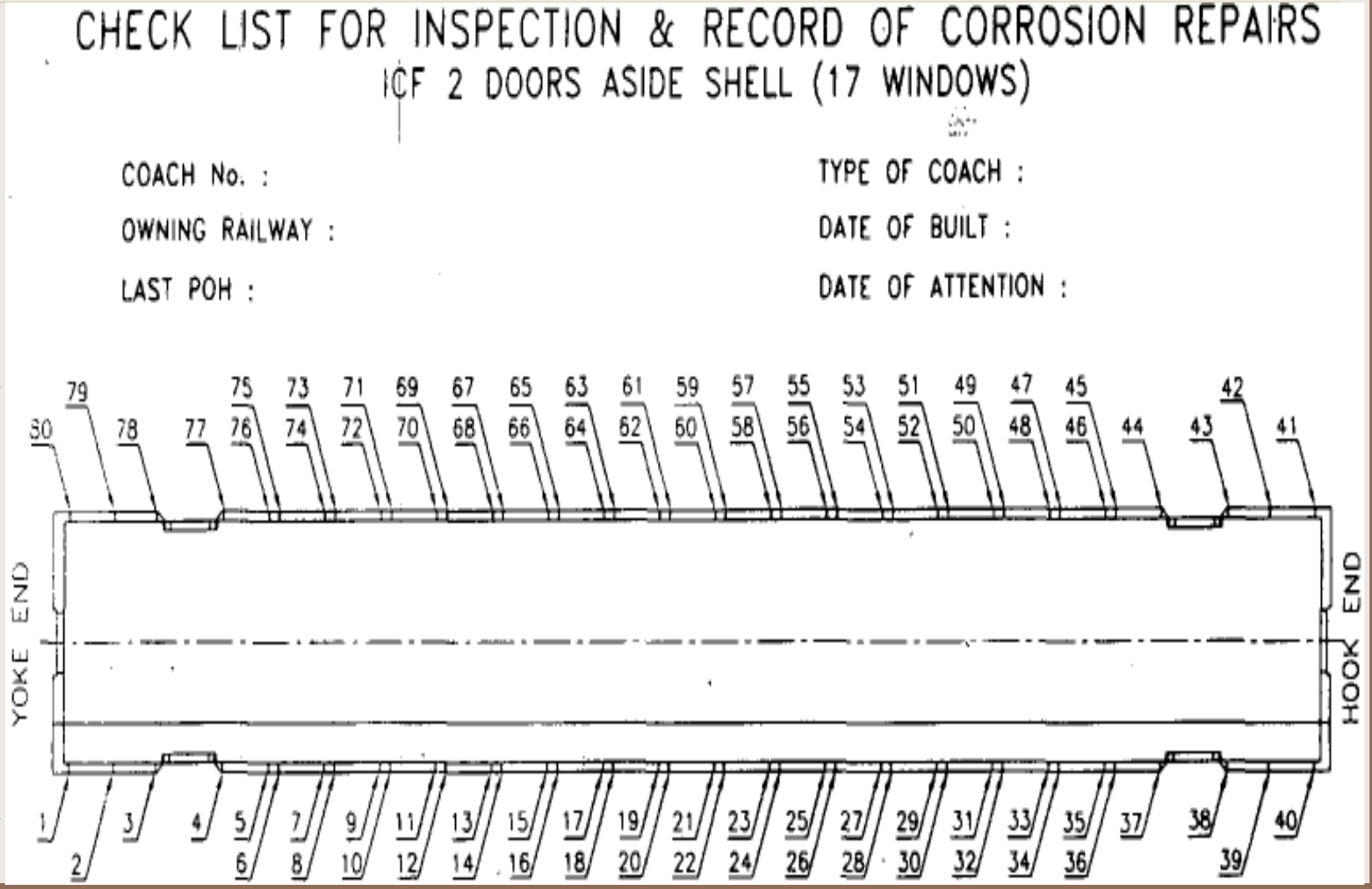
HWH / DLI

Sole bar..... B/ panel.....B /piller..... T/under.....T /Floor.....

S.B. Mod..... Yoke..... B / Tube..... T / Pipe.....

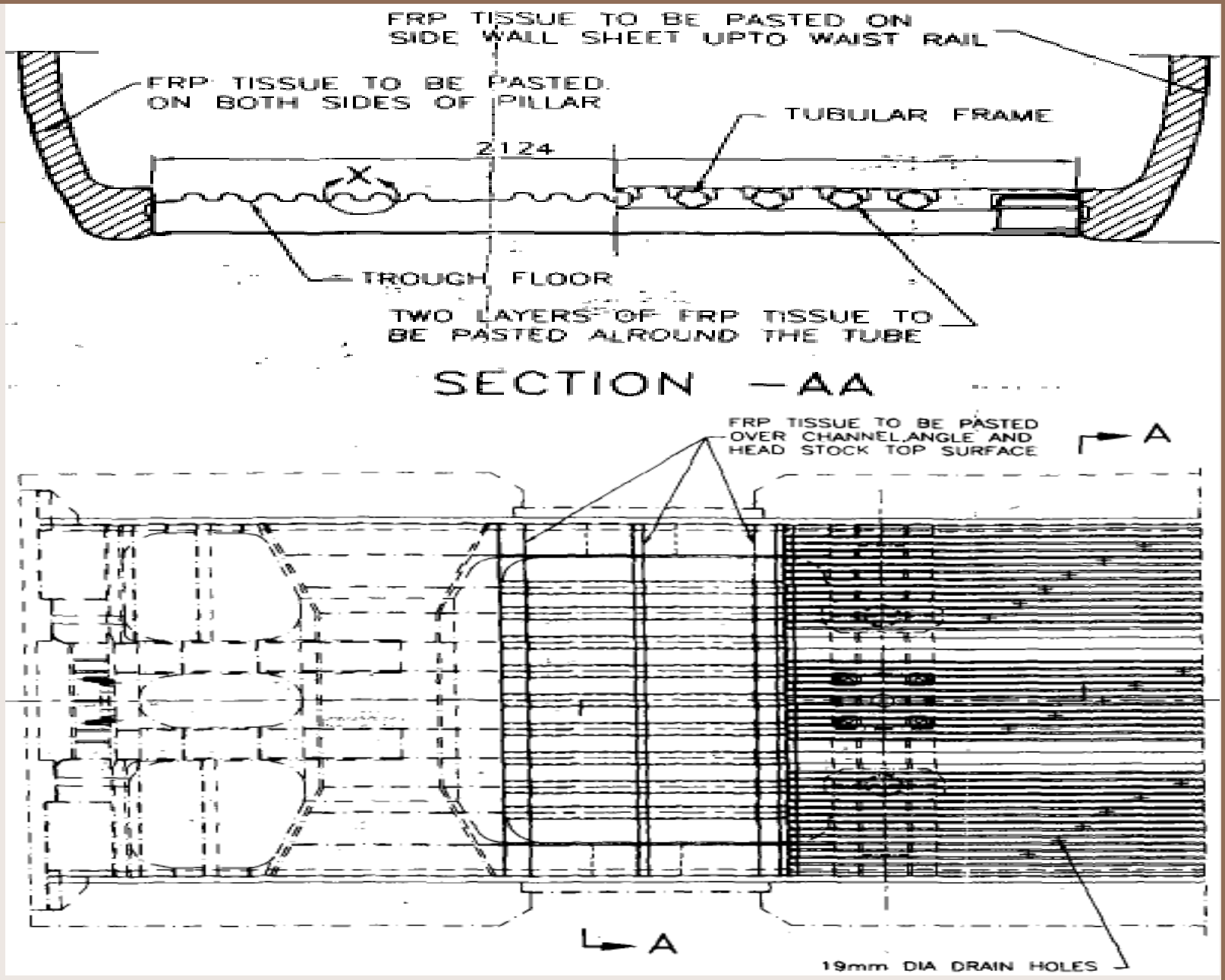
L /Mid Panel.....U /Mid panel.....W / Profile.....(T).....(B)

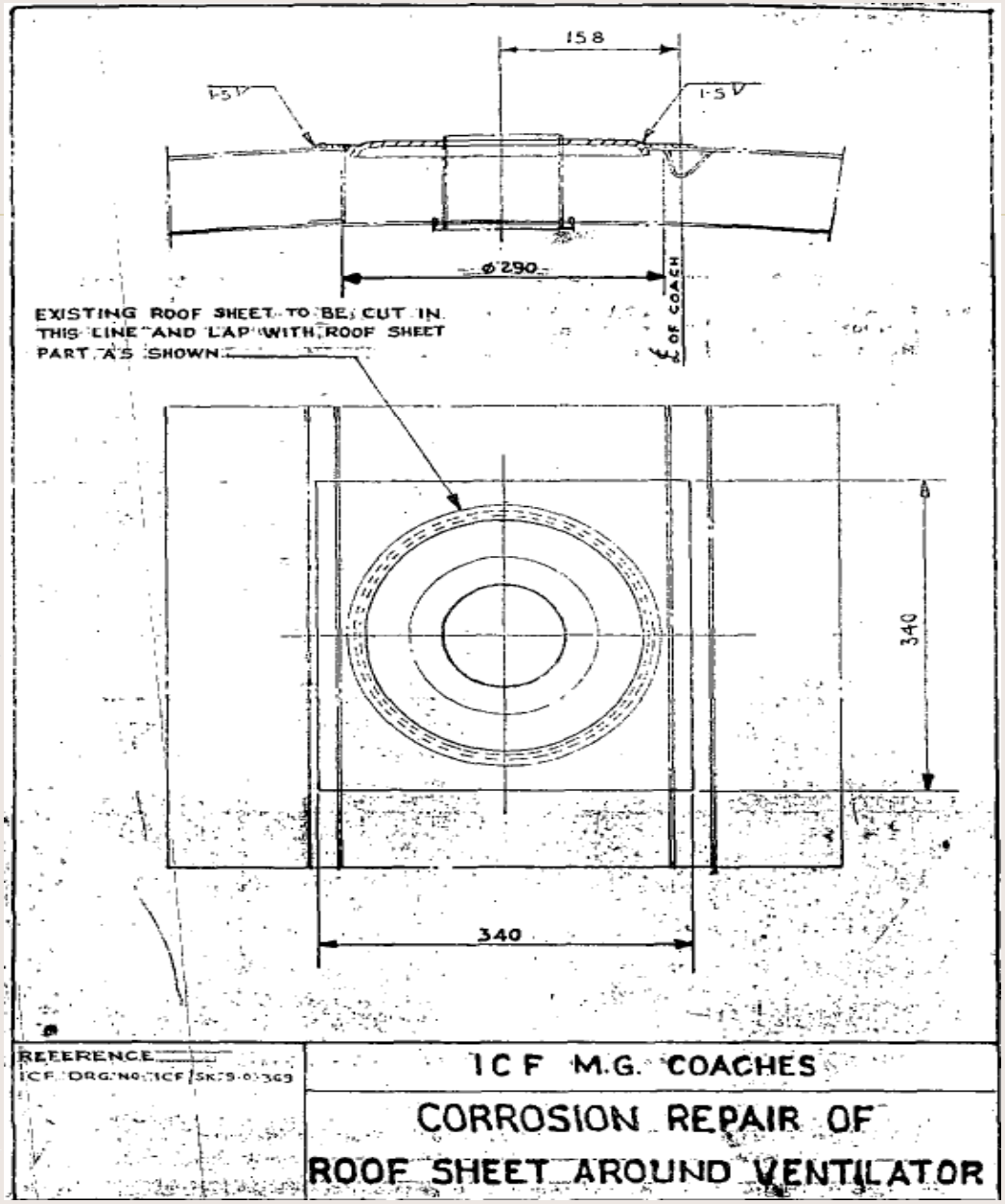
Corrosion Diagram : ICF MG coach Shell – Issued by RDSO {2003}.

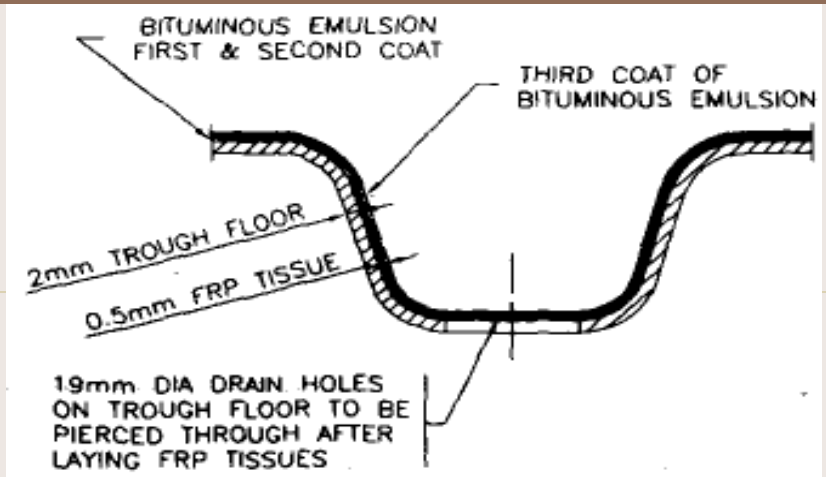


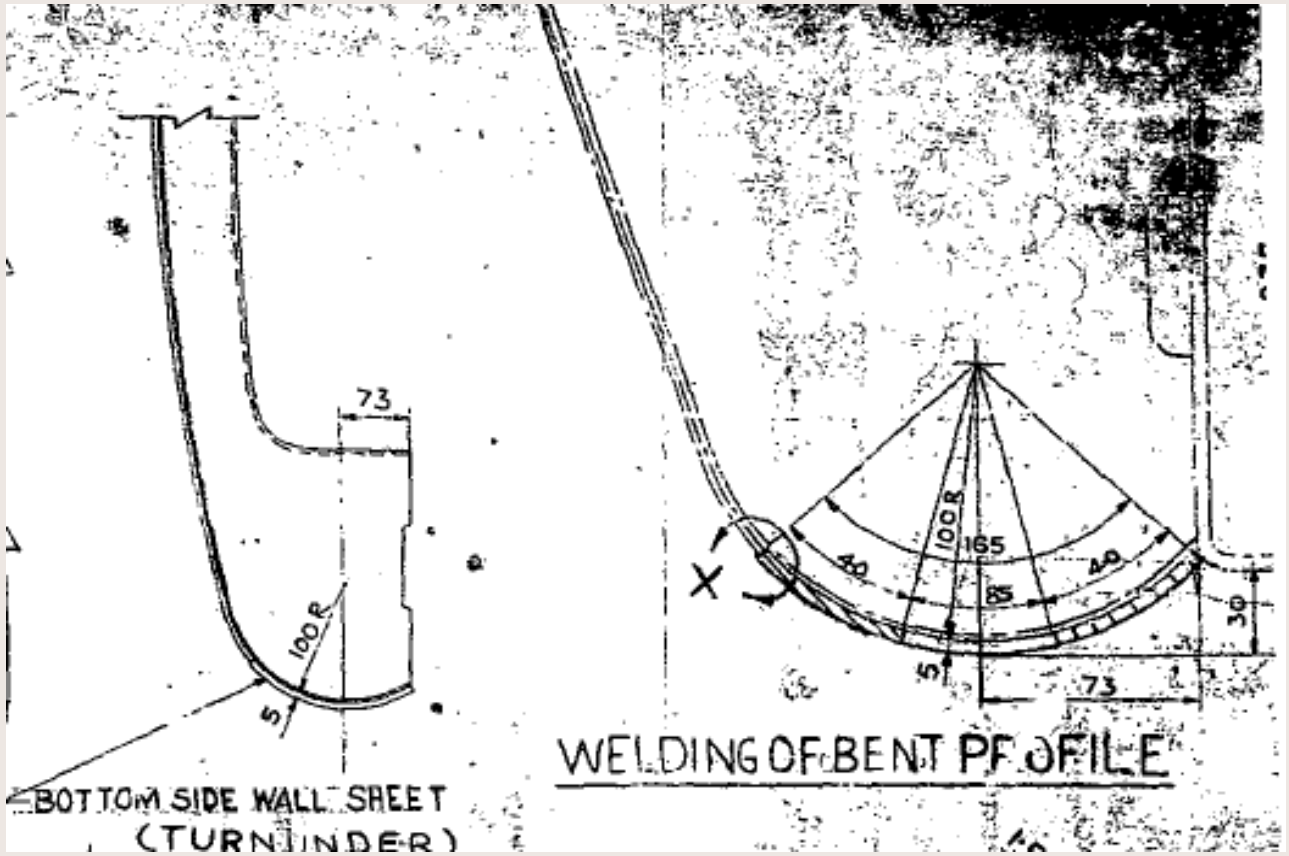
DETAILS OF INSPECTION & CORROSION REPAIRS (FILL IN PROFORMA)

S No.	DESCRIPTION	CORROSION REPAIRS NOMINATED AFTER INSPECTION	CORROSION REPAIRS ACTUALLY EFFECTED	COST OF CORROSION REPAIRS INCLUDING OVER-HEADS *			REMARKS
		FROM PILLAR No. TO PILLAR No. INDICATE HEIGHT FROM SOLE BAR BOTTOM FOR S.No. 1 & 2 ONLY	FROM PILLAR No. TO PILLAR No. INDICATE HEIGHT FROM SOLE BAR BOTTOM FOR S.No. 1 & 2 ONLY	LABOUR	MATERIAL	TOTAL	
1	SIDE WALL SHEET						
2	BODY PILLAR						
3	TURN UNDER						
4	SOLE BAR						
5	TROUGH FLOOR						
6	TUBULAR FRAME BELOW LAVATORY						
7	ANY OTHER PARTS OR ITEMS OF WORK (SPECIFY DETAILS)						
8							
	* COST SHOULD INCLUDE ALL INCIDENTAL EXPENDITURE AS RESULT OF CORROSION INSPECTION/REPAIRS		TOTAL COST				


FRP TISSUE TO BE PASTED ON SIDE WALL SHEET UPTO WAIST RAIL
FRP TISSUE TO BE PASTED ON BOTH SIDES OF PILLAR
TUBULAR FRAME
2124
X
TROUGH FLOOR
TWO LAYERS OF FRP TISSUE TO BE PASTED ALROUND THE TUBE
SECTION —AA
FRP TISSUE TO BE PASTED OVER CHANNEL ANGLE AND HEAD STOCK TOP SURFACE
A
A
19mm DIA DRAIN HOLES


158
1:5
1:5
ø 290
℄ OF COACH
EXISTING ROOF SHEET TO BE CUT IN THIS LINE AND LAP WITH ROOF SHEET PART AS SHOWN
340
340
REFERENCE
ICF DRG NO ICF/SK/S-0-369
ICF M.G. COACHES
CORROSION REPAIR OF
ROOF SHEET AROUND VENTILATOR


BITUMINOUS EMULSION
FIRST & SECOND COAT
THIRD COAT OF
BITUMINOUS EMULSION
2mm TROUGH FLOOR
0.5mm FRP TISSUE
19mm DIA DRAIN HOLES
ON TROUGH FLOOR TO BE
PIERCED THROUGH AFTER
LAYING FRP TISSUES


73
100 R
5
BOTTOM SIDE WALL SHEET
(TURN UNDER)
100 R
165
40
40
85
30
5
73
WELDING OF BENT PROFILE

Corrosion Repair: Golden Rules-

- If section thickness reduces by over 20% of the original value in the structural member, then go for corrosion repair by renewing {gas/plasma arc cutting & arc welding} the structural member
- Else scrap/remove the rust/scales/oxide film on surface & repaint by ROZ primer followed by Black Bituminous emulsion

What are the implications in ICF Coach Corrosion Repair ?

- New outer headstock {cold pressed channel} thickness = 8 mm
- New fabricated inner headstock outer & inner beams' {cold pressed channels} thicknesses = 10 mm
- New fabricated inner headstock base/centre plate thickness = 12 mm
- New Centre buffer stiffener thickness = 5mm
- New cold pressed Z section long bar/lavatory trimmer thickness = 8 mm

What are the implications in ICF Coach Corrosion Repair ?

- New fabricated boxform body bolster/centre “casting”/main transom flange thickness = 16 mm
- New fabricated boxform body bolster/centre “casting”/main transom web thickness = 10 mm
- New cold pressed Z section/C channel solebar/crossbars = 5 mm {WLRRM Solebar new thickness is however 8 mm}

What are the implications in ICF Coach Corrosion Repair ?

- If the outer headstock or longbar thickness comes down to 6.4 mm from the original value {8mm}, then it must be replaced by corrosion repair
- If the inner headstock beam thicknesses fall beneath 8 mm, then it must be replaced by corrosion repair
- If the Centre Buffer Stiffener i.e. Destruction Tube thickness falls beneath 4 mm, then it must be replaced by corrosion repair
- If the inner headstock base plate thickness falls beneath 9.6 mm, then it must be replaced by corrosion repair
- **{Contd.}**

What are the implications in ICF Coach Corrosion Repair ?

- If the body bolster flange thickness falls beneath 12.8 mm and/or its web thickness falls beneath 8 mm then replace the body bolster entirely
- Patchwork/partial renewal of headstocks & body bolster for ICF coach corrosion repair is not recommended by RDSO
- Huge corrosion repair manhours/cost & diminished outturn by repair shops
- Ineffective rolling stocks position in Divisions turns worse

What to do ? Can such corroded coaches be despatched from Workshops by local passing?

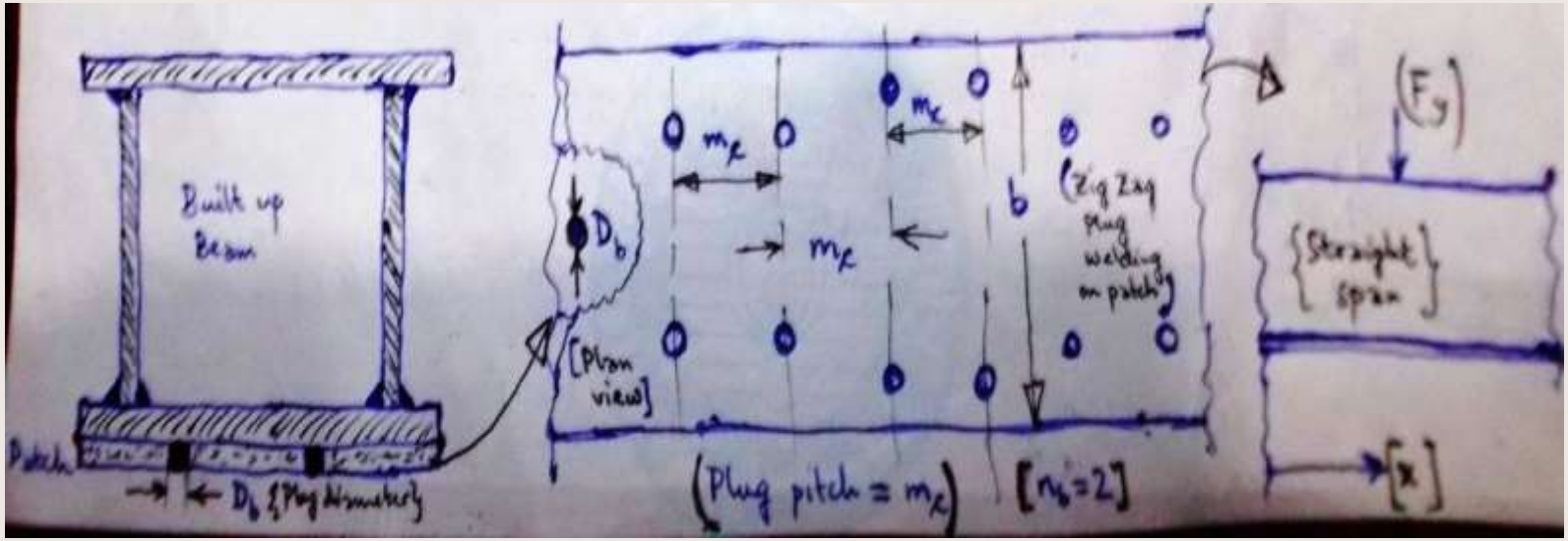
- The answer is a big NO i.e. Neutral Control Inspection & Passing cannot be avoided at all by the Workshops officers
- CME/Zonal Railway is empowered to issue fresh guidelines/LTOs {Local Technical Orders}/TSOs {Technical Standing Orders} for Repair Shops from Passenger Safety viewpoint similar to RCF issuing the STRs {Schedule of Technical Recommendations in LHB coaches}

ER LTO & TSO : ICF -

- If the outer headstock thickness falls to 4mm from 8mm, then it should be renewed
- Similarly if the inner headstock beam/base plate thickness falls to 6mm/8mm from 10mm/12mm, then it should be renewed
- From 16mm/10mm down to 11mm/6.85mm body bolster flange/web thicknesses, a 5mm/3.15mm thick IRSM41 patch can be suitably plug welded

ICF Body Bolster : Corrosion Repairs on Shopfloors -

- Patch fixing in built up beam
- Plug welded patch
- Shear stress induced during bending



Straight Beams: Bending Shears-

- Governing equations

$$[\frac{\partial \sigma_x}{\partial x}] + (\frac{\partial \tau}{\partial y}) = 0$$

$$[\frac{\partial \tau}{\partial x}] + (\frac{\partial \sigma_y}{\partial y}) = 0$$

$$Ay_c = \int y dA = 0$$

$$\{w = \frac{\partial F_y}{\partial x}\}\{F_y = \frac{\partial M_z}{\partial x}\}\{\varepsilon_x = \frac{y d\theta}{\rho d\theta} = \frac{y}{\rho}\}\{\sigma_x = E\varepsilon_x\}$$

Bending theory & Boundary Conditions in problem

- Normal stress in purely elastic bending

$$\sigma_x = \frac{yM_z}{I_{zc}}$$

- $\{M_z = \int y\sigma_x dA\}$ & 1st assumption

$$\varepsilon_y = 0$$

- $\{F_x = \int \sigma_x dA\}$ & 2nd assumption

$$F_x = 0$$

- Boundary Conditions $\{[\tau(y=a)]=0\}\{[\sigma_y(y=0)]=0\}$

Stress Calculations in bending

- Straight built up beams

$$\tau = \{\frac{a^2 - y^2}{2I_{zc}}\}F_y$$

$$\sigma_y = \{\frac{w}{6I_{zc}}\}y^3$$

$$\tau^2{}_m = [(\frac{\sigma_x - \sigma_y}{2})^2 + \tau^2{}_{xy}]$$

$$\tau_{xy} = \tau_{yx} = \tau$$

Patch : Plug welding pitch -

- Plug welding pitch formula

$$\tau b m_C = \{\pi n_b\}\tau_b D_b^{\,2}$$

Griffith's cracking, where, Cylindrical crack diameter = λ

$$W = 2\lambda z\gamma - \frac{\pi\lambda^2 z\sigma^2\{1-\mu^2\}}{2E}$$

$$Since, \{[\frac{\partial W}{\partial \lambda}(\lambda = \lambda_\tau)] = 0\}, therefore, \{\lambda_\tau = \frac{2\gamma E}{\pi\sigma^2\{1-\mu^2\}}\}.$$

Curved Beams: Bending Shears-

- Governing Equations

$$[\frac{\partial}{\partial r}(r\tau)]+\{\frac{\partial \sigma_\theta}{\partial \theta}\}=0$$

$$[\frac{\partial}{\partial r}(r\sigma_r)]-\sigma_\theta+\{\frac{\partial \tau}{\partial \theta}\}=0$$

$$AR_c=\int r dA$$

$$\frac{A}{R_n}=\int \frac{dA}{r}$$

$$\{w=\frac{\partial F_r}{R_c\partial\theta}\}\{F_r=\frac{\partial M_z}{R_c\partial\theta}\}\ \{\varepsilon_\theta=\frac{\{r-R_n\}d\Phi}{rd\theta}\}\ \{\sigma_\theta=E\varepsilon_\theta\}$$

Boundary Conditions {FIAT bogieframe corrosion & patch repairs}

- Normal stress in purely elastic bending

$$\sigma_\theta = \frac{M_z}{A\{R_c - R_n\}}\{1 - \frac{R_n}{r}\}$$

- $\{M_z = \int \{r - R_n\}\sigma_\theta dA\}$ & 1st assumption

  $\varepsilon_r = 0$

- $\{F_\theta = \int \sigma_\theta dA\}$ & 2nd assumption

  $F_\theta = 0$

- Boundary Conditions $\{[\tau(r = R_f)] = 0\}\{[\sigma_r(r = R_n)] = 0\}$

Curved Beams : Patch Pitch -

- Identical techniques

$$\tau = \frac{R_c F_r}{A(R_c - R_n)}[(\frac{r_f}{r} - 1) + (\frac{R_n}{r})\log_e(\frac{r}{r_f})];$$

$$\tau bm_C = \frac{\pi n_B \tau_B D_B^{\,2}}{4};$$

$$\sigma_r = \frac{M_z}{A(R_c - R_n)}[1 - (\frac{R_n}{r})\{1 - \log_e(\frac{R_n}{r})\}] +$$

$$\frac{wR_c^{\,2}}{A(R_c - R_n)}[(1 - \frac{R_n}{r}) + (\frac{R_n}{2r})\{(\log_e R_n)^2 - (\log_e r)^2\}].$$

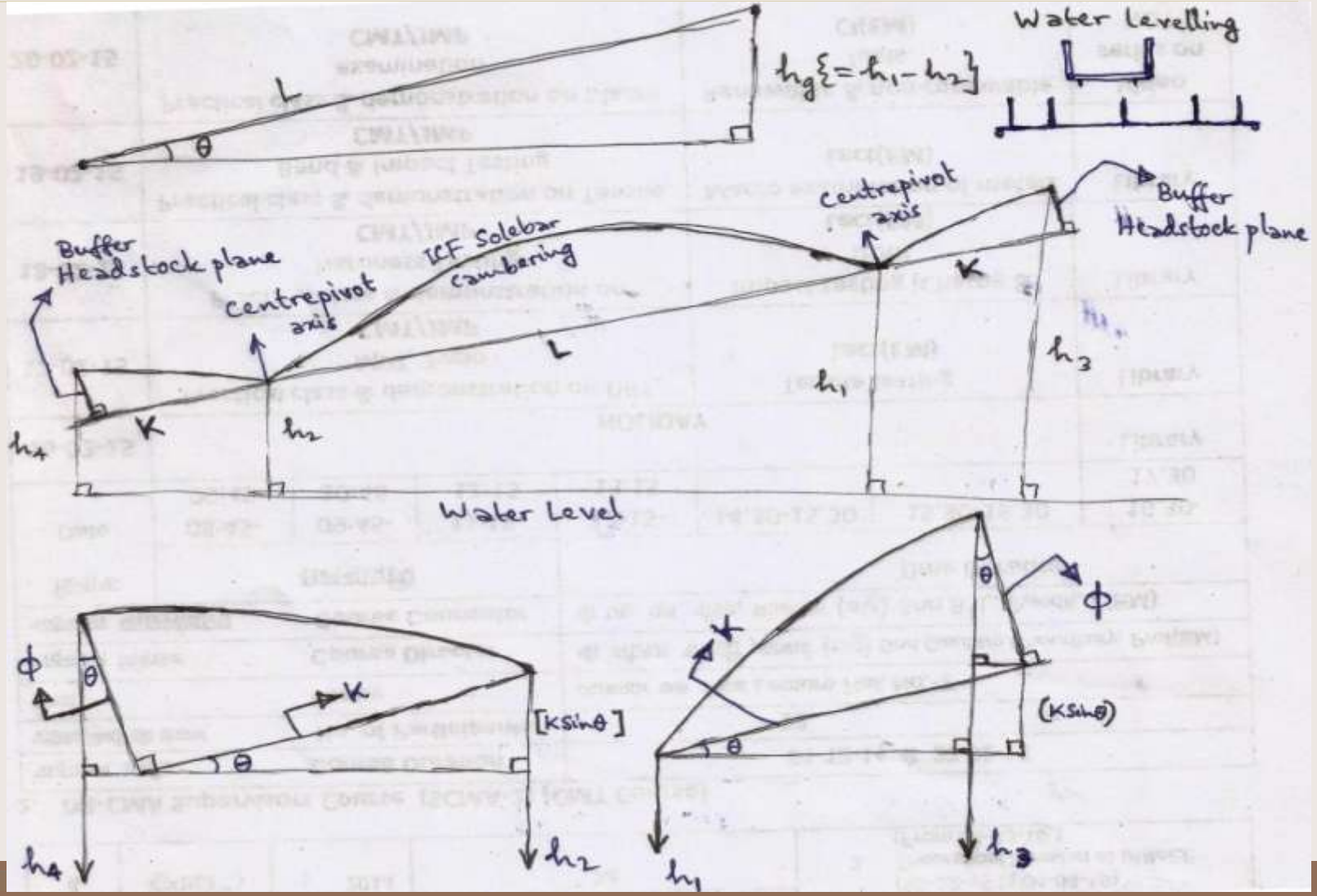
ER LTO & TSO : ICF -

- Minimum Solebar splicing length = 3ft, but the welded joint should not be in the doorway, body bolster & crossbar regions
- Maximum 1ft length in outer headstock upper flange can be match patched by butt welding {no lap welding allowed just as in body panels}

Corrosion vulnerability : ICF -

- All MS trough floors in the vicinity of doorway for ICF coaches are vulnerable
- Solebars, Turnunders, Body panels, Body pillars neighbouring lavatory, doorways & pantry car kitchen are vulnerable
- Roof ventilators {roof sheets are not skin tensioned} are vulnerable if roof is depressed around ventilators
- 1.8 mm thick U channel water wriggles {rainwater gutters} are vulnerable if there is stagnant rainwater

ICF Solebar recambering : Corrective actions – Central camber = from +15/12mm {NAC/AC} to -10mm {Reverse camber in ICF Solebars}.



ICF Solebar Recambering : Headstock ends – Corrosion Repairs in Coaches.

ICF Coach:

Solebar Cambering at buffer headstocks –

Recambering during POH at Workshops.

$\frac{h_1 - h_2}{L} = \sin\theta$; $h_1 - h_2 = h_g \Rightarrow h_g = L\sin\theta$.

$\because h_4 - \{h_2 - K\sin\theta\} = \phi\cos\theta \therefore h_4 = h_2 - K\sin\theta + \phi\cos\theta$.

$\because h_3 - \{h_1 + K\sin\theta\} = \phi\cos\theta \therefore h_3 = h_1 + K\sin\theta + \phi\cos\theta$.

✳ (ϕ = +6 mm in new ICF Carriage underframe)

✳Ⓐ {ϕ = 0 mm in Solebar Cambering loss}

✳ [ϕ = −5 mm in reverse Solebar cambering]

SS Types & Properties

SN	SS name	SS AISI Codes	Weldability	ρ(ss)/ ρ[ms]	β(ss)/ β[ms]	k(ss)/ k[ms]	Magnetic property
1	ASS	2XX & 3XX	Very Good	From 4 to 7 range	1.5	1/3	Paramagnetic
2	FSS	4XX	Good			1/2	Ferromagnetic
3	MSS	4XXM	Moderate				

SS Welding & Cutting

- SS has a 90micra Chromium Oxide passive film with a melting point higher than the base metal {Fe}
- Cannot be cut in Oxy Acetylene gas flame
- Can only be plasma cut or arc cut using N class special electrode
- Low heat input electrode selected in arc welding having less stub diameter & length
- MAG {CO_2} welding in ASS is not allowed {susceptible to weld decays}

Weld decay: Sensitising in ASS-

- C has greater affinity towards Cr than Fe
- Chromium Carbide complex is precipitated at grain boundaries if C content in ASS is more than 0.03%
- Cr depletion in ASS grains for formation of protective Chromium Oxide film
- Grains suffer Oxidation {PBR is low in Fe}
- Cr must be redissolved at high sensitising temperatures {around 700 deg. Celsius} from Carbides to prevent weld decays in SS grains
- Nb, Cb, Ti {with greater affinity towards C than Cr is having}are added to ASS for prevention of this granular corrosion

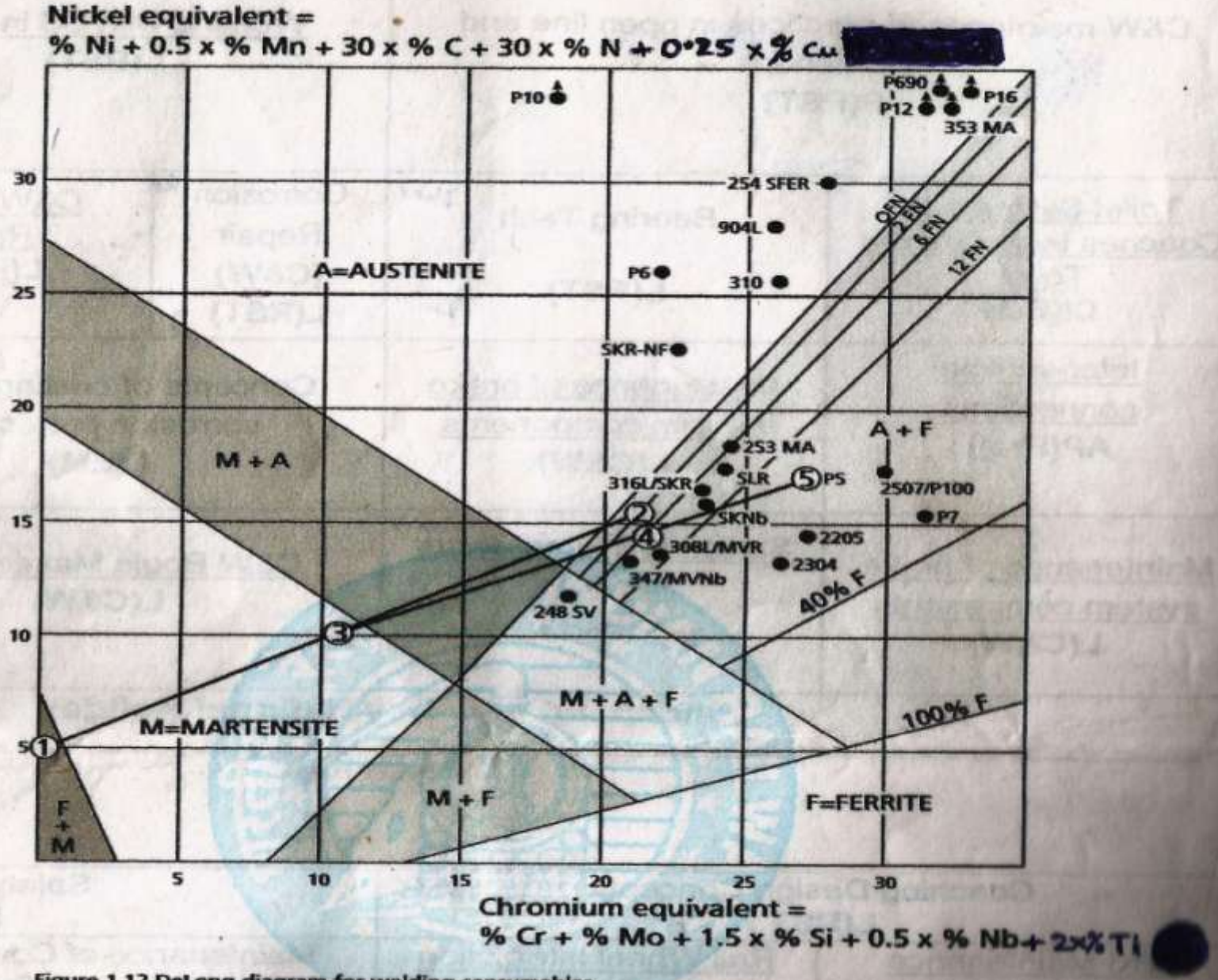


Figure 1.12 DeLong diagram for welding consumables

SS-MS Arc Welding : Electrode selection

A mild steel plate ① is welded to a stainless steel plate ② in Outokumpu 4404 (EN 1.4404/ASTM 316L) using P5 electrodes ⑤.

First, a line is drawn between the two metals ① and ②. Assuming that the metals melt equally into the weld, the halfway point ③ is marked on this line. Another line is then drawn between this point and the electrodes ⑤. Knowing that the composition of the weld metal will be approximately 30% parent metals and 70% filler metal, a further point ④ is marked as shown (i.e. the distance between ③ and ④ is 70% of the line's length).

The DeLong diagram predicts a ferrite content of approximately 6 FN for this weld metal. The WRC-92 constitutional diagram can be used in the same way.

Recovery point = 0·35 x Absolute melting point temperature.
Recrystallization & lattice reorientation point = 0·45 x Absolute melting point temperature.

RDSO recommendations: Arc welding– ICF BG coach Corrosion repairs.

The electrode must be preheated to about 250^{0}C for two hours or as recommended by electrode manufacturers before use.

While welding with AC, the welding transformer must have minimum OCV-80 volts for its smooth running.

If welding with DC equipment, the electrode must be connected with positive terminal of equipment.

During positional welding, 4 mm or less diameter electrodes to be preferred for better control of bead.

Welding shall be done by 'D' class electrodes to IRS – M 28 (latest Rev.) or class IV MIG/MAG welding wires as per specification IRS-M46 (latest Rev.) .

While welding with D class electrodes following special care should be taken as these are basic coated electrodes:

Welding shall be preferred in flat position , vertical up welding shall be used in place of vertical down.

The electrode must be preheated to about 250^{0}C for two hours or as recommended by electrode manufactures before use.

While welding with AC, the welding transformer must have minimum OCV-80 volts for its smooth running.

If welding with DC equipment, the electrode must be connected with positive terminal of equipment.

During positional welding, 4 mm or less diameter electrodes to be preferred for better control of bead.

Electrode & Welding Wire:

S.No.	Description	MMAW Electrode As per IRS M-28 2002 (Amendment-2)	MIG/MAG welding wire As per IRS M-46-2003 (Amendment-1)
1	IRSM-41 with IRSM-41	'D' class	Class IV
2	AISI 304 with AISI 304	M_1 Class	Class VI
3	IRSM-41with AISI 301	M_4 Class	Class VII
4	AISI 304 with AISI 301	M_1 Class	Class VI
5	AISI 409 M with AISI 409 M	M_2 Class	Class VI
6	AISI 301/AISI304 with IS:2062 E-250	M_4 Class	Class VII
7	IS: 2062 E-250 to IS: 2062 E-250 or IS:1239 Pt.I Tab.3	A_3/B_1 Class	Cass I
8	IRSM-41 with IS: 2062 E-250	'D' Class	Class IV

Arc Welding : MS –

- No edge preparation reqd. in butt welding sheets {e.g. 2mm thick body panels}
- Plasma arc cutting or Straight line Oxy acetylene gas flame cutting in body panels
- Lap welding avoided to prevent corrosion
- Kerf is better/smooth in gas cutting plates {viz. 8mm thick outer headstock}
- TiO_2 flux coated electrodes must never be overheated in drying ovens

Corrosion prevention

- Dissimilar material contact elimination in dissimailar materials' contact type Galvanic Corrosions
- Stress Cell elimination in Corrosion prone areas {proper stress relieving following mfg. & preventing overloadings/impacts}
- Concentration Cell elimination in corrosion prone areas {preventing water accumulation in pockets/corners}
- Cathodic & Anodic protection exploitations

Corrosion prevention

ANTICORROSIVE MEASURES

i. The most important anti corrosive measure to be taken in day to day working is to ensure that the wagon is kept thoroughly clean and receives special attention in this respect after it has transported a corrosive or hygroscope commodity.

ii. The second important step to prevent corrosion is to ensure that cleaning, surface preparation and painting are carried out with due thoroughness. The correct procedure to be followed in major maintenance schedules is given at the end of this chapter. The procedure to be adopted at the time of minor repairs should come as close to this as practicable.

iii. While attending to miscellaneous repairs, panel patching or welding; it is important to ensure that surfaces in contact are well fitted to avoid water pockets. Due care is to be taken to clean and paint the affected surfaces to prevent corrosion by electrochemical action.

iv. Use of Stainless Steel (IRS: M44) has been started in wagon rehabilitation/ new manufacture. This material has much better corrosion resistance.

Hot dip class B Zn Phosphating

- Carried out on sheets {beneath 5mm thick}
- Degreasing is 1st done in Caustic bath
- Pickling/derusting is done in dil. HCl or Phosphoric acid bath with Amine nascent Hydrogen inhibitor by removing outer Ferric Oxide, inner Ferrous Oxide rust scales
- Scholzit Solution i.e. Calcium Zinc Phosphate with Phosphoric acid solution & Potassium Nitrate accelerator in the phosphating bath at 65 deg. Celsius temperature {having free acid ratio about 1.1} then forms a 0.03mm thick layer of Zinc Phosphate on the substrate @ 4.3 gms/sq. m
- Chromic acid in the passivating bath then seals up the intergranular spaces between the Phosphate precipitates by about 30% in the form of Chromium Phosphate deposits
- Excess Chromic Acid is treated by Ferrous Sulphate , Sulphuric acid solution & precipitated by Slaked Lime

Phosphating plant

Rust Scales in 3 films
Oxygen



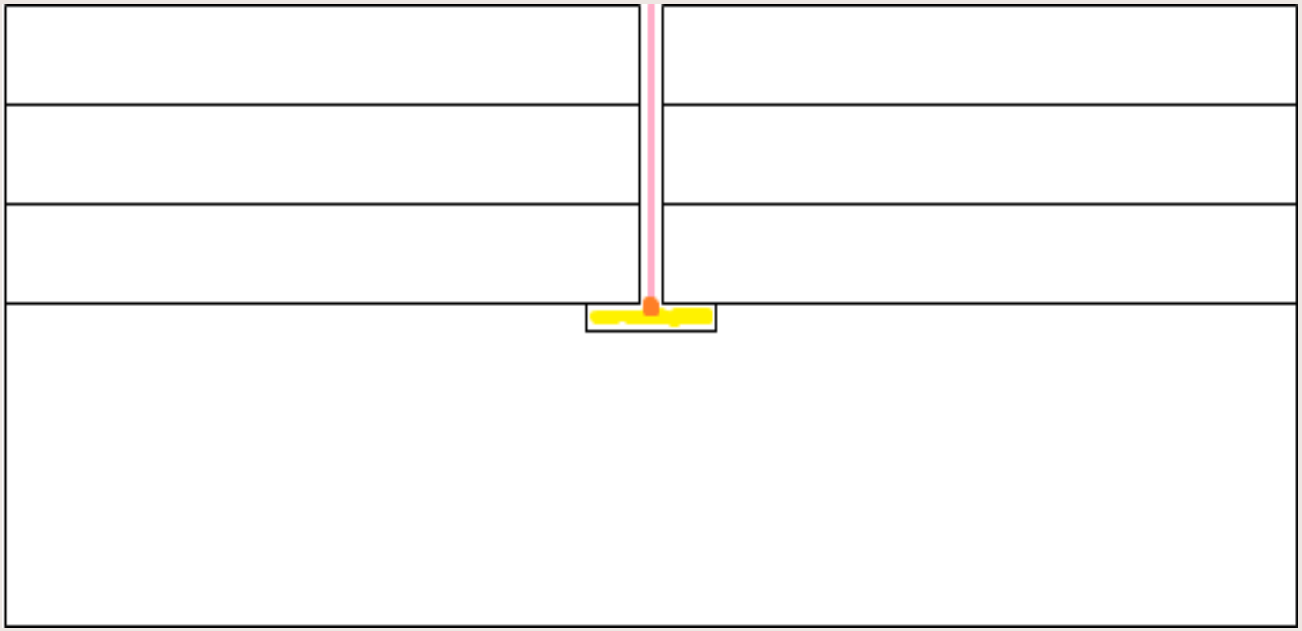
Base metal **Fe {MS}**

Rust films = **Fe_2O_3 Fe_3O_4 FeO**

Degreasing & Derusting

- **Degreasing {detergent action} by Caustic Soda {NaOH} followed by water { pH = 7 } rinsing**
- **Derusting/Descaling/Acid pickling : Internal Chemical Shot blasting followed by water rinsing**

Pickling by dilute HCl



H_2 gas

$Fe + 2HCl + [RNH_2(\text{Nascent H inhibitor})] = RNH_2 + FeCl_2 + H_2$.

Phosphating & passivating {30% conventional sealing}

- **$3Ca[Zn_2(PO_4)_2] + 6H_2O + [KNO_3$ (coating accelerator)] {overall hydrolysis} = {KNO_3} + $2[Zn_3(PO_4)_2]$ {@ 4.3 gms/mtr.^{2} X 0.03 mm} + $2H_3PO_4 + 3[Ca(OH)_2]$.**
- **$4CrO_3$ {Disproportionation reaction} + $4H_3PO_4 = 4CrPO_4 + 6H_2O + 3O_2$.**
- **1080 gms Scholzit solution having $Ca[Zn_2(PO_4)_2]$ produces $[Zn_3(PO_4)_2]$ precipitate of 770 gms**
- **100 gms CrO_3 reacts with 98 gms H_3PO_4 for producing 147 gms $CrPO_4$**

Anticorrosive treatments : ICF –

- Battery box frames are hot galvanised
- FRP tissue papers are pasted in layers on MS trough floors keeping drain holes open & following RDSO instructions
- Black bituminous paint is done over ROZ primer coatings
- Electrostatic PU spray painting following grit blasting on cleaned exterior surfaces & powder coatings on interior MS fittings

CR BOX BOXN BOBRN

CORROSION ON BOX/BOXN/BOBRN WAGONS i.e. Open type Wagons

Wagon Corrosion

CORROSION IN WAGON BODY

The corrosion of wagon floor and roof plates results from:

i. Water logging in crevices and overlaps. This is greatly accentuated if cleaning is neglected, since the accumulated dust and refuse retain moisture for a prolonged period.

ii. Contact of panels with residues from corrosive consignments e.g., salt, fertilizers etc.

iii. Spillage of corrosive fluids due to defective packing or rough handling.

iv. Escape of corrosive vapours from the consignment.

v. Inadequate protection from weathering because of poor painting or inadequate surface preparation.

vi. The current practice is to paint only the exterior of the wagon body and not the interior, except for inside panels up to a height of 230 mm from floor, rivet seams and in the case of covered wagons, the swing and flap doors and the roof. The interior is left largely unpainted because paints have hitherto not been available which could withstand the constant scrubbing action of the consignment against the wagon walls. It is nevertheless a fact that most of the time corrosion originates from the interior of a wagon rather than the exterior.

Corrosion : Phenomenon -

FACTORS RELATED TO CORROSION :-

1. Types of commodities loaded.
2. Pattern of loading.
3. Contamination of rain water with the Chemical substance.
4. Running through coastal areas.
5. Stagnation of rain water.
6. Overlapping of panel plates.
7. Improper painting without surface preparations.

Corrosion : Reasons -

1. STRESSED END PANELS AND STANCHIONS BY BAD LOADING OF MATERIAL AND LOOSE SHUNTING IMPACTS.
2. ACCUMULATION OF RAIN WATER CONTAMINATED WITH CHEMICALS OF MATERIAL LOADED.
3. STAGNATION OF RAIN WATER ON THE FLOOR.
4. SEEPAGE OF RAIN WATER FROM FLOOR TO THE SOLEBAR NEAR DOOR WAY.
5. DOOR HINGES IN CONTACT WITH MOISTURE.

Corrosion Prone regions : Wagons -

1. End Panels.
2. Side panels.
3. Floor.
4. Door panels, hinges, frames.
5. Body and end stanchions.
6. Sole bar near doorway.
7. Bulging out of side panels.
8. Corner and Top copings.

CORROSION PRONE AREAS IN BOXN WAGONS



- Side panel
- Overlapping joint
- Juggle angle

Main Reasons for corrosion

1.Contaminated water mixed with chemical substances of loaded Materials.

2. Running through coastal areas.

3. Accumulation of rain water.

CORROSION PRONE AREAS



- End stanchion
- Tarpaulin cleats

Corrosion takes place by impacts during loose shunting accelerated in contact with Rain water and moisture.

CORROSION PRONE AREA



- End panels adjoining with floor plates

Accumulation of rain water mixed with the chemical Substances of loaded Commodities.

CORRODED AND FINALLY BROKEN



Corrosion took place on the side coping channels due to rain water ingress. During unloading by tipplers the weak portion is Broken.

CORROSION PRONE AREA



- Intermediate copings

Corrosion takes place due to accumulation of rain water in sagged portion.

CORROSION PRONE AREA



- Sole bar
- Door Hinge
- Floor

Corrosion is caused by
Seepage of rain water
from floors near door way.
2. Door hinges get corroded
in contact with seeping rain water
from floor.
3. Floor gets corroded due to
accumulation
of rain water and water mixed with
Chemical substances of loaded
materials.

CORROSION PRONE AREA ON BOXN



- Inside end panel

Corrosion Prone Area On BOXN



- Corner angles
- Side and end top Channels

Corrosion Prone Area On BOXN



- Joint area in middle crib angle with side stanchion

Corrosion Prone Area on BOXN



- Door frame
- Door Hinge

Corrosion Prone Area on BOXN



Plate over joint of side panel and floor.

Corrosion Prone Area in BOXN & hence IR BOXNCR demands



- Joint area of top side panel and top end panel

Sl No.	Type of wagons/ bogies	No. envisaged in IRMP	No. provided at the end of March 2009
1	Corrosion resistant stainless steel wagons	10,000	278
2	Light weight aluminium wagons	2,000	922
3	Self steering bogies	Not mentioned	Nil

Corrosion on BOXN



- Side panel

Corrosion Prone Area on BOXN



- Side Stanchion

Corrosion Prone Area on BOXN



- Corner Angle

Corrosion Prone Area on BOXN



- Middle crib angle

Corrosion Prone Area On BOBRN



- Top Side Plate

Corrosion Prone Area On BOBRN



- Door

BOXN: Corrosion prevention-

1. IRS M-41 CORTEN Steel plates are used.
2. No small body patches are used. Only standard panel patches from pillar to pillar are used.
3. Full size, Half size and 1/3rd size body stanchions are used by riveting with sole bar.
4. Joints of stanchions are strengthened by providing Dome over the joints and inside patches with proper Welding.
5. Replacing floor by removing corroded old floor.
6. Replacement of full sole bar.

BOXN: CP- Contd.

7. Fitment of Drip trip arrangement near Door ways.

8. Provision of angles over side top Copings to avoid bulging of side panels.

9. Drain out holes on the floor have been blocked.

10.”L” type bracket is provided in between floor and body stanchions and welded to avoid distortion.

11.Surface preparation is being done before painting.

Why BOXN wagons are the most corrosion prone ones among Open top wagons ?

- BOBRN/BOBYN {Bogie type bottom/side discharge hopper} wagon has inclined flooring which helps rainwater to automatically drain out from floor
- BOXN {Bogie type open box} wagon has flat floor for accumulation of rainwater
- BRN {Bogie type open flat form} wagon has no damming wall that can hold water

BOXN corrosion repair standard body patches {IS 2062 MS}

- 2920mm X 1570mm X 6mm shear cutting
- 1500mm X 680mm X 5mm shear cutting
- 1500mm X 620mm X 5mm shear cutting
- 1500mm X 580mm X 5mm shear cutting
- 1500mm X 510mm X 5mm shear cutting

Further references :-

BG wagon maintenance manual by CAMTECH

3 Criteria : BOXN rehabilitation -

- Wagon service life should be from 14 to 16 years i.e. halfway around its 30 years codal life
- Centre Sill should be in sound condition or no crack should be in the fabricated centre sill & its associated joints
- Minimum camber at Solebar centre should be 2 mm
- {Solebar camber in newly manufactured BOXN wagon ranges from 9 to 12 mm at the centre with 0 mm at the CBC ends}

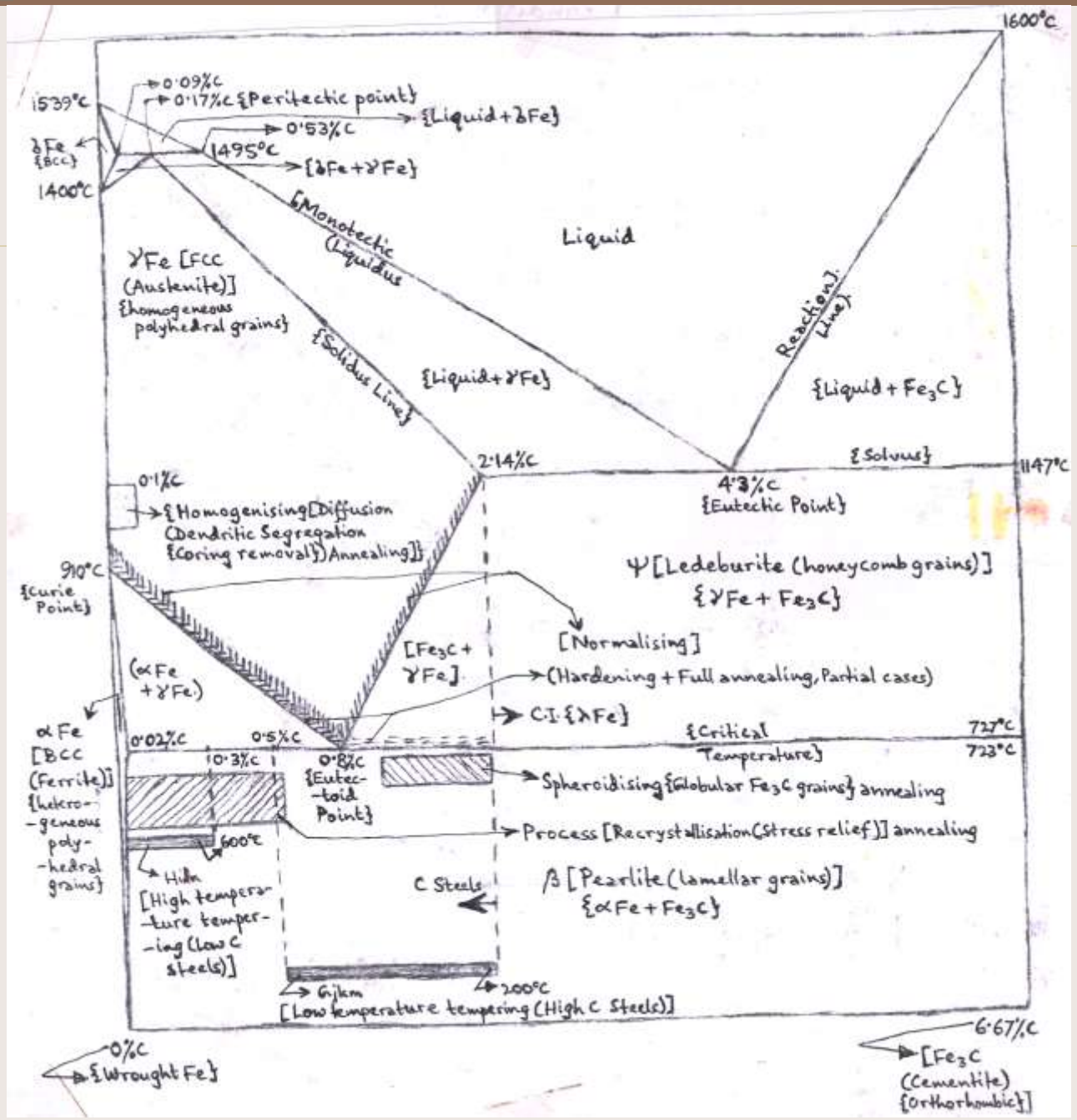
Midlife rehabilitation/corrosion repair at BKN WS, N.W.Rly. :{BOXNR}-

- Wagon side walls & end walls converted to AISI 409M {4mm thick Martensitic SS sheets being used} from MS
- Floor panel also converted to SS from MS
- Corroded MS {IS 2062} underframe members are gas cut & renewed by arc welding
- Huck/Avdel bolting or Blind riveting is adopted for joining SS superstructure i.e. body wall panels with MS underframe instead of dissimilar material welding

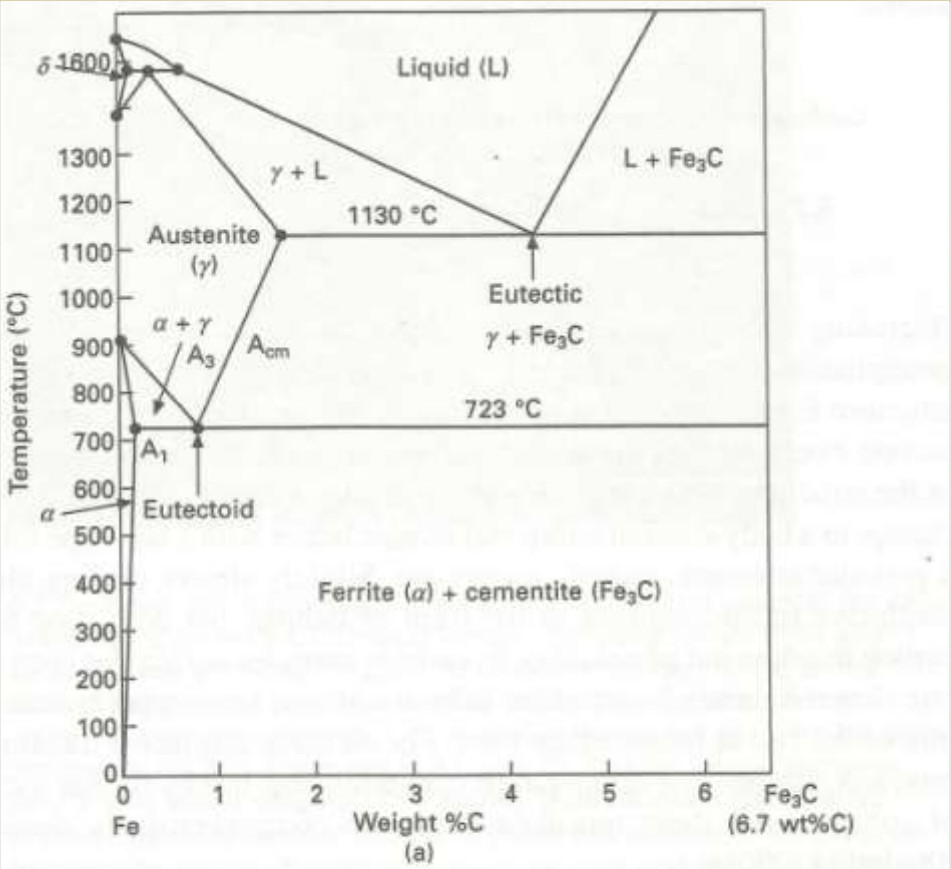
BOXNHL & BCNHL specialities

- 10 mm thick seamfree cold pressed hat section of SS for the one piece Centre Sill
- 4 mm thick AISI 409M U pressed channel section body side & end stanchions
- SS floor panel in BOXNHL
- All corrosion resistant materials
- Twin pipe Air Brake System in both

BCNHL = 20.9T tare + 70.9T CC

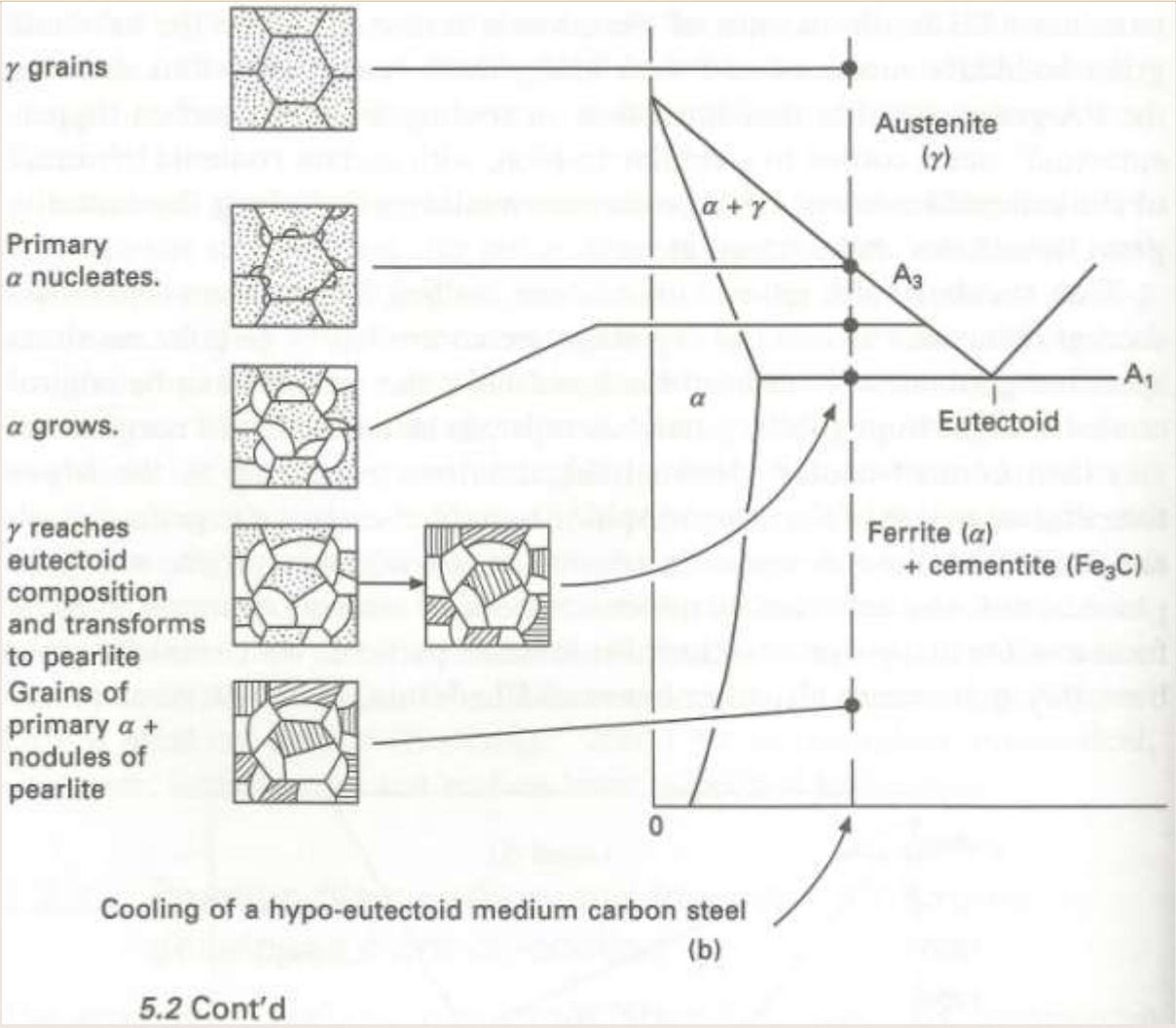

1600°C
1539°C
0·09%C
0·17%C {Peritectic point}
{Liquid + δFe}
0·53%C
δFe {BCC}
1495°C
{δFe + γFe}
1400°C
{Monotectic (Liquidus}
Liquid
γFe [FCC (Austenite)]
{homogeneous polyhedral grains}
{Solidus Line}
{Liquid + γFe}
Reaction Line
{Liquid + Fe3C}
2·14%C
{Solvus}
1147°C
4·3%C
{Eutectic Point}
0·1%C
{Homogenising [Diffusion (Dendritic Segregation {Coring removal}) Annealing]}
910°C
{Curie Point}
Ψ [Ledeburite (honeycomb grains)]
{γFe + Fe3C}
[Normalising]
[Fe3C + γFe]
(αFe + γFe)
(Hardening + Full annealing, Partial cases)
C.I. {λFe}
αFe [BCC (Ferrite)]
{hetero-geneous poly-hedral grains}
0·02%C
0·5%C
{Critical Temperature}
727°C
723°C
10·3%C
0·8%C {Eutec-toid Point}
Spheroidising {Globular Fe3C grains} annealing
Process [Recrystallisation (Stress relief)] annealing
600°C
Hdm [High temperature tempering (Low C steels)]
C Steels
β [Pearlite (lamellar grains)]
{αFe + Fe3C}
Gjkm
200°C
[Low temperature tempering (High C Steels)]
0%C
{Wrought Fe}
6·67%C
[Fe3C (Cementite) {Orthorhombic}]

Fe C phase equilibrium

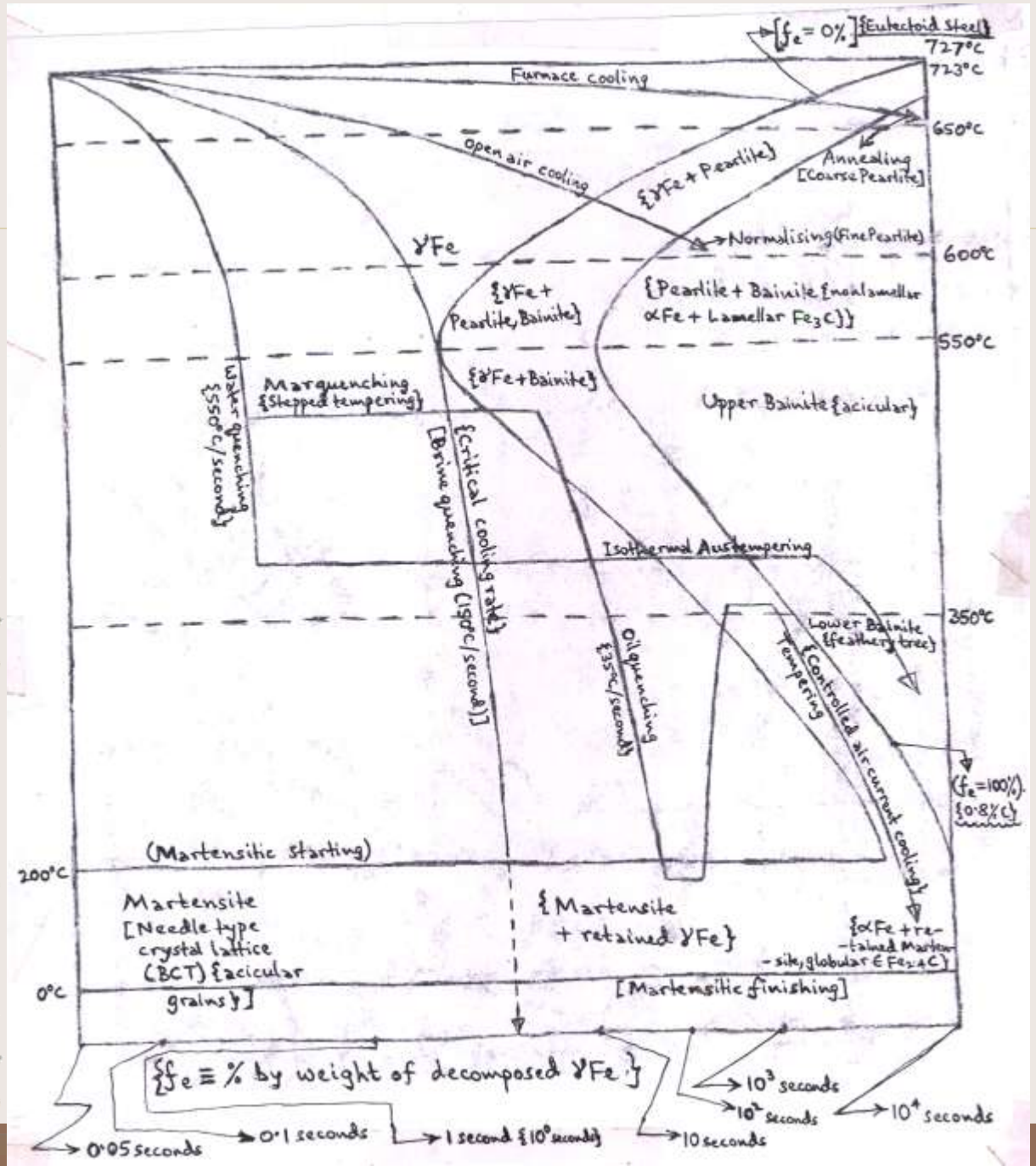


5.2 Iron–carbon phase diagram (adapted from Ashby and Jones, 1998). (a) Complete diagram covering steel and iron. (b) Detail of diagram plus schematic sketch showing the development of microstructure on slow cooling of a hypo-eutectoid, medium carbon steel.

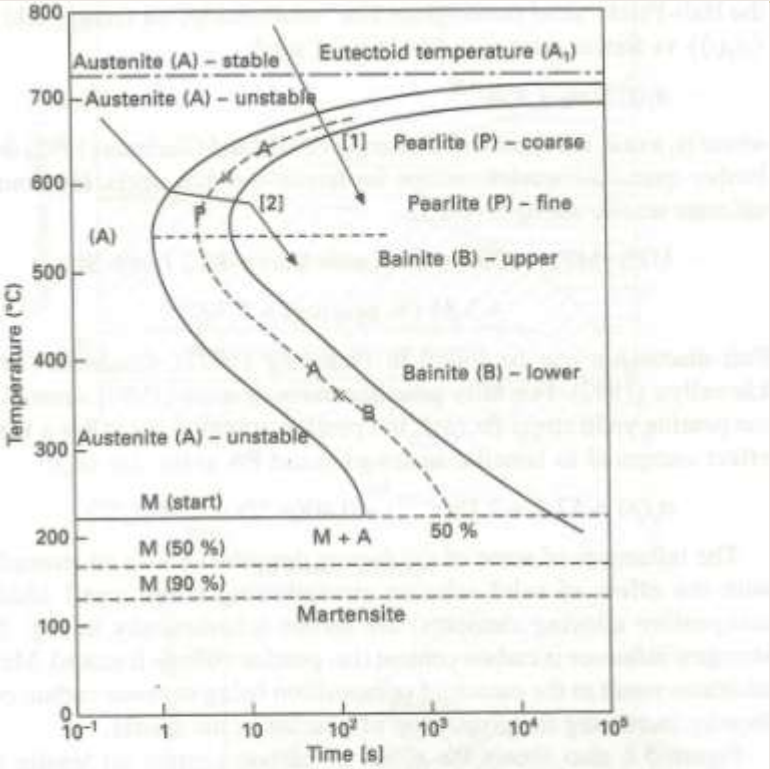
Medium C Steels



5.2 Cont'd

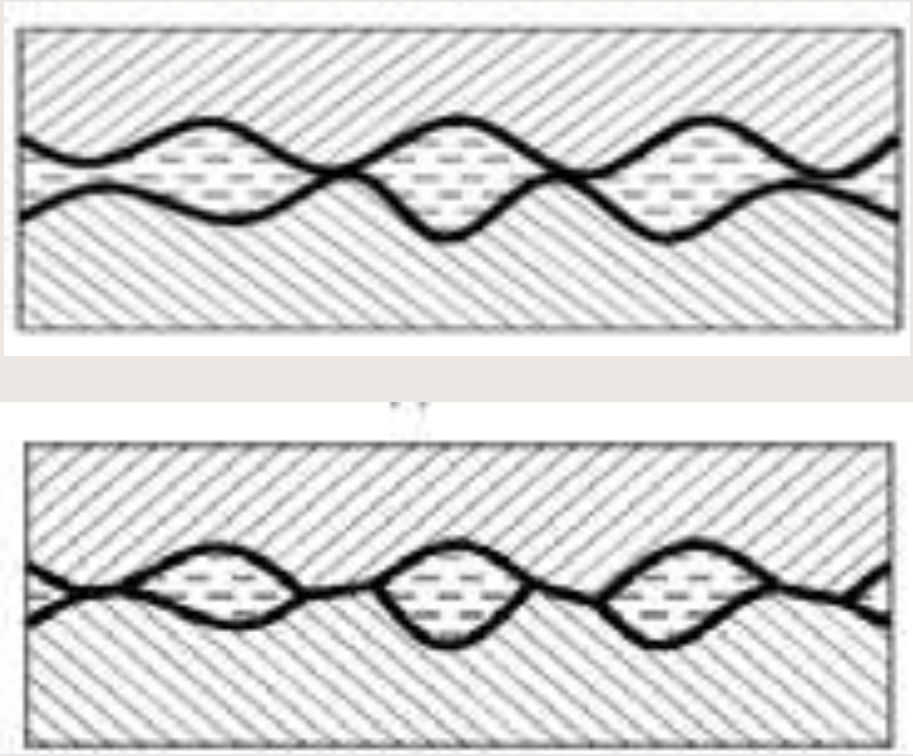

[f_e = 0%] {Eutectoid steel}
727°C
723°C
Furnace cooling
650°C
open air cooling
{γFe + Pearlite}
Annealing [Course Pearlite]
Normalising (Fine Pearlite)
γFe
600°C
{γFe + Pearlite, Bainite}
{Pearlite + Bainite {noal lamellar αFe + Lamellar Fe_3C}}
550°C
Marquenching {Stepped tempering}
{γFe + Bainite}
Upper Bainite {acicular}
Water quenching {550°C/second}
{Critical cooling rate} [Brine quenching (190°C/second)]
Isothermal Austempering
350°C
Lower Bainite {feathery tree}
Oil quenching {335°C/second}
{Controlled air current cooling} Tempering
(f_e = 100%) {0·8% C}
(Martensitic starting)
200°C
Martensite [Needle type crystal lattice (BCT) {acicular grains}]
{Martensite + retained γFe}
{αFe + re-talned Marten-site, globular ∈ Fe_3C}
0°C
[Martensitic finishing]
{f_e ≡ % by weight of decomposed γFe}
0·05 seconds
0·1 seconds
1 second {10^0 seconds}
10 seconds
10^2 seconds
10^3 seconds
10^4 seconds

0.8% C Steel transformations

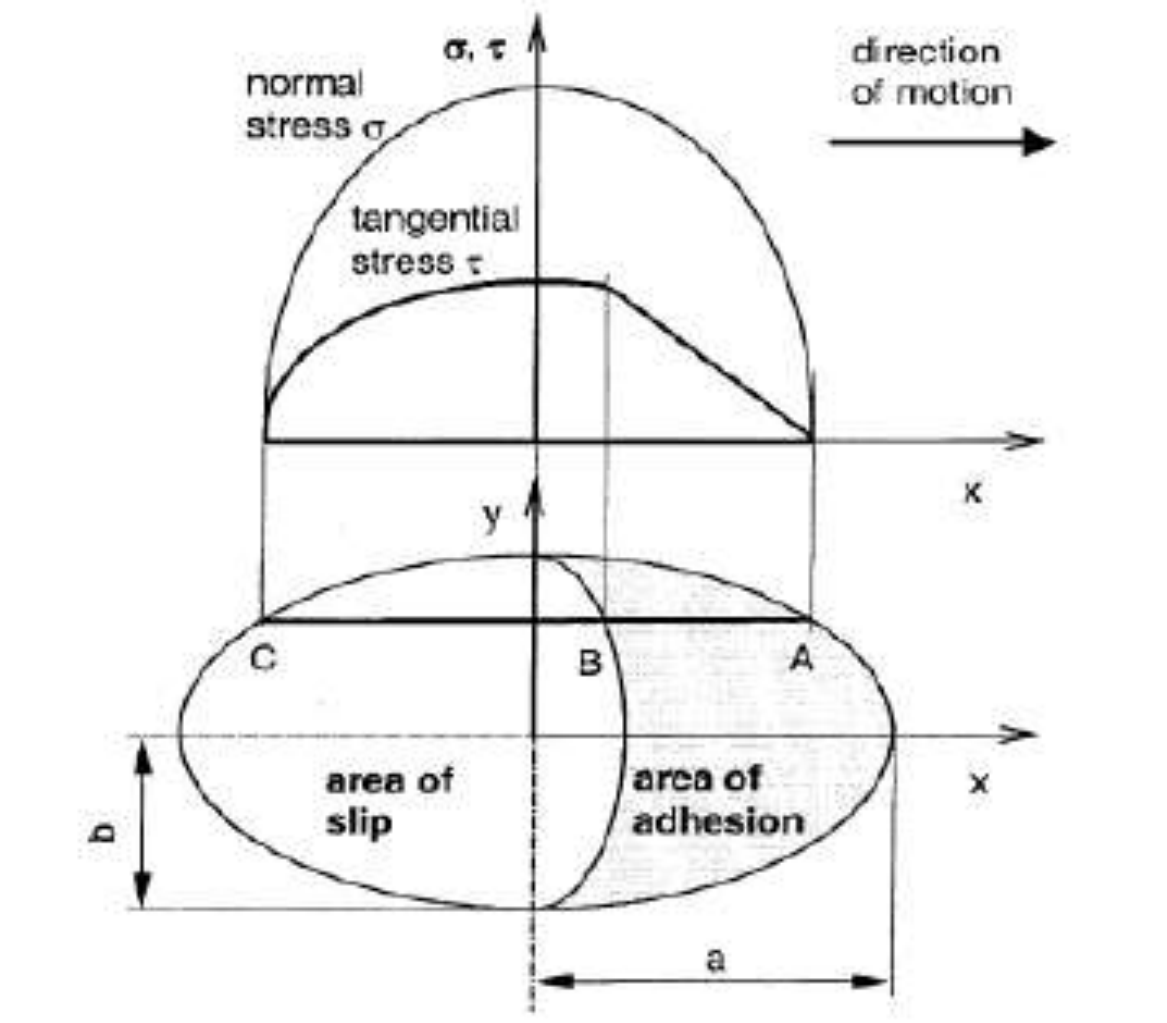


5.4 Schematic representation of an isothermal '*time–temperature–transformation* (TTT)' diagram for a eutectoid composition, plain carbon steel [adapted from Callister (1994), Pickering (1992), Gladman (1992), Krauss (1980), Honeycombe and Bhadeshia (1995)]. Most rail steels have slightly lower carbon content and some alloying, but this shows the general pattern of isothermal cooling. With continuous cooling, the transformation curve is shifted right to slightly longer times. Arrow [1] represents the normal air-cooling of hot rolled and normalised rail; arrow [2] represents the accelerated and controlled cooling required for head-hardening the rail.

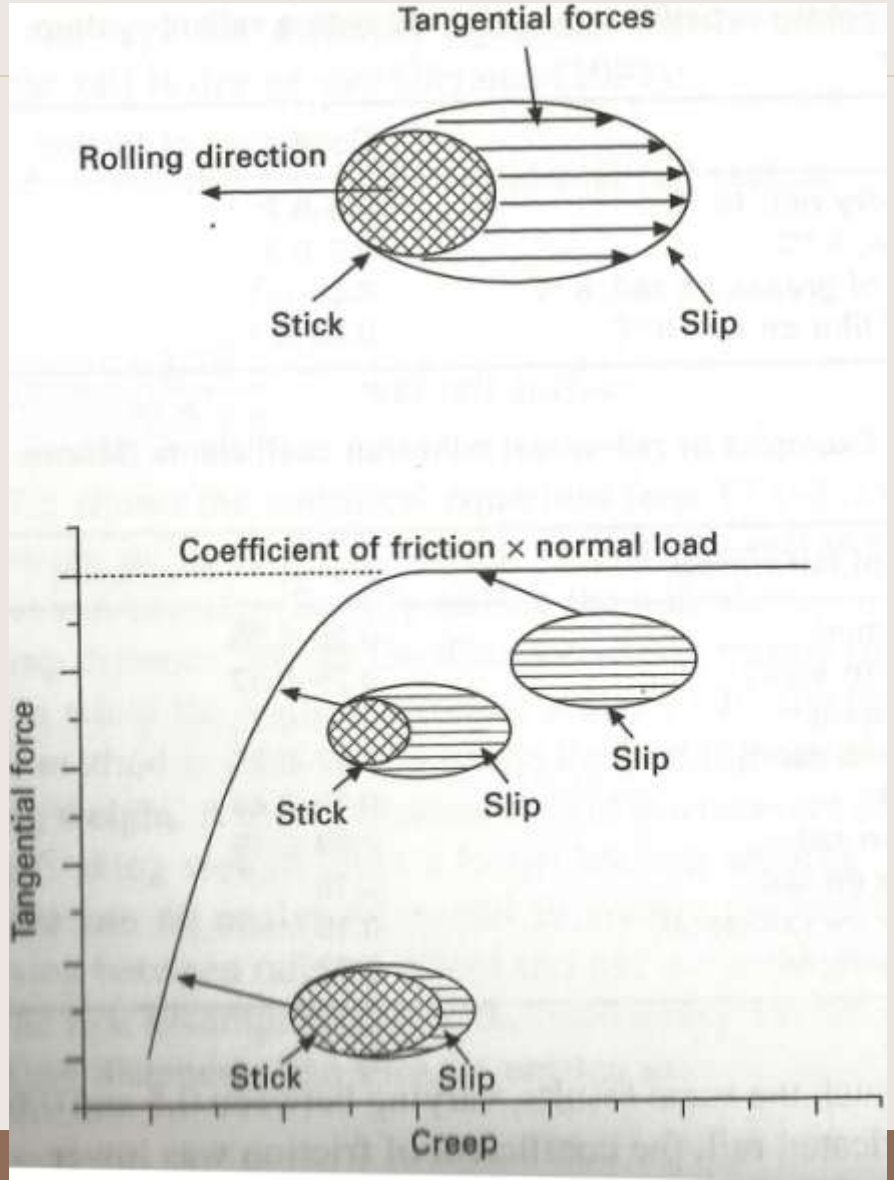
Rail wheel interface geometry: Contact bridges – Make & Break



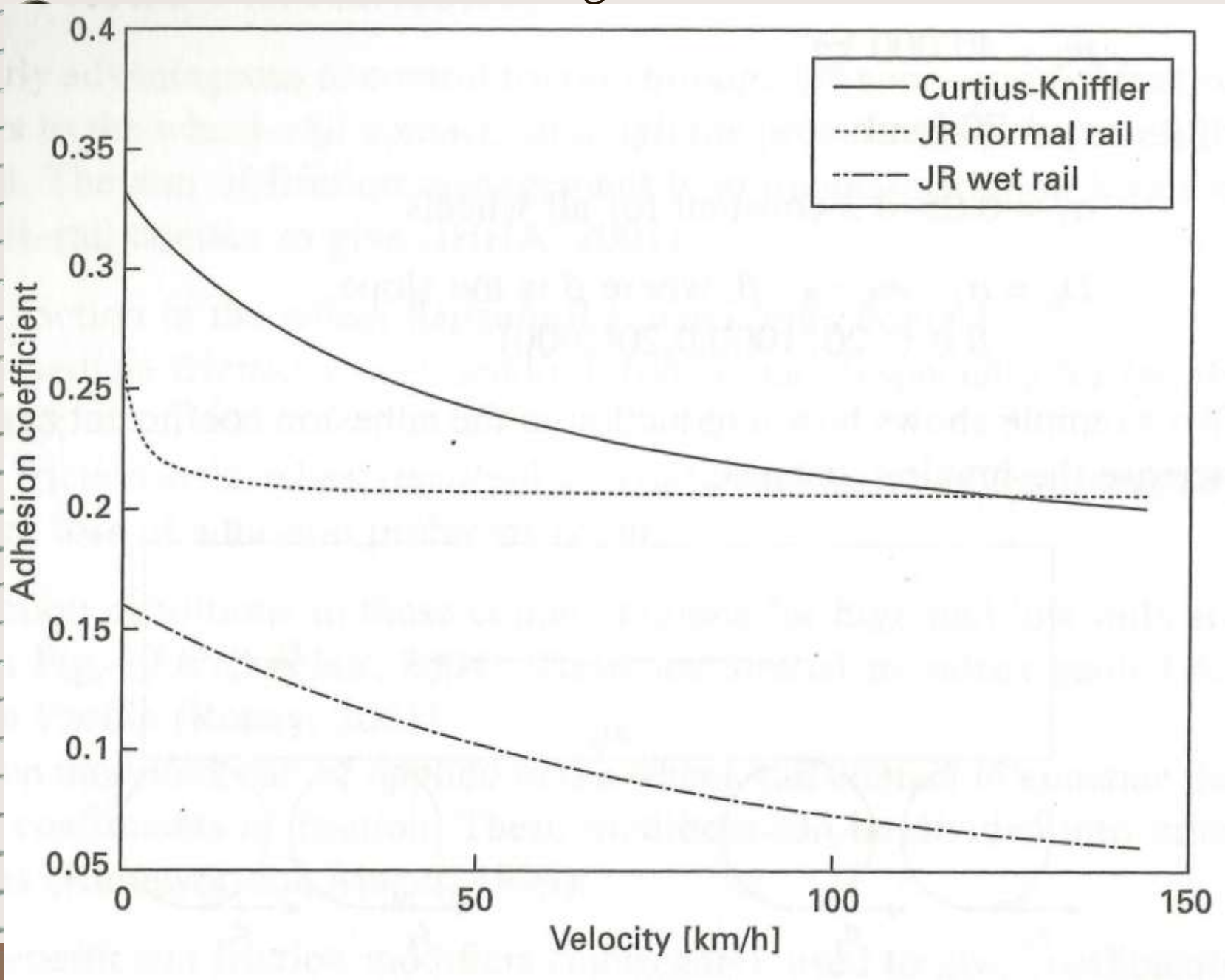
contact patch geometry Wheel-rail :



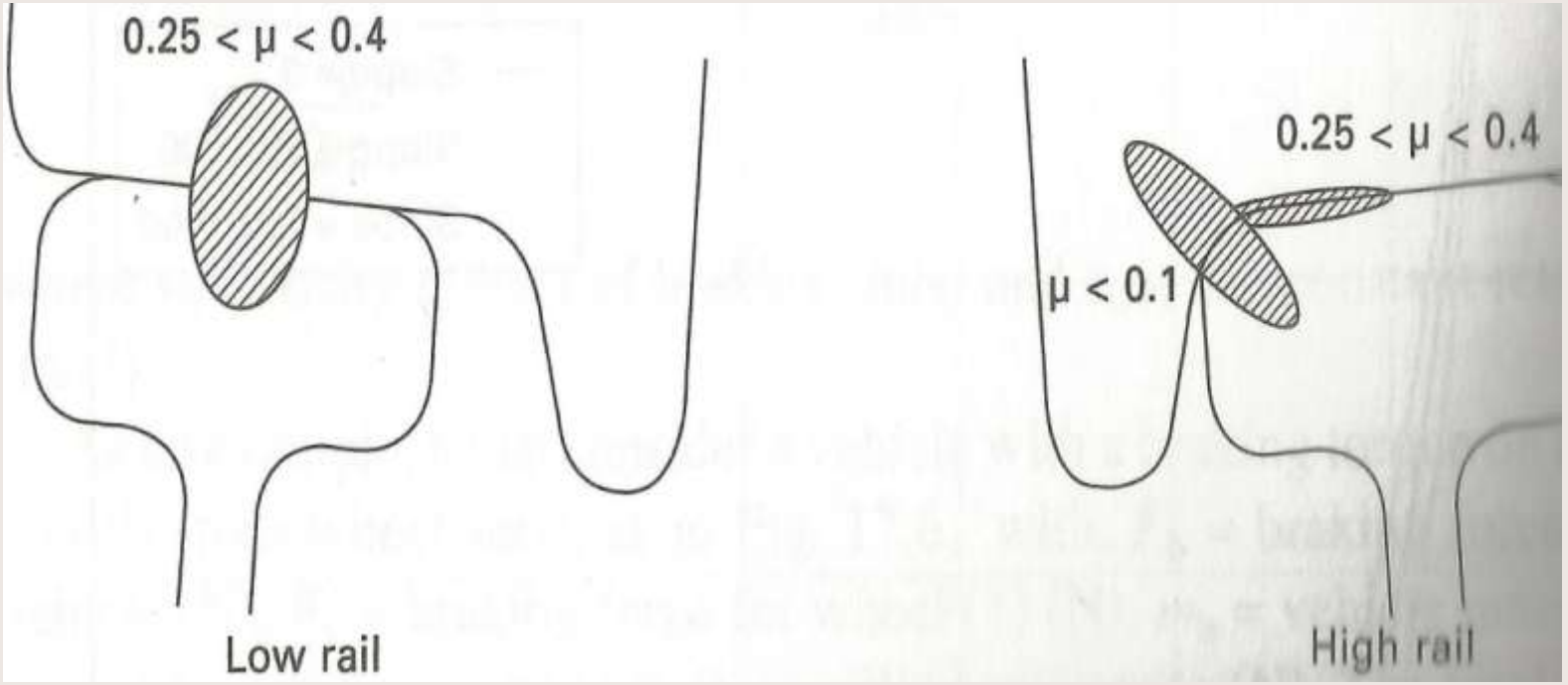
Creep = {Wheel's Angular velocity X Wheel's rail contact radius} - Vehicle speed



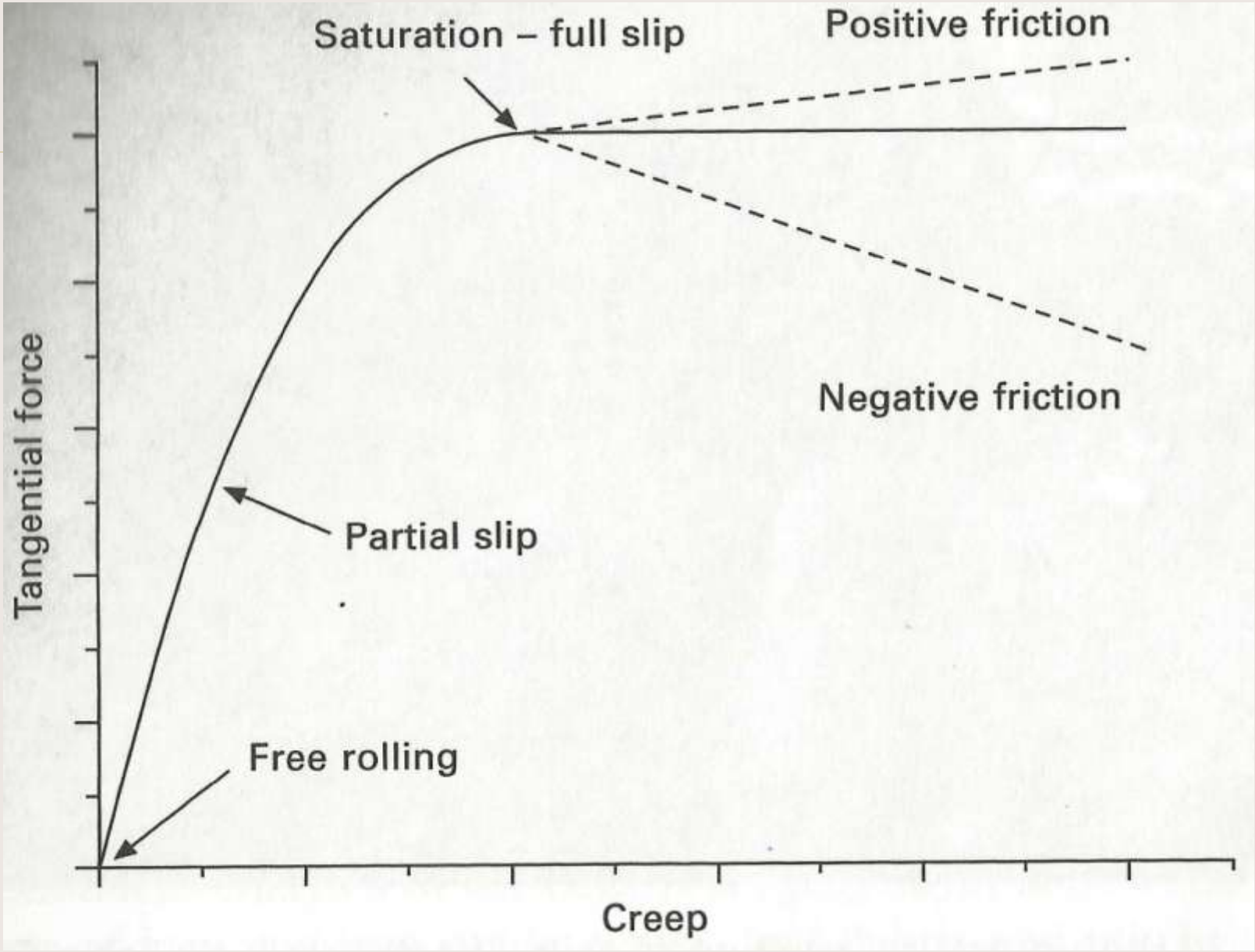
Rolling friction



Rail-Wheel interface: Interactions

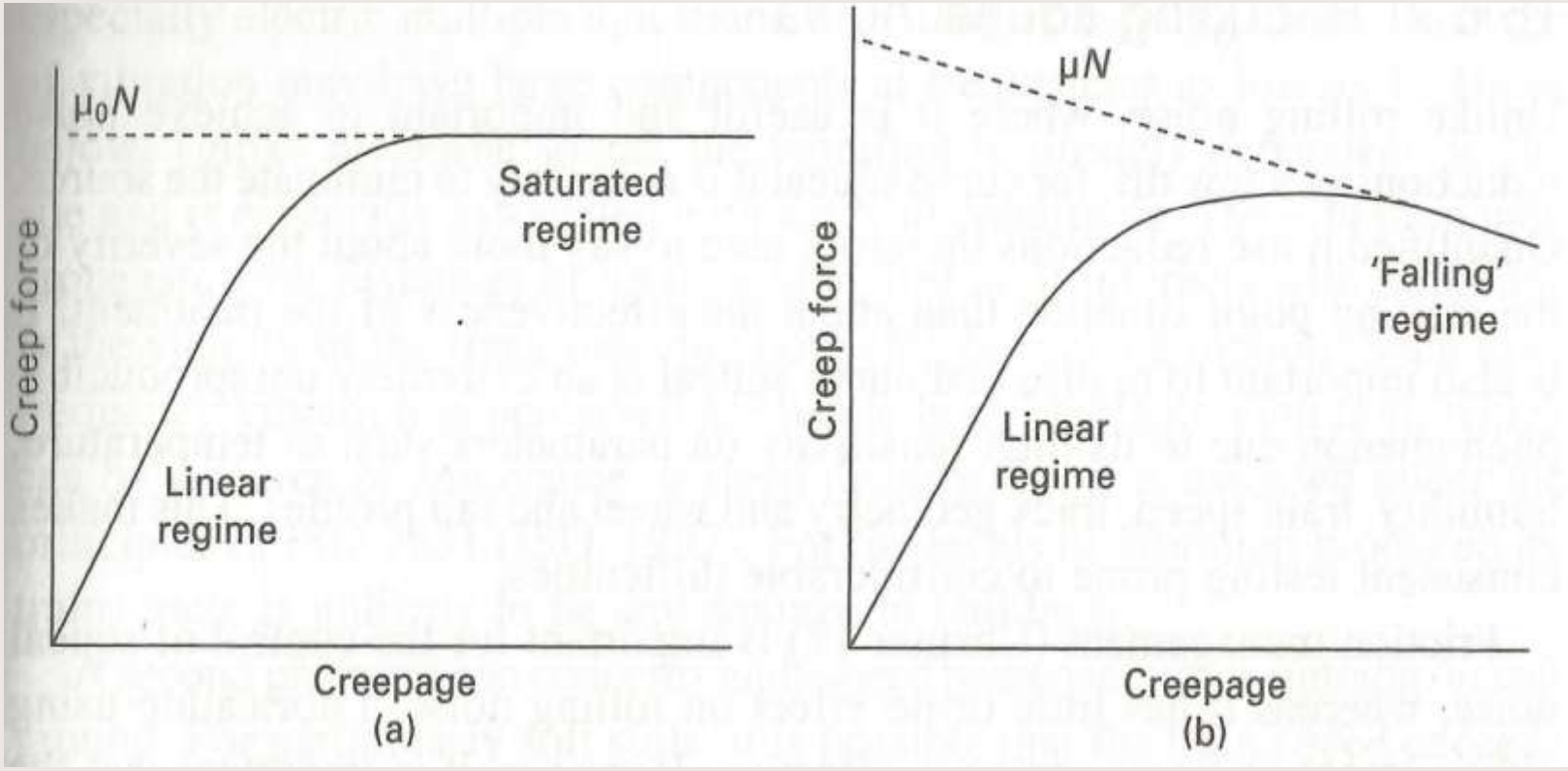


Friction modifier



Creep force = Tangential force.

- Sketch-a: Constant Rolling friction coefficient cases
- Sketch-b: Velocity dependent friction coefficient cases



Corrosion: Definition-

- Corrosion is a slow spontaneous electrochemical in situ degradation of materials in environment which results in loss of section and subsequently of strength.
- Corrosion in steel is reverse extractive metallurgy obeying thermodynamics' 2nd Law in an Oxidising environment.

REASONS FOR CORROSION

1. Concentration Cell formation by water accumulation : Net corrodent influx in Corrodent i.e. Oxygen starved region by Continuous Diffusion along Concentration gradient : this becomes Anode vis-à-vis Oxygen abundant region & gets corroded by the Corrodent.
2. Stress Cell formation by unrelieved tensile stresses : Tensile stress opens up surface cracks : Residual stress gives excessive free or activation energy in this region vis-à-vis the relatively unstressed region thereby forming Anode in the Galvanic Cell & selectively corroding it by the surrounding corrodent.

REASONS OF CORROSION {Contd.}

3. Dissimilar materials' contact : More electropositive material becomes the Anodic {i.e. +ve electrode} half Cell & gets corroded by the corrodent in Electrolysis type Chemical Reaction – Less electropositive material becomes the Cathodic {i.e. –ve electrode} half Cell & gets protected in this completed Galvanic Cell/Circuit.
4. Dry Oxidative Coulomb friction heat induced Corrosion i.e. Fretting.

Pilling Bedworth Ratio : PBR -

- PBR = {Oxide film volume/Oxidised metal volume in oxidative corrosion}
- Filiform Corrosion = Wet {electrolyte accelerated} galvanic corrosion {corrosion filament in rust has bluish green active head & a long reddish brown passive tail}
- PBR = or > 1 means protective film {logarithmic film growth rate rising over parabolic rate} but may give spalling [exfoliation (weathering rocks' peeling)] in ceramics
- PBR < 1 means catastrophic oxidation of porous oxide film {linear rate} for alkali metals mainly

Thank You

