# Stainless Steel Wagon Fabrication

**S. K. Gupta,** B.E., C. Eng., F.I.I.W., F.I.E., M.I.S.N.T., M.I.T.D., M.A.E.

## INTRODUCTION

Indian Railways is the largest Railways in the world, having the largest broad gauge network on which the highest number of passenger carrying Coaches and freight carrying Rolling Stocks ply. Varieties of rolling stocks , Open types, Covered types , Flat types, Tank types ply on Indian Railway tracks carrying millions of tons of food grains, cements, steels, ores, limestone, coal, live stocks, petroleum products, liquefied gases, finished consumer goods, fertilizers, perishable food and other materials and always in bulk quantities.

## A FEW GENERIC PROBLEMS

The problem of high tare weight to low load carrying capacity always forced a search for high strength low cost material . At the same time corrosion of wagons under varying atmospheric conditions in the sub-continent required high cost of maintenance as well as low cycle time of running a rake. The problems become compounded in operation when a single wagon becomes sick in a rake thereby slowing down the movement of all passenger and goods traffic in a sector or section.

Till a few years back the bulk of the rolling stocks were manufactured with conventional low carbon steels. The technology used was also age old.

Wagons were designed and manufactured with riveted joints on overlapping plates, sheets and other structural members requiring large volume and heavy weight of steel structurals.

In between, a few aluminum wagons were manufactured especially for carrying Alumina in the powdered form, using Fluidized Transfer Technology, a few milk wagons were also manufactured with stainless steel.

Now, with the advent of the state of the art technology of comparatively low cost high volume high quality stainless steels production in India, Indian Railways are poised to revolutionize the rolling stock manufacture in the sub-continent. At the same time, vast and rapid development of welding technology have totally replaced the assembly technology of wagon manufacturing.

There was also the problem of the low load carrying capacity of the track and a regular replacement of conventional fabricated crossing in the track. The problems of the track were solved to certain extent by introducing high manganese steel rails and cast manganese steel crossings. Experiments with Vanadium Steel rails are now on to increase the load carrying capacity further. Introducing high strength concrete sleepers instead of conventional steel sleepers helped.

## INDIAN RAILWAYS - FACTS TO KNOW

Freight Carried : 535 Million Tonns

**Production & Acquisition of Rolling Ctocks**

2000 - 01 : 9,903 V.U.
2007 - 08 : 18,223 V.U.
2008 - 09 : 24,491 V.U.

N.B. : Above figures are upto 30.11.08 in this year from 01.04.08

**Market demand**

- 25000 V.U. for Indian Railways
- 2000 V.U. for Domestic Market
- 2000 V.U. for Export Market

**Export market**

Bangladesh, Sri Lanka, Zambia, Kenya, Uganda, Yogoslavia, Australia

**Indian customers**

- Railway Board - Indian Railways
- Petroleum Industry
- Aluminium Industry
- Cement Industry
- Steel Plants
- N.T.P.C.

**Types of Wagon in Demand**

- BOXN Open Wagon
- BCNA Covered Wagon
- BTPN Tank Wagon
- BOBRN Open Hopper
- BRNA Flat Wagon
- BTPGLN Tank Wagon

**Statutory Requirement**

- License as Heavy Engineering Unit from Ministry of Industry, Govt. of West Bengal
- Registration with R.D.S.O.
- License as a factory to operate from Ministry of Labour, Govt. of West Bengal, Gram Panchayat.
- Clearance from West Bengal Pollution Control Board

**Technology Applied**

- Plasma Arc Cutting
- Submerged Arc Welding
- Metal Inert Gas Welding
- Automatic Shot Blasting
- Airless Spray Painting
- Mechanised Rotators, positioners and manipulator for sub-assembly and assembly operations.

**Infrasctuctural Facilities Needed**

- Machineries for cutting, machining, forging
- Equipment for gas cutting and metal arc welding
- Wagon shot blasting facility
- Wagon spray painting facility
- Equipment for compressed air
- Material Handling Equipment

**Standards**

- Manufacturing: I.R.S., I.S.I., U.I.C.IS.
- Quality : ISO 9001
- Environment : ISO 14000
- Welding : ISO 3834

**Infrastructural Facilities Needed**

- Manufacturing workshop connected to railway siding for receipt of steels and despatch of wagons
- Open storage area for storing steel & wheel sets
- Covered storage area for storing consumables
- Open storage area for finished wagons.

## THE NEW MATERIAL AND THE WAGON

Indian Railways have introduced stainless steel of the following composition as the main structural constituent of wagon fabrication

**IRS : M44**

| Element | Percentage |
|---|---|
| Carbon | 0.03 Max. |
| Silicon | 1.00 Max. |
| Manganese | 0.8 - 1.5 |
| Chromium | 10.8 - 12.5 |
| Nickel | 1.5 Max. |
| Phosphorous | 0.03 Max. |
| Sulphur | 0.03 Max. |
| Titanium | 0.07 Max. |

U.T.S. : 50 kg/mm2 Elongation : 25%

The wagons made with IRS : M44 stainless steel are first the BOGIE OPEN WAGON ( 91.6 T ), TYPE - BOXNHL produced by a few wagon manufacturers including JUPITER WAGONS LIMITED situated at Sahagunj, Hoogly, West Bengal, in its new plant with the state-of-the-art technology in material processing and welding. The technologists have gone into the details of the metallurgical behaviour and weldability of stainless steel before defining and planning Jigs, Fixtures, Sub-assemblies, Assembly, Welding Process, Welding Procedures, Welding Consumables.

Previously the Centre Sill, which is the backbone of the wagon was made up of two Z sections welded together. Two end sections were made from IS : 2062 E410 Cu and the Central Part was made of two CRF sections of IRS :M44 steels welded together. Now the entire Centre Sill is a CRF section. Other structural members of Floor, Cross Members, Sole Bar, Side Body, End Body, Doors are made from IRS : M44 material as CRF.

## STAINLESS STEELS AND THEIR CHARACTERISTICS

It is now imperative at this stage, that we must understand what is stainless steel and what are the main characteristics of it. Stainless Steels normally contain 11 to 30 percent Chromium apart from other elements. This Chromium forms a passive oxide layer on the surface which is adherent and regenerative. This Chromium Oxide prevents corrosive attack and gives the steel its "stainless" property. A minimum of 11 percent Chromium is necessary to protect against atmospheric corrosion. Elements like Nickel, Molybdenum, Copper, Niobium and Titanium are added to improve mechanical properties and corrosion resistance. Some of the physical properties of stainless steel are worth mentioning here.

Stainless steel has high coefficient of linear expansion, three times that of carbon steels. Stainless steel has poor thermal conductivity, half that of carbon steels. These result in much higher distortion after welding.

## WELDING OF STAINLESS STEEL

Ferritic stainless steels are softer and more ductile than martensitic steels , but of poorer formability than austenitic steels. Formability is improved by lowering the levels of interstitial elements like Carbon and Nitrogen to below 100 ppm. Also, Ferrite phase does not transform to martensite but susceptile to 475 degree centigrade embrittlement and sigma phase transformation in higher chromium grades. There is also the problem of grain growth during welding leading to brittle structure in HAZ. The grains may be refined only by cold work and recrystallisation

Although there is in general a good

weldability as there is no martensitic transformation but following problems are encountered during and after welding.

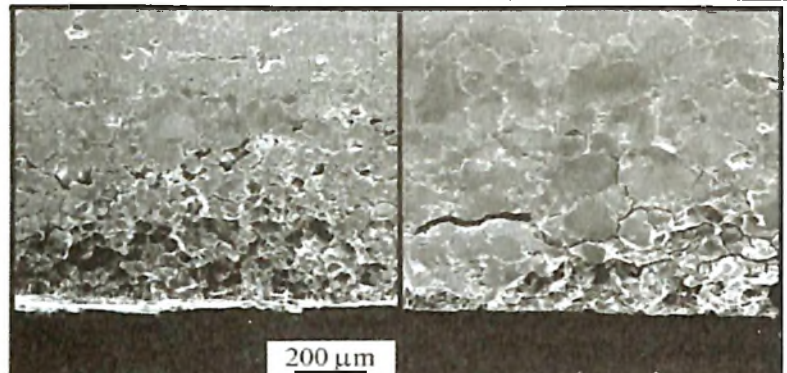
1. Sensitization leading to inter granular corrosion - ( IGC)
2. Hot cracking
3. Stress corrosion cracking - ( SCC)
4. Sigma phase formation leading to embrittlement
5. Higher distortion during welding

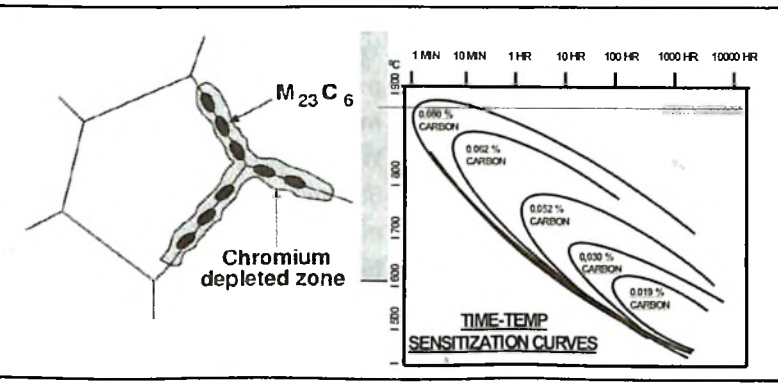
Due to precipitation of the chromium carbide in the grain boundaries at the temperature range of 650 - 800 degrees centigrade areas adjacent to the grain boundaries are depleted of chromium and become susceptile to corrosion. This is encountered to both sides of the Heat Affected Zone.

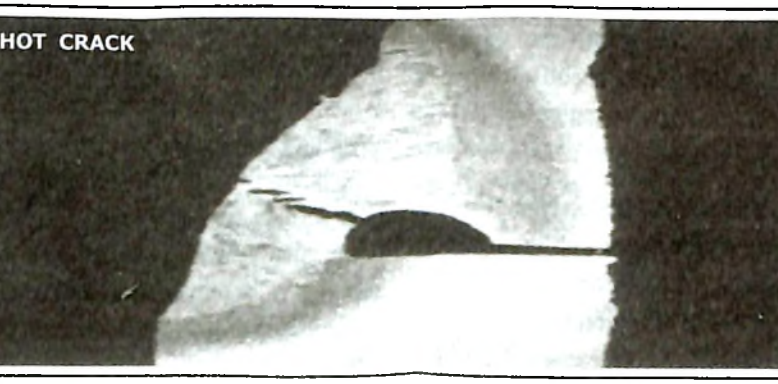
Hot cracking or solidification cracking is caused due to low melting eutectics formed at the grain boundary. As the weld solidifies, in combination with shrinkage stresses it leads to cracks in fully austenitic welds. It is promoted by sulphur, phosphorous, niobium, titanium, nitrogen, and prevented by adjusting weld metal composition to produce 5 - 10 percent ferrite phase in the deposit. It is also prevented by reducing heat input and controlling design stress.

Stress corrosion cracking is the combined action of static stress and corrosion which leads to cracking or embrittlement of the metal. Only tensile stresses cause this type of failure. Sensitized stainless steels are susceptile to an intergranular form of stress corrosion cracking. The stress involved is normally a combination of operating stress in the metal due to fabrication, welding or heat treatment.

IRS:M 44 is designed to have good weldability, but it is susceptile to grain growth.


in the heat affected zone (HAZ), although the grain growth is normally restricted by its chemical composition. Of course it is imperative that the correct welding procedure and correct welding techniques must be followed for IRS:M 44.

The process and the procedure selected are such that the heat input is restricted to a maximum of 1.0 KJ / mm.

## DESIGN FOR CORROSION SERVICE

Much can be done in the detailed design to improve corrosion resistance and obtain better service. There are two cardinal rules :

1. Design for complete and free drainage.
2. Eliminate or seal weld crevices.

## GENERAL GUIDELINES FOLLOWED IN FABRICATION OF IRS : M44

### STORAGE

IRS : M44 plates, Sheets and all structural members are stored separately away from plain carbon steel storage to avoid contamination. All racks and stallages have stainless pads welded to avoid direct contact. Lifting tackles made from carbon steels are used with stainless steel pads.

### WORK AREA

Fabrication area for IRS : M44 have been totally separated from other fabrication areas. Shearing, Plasma Cutting, Arc Gouging, Bending operations are conducted under strict vigilance to avoid contamination. All paints, oils and greases are meticulously removed before operations in machines and equipments.

### SHEARING

Most of the plates and sheets of IRS : M44 are cut to size by shearing. The shear blade's (high carbon high chromium tool steel) clearance is set to produce burr less edges. Grinding and resetting of the blades are done regularly.

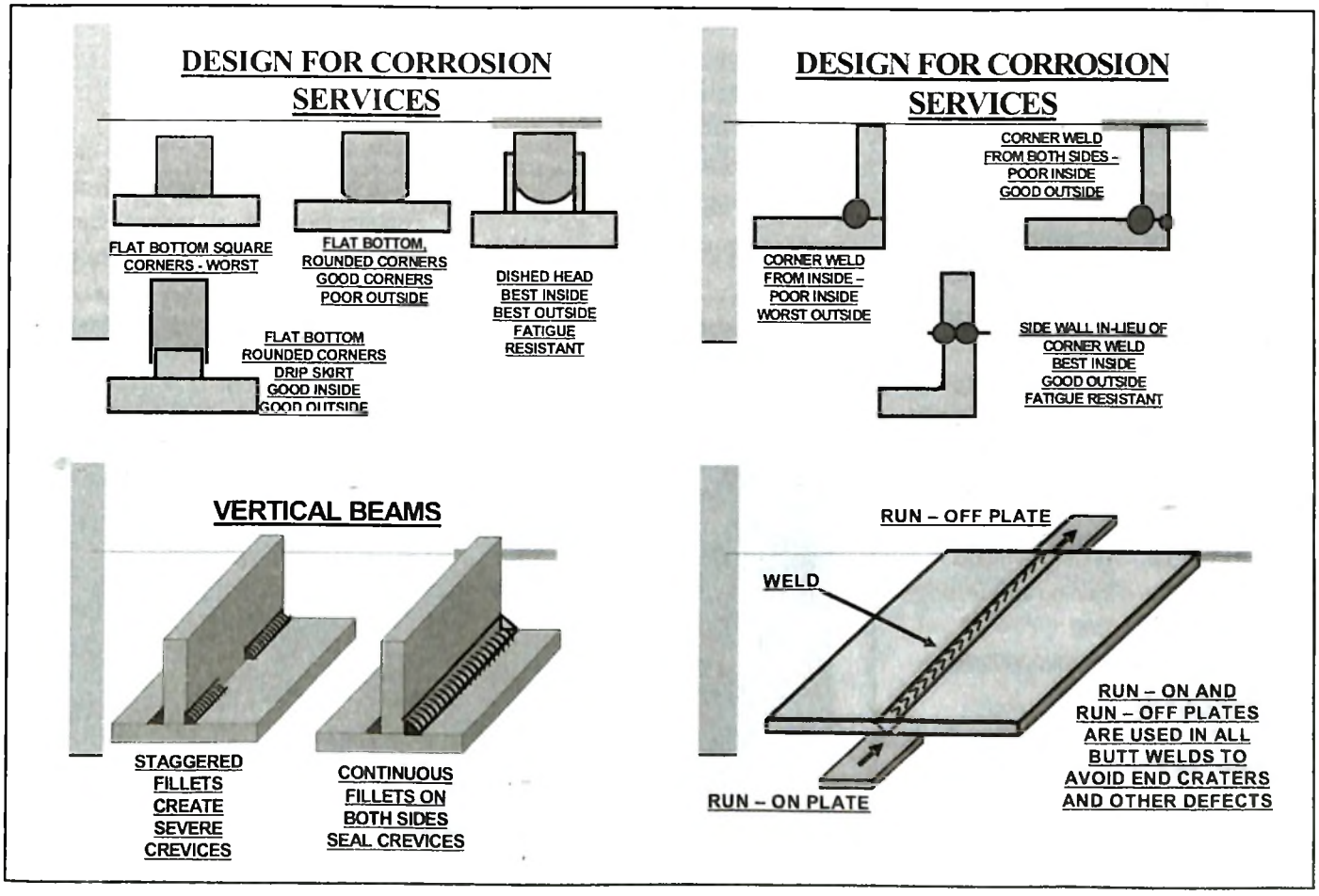
### PLASMA CUTTING

Plasma cutting of small and large components are done extensively especially for profile cutting. Apart from the portable plasma cutting machines a CNC PLASMA CUTTING MACHINE is used with programmed operations. Plasma cut edges are normally clean edges. Discoloured or burred eges are cleaned with stainless steel wire brush or grinding with aluminum oxide discs.

### ARC AIR GOUGING

There are two points of concern when arc gouging is used on IRS : M 44 materials.

The first one is the concern for carbon contamination and the second one is nitrogen pick up by the dross and the molten materials not blown away by the



air stream. This nitrogen if allowed to enter into the weld metal will promote formation of austenite thereby reducing the ferrite content to such a level which may cause solidification cracking. The correct technique is a pushing inclination to the carbon electrode with the air stream directed behind the advancing electrode with correct electrode extension and with the correct air pressure. Correct clean up of the cut edges is essential to remove all the dross exposing fresh surface by proper grinding

**MANUFACTURING PROCESS**

**BOXN - HL WAGON**

**Technology Applied**

- Plasma Cutting
- Submerged Arc Welding
- Metal Inert Gas Welding
- Automatic Shot Blasting
- Airless Spray Painting
- Mechanised Rotators, positioners and manipulator for sub-assembly and assembly operations.

**Standards Used**

- IS 813 : 1986 for welding symbols
- IS 812 : 1957 wor welding terms
- IS 7310 (Part 1)-1074 for Welders' Qualification Tests
- IS 9595 : 1996 for welding joints
- IS 823-04, 15.2.7 for rectification of weld defects
- IS 4353-1995 - submerged arc welding
- IS 813 - 1986 - Welding Symbols
- IS 817 - 1966 - Training and Testing of Welders
- IS 7307 - 1974 - Welding procedure approval test
- IS 3613-1974 - Wire - Flux combination for saw.

The wagon assembly is made in the production line with the main sub-assemblies as under :

Manufacturing Process BOXN - HI Wagon

1 Centre Sill sub-assembly
2 Centre Pivot Filler Support sub-assembly.
3 Cross Bars sub-assemblies.
4 Bolster sub-assemblies.
5 Underframe sub-assembly
6 Side Body sub-assemblies.
7 End Body sub-assemblies
8 Door sub-assemblies

Components for each of the sub-assemblies are processed through the following operations :

1. Shearing.
2. Hand Plasma Cutting.
3. CNC profile Plasma Cutting.
4. Drilling.
5. Edge Planing / Bevelling.
6. Straightening / Rolling.

While processing IRS M 44 material strict supervision is made to avoid any contamination of oil, grease, carbonaceous materials, steel wire brush etc.

CNC Plasma cutting of profiles

For each and every sub-assembly, Jigs and Fixtures especially designed to ensure accuracy as well as productivity are used. Each locating surfaces in the Jigs and Fixtures are normally Pads of IRS - M 44 material to avoid contamination.

BOXN - HL wagon is specifically designed as an all welded structure

The weld lengths of the wagon in terms of butt welds and fillets are :

1. Single Bevel (4, 5, 6, 7, 8, 10 and 20 mm Plates) : 178 meters
2. Square Butt (3, 4, 6, 7, 10 Plates) : 96 meters
3. Double Bevel (8 mm Plate) : 7 meters
4. Fillet Welds :
   - (i) 3 mm : 568 meters
   - (ii) 4 mm : 46 meters
   - (iii) 5 mm : 169 meters
   - (iv) 6 mm : 36 meters
   - (v) 8 mm : 5 meters
   - (vi) 10 mm : 5 meters

## WELDING PROCESSES

IRS : M 44 can be welded with ease by Manual Metal Arc Welding, Metal Inert Gas Welding and Tungsten Inert Gas Welding with different combinations of quality and productivity. Submerged Arc Welding is used with care controlling the heat input as much as practicable.

## MANUAL METAL ARC WELDING

MMAW though versatile in nature and can be used in all positions, its use in stainless steel wagon welding is restricted to mainly tack welding and relatively small lengths of welding where use of MIG is non productive. In MMAW.:

1. Direct Current Electrode Positive (DCEP) is used.
2. Rutile or Basic coated electrodes are preferred characterized by low slag inclusions.
3. All electrodes must be pre-heated.
4. As short length of arc as possible to be used with low current.
5. Stringer bead rather than weaving is preferred.

**Electrodes to be used in MMAW**

| Material | IRS Class | AWS Code for Electrode |
|---|---|---|
| IRS:M44 to IRS:M44 | Class M2 | E 19.9<br>LR26 |

**Recommended current and Voltage Ranges in MMAW**

| Electrode | | Voltage | Current |
|---|---|---|---|
| Type | Diameter | Voltage | Ampere |
| RUTILE | 1,6 | 19-21 | 30-40 |
| | 2.0 | 20-22 | 40-55 |
| | 2.5 | 20-22 | 60-75 |
| | 3.25 | 21-23 | 95-115 |
| | 4.0 | 21-23 | 120-140 |
| BASIC | 1.6 | 24-30 | 35-45 |
| | 2.0 | 24-30 | 45-60 |
| | 2.5 | 24-30 | 65-80 |
| | 3.25 | 24-30 | 100-120 |
| | 4.0 | 24-30 | 130-150 |

## GAS METAL ARC WELDING (MIG / MAG)

Due to the introduction of variety of wire compositions and Flux Cored Wires in MIG / MAG welding process immense increase of productivity along with the desired quality is achieved. As most of the welding in Floor Plate, Side Body, End Body, Door, Side Stanchion sub-assemblies is continuous and of equal sizes use of MIG is preferred and adopted in SS Wagon welding. Again, as the steel sections are not very thick and restricted to mainly 3 to 8 mm use of low heat input is preferred. This is achieved by using Synergic Pulsed MIG welding sets with auto control of pre-set welding parameters. In fact, about 90% of the welding is carried out by MIG welding.

In GMAW :

1. Direct Current Electrode Positive (DCEP) is used
2. Shielding gases and their combinations used are :

   Argon with 1 to 2 percent Oxygen

   Argon with 5 percent Carbon dioxide.
3. Flow rate is minimum 15 litre per minute for best result.

| Recommended Electrodes and Shielding Gases | | | | |
|---|---|---|---|---|
| Materials to be joined by GMAW | IRS Class | AWS Code | Wire Type | Shielding Gas |
| IRS M44 to IRS M44 | Class VI | ER 308L | Solid | ARGON +1-5% O |

| Recommended Welding Parameters in MIG/MAG Welding | | | | | |
|---|---|---|---|---|---|
| Type of Art | Position | Wire Dia mm. | Current Amp | Voltage Volt | Speed mm/sec. |
| Short | Flat | 0l.8 | 130-140 | 22-24 | 3.0-4.5 |
| Arc | Vertical | 0.8 | 110-130 | 20-22 | 3.0-4.5 |
| Spray | Flat | 1.6 | 325-375 | 25-28 | 3.0-4.5 |

Welding of Side Body


| Recommended Welding Parameters in MIG/MAG Welding | | | | | |
|---|---|---|---|---|---|
| Type of Art | Position | Wire Dia mm. | Current Amp | Voltage Volt | Speed mm/sec. |
| Short | Flat | 0l.8 | 130-140 | 22-24 | 3.0-4.5 |
| Arc | Vertical | 0.8 | 110-130 | 20-22 | 3.0-4.5 |
| Spray | Flat | 1.6 | 325-375 | 25-28 | 3.0-4.5 |


## SUBMERGED ARC WELDING

Submerged Arc Welding is used to weld two Z Sectios to form the Centre Sill, the backbone of the wagon Underframe.

### Welding Consumables

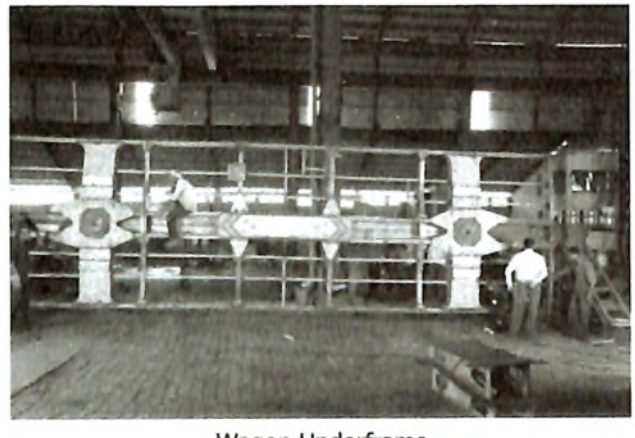
Submerged Arc Welding

- W4 Grade of wire and
- Agglomerated or
- Granular Flux of F4 Grade are used
- Agglomerated Fluxes are pre-heated to the temperature of 250°C for 60 min. in the drying oven just before use.

Submerged Arc Welding of Centre Sill

## WAGON WELDING PROCEDURES

Welding Procedures for all the sub-assemblies are worked out before the production starts. Some of the welding procedures are shown below as examples only to reduce the voluminous content to publish.



Wagon Underframe

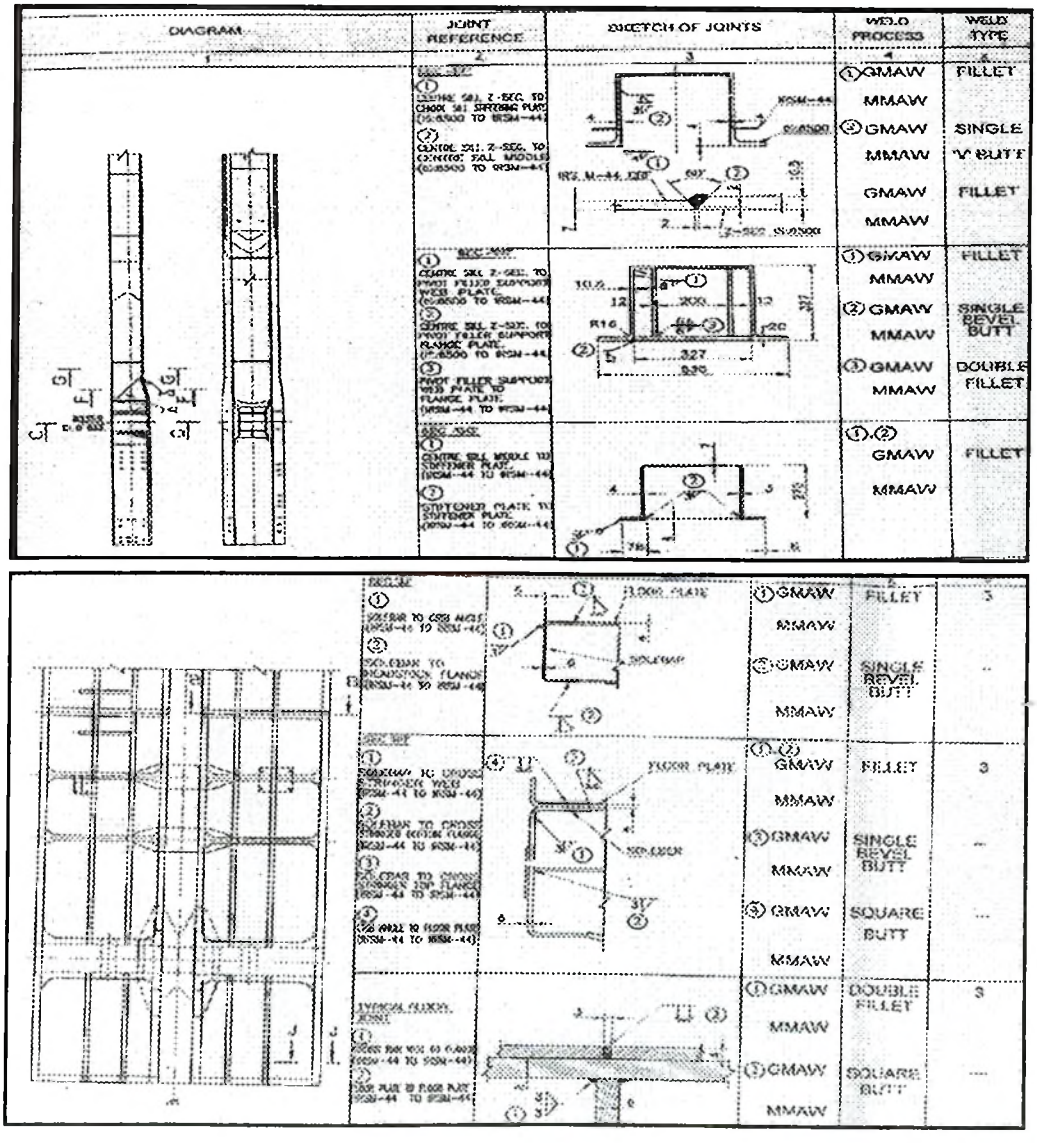
## CONCLUSION

In this paper a broad outline is provided about the freight carrying in India by the Indian Railways through Rolling Stocks manufactured indigenously. Customer needs have forced updation of technology, materials, processes and management of the systems which are being executed at an unprecedented rapid pace. One such advancement is in the introduction of Stainless Steel Wagons as bulk load carriers on the track. R.D.S.O., the Research Design and Standards Organisation wing of Indian Railways have done a very good job in detailing the process, procedure, consumable selection and general guidelines of allied work. It is now up to the manufacturers to develop further the technology and its implementation for enhancement of productivity and quality. Automation is definitely possible improving both productivity and quality, but it needs substantial investment and the return on investment naturally depends upon bulk order from the Railways and other customers at large.

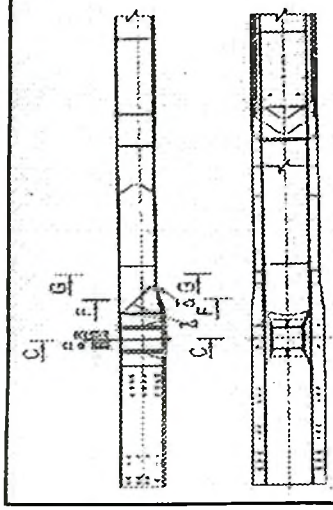
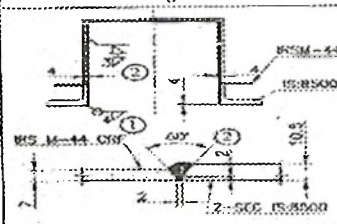
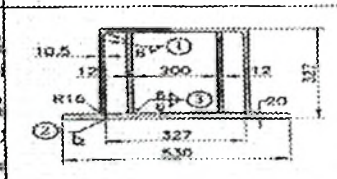
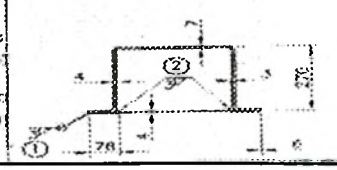

## ACKNOWLEDGEMENT

1. JUPITER WAGONS LTD.
2. R.D.S.O. Document Ref. WD - WPS - BOXNHL - 08
3. NiDI Reference Book. Series No. 11007.
4. Indian Welding Journal. Vol. 41.

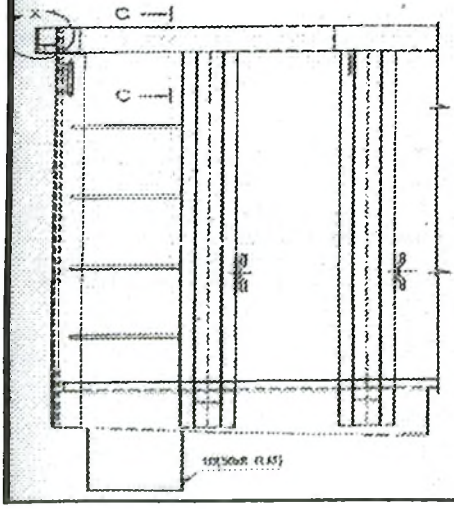
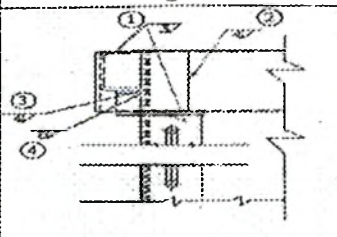
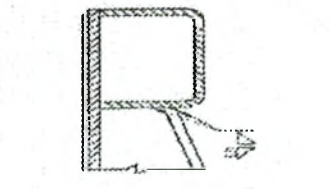

## UNDERFRAME WELD DETAILS



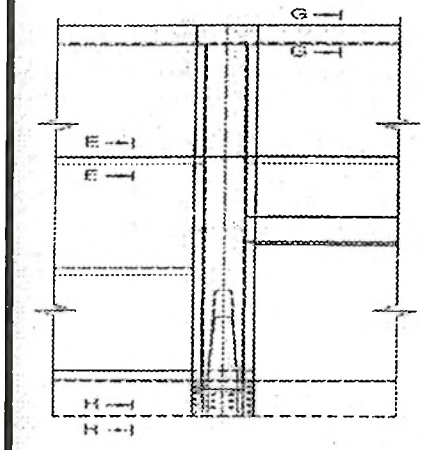
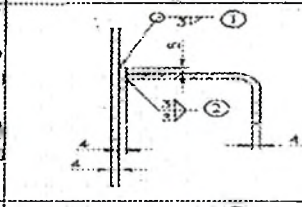
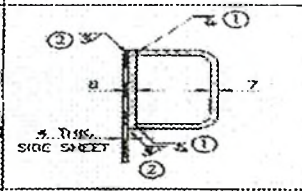
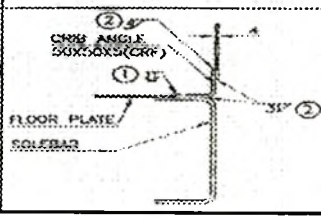
## UNDERFRAME WELD DETAILS

| DIAGRAM | JOINT REFERENCE | SKETCH OF JOINTS | WELD PROCESS | WELD TYPE |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|  | ① CENTRE SILL Z-SEC. TO CENTRE SILL STIFFENING PLATE (IS:8500 TO IRSM-44)<br>② CENTRE SILL Z-SEC. TO CENTRE SILL MIDDLE (IS:8500 TO IRSM-44) |  | ① GMAW<br>MMAW<br>② GMAW<br>MMAW<br>GMAW<br>MMAW | FILLET<br><br>SINGLE 'V' BUTT<br><br>FILLET<br> |
| | ① CENTRE SILL Z-SEC. TO PIVOT FILLER SUPPORT WEB PLATE (IS:8500 TO IRSM-44)<br>② CENTRE SILL Z-SEC. TO PIVOT FILLER SUPPORT FLANGE PLATE (IS:8500 TO IRSM-44)<br>③ PIVOT FILLER SUPPORT WEB PLATE TO FLANGE PLATE (IRSM-44 TO IRSM-44) |  | ① GMAW<br>MMAW<br>② GMAW<br>MMAW<br>③ GMAW<br>MMAW | FILLET<br><br>SINGLE BEVEL BUTT<br><br>DOUBLE FILLET<br> |
| | ① CENTRE SILL MIDDLE TO STIFFENER PLATE (IRSM-44 TO IRSM-44)<br>② STIFFENER PLATE TO STIFFENER PLATE (IRSM-44 TO IRSM-44) |  | ①,② GMAW<br>MMAW | FILLET<br> |

## BODY END WELD DETAILS

| DIAGRAM | JOINT REFERENCE | SKETCH OF JOINTS | WELD PROCESS | WELD TYPE |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|  | ① TOP COPING END COVER PLATE TO TOP & BOTTOM OF SIDE TOP COPING/TOP & BOTTOM OF END TOP COPING (IRSM-44 TO IRSM-44)<br>② TOP COPING END COVER PLATE TO SIDE OF SIDE TOP COPING/SIDE OF END TOP COPING (IRSM-44 TO IRSM-44)<br>③ CORNER STANCHION TO SIDE TOP COPING/END TOP COPING (IRSM-44 TO IRSM-44)<br>④ CORNER STIFFNER TO CORNER STANCHION (IRSM-44 TO IRSM-44) |  | ① GMAW<br>MMAW<br>②,③ GMAW<br>MMAW<br>④ GMAW<br>MMAW | FILLET<br><br>FILLET<br><br>FILLET<br> |
| | SIDE STANCHION TO SIDE TOP COPING CAP (IRSM-44 TO IRSM-44) |  | GMAW<br>MMAW<br>GMAW<br>MMAW | SINGLE BEVEL BUTT<br><br>FILLET<br> |

## BODY SIDE WELD DETAILS

| DIAGRAM | JOINT REFERENCE | SKETCH OF JOINTS | WELD PROCESS | WELD TYPE |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|  | DETAIL AT 'A'<br>① SIDE MIDDLE COPING TO SIDE WALL PLATE (IRSM-44 TO IRSM-44)<br>② SIDE MIDDLE COPING TO SIDE MIDDLE COPING BACK PLATE (IRSM-44 TO IRSM-44) |  | ① GMAW<br>MMAW<br>② GMAW<br>MMAW | FILLET<br>DOUBLE FILLET |
| | SEC-CC<br>① SIDE TOP COPING PLATE TO SIDE TOP COPING CRF (IRSM-44 TO IRSM-44)<br>② BODY SIDE PLATE TO SIDE TOP COPING CRF (IRSM-44 TO IRSM-44) |  | ① GMAW<br>MMAW<br>② GMAW<br>MMAW | SINGLE BEVEL BUTT<br>FILLET |
| | SEC-DD<br>① FLOOR PLATE TO CRS ANGLE (IRSM-44 TO IRSM-44)<br>② BODY SIDE PLATE TO CRS ANGLE (IRSM-44 TO IRSM-44)<br>③ SOLE BAR TO CRS ANGLE (IRSM-44 TO IRSM-44) |  | ① GMAW<br>MMAW<br>② GMAW<br>MMAW | SQUARE BUTT<br>FILLET |

WAGON ASSEMBLY WELDING ON ROTATING MANIPULATOR

PAINTING AND AIR BRAKE TESTING

SQUEEZE LOAD TESTING