Second Report

INDIAN ENGINEERING HERITAGE

(RAILWAYS)

Indian National Academy of Engineering

January 2008

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Cover Photo: *Fairy Queen*

The Fairy Queen has been honoured as the oldest working Steam Locomotive in the world by the Guinness Book of Records. It recently won the coveted National Award as the most innovative tourist product introduced. Built in 1855, this beauty is a celebrated creation of the British firm of Kitson, Thompson & Hewitson for the East Indian Railway. It is a delight for steam lovers all over the world.

The Fairy Queen takes 50 discerning passengers from around the world on weekend trips to Alwar in Rajasthan.

FOREWORD

India has traditionally been a land of brilliant engineers and is proud to possess examples of extraordinary engineering feats in diverse areas such as monuments; irrigation systems; bridges; metallurgy; engineering goods; engineering materials and textiles etc. The task of documenting these accomplishments is a mammoth one and the literature available in libraries of Archeological Survey of India, State Museums, Professional Societies and with individuals is fragmented, and not easily accessible.

In this direction, Indian National Academy of Engineering (INAE) constituted Experts Study Groups on Railways, Civil Engineering and Metallurgy to compile information and documentation on the outstanding engineering achievements and create an Archives of Indian Engineering Heritage in the Library of the Academy. Currently, it has three components, viz., Railways, Civil Engineering and Metallurgy which are headed by Shri VK Agarwal, Prof RN Iyengar and Dr. Baldev Raj respectively.

The history of the Railways though less than 150 years old, is complex and not systematically documented. There is a burning need to examine and collate the data available, and present a comprehensive historical Report on the Indian Railways. A study of this nature helps in improving the awareness, preservation and appreciation of this great engineering heritage. The first Report on Indian Engineering Heritage (Railways) was prepared by the Study Group which broadly covers History, Railway Gauge, Permanent Way, Railway Bridges, Railway Construction Projects, Railway Locomotives and other Railway Stocks, Mechanical Workshops, Production units and Signalling and Telecommunication. After the first publication, a number of new areas were taken up. Therefore, the Second Report is an updated version of the earlier Report and also includes some new areas such as use of Geotextiles· Mechanised Maintenance of Track including Track Machines; Railway Bridges, Railway Locomotives and other Rolling Stock; Electric Multiple Units (EMU); Coaches and Wagons (Freight Stock) etc and D.C. and A.C. Electrification

I have no doubt that this exercise will go a long way in creating awareness of the history of the Railways and generating sustained interest in the abundant engineering heritage of India. It is hoped that this Report on Indian Engineering Heritage (Railways) will be well received by the engineering community.

Dr. P.S. Goel
President, INAE

PREFACE

FIRST PRELIMINARY REPORT [12th Dec-2000]

The Indian National Academy of Engineering (INAE) is a peer body of around three hundred reputed Engineers in the country. The Academy aims to bring together top professionals in various branches of engineering to discuss issues at the interface between engineering and society at large. In recent decades, engineering has come to have a profound impact on every aspect of society and affects the health and welfare of humanity itself. Those impacts can be benign and at times, malignant too. It is the endeavour of the INAE to evolve and present optimum solutions for the consideration of policy makers and for the enlightment of the general public. The Academy was registered on the recommendation of the Ministry of Civil Supplies on April 20, 1987 by the Registrar of Societies and formally inaugurated on April 11, 1988 at New Delhi. The Academy has been recognized by the Department of Scientific and Industrial Research as a Scientific and Industrial Research Organisation (SIRO) and is now an autonomous Institution aided by the Government of India (Department of Science and Technology).

India has a long tradition of outstanding engineering achievements in diverse fields, such as monuments, bridges, irrigation systems, metallurgy, textiles, etc. The documentation on these achievements is available in the libraries of Archeological Survey of India, State Museums & Libraries with professional societies, Institutions and with individuals. A major initiative taken by the Academy in 1996 was to constitute Expert Study Groups on Railways, Metallurgy and Civil Engineering to create an Archieves of Indian Engineering Heritage. In the Meeting of the Governing Council held on 24.02.96 it was decided that INAE should set up teams to study and compile information & documentation on the outstanding Engineering achievements. The Council further decided to request the following Fellows to head the study groups for collection and documentation of the source material for the selected disciplines:

Metallurgy	-	Prof. S Ranganathan
Civil Engineering	-	Prof. RN Iyengar
Railways	-	Shri RK Jain

After accepting the assignment, the Chairman of Railways group held preliminary discussions with INAE officers and experts of National Academy of Sciences to clarify the approach to the project group of voluntary railway experts who held their first meeting on 10.05.96 attended by Dr. YP Anand, Shri RK Vir and Shri MM Agarwal. The Group gradually enlarged to a strength of seven as under by 04.02.96.

Shri RK Jain	Former Chairman Railway Board
Shri YP Anand	Former Chairman Railway Board

Shri RK Vir	Former General Manager, Chittaranjan Locomotive Works, Chittaranjan,
Shri OP Jain	Former Director General, R.D.S.O. Alambagh, Lucknow.
Shri LR Gosain	Former General Manager, Integral Coach Factory, Perambur.
Shri MM Agarwal	Former Chief Engineer, Indian Railways and currently Executive Director I.P.W.E. (India)
Shri RR Bhandari	Working as Chief Personnel Officer, S.E. Railway, Calcutta, and a reputed author on Railway developments and history.

The Group held 21 Nos Group meetings upto 31.08.2000 besides several meetings with Senior Officers of Railway Board, Zonal Railways, Training Institutions, RDSO, Rail Transport Museum, and formed subgroups with a few volunteers to collect data and material in specialized sub-fields.

Though comparatively a fairly recent Railway history (less than 150 years old), the collection of archival material and data for Indian Railways is complex as it is wide spread and most of it has not been properly documented. This exercise by INAE is a step in this direction. The present attempt could only be a selective exercise from the material readily available and is in no way either exhaustive or final. More material and evidence will become available in future necessitating further modifications and additions to this venture. Even otherwise technology is always growing every day. This attempt will create a new interest and awareness in finding out the rich heritage.

The problem in collecting reliable material was aggravated because of very few people being interested in the hard research work to dig out the material, further compounded by the fact that INAE had very limited financial resources. It could make available only Rs.10,000/- in each of the years 1996-97 and 1997-98. While individual efforts were made by Members in collecting the material based on their past experience and knowledge in their personal visits outside Delhi, these could not be edited or studied in sufficient detail due to lack of supporting officers. It was at this stage that on a suggestion from the Group, INAE approached Railway Ministry which agreed to support the project and provided assistance of Rs.2 lakhs upto 31.03.2000 to INAE. The Group received the first instalment in September, 98 and worked to revitalize the activity which had become dormant due to lack of resources, particularly for almost a year.

The first three chapters in this document deal with Growth, Management structure, and the History of track gauge of IR, to give an idea how IR has been continuously seized with variety of problems and reviewing its policy. It is interesting to note that during its history Indian railway system was built and managed by following eight different agencies.

1. Lines constructed and managed by the guaranteed railway companies.
2. Lines constructed and managed by the State.
3. Lines constructed and managed by the assisted companies.
4. State Railways worked by the guaranteed companies.
5. Lines owned by the princely States but worked by the Government.
6. Lines owned and managed by the princely States.
7. Lines owned by the princely States and worked by private companies.
8. Foreign lines.

Finally, after Independence emerged the rightful policy of integrating the existing systems into one constructed and managed by the State (Government through Ministry of Railways-Railway Board).

Subsequent chapters have been arranged for engineering disciplines Civil, Mechanical, Electrical, Signalling, etc. They will be expanded as more material gets collected and edited, besides the addition of other disciplinary activities in technical fields as sufficient contribution is made by them also for IR. A table of Contents and an List of Abbreviations have been given in the beginning for facilitation and a Bibliography at the end, for a study in depth.

The Group acknowledges the assistance provided by the National Academy of Sciences; Chairman, members, Additional members and other officers of Railway Board; General Managers of Zonal Railways and their officers; Director General, RDSO; Principal, Railway Staff College; Directors of all the four Central Training Institutions; Director Rail Transport Museum and several other for their valuable discussions, contributions, library and other assistance, but for which this exercise could not have been successful. We acknowledge also the valuable help given in researching by several dedicated individuals whose devotion and research mindedness has made the material available for several chapters. The Group would like to particularly mention the names of Sarvashri Rama Kant Gupta, GS Agarwal, KP Mathur, GP Dudeja, Late Shri SK Kanjilal, Raj Mehndiratta and GD Patwardhan.

The Group feels that this attempt will create the necessary interest in the public mind and railway engineers, to appreciate the great efforts done by their predecessors in giving the present IR system its technological and other uniqueness in the given political, social and economic circumstances which were not always very favourable.

Sd/-
(Raj Kumar Jain)
December 12, 2000 **Chairman, Study Group**

FIRST REPORT – SEPTEMBER 2002

The First Preliminary Report submitted on 12th December, 2000 by Shri Raj Kumar Jain, to the INAE has been updated by the newly constituted Group consisting of the following members working under the Chairmanship of Shri V.K. Agarwal. This Group has some members from the earlier Group also, who very kindly consented to assist the newly formed Group.

New Members

1.	Shri V.K. Agarwal	–	Former Chairman, Railway Board (Chairman of Study Group)
2.	Shri L.C. Jain	–	Former Additional Member (Works)
3.	Shri Hari Mohan	–	Former Director General, RDSO
4.	Shri A.K. Jain	–	Former Additional Member (Elect.)
5.	Shri Chandrika Prasad	–	Former Additional Member (S&T)
6.	Shri K.P. Singh	–	Former Executive Director (Works) and currently Executive Director IPWE (India)

Members from the earlier Group

7.	Shri RK Jain	–	Former Chairman Railway Board
8.	Dr. YP Anand	–	Former Chairman Railway Board
9.	Shri RK Vir	–	Former General Manager, Chittaranjan Locomotive Works, Chittaranjan,
10.	Shri MM Agarwal	-	Former Chief Engineer, Indian Railways
11.	Shri RR Bhandari	-	Presently Chief Mechanical Engineer, S. Railway

The newly constituted Group in its meetings held on 22.03.2002, 30.05.2002 and 31.07.2002 and Sub-Group meetings has effected minor changes in the text of the Report and some Figures, Maps and Photos have also been added as considered necessary.

-Sd-
(V.K. Agarwal)
Chairman Study Group

September 30th, 2002

SECOND REPORT – SEPTEMBER 2006

The "First Report – Indian Engineering Heritage (Railways) – Sept. 2002" referred to above was sent to the INAE Secretariat on 21.10.2002 and was published under the title "Indian Engineering Heritage-Railways" (2004) by The Indian National Academy of Engineering.

Additions and modifications to the Report is an ongoing process and the Study Group has continued its efforts to make new additions and supplement the existing data. Due to preoccupation the Study Group members with several other activities, and very limited financial support for collecting data from the old records, process has been rather slow. Meetings of the Study Group have been held on an average once every two months. The compositon of the present Study Group is more or less same except that after Shri L.C. Jain, Former Additional (Works), left due to health reasons two new members viz S/Shri B.K. Agarwal, Former Advisor Land Management, and S.P.S. Jain, Former Member Engineering, were co-opted. Thus the Study Group currently has twelve members covering all the Engineering disciplines of the Indian Railways.

The "Second Report- Indian Engineering Heritage (Railway)-September 2006" is an updated version of the earlier report and also includes some new areas like:

- In the Chapter on "Permanent Way" details concerning Ballast, Formation, Use of Geotextiles, Track Maintenance, Measured shovel Packing, Directed Track Maintenance, Meachanised Maintenance of Track including Track Machines have been added.
- The Chapter on "Railway Bridges" includes details about some more bridges. Further, details about Civil Engineering and Bridge Workshop etc. also now find a place.
- The Chapter on "Railway Locomotives and other Rolling Stock" has been re-written and in addition to details about Steam Locomotives, aspects concerning modern Diesel and Electric locomotives, Electric Multiple Units (EMU), Coaches, and Wagons (Freight Stock) have been fully covered.
- While the Chapters on D.C. and A.C. Electrification have been updated it was found necessary to cover aspects of "Train Lighting and Air Conditioning" in a new Chapter.
- Work for the Chapter on "Urban Railway Transport" is underway and this will be included in the next Report

I as Chairman of the Study Group will like to thank all members of the Study Group and also all those who helped in this effort without any financial remuneration and collected data and information from old records and sources.

(V.K. Agarwal)
Chairman Study Group

15th September 2006

SECOND REPORT - MARCH 2007

The "Second Report – Indian Engineering Heritage (Railways) – September 2006" referred to above has been slightly modified and updated.

(V.K. Agarwal)
Chairman Study Group

17th May 2007

Contents

CHAPTER I

RAILWAYS IN INDIA (INDIAN RAILWAYS)

1.1 THE BEGINNING

1.1.1 The railway age started in England on September 27, 1825 with the commissioning of railway line from Stockton to Darlington. Its success was followed by railway development in many other countries - France in 1829, U.S.A. in 1830, Germany in 1835, Russia in 1837, Holland and Italy in 1839, Spain in 1848 etc.

The construction and development of railways in India involved heavy investments of British Capital. The terms under which this capital moved and the long drawn struggle in discussions and negotiations preceding it, are well documented in Daniel Thornero's book `Investment in Empire: British Railways and Steam Shipping Enterprise in India 1825-1849", and in "Railway Construction in India, Vol –I" by Indian Council of Historical Research. A substantial portion of British Capital was rechannelled back to U. K. for purchase of materials produced by British industries (entire rolling stock, rails, fabricated bridges, stations, workshops including simple structures like hospitals, clubs and housing).

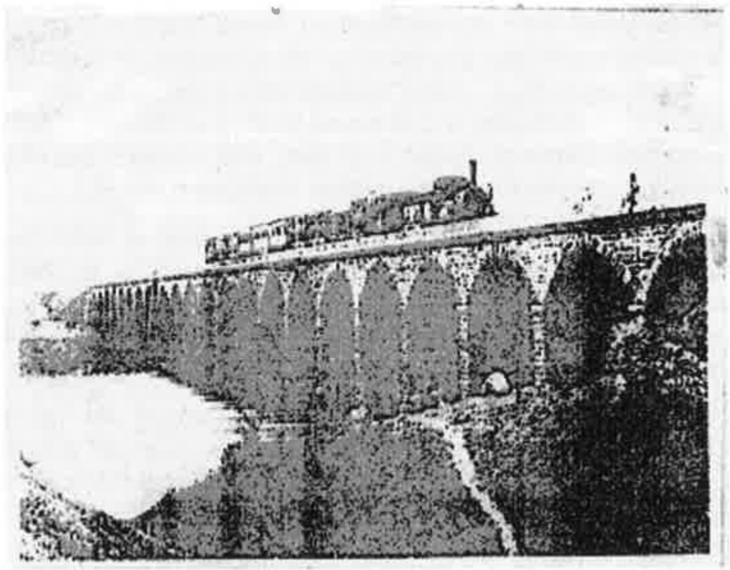
1.1.2 The first unsuccessful attempt for preparing a railway project in India was made in 1831 for the Presidency of Madras for having a railway line hauled by horses. An experimental small length of railway line was laid near Chintadrapettah Bridge drawn by manual effort to demonstrate the very low effort in pulling loaded carts on railway line on a slightly inclined plane.

1.1.3 To merchants and manufacturers of early Victorian Britain, India was an unsatisfactory place. They could not reconcile themselves to the fact that England's greatest overseas possession took only one-tenth as much per capita of British manufacturers as Brazil, which did not even belong to Britain. The first step was the ending of East India Company's monopoly of trade with India in 1813. Twenty years later the Company's control over the movement of private British merchants within India was terminated. During these years the British exports increased. To put this trade on a modern footing, British businessmen campaigned for the application to India of two of the principal achievements of Industrial Revolution, "the steamship" and "the steam railway". Systematic efforts to obtain government support for steamship lines began in 1820's and 1830's and reached their climax in 1840 with signing of an agreement for a regular service to be operated by Peninsular and Oriental Steam Navigation Company, with the aid of annual subsidies from British Government and the East India Company.

1.1.4 The next step was to cover India with a net work of railways. The railway promoters strove to convince the heads of the East India Company that railways would reduce the Company's expenses in India and strengthen its political and military power. R. M. Stephenson, the promoter of East Indian Railway Company (EIR) played a key role for bringing Railways in India. In 1845-46 a trial survey was conducted by him to link Calcutta with Delhi and later he requested Board of Directors of the Company to dispatch men and materials by sea for the construction of the Railway line in May/June 1847 to utilise the cold working season of 1847-48. After a lot of correspondence and crossing various hurdles, the first tender for constructing a railway line of 61 km (38 miles) between Howrah and Pandooah was sanctioned by the Governor General of India. The letter was signed by Mr. F. J. Holliday on September 6,1850. Due to certain unfortunate events in supply of equipment, the line could only be commissioned on August 15,1854 for a length of 38. 4 km (24 miles).

1.1.5 Simultaneous similar vigorous efforts were made in both the Presidencies of Bombay and Madras to construct Railway lines linking the two towns to the hinterland points supported by the respective government officials and merchant community resulting in formation of Great Indian Pennisular Railway company (GIP) and Madras Railway Company along with others like Great Western of Bengal Railway Company, Great North of India Railway Company, Direct Bombay and Madras Railway Company, etc. All these companies individually and jointly lobbied for Government support for railways in India & U. K. Among the Indians, Shri Jagannath Nana Shanker Shett from Mumbai formed a Company in 1843 for construction of Railways in India which became the Front-runner of Greater Indian Pennisular Railway (GIP) in 1845. He was the only Indian Director of GIP Railways.

1.1.6 Lord Dalhousie, Viceroy of India, observed in his minutes in April,1853. "It can not be necessary for me to insist upon the importance of speedy and wide introduction of railway communication through out the length and breadth of India. A single glance on the map of India will suffice to show how immeasurable are the political advantages to be derived from a system of internal communication which would admit of full intelligence of every event being transmitted to the Government under all circumstances at a speed exceeding five-fold its present rate and enable the Government to bring the main help of its military strength to bear upon any given point in as many days as it now requires months and to an extent which at present is physically impossible". These seem very clearly to be the objectives behind the commissioning of first Railway line in India from Bombay to Thane on April 16,1853 forming part of the originally cleared proposal of a 112 km (70 mile) experimental line from Bombay to Callyon (Kalyan) in September,1847. It was the network concept of connecting two main centres by more then one route for emergency that governed the initial policy of framing railway projects.



Run of the 1st train of INDIAN RAILWAY passing over Thane Bridge (1853)

1.2 EXPANSION PHASE

1.2.1 By 1879 (in about 25 year) 9,862 km of railway lines were laid by private companies and 3,500 km. by the State. The tempo of construction further increased in next two decades. Table I is illustrative.

TABLE I (Para 1. 2. 1)

Year	Route kilometers in the year in column (1)	Route kilometers added per annum during the period
(1)	(2)	(3)
1853	32	--
1879	13,362	513
1880	14,745	1,383
1900	39,834	1,254
1914	55,773	1,139
1920	59,119	558
1940	66,067	347
1947	54,694 (After partition)	--
1997	62,725	161
2001	63,028	76
2002	63,140	112
2003	63,122	(-) 18

1.2.2 The tempo slackened after the out-break of World War I in 1914 due to resources getting diverted to war effort and depletion of net-work due to despatch of 754 km of rail track to war theatres in East Africa, Mesopotamia, etc. After the war, the tempo slackened again due to great slump and depression all over the world during 1920-1940, which affected Indian national trade activities and exports/imports even more disastrously. The two major earthquakes in Bihar and Queta in 1930s also took their toll.

1.2.3 The out break of World War II stopped all expansion of railways net work and instead brought its depletion from 66,067 km. in 1940 to 65,217 in 1947 (in combined India & Pakistan) due to dismantling of less important lines for providing resources for war effort. About 11,000 route km of railway line were transferred to Pakistan territory after partition of the Country leaving 54,694 km in India.

1.2.4 Immediately after Independence, the policy changed for using the existing railway network more efficiently and productively and to expand it only for generally new areas of growth or strategy. By 2003 the addition has been only 8428 km on an average of 150 km per year in 50 years. This has affected the availability of infrastructure for speedier growth of economy. It is interesting to note that even now, after 98 years, the target of Mackey committee given in 1908 has not been achieved even half way for the expansion of system to 1,00,000 route miles. The earlier policy approach of planning new railway lines to strengthen the network was given a secondary place in favour of "project linked lines" or as "spurs to serve some local interests" as against that of network as a whole. This low rate of expansion is in contrast to the world scene. A report in Railway Gazette of January,1987 mentioned that over 70,000 km of new Railway lines were being built or proposed in various countries despite the economic recession which hit the railway industry in the 1980s. There has been renewed interest in expansion of railway network globally after oil prices started rising and many new line projects in India are on hand now.

CHAPTER II

HISTORY OF RAILWAY ORGANISATION

2.1 ORGANISATION OF RAILWAY BOARD

2.1.1 The initial policy of the Government of India for the construction and working of railways was the establishment of guaranteed railway companies of English domicile. Control over the operations of these companies was at first secured through the appointment of a Consulting Engineer of guaranteed railways. Later Local Consulting Engineers were appointed for the exercise of control over guaranteed railways and over State owned railways. These officers combined the duties of supervision and control on behalf of the Government of India.

2.1.2 The Government of India adopted the policy of direct construction and ownership of railways in 1869 and a period of rapid development of railway construction ensued. In 1874, a State Railway Directorate was established and the greater portion of the State Railway establishment and business connected with State Railway administration was transferred to the control of the Director of State Railways. Early in 1877 a further change was made. In place of one Director of State Railways, three Directors on territorial system and one Director of State Railways Stores were appointed. In 1880, a post of Director General was created in lieu of the three Directors.

2.1.2.1 The Consulting Engineer to the Government of India for State Railways was associated primarily in an advisory capacity with the Director General of Railways and assisted the latter in matters of civil engineering, and with the Director of Stores in matters concerning stores and rolling stock besides being an adviser in matters affecting establishment. A Director of Traffic was appointed at the same time as an adviser on traffic problems and the accounts work of the department was placed under the Accountant General, Public Works Department.

At the turn of the century, there were four categories of Railways in India, viz (a) The Guaranteed Railways; (b) Guaranteed Railways purchased by Government ; (c) State Railways leased to companies for management and operation; and (d) State Railways directly managed by the State.

2.1.3 In 1897, The post of Director General of Railways was abolished and the post of a Secretary to the Government of India in the Public Works Department was created in its place. The post of Consulting Engineer for State Railways was also abolished. In October 1901, Sir Thomas Robertson, C.V.O. was appointed as special Commissioner for Indian Railways to enquire into and report on the administration and working of Indian

Railways. On his recommendations, it was decided early in 1905 that the Railway Branch of the Public Works Department of the Government of India should be abolished and that the control of the railway system in India should be transferred to Railway Board consisting of three persons, a Chairman and two Members. The Railway Board was made subordinate and directly responsible to the Government of India in the Department of Commerce and Industry.

2.1.4 In October 1908, on the recommendations of the Railway Finance Committee presided over by Sir James Mackay (later Lord Inchcape), the following changes were introduced:-

1. the appointment of the Chairman of the Railway Board was changed into that of President of the Railway Board and enhanced powers were vested in the President;
2. the Railway Board with its staff became collectively the Railway Department under the administrative charge of the Hon'ble Member, Commerce and Industry Department
3. the President of the Board was given direct access to the Viceroy as a Secretary to the Government of India.

2.1.5 The Railway Board was reconstituted in 1924 and consisted of the Chief Commissioner as President, the Financial Commissioner and two Members, the Chief Commissioner being ex-officio Secretary to the Government of India in the Railway Department. With the experience of the working of this organisation during 1924-25, it was decided and agreed to by the Legislative Assembly in September 1924 to separate railway finances from the general finances of the country.

2.1.6 Immediately after Independence in 1947, there were five members of the Railway Board including the Chief Commissioner, Financial Commissioner and three Members for Engineering, Staff and Transportation matters. Commissioner for Railways was renamed as Chairman, Railway Board with altered delegation of authority. A new position of Member Mechanical (including Electrical & Stores matters) was brought in 1959 which was further split to provide a new position of Member Electrical in 1987. Till 1985, Chairman, Railway Board also held the position of one of the Member in addition to the Chairman's responsibility. On July 1, 1985 he was relieved of this duality by adding one more Member in the Board. Again for a short period between April 1, 1992 to January 1, 1997 Chairman once more took the responsibility of a Member as a measure of economy. As in 2000, the Railway Board consists of 7 members including the Chairman. It is interesting that Administrative Reforms Commission in its report in 1970 had suggested that the Railway Board should not normally exceed 6 Members excluding the Chairman and the Financial Commissioner.

2.2 CONSOLIDATION & RESTRUCTURING (1947-2000)

2.2.1 From 1853 onwards Railways developed in India both as private enterprise and State enterprise including by State rulers. Immediately after independence, in 1948, there were forty two independent railway systems of which twenty one were private or princely state railway systems, the largest being 2247 km for the Nizam State Systems Railway and the smallest being 8 km only for Sangli State Railway. Along with the merger of princely States in the Indian Union Territory, it was a corollary to regroup the railway system in the interest of economy and efficiency as also for defence strategy and bringing unity in national fabric. Most of the system was regrouped in six railway zones; Southern Railway (SR) on April 14, 1951; Central Railway (CR) & Western Railway (WR) on November 5, 1951, Eastern Railway (ER), Northern Railway (NR) & North Eastern (NE) Railway on April 14, 1952, leaving a few private Railways to run till their existing lease contracts expired. Other than IR, there is hardly any private railway now left except for Port Railways.

2.2.2 Some managerial and operational difficulties were encountered in the regrouping exercise. Broadly South Eastern (SE) Railway was carved out of erstwhile ER on August 1, 1955 due to heavy workload while North East Frontier (NF) Railway out of erstwhile NE Railway due to unwieldy size on January 15, 1958. As the system got further overburdened in certain areas due to economic growth and construction of new railway lines, etc. South Central (SC) Railway was carved out largely from CR & SR on October 2, 1966. From 1966 onwards, as the workload on the systems started growing, relief was generally provided by providing more divisions on the same system thus giving better customer accessibility and operational control.

2.2.2.1 In 1947, various railway systems worked on Regional, Divisional or District system. The divisional system was the preferred one for a reasonably loaded unit to provide a single point unified control for all corporate functions. By 1969, all the Government Railways were brought completely to the divisional system.

2.2.3 In 1982, Railway Reforms Committee while examining the work load on existing 9 zones had recommended carving out 4 additional zones in different phases after taking into account various workload indices developed by Efficiency Bureau (now Efficiency & Research Directorate) in Railway Board in their studies in 1954, 1961 and 1965 along with other influencing factors. It was in 1996 that Railway Minister announced in his budget speech the setting up 6 additional zones and the Seventh was sanctioned later on bringing the total to 16. These have gradually been set up, after inauguration on dates as below:

1. East Coast Railway, Bhubaneswar	08.08.1996
2. North Central Railway, Allahabad	28.08.1996
3. East Central Railway, Hajipur	08.09.1996
4. North Western Railway, Jaipur	17.10.1996
5. South Western Railway, Bangalore	01.11.1996
6. West Central Railway, Jabalpur	08.12.1996
7. Bilaspur zone, Bilaspur	20.09.1998

It is significant that besides work load evaluation on various merits, these exercises have been and will continue to be significantly influenced by political factors and conveniences as major restructuring and improvements have considerable economical, social and political impact. As in 2003, there are 67 functional Divisions and 16 Zonal Railways.

2.2.4 Research & Design

Though the Indian Railway Conference Association (IRCA) was set up in 1903 for co-ordination and standardisation for various Railways which had come up, a firm policy decision for progressive standardisation was taken in 1920 with various Standards Committees being set up, e.g. for Track, Bridges, Loco, Signalling etc. Central Standards Office (C.S.O.) was set up in 1930 for standard designs & specifications in Simla and later separately a Railway Testing and Research Centre (RTRC) was set up in 1952 in Lucknow. The two were merged to constitute Research, Design and Standards Organisation (RDSO) at Lucknow in 1957. This has played an important role in developing indigenous technical `know how' to the extent that IR is now largely self sufficient in design & research activity in respect of Permanent way, Bridges, Locomotives, Rolling Stock and Signalling equipments except for very sophisticated latest technologies which are usually imported along with transfer of technology.

2.2.5 Production Units

Due to substantial requirements of Rolling Stock by IR, it was considered necessary to set up indigenous production capacity to reduce and eliminate dependence on imports and to develop necessary research and design facilities in the country. In view of limited capacity of private enterprise to provide the capital base, these were set up as units under the control of Railway Ministry as under

- I. Chittaranjan Locomotive works at Chittaranjan (CLW) in 1950 for making Steam locomotives.
- II. Integral Coach Factory at Perambur (ICF) in 1955 for manufacturing railway coaches.
- III. Diesel Locomotive Works at Varanasi (DLW) in 1964 for making Diesel lomotives.
- IV. Wheel and Axle Plant at Bangalore (WAP) in 1984 for making wheels & axles.
- V. Diesel Component Works at Patiala (DCW) in 1987.
- VI. Rail Coach Factory at Kapurthala (RCF) in 1988 for making coaches.

These have expanded substantially in their production capacity over the years and now supply most of the requirements of rolling stock and components, supported by private and other public sector enterprises bringing down the import content to a very small fraction. They have helped in development of indigenous skills and technology and provided scope for supplementing Research activities of RDSO.

2.2.6 Training Institutions

Considering the importance of training, refresher and upgradation courses for junior and senior managers, IR has set up following five major centrally controlled institutions besides several other smaller units for junior staff under the control of Zonal Railways, Workshops etc.

1. Railway Staff College (RSC) at Vadodra in 1952
2. Indian Railway Institute for Mechanical & Electrical engineering (IRIMEE) by upgrading in the existing Jamalpur Technical School, which was established around 1905.
3. Indian Railway Institute for Civil Engineering (IRICEN) at Pune in 1955.
4. Indian Railway Institute for Signal and Telecommunication Engineering (IRISET) at Secunderabad in 1957.
5. Indian Railway Institute for Electrical Engineering (IRIEEN) in Nasik in 1986.

2.2.7 These organisational changes have been a part of gradual change process. Periodic reviews have been made as new situations have arisen to develop new strategies and these have helped IR to generally be a profitable concern despite various political, economic and social factors affecting their operational efficiency.

CHAPTER-III

RAILWAY GAUGE

3.1 Gauge is the distance between running faces of the two rails on straight track. It is a basic parameter of railway track to be decided before the construction of a new railway line. Various gauges have been adopted on the railways in the world due to historical and technical reasons and local factors.

3.2 THE STANDARD (4′ 8-½″) GAUGE

The width of track of ancient cart ways in U.K. seems to have set the standard for the railway gauge. Jessop in 1789, introduced rails with an outside gauge of 5′-0″ as he intended to use outside flanges for the wheels of his vehicles. While his first railway project was in course of construction, he decided to change to inside flanges for the wheels of his vehicles. The alteration was made without interfering with the rails. This appears to be the reason, why the gauge of 4′8-½″ (an odd figure) is in existence today. It is a 5′00″ gauge reduced by width of two of Jessop's 1-¾″ wide wheel flanges. Although an increase in the width of this gauge was strenuously advocated in the early days of the Railways, practical considerations held the field and 4′-8 ½″ became the standard gauge of the principal Railways of the world. The Great Western Railway of England, however laid its railways tracks to a gauge of 7′– 0 ¼″, which was eventually altered to 4′ - 8 ½″, in 1892.

3.3 GAUGES IN INDIA

Recognising that multiplicity of gauges on a system is an evil, the question of a uniform gauge was considered in detail by the Government of India in all its aspects. The gauge originally proposed by the Court of Directors of The East India Company for adoption in India, was the normal English gauge of 4′-8 ½″, known as "standard gauge'. The first agreement of 1849 with EIR and GIP Companies stipulated a gauge of 4 feet 8 ½ inch and rails of weight 84 lbs to the yard, for combining the greatest utility and economy. Lord Dalhousie, Governor General Of India (1848-56) and Mr. Simms, Consulting Engineer to the Government of India disagreed with the recommendations of the Court of Directors of East India Company for the 4′-8 ½″ gauge. Mr. Simms favoured 5 feet 6 inch while Lord Dalhousie recommended 6 feet gauge.

Mr. W. Simms, the Consulting Engineer, recorded in the year 1852 the following reasons for recommending 5′-6″gauge, which was wider than 4′-8 ½″,

> "The wider gauge of 5 feet 6 inches, which I would recommend for adoption, will give 9 ½″ more space for the arrangement of several parts of the working

gear of the locomotive engines and this additional space will be more needed in India than in Europe, not only on account of the machinery itself, but it would also lower the centre of gravity of both engines and carriages, the result of which would be to lessen their lateral oscillation, and render the motion more easy, pleasant, and at the same time diminish the wear and tear."

"The lowering of the centre of gravity, consequent on the adoption of the wider gauge appears to me of great importance for another reason, namely, the fearful storms of wind so frequent at certain seasons of the year and I think it is a very probable that in one severe northwester, not to mention such hurricanes as that of 1842, the additional 9 ½" of width might make all the difference between the safety and destruction of the trains, and one such accident attended, as it doubtless would be with great loss of life, would probably retard the progress of the railway system in this country considerably."

The Court of Directors finally decided to adopt the 5'-6" gauge (BG) and this decision being accepted by the Government of India, it became the prevalent gauge in India and was used on the early guaranteed lines.

3.3.1 Metre Gauge (MG)

Lord Dalhousie left India in 1856. Soon thereafter began the correspondence regarding adoption and advantages of narrower gauges in India. In 1861, during the Viceroyalty of Lord Canning, the Public works Department prepared a long note recommending a narrower gauge. In December 1862, the Indian Branch Railway company proposed to construct light railways. Lord Elgin (1862-64) succeeded Lord Canning as Governor General. He laid a policy that his Government will have no narrow gauge railway except in such detached and fragmented sections as held out no promise of being overworked. Sir John Lawrence (1864-69) succeeded Lord Elgin and in the early years of his Viceroyalty, he followed Elgin's policy about narrow gauge railways.

Early in 1869, railway enterprise in India was at a low ebb: the lines built had cost exorbitant sums: their working expenses were high, their profits were meagre and they were a great burden on the revenues of India. It was, therefore, realised that if railway extension was not to be stopped, a line of the cheapest description consistent with safety and durability should be constructed.

Lord Mayo (1869-72) carried on voluminous correspondence with Secretary of State favouring Narrower Gauge on grounds of economy and the rapidity of railway expansion. Lord Mayo can be said to be the author of Metre Gauge Railways in India.

Lord Mayo's views are indicated in his dispatch No. 51 of 17th May, 1870

"Firmly convinced of the sufficiency of a narrow gauge to carry the traffic of our secondary lines, and fully satisfied that an important economy must ensure in the aggregate over the whole extension system, we should fail in our duty to India, if we hesitated to advocate the adoption of gauge narrower than the present standard. Whether the gauge should be 3 feet or 3 feet 6 inch is comparatively a matter of detail.

As at present we should regard 3 feet 6 inch as the maximum width that should be adopted. An early decision on the point is called for, so as to admit of timely arrangements being made for rolling stock. We should be glad if your Grace would determine it after communication with the best authorities on the subject".

Subsequently Government of India recommended more extended use of narrow gauge. It proposed to divide the railways into two classes:-

(a) A system of trunk lines on 5 feet 6 inch gauge, and
(b) Lines of secondary importance designed to open out the resources of the country. These secondary lines, as proposed, were very extensive and formed systems in themselves. The Government of India concluded that substantially built narrow gauge lines were all that were necessary.

For some time, any gauge narrower than 5 feet 6 inch gauge was referred as narrow gauge. It was only after 1880 that 2 feet and 2 feet 6 inch gauges specifically came to be known as narrow gauges.

In 1870, a committee consisting of Colonel R. Strachey, R.E., colonel C.H. Dickens, R.E., Mr. John Fowler, C.E. and Mr. A.M. Rendel, Consulting Engineer to EIR was appointed to consider the precise gauge of railways in India. Three of the members recommended 2 feet 9 inch while one member recommended 3 feet 6 inch.

On 30th December 1870, Lord Mayo recorded his reasons for not adhering to the previous policy of the Government of India regarding adoption of 5 feet 6 inch gauge. Extracts from these minutes are reproduced below:

> "In considering unprofessionally such a subject and in endeavoring to arrive at a sound conclusion as between the two narrow gauges recommended, viz. 3 feet 6 inch and 2 feet 9 inch, we can only be guided by experience and authority. In this view there is no doubt that we should be quite safe in adopting the 3 feet 6 inch gauge: for it has been well and effectively tried, and is admitted to be sufficient for conveyance of a large amount of traffic.
>
> I think, therefore, that the adoption of a 3 feet 3 inch, one will provide for all the possible requirements of the country. I should prefer it.
>
> The 3 feet 3 inch gauge would give, according to these proportions, a horse box 6 feet 6 inch in the clear, and 5 feet 6 inch in the interior. This would give a space for two horses abreast of 2 feet 9 inch each(including the partition) which is precisely the space allowed on the horse boxes of the EIR"

Thus in 1870, after careful analysis of the situation, Lord Mayo considered that 3 feet 3 inch gauge was the best gauge for the secondary network of railways in India.

At that time the Government of India was considering adoption of Metric weights and measures. This gauge being very close to the metre, rounding off to 3 feet 3.3/8 inch or one metre was made and termed as `Metre Gauge".

In 1871, the decision to construct cheap and economic Railways by State Agency, led to the introduction of the Metre gauge. As a result of this, the Metre gauge system grew almost as rapidly, as that of Broad gauge. The issue was clinched for reasons of military strategy and limited financial resources.

3.3.2 Narrow Gauge

The first narrow gauge line on 2'-6" gauge was constructed due to economical reasons in 1862 by Gaekward Baroda State Railway (GBSR) from Dabhoi to Miyagram. Maharaja of Baroda, the owner of GBSR built a net work of light Railways connecting most of the towns of the state with the main line stations of Bombay, Baroda and Central India Railway.

Next on the narrow gauge scene appeared the Darjeeling Himalayan Railway line opened on 2'-0" gauge in 1881. During the next 25 years (1882-1907) about 10 narrow gauge lines were introduced in various parts of the country mostly on hilly terrains. Some important narrow gauge lines opened were Barsi light Railway on 2'-6" gauge (1897), Kalka Simla line on 2'-6" gauge (1903), Matheran light Railway on 2'-0" gauge (1907), Satpura line on 2'-6" gauge (1903)

3.4 DIFFERENT GAUGES ON INDIAN RAILWAYS

Inspite of initial thinking of a uniform gauge on Indian Railways, due to economical and historical considerations, 3 different gauges, viz. Broad Gauge, Metre Gauge and Narrow Gauge have finally been adopted on IR. The width and Kilometerage of these 3 different gauges on 31.03.2003 on I.R. is given below:

Std.of Gauge		**Gauge width in FPS System**	**Gauge width in Metric System**	**Route kms as on 31.03.2001**
(i)	Broad Gauge	5'-6"	1676 mm	45622 km
(ii)	Metre Gauge	3'-3 3/8"	1000 mm	14364 km
(iii)	Narrow Gauge	2'-6"	762 mm	3136 km
		2'-0"	610 mm	
(iv)	Total all Gauges			63122 km

Map of Indian Railway as in 2005 is attached at the end of the Chapter.

3.4.1 Problems of Change of Gauge

A number of problems cropped up on IR because of multiple gauges. Some of the evil effects due to the change of gauge (more popularly known as break of gauge) are given below:-

1. Inconvenience to passengers.
2. Difficulty in transhipment of goods.
3. Inefficient use of rolling stock.
4. Hinderance to fast movement of goods and passenger traffic.
5. Requirement of additional facilities at stations and yards.

6. Difficulties in balanced economic growth of regions.
7. Management and operating problems due to different gauges and difficulties in decision making as to the priority to be given to each gauge.

3.4.2 Gauge-wise traffic analysis:-In the year 2000-01, BG although forming 71% of the route kms generated 98.8% of the freight output in terms of net tonne kms and 91.8% of the passenger output in terms of passenger kms. Metre Gauge, with 23.8% of the route kms generated 1.15% of the freight output and 7.8% of the passenger output.

3.5 UNI-GAUGE POLICY OF INDIAN RAILWAYS

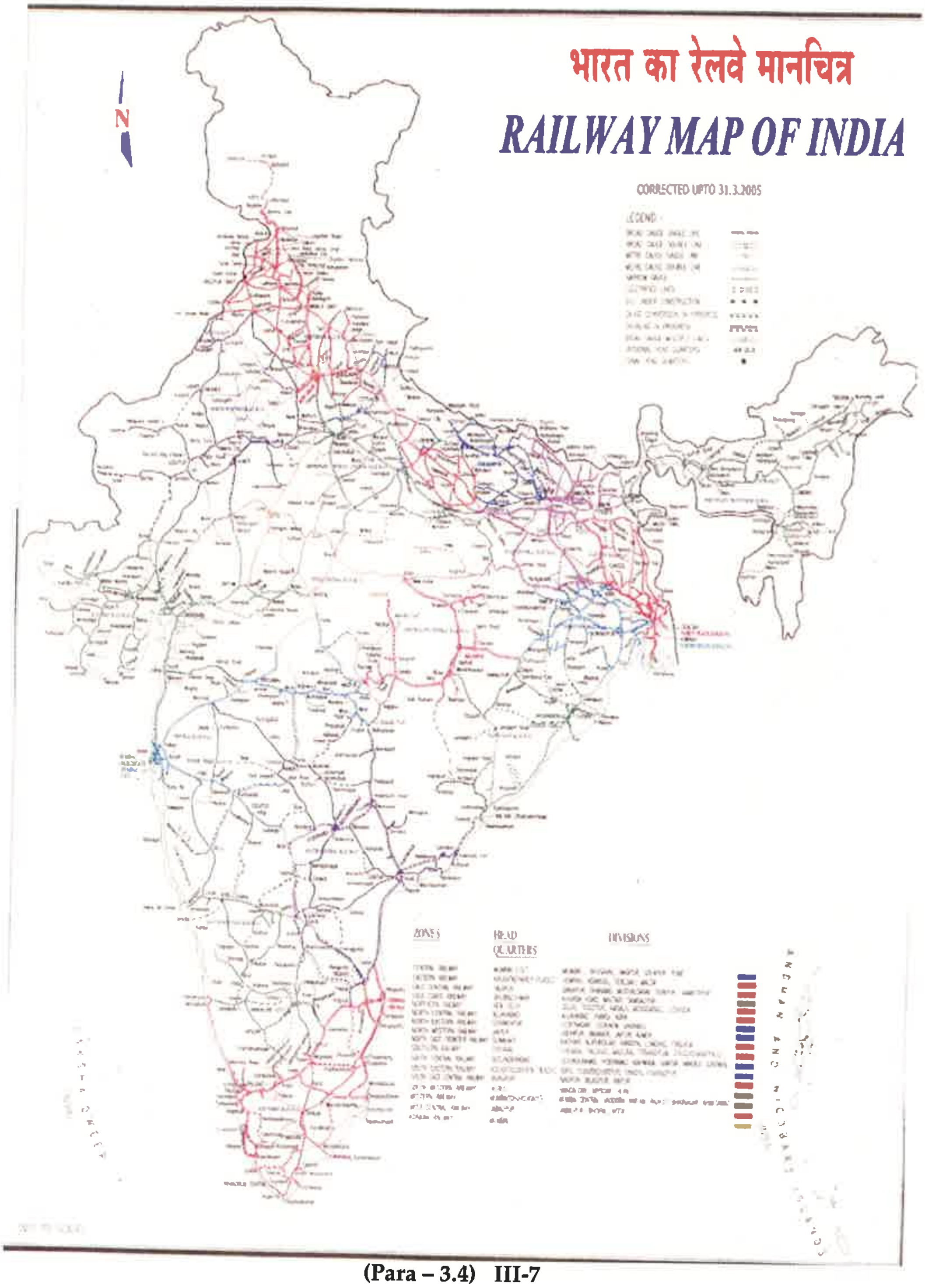
In the post Independence period, the policy of multiple gauges came up for reconsideration again & again. Firstly it was decided after partition in 1947 that broken links should be connected by the same gauge and similarly missing links in MG system be constructed to do away with some of problems associated with break of gauge to have a whole system of one gauge. Also extension of lines to new areas was to be done on the same gauge where it was to join the existing system. In 1971, the concept of gauge conversion as a policy seems to have emerged. Earlier gauge conversion schemes were considered where increased traffic could be more economically handled on wider gauge taking into account the expenditure on conversion. In 1971-72 the Railway Minister announced to "do away with the economic drag of multiple gauges." This meant that all new lines were to be constructed on the BG only and progressive conversion of selective MG lines was to be done, subject to availability of financial resources. The policy resulted in a gradual neglect of maintenance of MG track and rolling stock .

3.5.1 Recognising the financial limitations and also the maintenance neglect that was affecting the safety of MG system, the policy got reviewed during 1983 to 1986 to improve capability of the MG system by upgradation. It was experimented and found practical to increase the speed of MG passenger trains to 120 kmph and freight trains to 75 kmph on IR. World experience supported the view that in the well designed upgraded and maintained narrow gauge tracks (Metre/3'-6") could handle with safety and comfort similar magnitudes of passenger and freight traffic as IR's BG system. Accordingly new inputs were planned on MG system along with fresh Research & Design work in RDSO for such an upgraded MG system.

3.5.2 IR decided again in 1992 to reduce multi gauge system quickly and proceed to a uni-gauge policy by adopting BG (1676mm) uniformly despite additional investment to be made for this purpose with the prospect to boost economy in areas served by MG system. Thousands of route kms of MG and NG lines were identified for conversion irrespective of traffic or economic needs and completion during 1992-2000. The position of MG system on IR from 1947 is indicated in the following table :

Table (Para 3.5.2) Metre gauge Route Kms

Year	Route km
1947-48	24133
1950-51	25237
1960-61	25168
1970-71	25847
1980-81	25424
1990-91	23599
1997-98	17044
1999-2000	15072
2000-2001	14987
2001-2002	14776
2002-2003	14364



भारत का रेलवे मानचित्र
RAILWAY MAP OF INDIA
CORRECTED UPTO 31.3.2005
N
ZONES
HEAD QUARTERS
DIVISIONS

CHAPTER-IV

PERMANENT WAY

4.1 INTRODUCTION

The history of railways is closely linked with the growth of civilisation of mankind. In the primitive days the goods were carried by head loads. As the civilization grew, the goods were transported by carts drawn by men or animal. In 15th century, stone slabs or wooden baulks were laid flush with the road surface for carriage of heavy goods loaded on carts drawn by men or animals. These were called "Tram Ways". These tram ways were extensively used in 16th century in mines in central Europe for carriage of coal and other minerals. The present permanent way or railway track is a gradual evolution from these tram ways.

The first public railway in the world was commissioned on 27th September, 1825, when the first train made its maiden journey between Stockton and Darlington in U.K. Simultaneously other countries in Europe also developed railway systems. Most of the European countries introduced trains for carriage of passenger traffic at that time followed by a spate of development of railway systems throughout the world.

The first railway line in India was opened in 1853. The maiden trip of the first train consisting of one steam engine and 4 coaches was made on 16th April, 1853, when it traversed a 21 mile stretch between Bombay and Thana in about 1 hr. 15 mts. time. IR system has grown up in 2003-2004 into a network consisting of 63,221 route kms. Criss-crossing the country from Himalayan foot-hills in the north to Cape Comorin (Kanniya Kumari) in the south and Dibrugarh in the east to Dwarka in the west, it is the 2nd largest state owned railway system in the world under unitary management.

4.2 In the Railway System, Civil Engineering mostly covers the basic infrastructure for movement of trains and their operational requirements. It consists of the following main items:

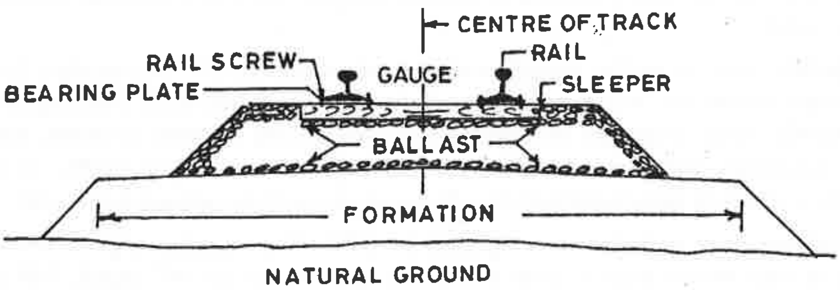
- (i) Permanent Way or Railway Track
- (ii) Railway Bridges
- (iii) Other Civil Engineering Structures.

4.3 PERMANENT WAY

Permanent way is the rail-road on which trains run. It basically consists of two parallel rails having a specified distance in between them (termed as gauge). The rails are fastened to sleepers, which are embedded in a layer of ballast of specified thickness spread over the formation. Conventionally, the rails are joined to each other by fishplates and bolts and fastened to the sleepers by various fittings like keys and spikes, etc. The sleepers are spaced at a specified distance and held in position by embedding in ballast. The standard type of track is termed as "Permanent Way" to differentiate it from "Temporary track", which is laid for carrying earth and other building materials for construction of railway lines to be removed subsequently after completion of work.

Each of the components of track has a basic function to perform. The rails act as girders to transmit the wheel loads of trains to the sleepers. The sleepers hold the rails in proper position and provide correct gauge with the help of fittings and fastenings and transfer the load to the ballast. The ballast is placed on level ground known as formation. The sleepers are embedded in ballast, which gives a uniform level surface, provides drainage and transfers the load to a larger area of formation. The formation gives a level surface where the ballast rests and takes the total load of the track and that of the trains moving on it.

Permanent way or track, therefore, basically consists of (i) rails (ii) sleepers, (iii) fittings and fastenings, (iv) ballast, and (v) formation as shown in the Figure.



(Para 4.3)

4.4 DEVELOPMENT OF PERMANENT WAY

The development of permanent way has taken place basically out of the necessity coupled with economy. The earlier engineers were aware of the fact that effort required to pull a vehicle depends directly on the friction of the surface on which the vehicle is pulled. This concept was utilised by the engineers to develop the present permanent way where a smooth surface of metal in the form of rail head is provided for passage of vehicle. Some developments are given below:

(i) In early 15th century stone slabs or wooden baulks were laid flush with the road surface for carriage of heavy goods loaded on carts and drawn by animals in England and other parts of Europe.

(ii) Wooden rails were subsequently employed in England and other parts of Europe, for the movement of horse drawn trucks. These tracks in England were known as "Tram Way", since one unit load of timber was referred to as a "Tram".

(iii) The timber baulks were replaced by iron plates to reduce wear and were called "plate ways". These iron plates were substituted in course of time by angle iron to give lateral support for better safety. As a further improvement, William Joseph of U.K. in 1789 replaced iron plates with cast iron beams having stone supports at ends for better working.

(iv) In 1804, Trevithick discovered that trucks or vehicles could be propelled more easily "by the adhesion of a smooth wheel to a smooth rail" because of less friction. This perhaps, more than anything else, paved the way to the use of the moving steam engine, pulling a number of coaches or wagons.

(v) In middle of 19^{th} century, rails were designed as double headed (D.H.) rails and made of "I" section or Dumb-bell section. When the head was worn out during the service, the rail could be inverted and reused. The experience showed that the bottom table of the rail got dented in service by long and continuous contact with chairs and it was not possible to reuse it. This led to the development of Bull headed (B.H.) rail which had an almost similar shape but with more metal in the head to allow for greater wear and tear. This rail section had a drawback that special chairs were required for fixing it to the sleepers.

A flat-footed rail, also called Vignole rail, having a cross section of inverted "T" was developed which could be fixed directly to the sleepers with the help of spikes etc. The flat-footed (F.F.) rail is standardised for adoption on IR

(vi) Initially wooden sleepers of hard wood or soft wood were used in the early period as wood was the material used for making sleepers in Europe. This was possibly the most convenient and versatile type of sleeper and its versatility and utility has not decreased with the passage of time. On IR, however, in the interest of conserving forests for better ecology, the use of wooden sleepers has been restricted inspite of its advantages.

The shortage of wooden sleepers and the heavier requirements of traffic led to development of metal sleepers on the railway system some time in the beginning of 20^{th} century. These metal sleepers had longer life, required less maintenance and provided better lateral stability. On IR the different types of metal sleepers mostly used were steel trough sleepers and cast iron sleepers like CST-9.

In the year 1877, Mr. Monnier, a French gardener and inventor of reinforced concrete, suggested that cement concrete could be used for making sleepers for the railway track. Monnier designed a concrete sleeper and obtained a patent for it, but this did not work successfully. The design was further developed and Railways of Austria and Italy produced first concrete sleeper with promising design around the turn of the nineteenth century. This was closely followed by other European Railways where large scale trials were made due to economic considerations. Much progress, however could not be achieved till 2^{nd} world war, when the wooden sleeper practically disappeared from the European market and the prices shot up. Almost at the same time as a result of extensive research carried out by French and other European Railways, modern track was born. Heavier rail sections and long welded rails came into existence. The necessity for a heavier and better type of sleeper which could fit in the modern track was felt. These conditions gave a spurt to development of concrete sleepers and countries like France, Germany and Britain went for development of these concrete sleepers to perfection.

Concrete sleepers came very late on Indian sub-continent. The concrete sleepers were manufactured and used from 1967 onwards on IR. Starting from that beginning, IR today manufactures and uses about 50 lacs concrete sleepers every year and is a world leader in their use.

(vii) Rails are laid end to end with a gap in between to cater for expansion & contraction of rails due to temperature variation. The rail joints, considered a necessary evil, require special effort for proper maintenance. Welding of rails was first developed in the year 1900 and the same was perfected in another 25 to 30 years. On IR welding of rail joints was adopted sometime in the fifties. Most of the rail joints on IR are welded now. The technology of welding of rails has been developed in various stages. IR today carry out welding of rails by flash butt, alumino thermic and by gas pressure welding technologies.

(viii) Rails are joined by fishplates to hold the rails together both in the horizontal and vertical planes. The fishplate has been evolved to better design and standards to provide maximum strength at the rail joint.

(ix) The rails are fastened to sleepers by different fittings depending on the type of rail and the type of sleepers. In the beginning, with wooden sleepers, the rails were held by dog-spikes but subsequently screw spikes were evolved to avoid damage to sleepers. In case of steel sleepers the rails are held with help of loose jaws and keys. In case of cast iron sleepers, the rails are held with the help of the bars and cotters. In order to give proper elasticity to the track, most of the conventional fittings in the beginning of 20^{th} century have been progressively replaced by elastic fastenings like elastic rail clips, rubber pads, etc., to give resilience to track for better riding quality.

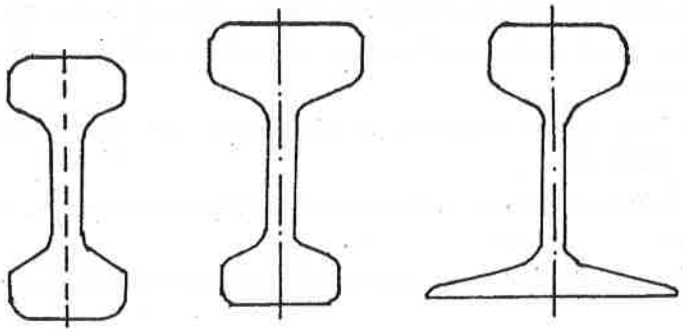
4.5 Following aspects of permanent way are dealt with in details in separate paragraphs:

(i) Track structure covering rails, sleepers, rail joints & welding, fittings, switches (points & crossings), ballast, formation, curves;

(ii) Track maintenance & modernisation covering manual & mechanised maintenance, track monitoring, rail failures and their management, floods and breaches and the `rehabilitation' of the railway track.

4.6 RAILS

Rails are of various shapes (sections), like double headed, bull headed and flat footed as shown in the Figure. These are designated by their form, design, type of steel, and weight per unit length. In F.P.S. unit, it is the weight in lbs per yard and in metric units it is in kg per metre.



(Para 4.6)

4.6.1 Design of Rails

The earliest railways started with iron flat bars fixed on to wood or stone to serve as a metallic rolling surface. Subsequently, iron plates were replaced by angle iron sections. Finally the 'I' section was adopted.

4.6.2 Double Headed (DH) Rails

The first typical rail section was designed as a dumb-bell section, termed as double headed (DH) rail. This was achieved in the first half of nineteenth century. The following sections of DH rails (in lbs per yard) were used on IR:

64 DH, 67 DH, 68 DH, 69 DH, 73 DH, 78 DH, 82, DH, 86 DH, 88 ½ DH, 100 DH.

4.6.3 Bull Headed (BH) Rails

Bull headed (BH) rail had almost a similar shape but with more metal in the head to allow for greater wear and tear. The following sections of BH, rails (in lbs/yard) were used on Railways:

50 BH, 60 BH, 68 BH, 73 BH, 75 BH, 76 BH, 77 ½ BH, 80 BH, 82 BH, 85 BH, 87 BH, 88 ½ BH, 90 BH, 100 BH.

4.6.4 Flat Footed (FF) Rails

The design of rail was improved upon to do away the use of intermediate chairs and a flat footed rail having a cross section of inverted T was developed which could be fixed directly to the sleepers. It was originally designed by Mr. Vignole and termed as

'VIGNOLE RAILS'. The following sections of FF rails (in lbs/yard) were used on IR.

18 FF, 24 FF, 30 FF, 31 FF, 35 FF, 36 FF, 40 FF, 41 FF, 41 ¼ FF, 42 FF, 50 FF, 58 ½ FF, 60 FF, 70 FF, 74 FF, 75 FF 75/87 FF, 75/ISR, 75/1904, 80 IMR, 87 FF, 90 FF, 93 ½ FF, 100 FF, 115 FF.

4.6.5 British Standard Specification (BSS)

Further modification in the design of flat footed rails followed to meet the requirements:

(i) To have most economical section consistent with strength, stiffness and durability;

(ii) To have the center of gravity of rail section very near to the centre of the height of the rail;

(iii) To have an economical and balanced distribution of metal in its head, web and foot

The first such designs were termed as BSS rail section and following sections were used on IR:

50 BSS, 60 BSS, 75 BSS, 90 BSS

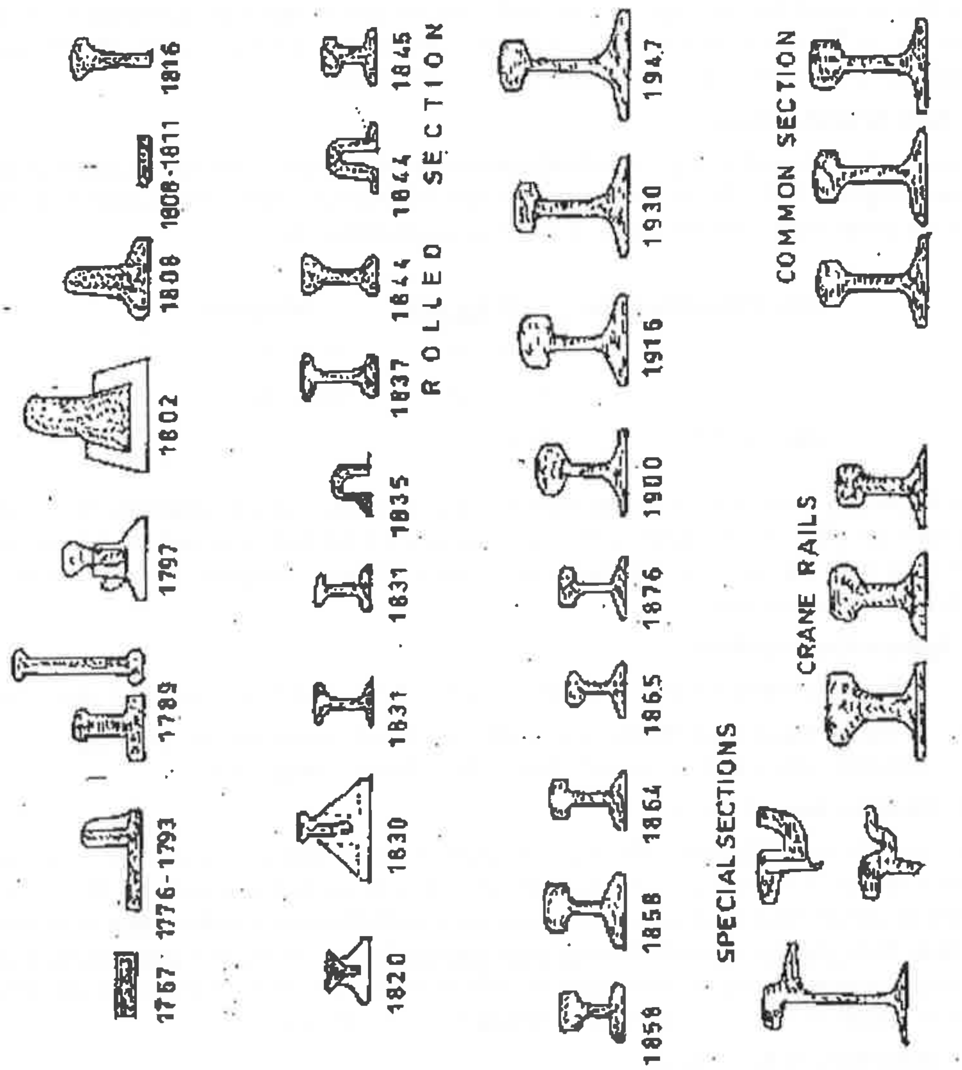
This was redesigned for improvement and termed Revised British Standards Specifications (RBS). The following sections were used on IR:

50 RBS, 55 RBS, 60 RBS, 75 RBS, 90 RBS, 115 RBS

4.6.6 Indian Railways Standards (IRS):- Development of rail shafes

After Independence Indian Railways designed their own rail sections to suit the requirement of increasing traffic and speeds improving upon RBS design. This was designed in metric units and termed as for example, 53 kg IRS. By this time International Standards were developed and adopted on world Railways. Indian Railways also adopted the 60 kg U.I.C. rail section for its very busy routes.

Development in rail shapes in chronological order is shown in figure on next page.



DEVELOPMENT IN RAIL SHAPES IN CHRONOLOGICAL ORDER
(PARA 4.6.6)

4.6.7 Length of Rails

The rails are manufactured in convenient lengths depending upon rolling, handling & transportation facilities available. To start with rail length was limited to 21, 24 & 27 feet which was further increased to 30, 33 & 36 feet length. With increase in the length of special trucks used for carriage of rails (BFR) the length of rail was increased to 39 & 42 feet for MG & BG respectively (12 & 13 metres). Presently on CGS system, 25/26 metres long rails are being considered for adoption in near future.

4.6.8 Rail Specifications

Rails are manufactured to high standards and strict tolerances. Various qualities of steel, viz. steel of grade 710, 880 or 1080, are specified for manufacture of rails with following standards permitting different type of loading as given below:

Steel Specification	52 kg rail	60 kg rail
72 U T S	350 G M T	500 G M T
90 U T S	525 G M T	800 G M T
100 U T S	N.A.	N.A.

Indian Railways were earlier using rails having ultimate Tensile strength (UTS) of 72 kg/sq.mm. In 1985 use of higher UTS rails was started for higher speeds and load. With higher UTS rails the service life increases. Lately IR have adopted 90 UTS rail for all main line and trunk routes.

4.6.9 Special Quality Rails

(i) **End Hardened Rails:** are with rail ends hardened by oil or water quenching.

(ii) **Head Hardened Rails:** are with rail head hardened by passing the rails through a thermal treatment plant. These have a longer life.

4.6.10 Manufacture of Rails

On IR right from 1853, the rails were imported from England and other European countries. It was in 1940s that manufacture of rails was started in Indian by M/s Tisco & M/s IISCO. After independence a new steel plant with Russian collaboration was started by Bhillai. This plant is manufacturing rails mainly for use of IR. The manufacture of 52 kg-IRS rails was taken up by this plant in 1959. Initially this plant manufactured only 72 UTS rails. Lately it has started manufacturing 90 UTS rails also.

4.6.11 Detection of Rail Flaws

Visible rail flaws can be detected visually by naked eye or by using magnifying lens. A mirror is also used for the bottom surface. For detection of internal flaws, non-destructive testing techniques are available by using ultrasonic or radiography. Of the two the ultrasonic technique is more convenient and economical and is widely used on the Railways. For rail testing, frequencies of 1 to 5 megacycles are used.

4.6.12 Ultrasonic Rails flaw Detectors

(i) Ultrasonic testers are portable (trolley type) or mounted in a railway coach. The portable testers can test about 1 to 2 km track in a day, the testing is accurate with respect to size and location of flaw. Ultrasonic rail testing was started on IR in 1970, when six portable rail-testers were imported from West Germany. 40 portable rail-testers of the same make were assembled in India in 1971-72. In 1974 indigenous production of portable testers started in India.

(ii) **Ultrasonic Rail Flaw Detection Car:** It is a railway coach in which all the testing gadgets are fitted between the wheels and the instrumentation is inside the coach.

(iii) **Ultrasonic Rail Flaw Detector Trolley:** It is a mono-rail hand pushed trolley in which the flaw detecting gadgets are fitted between the two wheels while the instrument is fitted on the trolley. A two wheel trolley capable of covering both the rails has been developed and is in use.

4.7 SLEEPERS

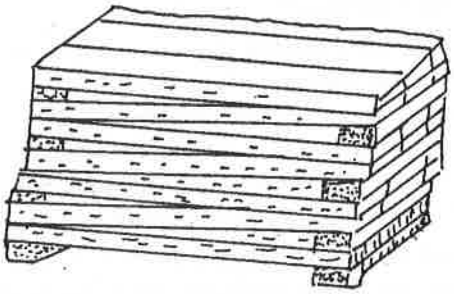
The sleepers can broadly be classified into wooden sleepers, cast iron sleepers, metal sleepers, steel sleepers, reinforced concrete sleepers and prestressed concrete sleepers.

4.7.1 Wooden Sleepers

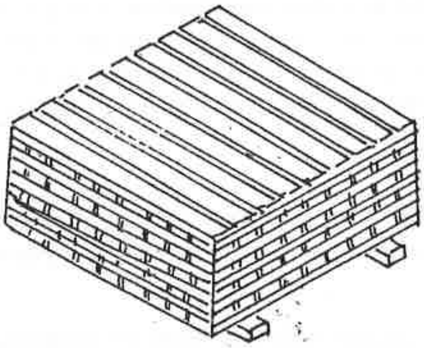
It can accommodate any gauge, rail and type of fastening. The wood being a non conductor of electricity, the sleeper provides insulation to the rail rendering it fit for use on track circuited lengths. Wooden sleepers are of two types:

1. Hardwood (Durables) e.g. Sal and Teak, or
2. Softwood (Non-Durables) e.g. Deodar, Chir, Pine, Kail and others.

The sleepers are suitably treated increase their life. While the hard wood sleepers are laid as such, the soft wood sleepers are treated with creosote oil in sleeper creosoting plants for the purpose. Alternatively, air seasoning of wooden sleepers is done by stacking them properly either by 'one and nine method' or 'open crib method' keeping provision for enough space for air circulation as shown in Figure. With the reducing availability of wood due to depleting forests in India, the use of wood for railways sleepers is being minimized. For ordinary track sleepers it is abandoned. The requirement of timbers (also called wooden specials) is being met partially by import from neighbouring countries. Alternatively, air seasoning of wooden sleepers is done by sacking them properly either by one and nine method or open crib method, keeping provision for enough space for air circulation as shown in figure.



(a) ONE AND NINE METHOD



(b) OPEN CRIB METHOD

(Para 4.7.1)

4.7.2 Steel Sleepers

In early thirties along with the development of cast iron sleepers a trough type design of steel sleepers was developed consisting of a rolled steel plate of about 12 mm (1/2 inch) thickness pressed to a suitable trough shape and the rail seat canted to 1 in 20 slope. The ends of the rolled section are flattened out in the shape of a spade to retain the ballast. The sleeper is designed for all gauges and required rail sections (only flat footed rails).

The following types of steel sleepers are used on IR:

(i) Pressed-up Lugs and Key Type.
(ii) Reinforced Pressed up Lugs and Key Type.
(iii) Clip and Bolt Type.
(iv) Loose Jaw and Key Type.
(v) Modified Jaw and Elastic Rail Clip Type

(i) Pressed-up Lugs and Key Type Steel Sleepers:

The Lugs/jaws are pressed out of the plate itself to accommodate the foot of the rail and the key. On IR the following type of such sleepers have been used:

NWR (2 key type & 4 Key type), GKN type, Henry William (Forced up Lugs, Reinforced, Forced up Lugs).

(ii) Clip and Bolt Type Steel Sleepers:

This employs 4 bolts and 4 clips for each sleeper. These are not used now a days in India.

(iii) Loose Jaw and Key Type Sleepers:

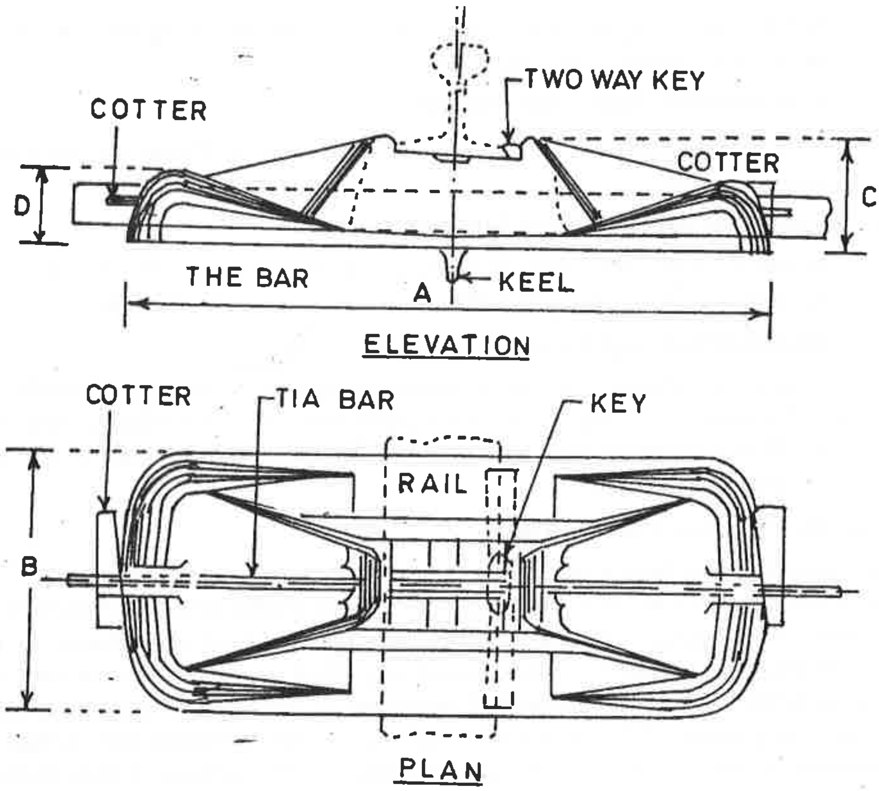
In this 4 loose lugs/jaws are used in the holes. The rail foot is then fastened by driving 4 keys. Such sleepers are used in general over IR.

(iv) Modified Jaw and Elastic Rail Clip:

This is a modified version of the above sleeper wherein modified loose jaws and elastic rails clip (Pandrol Clips) are used. An elastic rubber pad is provided between rail foot and the sleeper. This is one of the standard sleepers in use of IR.

4.7.3 Cast Iron Sleeper: (See Figure)

Cast Iron Sleepers have been extensively used on IR from the beginning of 19^{th} century. Cast Iron (CI) Sleepers had been in the form of pots or plates with ribs below the plates. Pots had holes for packing from top or filling up. Another type of CI sleeper in the form of `Box" continued for sometime. This sleeper was filled up with ballast or sand from top to give it stability. A tie rod connected two pots or plates to maintain gauge. Some private railways preferred a short tie bar, others provided a longer one. Longer tie bars were preferred as they countered the act of tilting of pots outside. Every Railway was designing the pots to suit their needs and making developments till the Central Standards Office (CSO) took up the evolution of a standard sleeper during the third decade of 20^{th} century. A series of trial designs (Central Standard Trials) known as CST-1,2,3, 3A to 13 had been made and tried. Out of all these designs, CST-9 has been the most extensively adopted. Its behaviour in the track has been very satisfactory. The CST-9 sleeper may be described as a combination of a pot, plate and box sleeper. It has bowls on either side of rail seat to accommodate packing and a rib under the plate. The rail is supported on a box. The rails are held to the sleeper with steel keys. Tie bars are provided with cotter pins to hold the rails to the pots.



(Para 4.7.3)

A joint sleeper of cast iron known as " Rail free duplex sleeper" has been designed and used at joints. Later this was replaced by joint wooden sleepers. Some important developments are described below -

(i) Track Standards Committee (TSC) had been deliberating on various aspects of cast iron sleepers in improving and standardising on various aspects from Feb-May, 1926. 13th TSC (20-30th March, 1934) discussed East Indian Railway type cast iron plate sleepers already laid in track, and finally accepted these. Cost of a complete sleeper was Rs.5/- and 12.5 annas, believed as the cheapest. This price was assessed with 65 % scrap CI + 15% scrap mild steel and 20 % pig iron. Assuming if the plate is totally made of pig iron at Rs. 60/- per ton, the sleeper would have cost Rs.6 and 13 annas (including cost of tie bars as 14 annas).Thus CST sleeper was finally cleared for trials in the year 1934.

(ii) 15th TSC report considered a cast iron sleeper submitted by M/s Guest Keen Williams Ltd. to CSO in which an entirely new type of tie bar was used with spring steel keys instead of cotters.

(iii) 19th Track Standards Committee report summarised the experience of CST-9 sleeper on various railways i.e. GIP Railway, Bengal-Nagpur Railway, North West Railway, East Indian Railway and South Indian Railways. South Indian Railway laid 3 miles of track with design of T-432 and T-478 with 90 R FFBS rails to N+2 density. EI Railway reported CST-9's behaviour as appreciable. NW Railway expressed satisfactory performance of sleeper but expressed 3 main difficulties during maintenance, in regard to corrosion and replaceability of tie bar, and blowing of joints. BNR expressed difficulty in driving keys. Keys were driven too far into the jaw. GIP expressed satisfaction with CST-9 in both good and bad formations. Finally, 19th TSC recommended standardisation of CST-9 with both short and long tie bars after this feedback of various railways. 20th TSC concluded and justified use of "reverse jaw" CST-9 sleeper.

(iv) 29th TSC report considered modification to CST-9 sleeper viz. provision of packing holes or alternatively a corrugated or flat base to facilitate quick consolidation of packing. CST-10 sleeper was evolved as an improvement over CST-9. Rubber pads were provided below the rail seat; but this was not adopted as it could not be used with elastic fastenings. CST-11 type sleeper was discussed in 46th TSC (May-1970) for a design adopted to suit Pandrol T-401 clips with rubber pads. It was not found successful. There were further developments as CST-12 and CST-13 for special fittings and to suit welded tracks with elastic fittings, but these were not found suitable.

(v) CST-9 is light in weight and is not suitable for LWR tracks. CST-9 track is not providing adequate lateral and longitudinal resistance needed for welded tracks. Wear in rail seat allows the keys to work out and drop which increases creep. Shape of sleeper is not suitable for MSP and machine maintained tracks. Effective bearing area of CST-9 is less than mono-bloc concrete sleeper. By middle of 80s, concrete sleepers had started coming up and soon were being mass manufactured. These started replacing CST-9 as conventional sleeper and thus further relaying of track using CST-9 sleepers has been stopped. Gradually this will be available on very light density branch lines or MG tracks only.

4.7.4 Concrete Sleepers

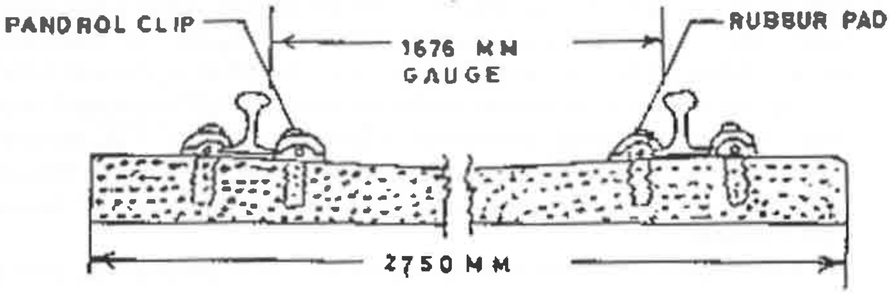
The evolution of concrete sleepers has been due to economic reasons, higher speeds, modern track structure and depleting forests all over.

In India there had been a chronic shortage of wooden sleepers over the last few decades. The life of wooden sleepers was also very short (15 to 20 years). Use of C.I. sleepers resulted in heavy use (40%) of pig iron in the country. To reduce the consumption of pig iron as also to cater the need for high speeds the need for a suitable concrete sleeper arose.

4.7.5 Design Development

The development of concrete sleepers, was mainly in the following different lines:

(i) **Mono Block Sleepers:** These consist of RCC or prestressed concrete sleepers somewhat similar in shape and size to wooden sleepers. (See Figure)



(Para 4.7.5(i))

(ii) **Two Block Sleepers:** These consist of two blocks of concrete directly supporting the rail, connected by a tie bar. These could either be (a) Sleepers with RCC block and steel tie bar, or (b) Sleepers with prestressed concrete block and concrete or composite tie bar.

(iii) **Longitudinal Sleeper:** Instead of being transverse to the rails, are placed longitudinally with reference to the rail. These could either be RCC or prestressed.

(iv) **Concrete Shell:** These are a continuous prestressed concrete shell type provided to match the length of the rails.

Sleepers of type (i) and (ii) have been developed further on large scale and sleepers of the mono block type and the two block type with RCC blocks and steel tie bars, are in wide use all over the world. The longitudinal sleepers and the concrete shell did not find wide applicability and remained in experimental stage of development only.

IR have adopted two designs: (i) mono block prestressed type and (ii) two block RC type. The former is being preferred.

Mono block Prestressed Concrete Sleepers: The Indian design is similar to German B-58 type of sleeper. Two rubber pads, one under each rail seat, and four elastic rail clips are used with each sleeper to fasten the rail.

4.7.6 Manufacture

Two processes are adopted for the manufacture of prestressed concrete sleepers. These are, (a) pretensioned type concrete sleepers and (b) post tensioned type concrete sleepers.

The pretension design has since been developed both for BG and MG for plain track as well as for points and crossing layouts.

There are factories set up for manufacture of B.G. concrete sleepers on IR, which are under regular production. In addition, a large concrete sleeper factory with post tensioning system, with a capacity to produce 3 lakh sleepers annually has been set up at Allahabad producing since September 1981. Another departmental factory has also been set up at Khalispur near Varanasi, in 1982, with an installed capacity to produce 50,000 sleepers per year. Lately turnout sleepers are also being manufactured in this factory. For the manufacture of MG concrete sleepers two departmental factories at Sabarmati and Garden Reach are functioning.

4.7.7 Prestressed concrete Sleepers for Turnouts and special locations

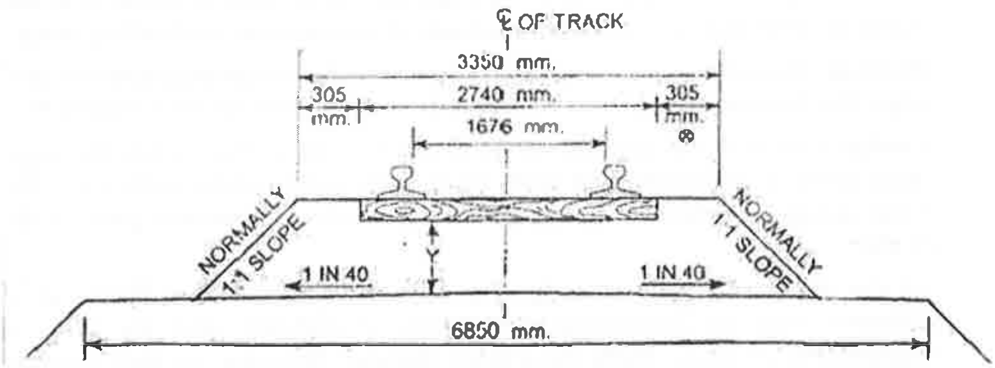
IR developed a design of PRC sleepers for turnouts in 1986. These sleepers were tried and design was modified for improvement. Their mass scale production has since been started.

Development of concrete sleepers is in hand specially for locations like level crossing, curves and fish plated joints. When fully developed, these designs shall help in laying concrete sleeper track through and through.

4.8 BALLAST

4.8.1 Introduction

Ballast is one of the main components of track and plays a vital role in maintenance of the track. Ballast consists of broken stone, gravel, mooram or any other gritty material, which is placed below and around sleepers for distributing load from sleepers to the formation.



BALLAST PROFILE FOR BG SINGLE LINE FOR FISH PLATED TRACK

(Para 4.8.1)

Indian Railways has come a long way to improve the quality of ballast to cater the need of higher speeds, heavier axle loads and heavier traffic density. The present track is laid on concrete sleepers with welded rails and is maintained with track machines. The quality of ballast has been upgraded to meet these requirements.

4.8.2 Improvement in quality of ballast

During 1960s, Indian Railways took up the prestigious project of increase of speed with heavier axle load of trains. Accordingly, quality of ballast was upgraded to suit this modernisation of track.

In general, the change in quality of ballast on Indian Railways can be seen through following four important parameters:

(i) Material of the Ballast.
(ii) Size and grading of the Ballast.
(iii) Quality control through measurement of Physical and weathering properties.
(iv) Mode of Manufacture.

These details have been discussed in subsequent paras.

4.8.3 Material of the Ballast

(i) **Broken Stone:** This was the best material and was normally broken from hard trap, quartzite, granite, etc.

(ii) **Gravel:** Next to broken stone, crushed gravel is the most suitable ballast, but small pebbles tend to slip and slide due to vibratory loading, which are harmful to track.

(iii) **Ashes and Cinder:** Coal ashes and cinders were used in unconsolidated new lines. Ashes used to get crushed and pulverized quickly under traffic and were not therefore, suitable for high speed on track.

(iv) **Sand:** This material drains well and also serves as an excellent cushioning material to produce a quiet running track. However, sand is found to cause excessive wear and tear of under-carriages of locomotives and rolling stock.

(v) **Moorum:** Moorum was more suitable than sand for ballasting purposes and larger the fraction of hard and rocky modules the better suited is moorum.

(vi) **Kankar:** This is a lime agglomerate with clayey soils and has nearly the same characteristics as laterite and both have been used satisfactorily over the meter gauge and narrow gauge tracks especially in southern part of the country.

All the above materials of ballast have been used by Indian Railways in different locations depending upon their availability and the type of requirement of track. There have been changes, however, in their quality, gradation and mode of manufacture as explained in subsequent paras.

4.8.4 Size and Grading of the Ballast

(i) **In 1960,** then `Indian Railway Way and Works Manual' prescribed the following sizes for ballast of broken stone:

Track with wooden sleepers and CI Pots	.... 2″ gauge (50mm)
Track with CI plate sleepers and steel troughs	.........1½″gauge (40mm)
Track on points and crossings	.... 1″ gauge (25mm)

(ii) **In 1987,** Standard size for points and crossings was changed as given below:

40mm gauge ballast:

Retained on 40mm sq. mesh sieve	:	Note more than 10%
Retained on 50mm sq. mesh sieve	:	Nothing will ɒe retained and 100 % ballast shall pass through the sieve.

(iii) **In 1987,** due to introduction of concrete sleeper and machine maintenances, Indian Railways introduced mechanically crushed stone ballast. The standard size of ballast was specified as follows:

Nominal Size of ballast.....................50 mm (2″ size)

Gradation:

(a)	Retained on 60mm sq. mesh sieve	-	Nil
(b)	Retained on 50mm sq. mesh sieve	-	Not more than 10%
(c)	Retained on 20mm sq. mesh sieve	-	Not less than 95%
(d)	Passing on 6 mm sq. mesh sieve	-	Maximum 1%

Dust: Material passing through 6mm sq.mesh, classified as 'dust', was limited to 1%

(iv) **In 1990,** on account of introduction of Ballast Cleaning Machines, Ballast Specifications were further revised as follows:

(a)	Retained on 65 mm sq. mesh	-	Nil
(b)	Retained on 50mm sq. mesh	-	Not more than 15%
(c)	Retained on 20mm sq. mesh	-	Not less than 99% for machine crushed. Not less than 95% for hand broken.

(d) The ballast, should be PURE, i.e. it should not contain inorganic or organic residences, and must be free from inferior or harmful substances.

These specifications were applicable to both machine and manually crushed ballast, and also for points & crossings and plain track.

(v) **In 1993,** intermediate sieve size was changed from 50mm to 40mm to ensure proper grading of ballast as detailed below:

Retained on 50mm sq. mesh .... Not more than 15%

Retained on 40mm sq. mesh .... between 55 & 70 %

(vi) **In 1995,** passing through 20mm was relaxed to 2% for machine crushed ballast. Further ballast retained on 65 mm and 40 mm sq. mesh if at variance than stipulated in para 3.5 above, the stack was to be rejected i.e. no relaxation even for payment on reduced rate.

(vii) **In April, 1997** the Ballast specification was again revised to ensure proper grading and techno-economic viabilities. The details are as given below:

(a) Retained on 65 mm sq. mesh sieve - Nil

(b) Retained on 40mm sq. mesh sieve - 40% to 60%

(c) Retained on 20mm sq. mesh sieve - Not less than 98% for machine crushed.

Not less than 95% for hand broken

(viii) **In January 1999,** Ballast specifications were again revised to suit field conditions and also to standardise its physical properties. As per these specification, physical properties are as stipulated below :

Type of Value	Maximum %			Relaxed
% with	B.G.	M.G.	N.G.	approval of CE/CTE
Aggregate Abrasion Value	30	30	35	35 for B.G. & M.G,
Aggregate impact value	20	20	30	25 for B.G. & M.G.
Flakiness index	50	50	**	---
Water absorption test	1	1	**	---

Size of the ballast specified was as below:

Mesh size	% retained
Retained on 65mm sq. mesh sieve	5% maximum
Retained on 40mm sq. mesh sieve*	40%-60%
Retained on 20 mm sq. mesh sieve	Not less than 98% for machine crushed & not less than 95% for hand broken.

(ix) **In June 2004,** ballast specificities were again revised to make it more practical from economical considerations. The new specificities included the following special features:

(i) <u>**New acceptance & Payment norms for oversized ballast**</u>.

- Retention on 65 mm square mesh sieve.

- A maximum of 5% ballast retained on 65 mm sieve shall be allowed without deduction in payment.
- In case ballast retained on 65 mm sieve exceeds 5% but does not exceed 10% payment at 5% reduction in contracted rate shall be made for the full stack. Stacks having more than 10% retention of ballast on 65mm sieve shall be rejected.
- In case ballast retained on 40mm square mesh sieve (machine crushed case only) exceeds 60% limit, payment at the following reduced rates shall be made for the full stack in addition to the reduction work out at i) above.
- 5% reduction in contracted rates if retention on 40mm square mesh sieve is between 60% (excluding) and 65% (including)
- 10% reduction in contracted rates if retention on 40mm square mesh sieve is between 65% (excluding) and 70% (including).
- In case retention on 40 mm square mesh sieve exceeds 70% the stack shall be rejected.
- In case of hand broken ballast supply, 40mm sieve analysis may not be carried out. The executive may however ensure that the ballast is well graded between 65mm and 20mm size.

(ii) Slight modification in procedure and payment norms for ballast supplied as per `wagon measurement'.

(iii) More standardisation of sampling and testing of ballast.

4.8.5 Quality Control through Physical Properties

(i) **In 1960s** practically, no control was exercised on quality of ballast by means of checking its physical properties.

In 1977, following tests were prescribed for measuring physical properties of ballast to ensure better quality:

Aggregate Abrasion Value	:	35% relaxable upto 45%
Aggregate Impact Value	:	25% relaxable upto 30%

(ii) **In 1987**, parameters for these physical properties were changed for machine crushed ballast, as given below:

Aggregate Abrasion Value	:	30% relaxable upto 35%
Aggregae impact value	:	20% relaxable upto 25%

On other than `A' route on ground of economy.

(iii) **In 1995,**

(a) The ballast specification were separately laid down for the source selection stage as well as supply stage.

(b) Mechanical crushing was specified to ensure good quality of ballast and CE's personal approval was laid down in each case for manual crushed/hand broken ballast.

(c) Power of CAO (C) & CE in regard to relaxation in the specification for abrasion and impact test were withdrawn for `A' and `B' routes as well as sections with PSC sleepers.

(d) Additional tests were advised to ensure better quality of ballast. These are Flakiness Index test, Elongation Index test, Specific Gravity test, Water Absorption test.

However, specific gravity test and water absorption tests were not mandatory.

(e) Crushing of small size boulders (less than 10 mm dia) was disallowed.

(iv) **In April 1997,** these tests have been further reviewed and some more tests have been prescribed: These are Abrasion test, Impact test, Flakiness Index test, Water Absorption test.

4.8.6 Mode of Manufacture

Before 1987, most of the ballast on Indian Railways was hand broken.

In 1987, specifications for machine crushed ballast were finalized and instructions were issued to ensure to take as much quantity as possible from mechanized quarries. From that time onwards, procurement of machine crushed ballast is increasing day by day.

4.9 FORMATION

4.9.1 Introduction

The prepared flat surface, which is ready to receive ballast of the track, is called the formation or sub-grade. It is an important constituent of the track as it supports the entire track structure.

Old practice for construction of railway fills (banks) was to dump the borrow material and then allow it to consolidate for a few rainy seasons. Stone ballast was generally not placed until the fill had seasoned for several years. Suitable shrinkage allowance was taken into account to cater for settlement of natural ground over which the fill was constructed. The bank slopes was usually 2 horizontal to 1 vertical. Such banks resulted in development of deep ballast pockets and in case of high banks, slopes failed in may cases.

4.9.2 Need for improving the design of formation

The tradional formation was required to be modified in 1960s due to following considerations:

(i) The need for proper design of bank was felt to cater for high speeds and heavier axle loads.

(ii) There was difficulty in maintaining higher banks and there were repeated failures. The maintenance cost was also becoming very high.

(iii) "Soil Mechanics' technology was developed and it was possible to design the formation to meet requirement of modern track.

Items for design of formation

In general the design of formation to meet the modern traffic was seen through following parameters :

(i) Selection of fill material & use of Blanket and Blankething material to improve quality of formation.

(ii) Side slopes and its treatment.

(iii) Drainage of formation

(iv) Soil stablisation and mechanical compaction.

These parameters are discussed in subsequent para.

4.9.3 Design of Formation

The existing formations on almost all the important core routes were constructed many decades ago as per the old practice. These formations were suitable upto 14 tonne axle load and low frequency of slow moving trains. With increase in traffic level, over the period, axle load of wagons has also increased from 14 tonne to 20.32 tonne. As a result, old formations designed on empirical formula have gradually started showing signs of distress. Therefore, detailed design is now being done as per the following policy:

(i) Formations on all new lines including doublings on core routes are being designed and constructed for 30t axle load wagons.

(ii) Formations on existing routes are being strengthened to introduce heavier axle load wagons in phased manner.

Specifications for fill material were improved. It was felt that in order to ensure a trouble free formation, soils having following characteristics should be preferred:

(i) Fine particles (less than 75 micon size) less than 50%

(ii) Liquid Limit under 35% and plasticity index under 15

(iii) Uniformity coefficient greater than 7

(iv) Minimum achievable dry density with heavy compaction as per IS: 2720 Pt VIII, should be greater than 1.85 gm/cc

4.9.4 Slope of formation

The side slopes of both embankments and cuttings depend upon the shearing strength of the soil and its angle of repose. The stability of the slope is generally determined by slip circle method. In actual practice, the average soil like sand or clay may require a slope (horizontal:Vertical) for embankment of 2:1. The slope of the cutting may be 1:1 or ½:1 or even steeper, particularly when rock is available.

To prevent erosion of the side slopes due to rain water etc., the side slopes are turfed. A thin layer of cohesive soil is used for this purpose. Alternatively the slopes are turfed with suitable types of grass. Erosion of bank also takes place sometimes due to water standing in the adjoining land. Provision of a toe wall and pitching is resorted to in such cases.

4.9.5 Blanket and Blanketing Material

In 1960s the concept of provision of `blanket' came into practice.

Blanket can be defined as an intervening layer of superior material which is provided in the body of the bank just under-neath the ballast cushion. It is different from sub-ballast which is provided above the formation. The functions of the blanket are two-fold:

(a) To minimise the puncturing of stone ballast into the formation soil.

(b) To reduce the ingress of rain water in the formation soil.

The blanket should generally cover the entire width of the formation from shoulder to shoulder except that in case of sand or similar erodable material, it should be confined within berms of width 60 to 75 cm. The depth of the blanket should normally be about 30 cm. in ordinary clay soil. However, if formation soil is particularly weak, a thicker layer upto 60 m. may be necessary depending on the shear properties of the formation soul.

4.9.6 Failure of Railway Embankments

The failure of Railway embankment may take place due to the following causes:

(i) Failure of the natural ground.

(ii) Failure of the fill material in the embankment.

(iii) Failure of the formation top.

What ever may be the cause of failure, the normal symptoms which give an idea about failure of Formation are:

(i) Variation in cross levels.

(ii) Loss of ballast.

(iii) Up heaval of the ground beyond toes of embankment.

(iv) Slips in bank slopes.

4.9.7 Remedies for formation trouble & better drainage

Most of formation troubles are because of poor drainage. Earlier drainage of formation was done by

(i) Provision of proper slope of formation by giving cross falls.

(ii) Turfing side slope of embankment.

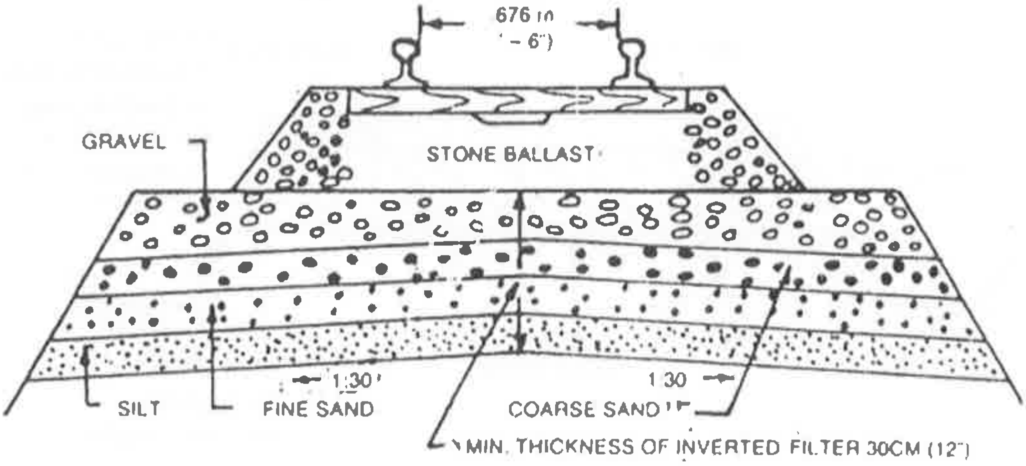
In this system sanctions when the soil was not good, water used to percolate in formation causing variation in cross level and slips as well as laying of formation.

Modern methods of formation drainage are:

(a) Provision of an inverted filter

The bearing capacity of the soil is improved by provision of a blanket of adequate thickness (Inverted filter) between the ballast and weak formation.

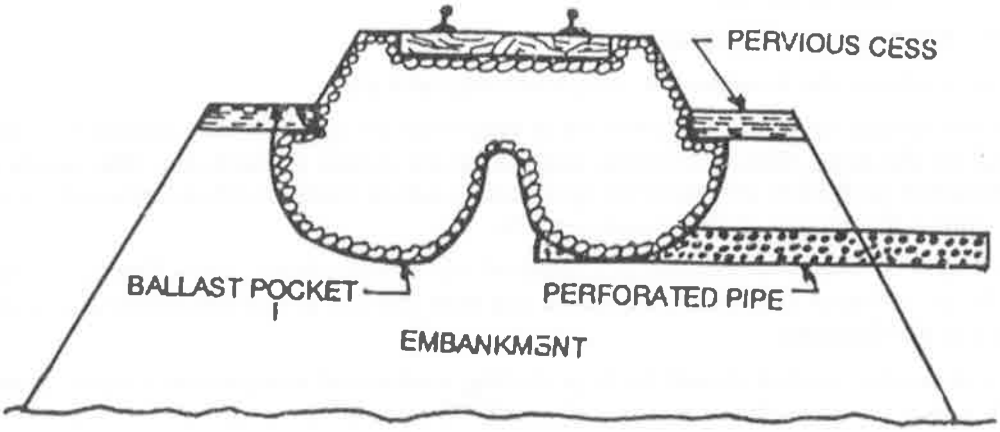
The blanket should be of non-cohesive material and should have adequate bearing capacity to take the load thereon.



PROVISION OF AN INVERTED FILTER (Para 4.9.7a)

(b) Deep Screening and Drainage of water pockets

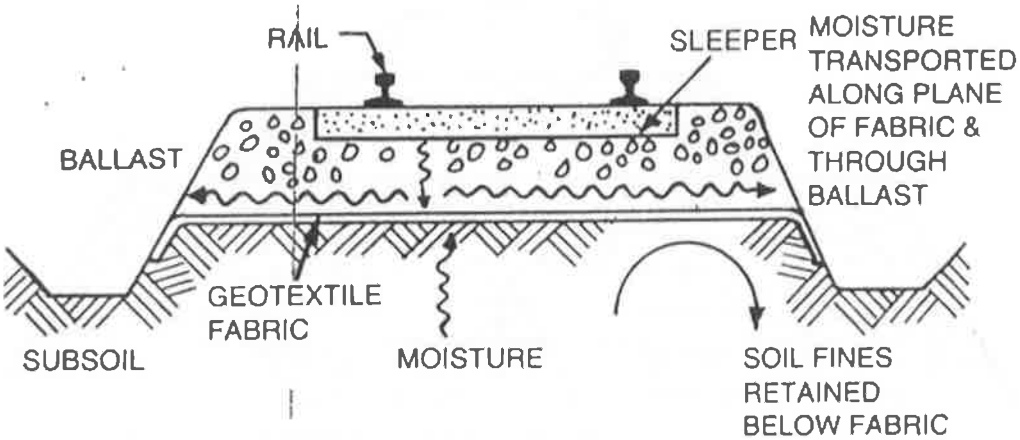
Due to poor drainage & bad soil, Ballast gets punctured in formation causing formation of ballst pockets & collection of water. Drinage of water pocket can be done by perforated pipe drain inserted with the help of a jack, as shown in figure.



DRAINAGE OF WATER POCKETS BY PERFORATED PIPES (Para 4.9.7b)

(c) Soil Stabilisation by Gerotextiles Method

The new method of stabilisation of soil has recently been develop use of GEOTEXTILES. This new material is basically made up of polymus and has unique property of allowing the water to pass through but not the soil fines. GEOTXTILES work not only as separators and filters, but also drain the water and provide reinforcement to the soil bed. (see figure)



PROVISION OF GEOTEXTILES (Para 4.9.7c)

4.9.8 Compaction of Soil

(i) Earlier soil used to be compared manually by hand rammers. Also the formation used to be exposed for one or two rains so that the soil is compared naturally.

These were no method of assessing the extant of compaction, which have been achieved.

4.9.9 Mechanical Compaction

In recent times, the formation is compacted mechanically.

For mechanical compaction, earthwork is done in layers not exceeding 300mm to 650mm thick in the loose state with static and vibratory rollers respectively. The layers are compacted preferably at or near the optimum moisture content with suitable rollers so as to achieve the maximum dry density of 98%.

The top of formation is finished to a slope of 1 in 30 away from center. Extra wide bank by 50 cm on either side should be rolled and then dressed to size for avoiding any loose earth at the shoulder.

Proper quality control should be kept during mechanical compaction. Coarse-grained soil which contains fines passing through 75-micron sieve up to 5 % should be compacted to get relative density of a minimum of 70 per cent. However, all other types of soil when compacted should normally have atleast 98% of the maximum dry density as determined by using compaction.

4.10 TRACK MAINTENANCE

4.10.1 Necessity of track maintenance

The railway track has to be maintained properly in order to enable trains to run safely at highest permissible speed and to provide passengers a reasonable level of riding comfort.

Due to vibrations and impact of the fast moving trains, fittings of track get loose and there is heavy wear and tear of track and its components; also packing under the sleepers gets slackened and track geometry gets disturbed. The gauge, alignment, longitudinal and cross levels thus get affected adversely and safety of the track is likely to be jeopardized. The track and its component also get wornout due to weathering effect of rain, water, sun and sand.

In view of the above, it is essential to maintain the track in good condition so that trains may run over it safely, comfortably and efficiently at specified speeds. If the track is not properly maintained, this would result in faster wear and tear, rough-riding and discomfort to the passengers and then may result in extreme cases of derailments of trains with possible loss of life and property.

4.10.2 Manual Maintenance of track

For over a centaury since the beginning of railway in 1853, track maintenance has been done by manual efforts with the help of gangmen using tradional tools like beater, pickaxe etc. Abundance of labour & dearth of mechanical appliances have been the main reasons for preference of manual method of track maintenance in India.

Track maintenance in India is being done manually by 'Calendar System of maintenance. In this system a programme of track maintenance works are to be done cyclically as per calendar on an yearly basis by Permanent way gangs. The twelve months cycle of maintenance as per the time table or the Calendar consists of the following operations:

a. Through Packing
b. Systematic over-hauling
c. Picking up slacks

4.10.3 Annual Programme of Regular Track Maintenance

There is recommended annual programme for regular track maintenance in which period for each of the major activity is specified as per fixed time table (calendar). This is given in a tabular form.

Time Table for Regular Track Maintenance

	Period	Work to be done
1.	Post monsoon attention: For about six months after end of monsoon.	1. Attention to run down lengths in the entire gang beat to restore the section to good Shape. 2. One cycle of systematic through packing/ systematic Directed track maintenance from one end of the gang length to the other and including overhauling of nominated sections 3. Normally 4 to 5 days per week should be allotted for through packing/overhauling and the remaining days for picking up of slacks, attention to bridge approaches, level crossings and points and crossings over the entire gang beat. Works such as Lubrication of rail joints, doing joints, gap adjustment as required and realignment of curves should be done during this period
2.	Pre-monsoon attention: For about 2 months prior to break of monsoon.	Normally two to four days in a week should be devoted to clearing of side and catch water drains, earthwork repairs to cess, clearing waterways and picking up slacks. In the rest of the days normal systematic maintenance will be carried out.
3.	Attention during monsoon: For about four months.	Attention to track as required. This will consist primarily of picking up slacks and attention to side and catch water drains and water-ways. During abnormally heavy rains, patrolling of the line by gangs should be carried out in addition to regular monsoon patrolling.

4.10.4 Through Packing

Through packing consists of the following works being done systematically in the following sequence:

(i) **Opening of road:** Ballast is opened out on either side of the rail seat for a depth of 50 mm (2") below the bottom of sleeper with the help of shovel of wire claw.

(ii) **Examination of rails, sleepers and fastenings:** The rails, sleepers and fastenings are thoroughly examined; Defective sleepers are removed and loose fastenings are tightened.

(iii) **Squaring of sleepers:** The sleepers get out of square quite frequently resulting in gauge variations and kinks. The sleepers are made square, whenever required at correct spacing and then attended.

(iv) **Aligning the track:** The alignment of the track is normally checked by "eye judgement", sighting the rail from a distance of about 4 rail lengths or so. Small error in the alignments is corrected by slewing the track after loosening the cores at ends and drawing out sufficient ballast at the end of sleepers. Slewing is done by about 6 persons by planting the crow bars deep in the ballast at an angle not exceeding 30 degree from the vertical.

(v) **Gauging:** The gauge should be checked and a uniform gauge within permissible tolerance should be attempted.

Gauge adjustment is done with wooden sleepers, steel tough sleepers & CST-9 sleepers by adjusting the position of spikes, keys and cotters.

(vi) **Packing of Sleepers:** The procedure adopted in packing ballast under sleepers is as follows: The ballast round the sleeper is pulled aside, with ballast forks or shovels; ballast is thus removed to a depth a little below the bottom of the sleeper, Ballast is then packed under the sleeper with pick-axes, until the level of rail is raised to the required height.

A sleeper may be packed by one man, but when this is done, the sleeper is likely to have an uneven bearing. A better method is to position two men, back to back, on the same sleeper, one man in the inter-rail space and the other on the shoulder, and to make them pack diagonally under the rail seat. Known as "Scissors packing".

(vii) **Repacking of joint sleepers:** The joint sleepers are then packed once again and the cross levels checked.

(viii) **Boxing ballast section and dressing:** The ballast section is then properly boxed and dressed with the help of a special template. The cess should be dressed up and its level maintained in a way that proper drainage is ensured.

Through packing is done on a programme basis after the monsoon from one end of the section to the other. A minimum round of one through packing must be given in the year.

The normal output of a gangman for through packing is 11 m to 12 m (36 ft to 39 ft) on B.G., 16 m to 17 m (51 ft to 54 f t) on M.G. and 23 m to 24 m (72 ft to 75 ft) length on N.G.

4.10.5 Systematic Overhauling

The track should be overhauled periodically with the object of restoring it to the best possible standards.

Systematic overhauling of track should normally commence after completion of one cycle of through packing. It consists of the following operations in sequence:

(i) Shallow Screening and making up of ballast section.

(ii) Replacement of damaged or broken fittings.

(iii) All items included in Through packing

(iv) Making up the cess.

4.10.6 Picking up Slacks

Slacks are normally those particular points in the track, where running is bad.

A certain number of days in a week (normally one or two days) are allotted in each working season, depending upon monsoon pattern and other local conditions, to pick up the slacks. During rainy seasons, however, no through packing is done and only slacks are picked up in order to keep the track safe and in good running condition.

4.10.7 Other track maintenance works

These are some other important track maintenance works as given below:

(i) Deep Screening of Ballast:

Deep Screening of ballast is done to ensure that a clean ballast cushion of required depth is available below the bottom of sleepers, which is very necessary for proper drainage and giving elasticity to the track. In the absence of a clean ballast cushion of desired depth, the track geometry may get disturbed and the running of the track gets affected aversely.

There is a detailed procedure to do deep screening, which ensures safety of track and work done in a planned way.

(ii) Other track works include lifting or lowering of track, adjustment of creep, lubrication of rail joints and renewal of track defects like creep etc.

4.10.8 Working of Permanent Way Gangs

On Indian Railways track is mostly maintained by Permanent Way gangs. Each P. Way gang has strength of about 10 to 20 persons and has a beat of about 6 to 10 kms. Depending upon various conditions, the gangs follow normally the Annual programme for regular track maintenance and do atleast one round of "Through Packing" in a year. A gang works under the control of a Mate who assigns the track works to P. Way gangmen.

4.10.9 Tools of P. Way Gang (See Figure)

Each gang should have the following maintenance tools & equipments. The worn out tools and equipments should be replaced every month.

(i) Level-cum gauge to check the level and gauge of track.

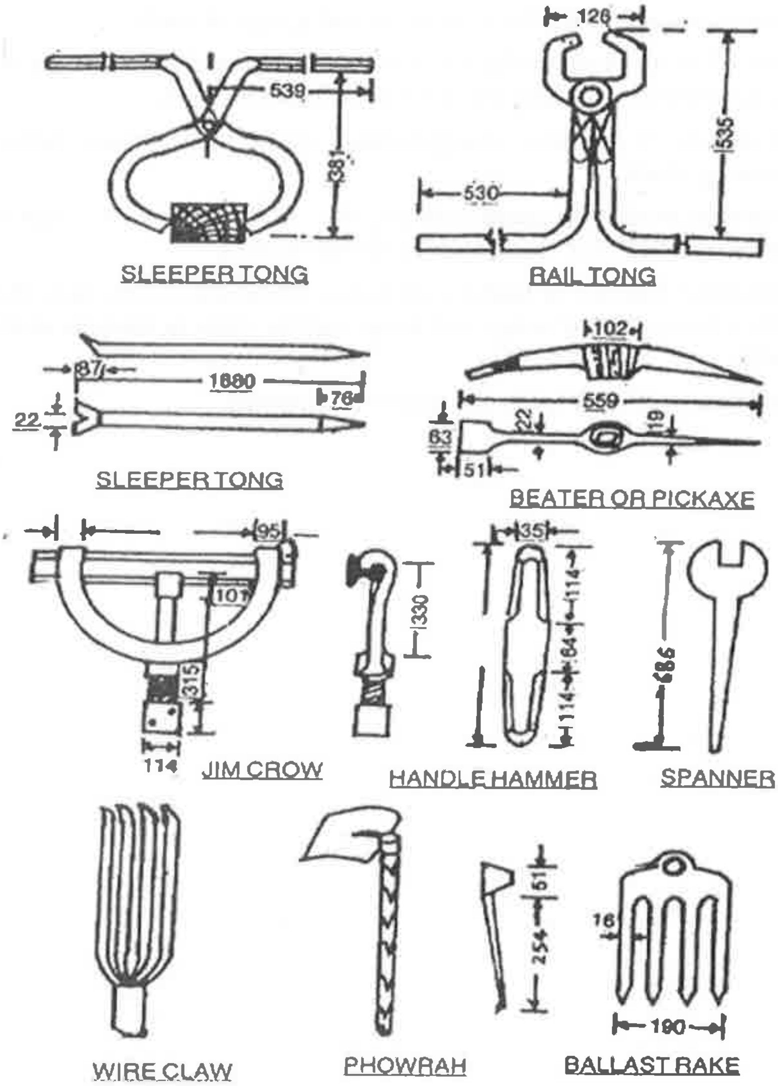
(ii) One set of hand signal flags red and green (2 hand signal lamps at night) and 12 detonators to protect the track in case of emergency.

(iii) Steel scale 30 cm long, straight edge 1 metre long, square, hemp, cord and marking chalk.

(iv) Wooden mallet or canne-a-boule, fish bolt spanner, keying and spiking hammer and M.S.P. equipments, if MSP is done

(v) Sufficient number of Beaters, pickaxes, Phowrahs, Crow bars, Ballast rakes, wire claws, sleeper tongs rail tongs mortar pans or baskets and such other tools.

Some of the important P. Way tools are shown in diagram.



IMPORTANT P. WAY TOOLS OF GANGMEN (Para 4.10.9)

4.10.10 Gang strength for track maintenance

The gang strength was earlier calculated by Mafflin formula, which was subsequently revised to modified Mafflin formula. Lately special committee formula have been prescribed for calculating the number of men for each gang.

The special Committee formula is

N = MKE+MKLU (1+A+B+C)

Where N = Number of men per km

M = Manpower factor.

K = Correction factor due to modernisation of track standard of maintenance etc.

E = Equated Track Kilometre (ETKM) and is equal to LxU(1+A+B+C), A.B, & C are variable factors.

(i) Man power Factor (M)

Man power factor is a factor giving the weightage for the actual man-days required to do normal P. Way maintenance job in a year vis-s-vis the actual number of man-days available.

(ii) Correction Factor (K)

The factor is the factor required to be taken because of modernization of track. IT was felt that the efforts required to maintain short welded rails and long welded rails are much less compared to fish plated track.

4.10.11 Concluding Remarks

The manual maintenance of track has stood the test of time and has been in vogue for over a centuary from the beginning of railway in India (1853) till 1960s. A thinking grew up subsequently that this method of maintenance may require changes due to technological and social considerations. Other methods of maintenance like Measured Shovel Packing, Directed Track Maintenance & mechanized method of maintenance were accordingly tried and adopted as explained in subsequent paras.

4.11 MEASURED SHOVEL PACKING

4.11.1 Introduction

Measured Shovel Packing (M.S.P.) is an improved form of manual packing and aims at a scientific method of maintenance of track without the use of any sophisticated mechanical aid. This method, which was perfected on SNCF (French Railways) in 1900s, has been the standard method of maintenance of track in U.K. prior to introduction of mechanical maintenance of track. Using this method of maintenance of track, it has been possible to maintain fish-plated track in these countries for speeds up 150 Kmph. The method as such had once the potential of being used as a standard method of maintenance for high speed routes, particularly for flat, bottom sleepers.

4.11.2 Development of M.S.P. Technique on Indian Railways

M.S.P. was first attempted on Indian Railways as early as in 1935-36 and again in 1950 by using ABTUS Equipment, but the results obtained were not very encouraging and the project was given up. In 1967 again, maintenance of some trial sections on Northern Railway and North Eastern Railway was taken as a fresh bid to study the suitability of

M.S.P. for flat bottom sleepers. The results of these trials were encouraging and it was felt that M.S.P. can be quite useful in maintaining wooden sleepers. M.S.P. was therefore, accepted as one of the standard methods of maintenance of track being used for specified works.

4.11.3 Essentials of M.S.P.

M.S.P. essentially consists of accurate measurements of track defects particularly the unevenness and voids caused in the course of service and attending the same by placement of measured quantity of small sized stone chips under the sleeper to bring the track to predetermined levels; the compaction of chips is obtained by passage of traffic.

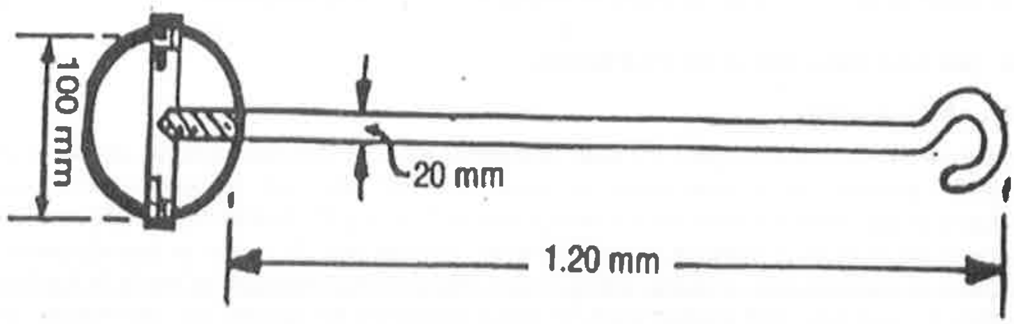
The extent to which the track is required to be lifted is calculated by measuring the longitudinal unevenness in the track after applying corrections for cross levels and voids under the sleepers. The longitudinal levels are measured with the help of optical instruments called *'viseur and mire'* and the voids under the sleeper bed are assessed by a ball ended rod called *'canne-a-boule'* and checked with the help of a mechanical device called *dansometer*. The track is lifted by 40 mm by special type of *non-infringing jacks* and a measured quantity of stone chips is then placed in the sleeper bed with the help of special type of *packing shovels*. The jacks are then tripped off and alignment is finally corrected.

The track is finally consolidated and gets packed by the passage of trains.

4.11.4 Equipments of M.S.P.

Special type of equipments required for the use of M.S.P. are given below:

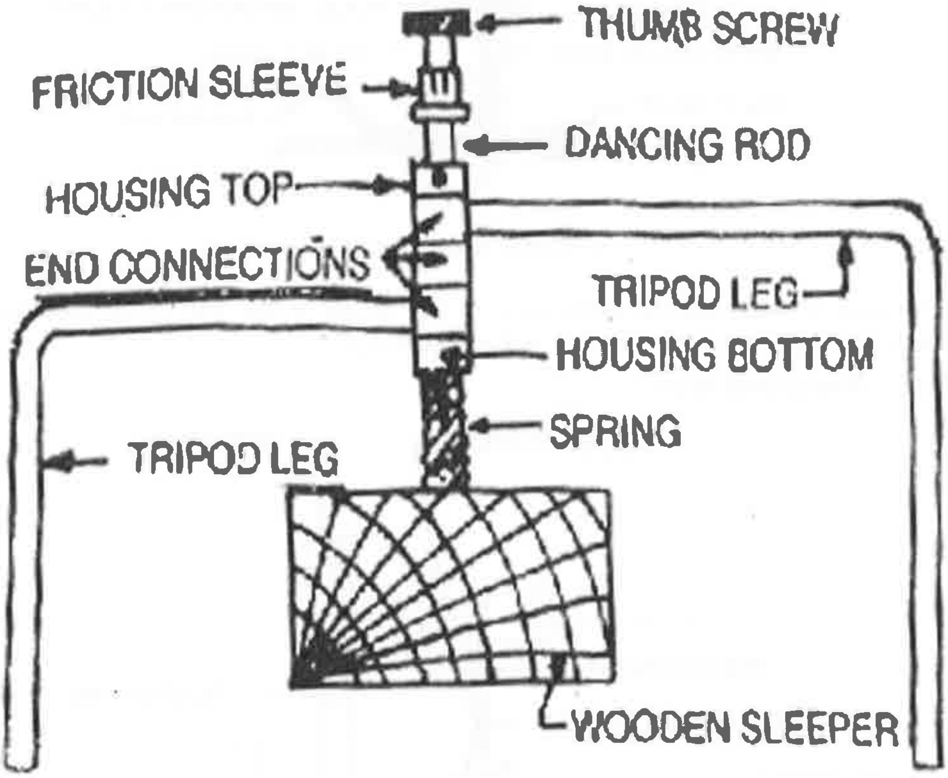
(a) **Canne-a-boule (Fig 4.12)**



CANNE-A-BOULE (Para 4.11.4a)

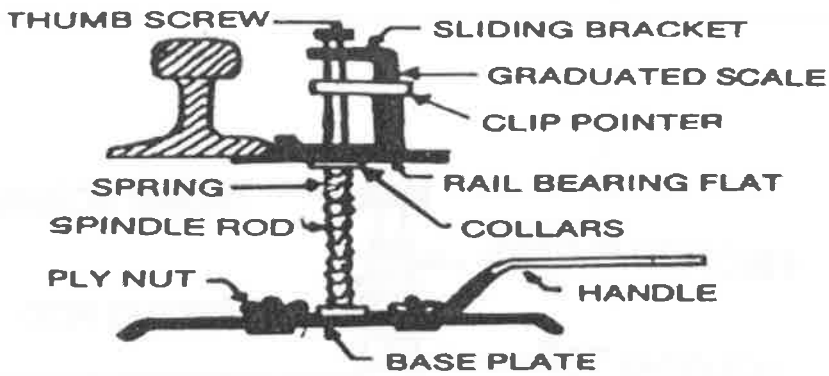
This is used for assessing the extent of packing voids under the sleepers. For wooden sleepers, it is an iron ball of 100 mm dia having a mild steel rod handle of 20 mm dia and 1.20 metre long. For steel trough sleepers, a wooden canne-a-boule 1.20 metre long is used with a cylindrical wooden block of 100 mm dia & 155 mm long. The canne-a-boule is dropped from a height of 40 cm at both ends of the sleeper and the height of rebound and the sound emitted determines the extent of packing voids.

(b) **Dansometer (See Figure)** This is used for measurement of packing voids under the sleeper ends.



DANSOMETER (Para 4.11.4b)

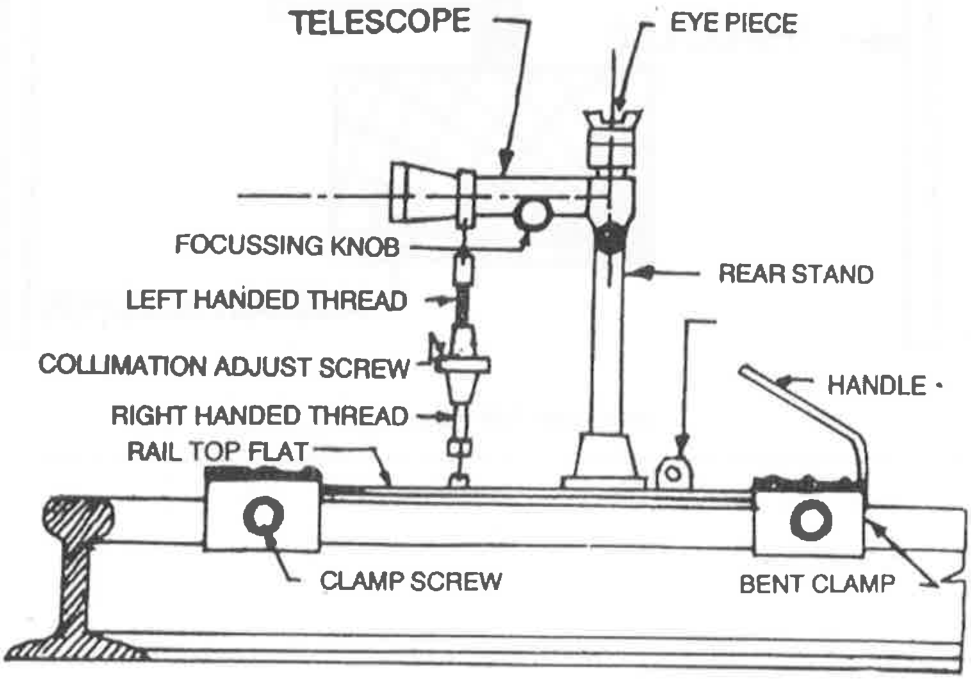
(c) **Fleximeter**



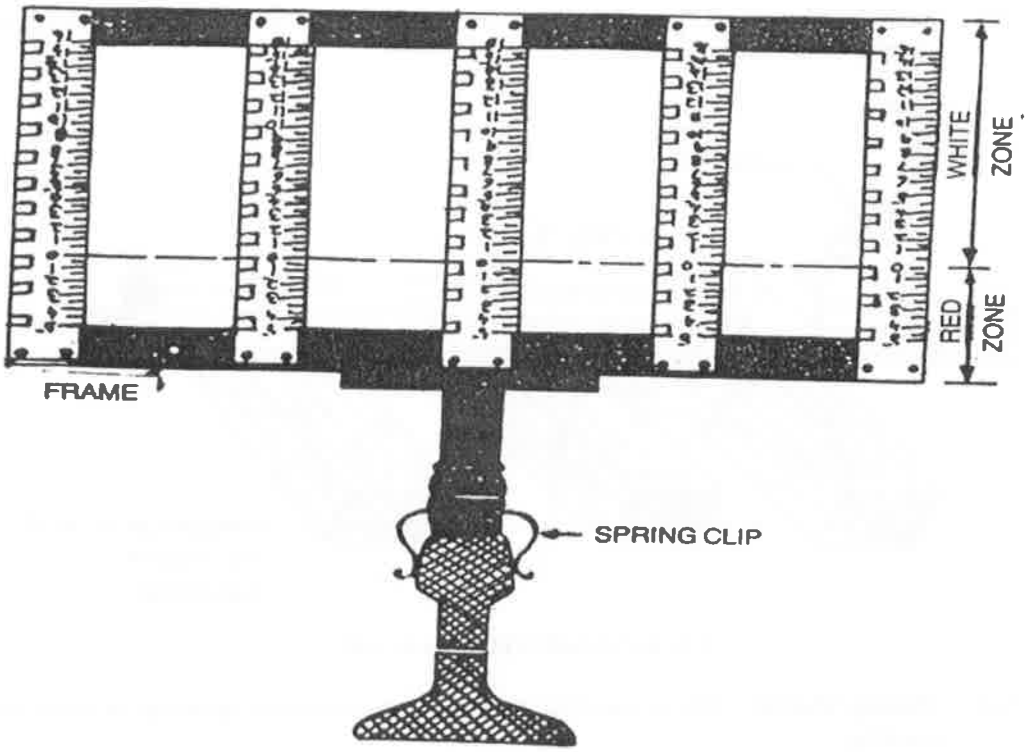
FLEXIMETER (Para 4.11.4c)

This is used to measure the depression of rail under traffic and gives the amount of packing void together with the play in the fastenings.

(d) **Viseur and mire**



VISEUR (Para 4.11.4d$_1$)

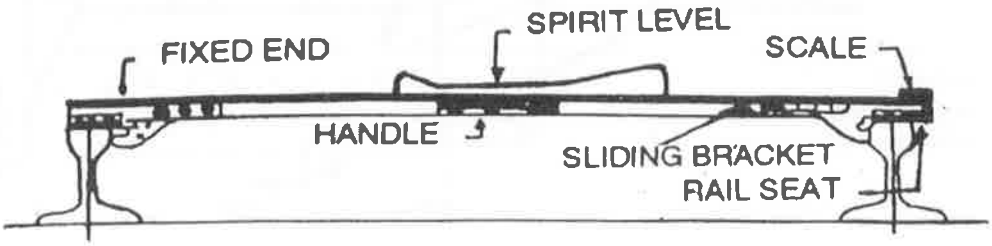


MIRE (Para 4.11.4 d_2)

Viseur and Mire are used for measurement of unevenness of rail top and rectification of alignment. Viseur is a type of telescope having a magnifying power of about 120and is supported on a stand which can be fixed to the rail seat with help of two clamps.

Mire is a staff having 5 graduated scales, printed in mm. The mire has a supporting frame which can be fixed to the rail head by means of bent clamps.

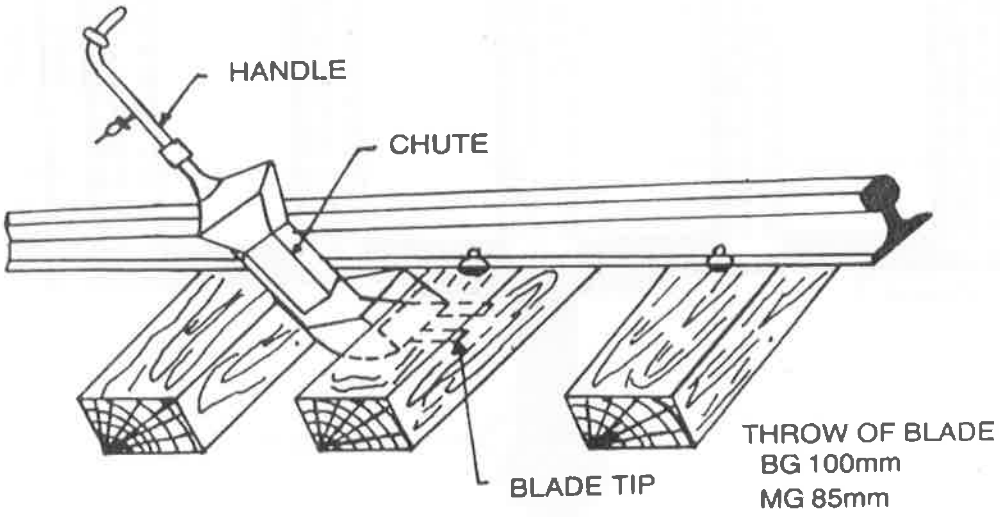
(e) **Gauge-cum Level (See Figure)**



GAUGE-CUM LEVEL (Para 4.11.4e)

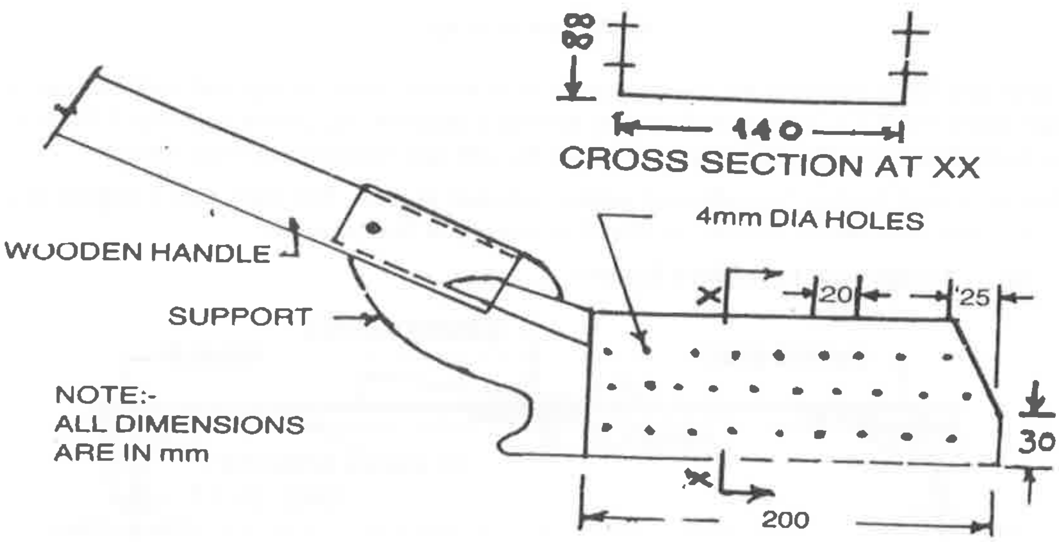
Gauge-cum-Level is used for measuring the gauge of the track and the cross level.

(f) **Packing Shovel -** This is used for placement of chips over the full width of the sleeper under the rail seat.



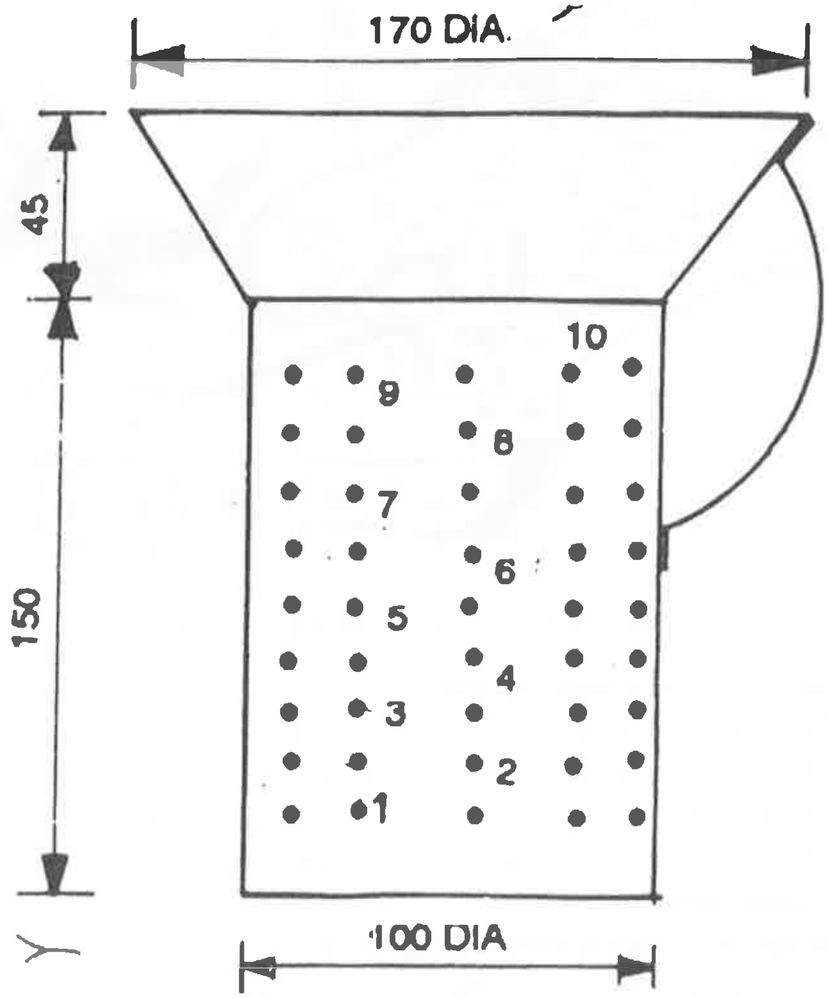
PACKING SHOVEL (Para 4.11.4f)

(g) **Dosing Shovel -** This is used for picking up a measured quantity of chips for packing.



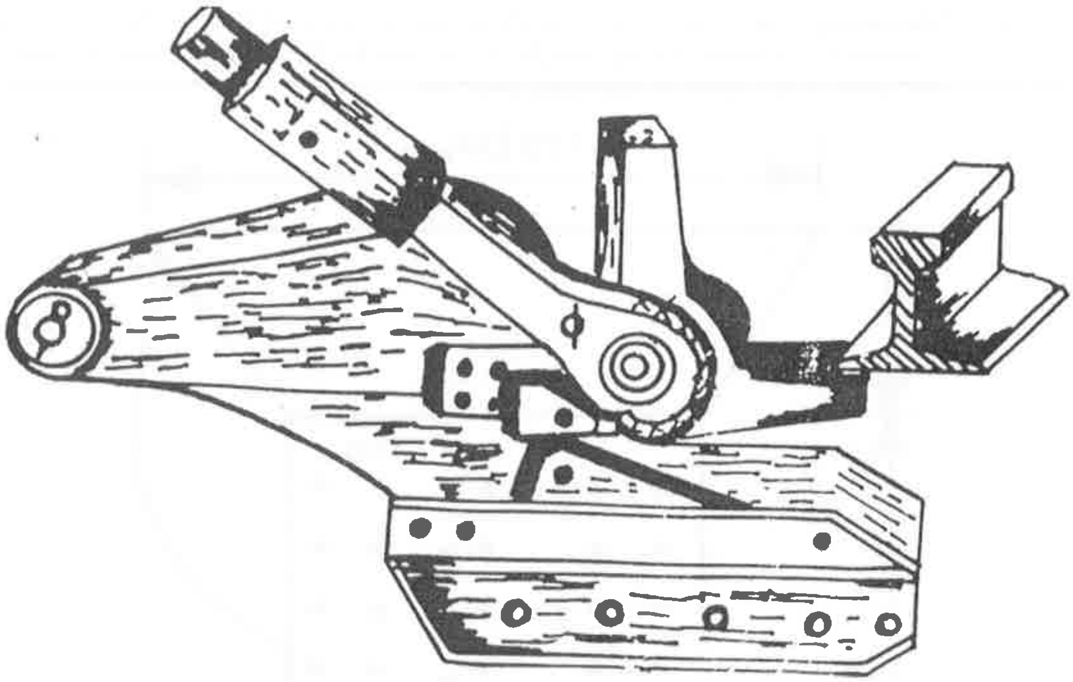
DOSING SHOVEL (Para 4.11.4g)

(h) **Measuring Can -** This is used to check the accuracy of dosing shovel. It is a cylindrical container having height of 150 mm for B.G. and 120 mm for M.G. with perforated holes at calibrated intervals.



MEASURING CAN (4.11.4h)

(i) **Non-infringing Track Jacks -** Non-infringing track jacks are used for lifting the rail to a desired height. The non-infringing feature of the jack is that it can be easily released to normal position in the face of an approaching train with little manipulation and can be left in the track as none of its components project above the rail level and infringes the moving dimensions. The jacks are designed for a safe working load of 5 tonnes and a maximum lift of 200 mm for B.G. and 160 mm for M.G.



NON INFRINGING TRACK JACKS (Para 4.11.4i)

4.11.5 Scope of MSP on Indian Railways

The M.S.P. was popularly used on Indian Railways for the following works:

(i) Through packing of flat bottom sleepers.

(ii) Packing of joint wooden sleepers in metal sleeper track.

(iii) Through packing of turnouts with wooden or steel sleepers.

(iv) Dehogging of rail ends

4.11.6 Through M.S.P. of Flat Bottom Sleepered Track

M.S.P. has been found to be very suitable for flat bottomed sleeper particularly wooden sleeper. The Indian Railways had at that time 33 % of its running track on wooden sleepers and the scope of M.S.P. was limited to this length only as the work was to be done for flat bottomed sleepers only.

(i) Measurements of voids

The assessment whether a sleeper is fully packed or not, and if not to what extent the packing voids exist, is done with the help of *canne-a-boule.*

(ii) Fixation of high points

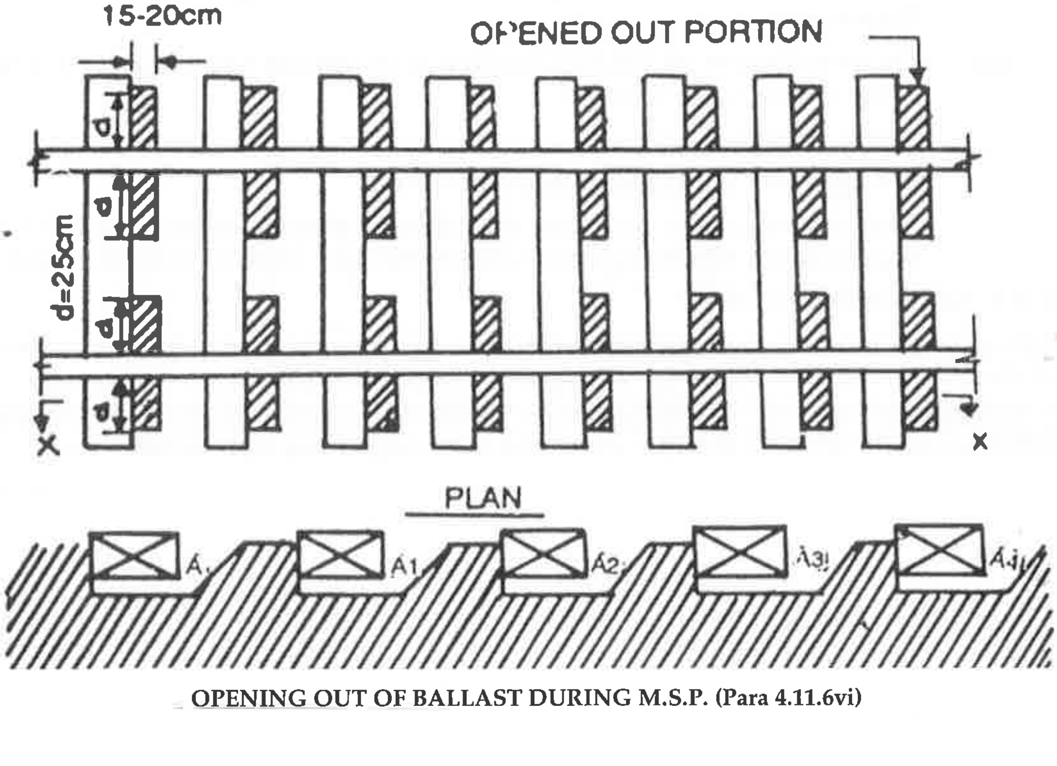
The high points are then fixed on each rail with the help of a naked eye. The cross levels are measured up to 1 mm accuracy with gague-cum-level at these high points and these are corrected for cross level errors. These high points are *'PH points'* as per the French terminology. These are normally spaced not more than 25 metres apart.

(iii) Transferring High Points to Good Points
A general lift of 10 mm for the Ist round of M.S.P. and 5 mm for the 2nd round of M.S.P. is normally given to the track so that packing under the sleepers may be effective. The points are then transferred as good points *(Called PB points)* and the same marked on both the rails.

(iv) Longitudinal Levelling
The longitudinal levels are then taken between two high points on every alternate sleeper with the help of Viseur and Mire. The readings on the intermediate sleeper are obtained by interpolation.

(v) Total Lift
The total lift is then calculated by adding the packing voids assessed to he amount of lift found out as per the requirement of longitudinal levels. This values is called *"Mark Definitive"* and is marked on the inside of the foot of the rail.

(vi) Opening out of Ballast (See Figure) The ballast section is then opened out with the help of non infringing jacks.



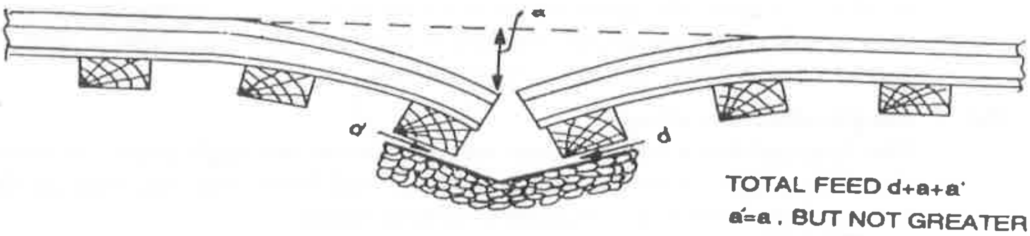
OPENING OUT OF BALLAST DURING M.S.P. (Para 4.11.6vi)

4.11.7 M.S.P. of Turnouts

M.S.P. of turnouts laid on wooden sleepers is quite effective

The principal followed is the same as in earlier case.

4.11.8 Dehogging of Rail Ends (See Figure)



DEHOGGING OF RAIL ENDS (Para 4.11.8)

The hogged rail ends can be dehogged with the help of M.S.P. as given below:

(i) The dip at the joint sleeper, (a), is measured by using a 1.5 metre straight edge and a feeler gauge at a distance of 50 mm from the rail end.

(ii) The dance at the joint sleeper, (d), is measured by Canne-a-boule or Dansometer.

(iii) The joint sleepers are lifted and packed to the desired value equal to d+a+a' where d is the value of dance.

a is the amount of dip

a' is equal to a, subject to a maximum of 5 mm.

After allowing traffic for 2 days the adjoining sleepers are beater packed or shovel packed depending upon whether these are metal or wooden sleeper.

4.11.9 Organisation for M.S.P.

A proper organization is necessary for successfully implementing the M.S.P. programme on the Indian Railways. Normally, a gang of 9 to 15 persons headed by a P.W.I. grade III is required for carrying out M.S.P. work of different types. The average progress achieved and the strength of M.S.P. party on a very rough basis is given below:

Type of M.S.P.	Strength of M.S.P. party Excluding PWI and Mate	Progress likely to be achieved per day	Remarks
1. Through M.S.P. of wooden sleepered road	9 men	243 sleepers	output approx. 27 sleepers/man/day
2. M.S.P. of joint wooden sleepers	8 men	28 joints	output approx 3 to 4 joints/man/day
3. M.S.P. of Turnouts	12 men	1 turnout	

4.11.10 Present position of M.S.P. on Indian Railways

MSP which was introduced on Indian Railways in 1967-1968 became quite popular for about 2 decades. The method was simple but scientific, giving better and lasting surface and effecting considerable economy. The method was particularly suited to Indian conditions due to abundance of cheap labour and the simple equipments which could be developed indigenously in the country.

With the introduction of long welded rails & concrete sleepers, it became difficult to continue MSP as effective method of track maintenance. Mechanised Maintenance which could maintain the track more effectively with the help of sophisticated machines had certain advantages. To meet the challenges of modern traffic, mechanized maintenance became the demand of the day & MSP slowly started losing popularity. Indian Railways by and large abandoned the MSP in 1980s and patronised track machines for mechanized maintenance of track.

4.12 DIRECTED TRACK MAINTENANCE (D.T.M.)

4.12.1 Introduction

For over a century, track on the Indian Railways was being maintained by what is called as 'Systematic Through Packing" based on 'Calendar system of maintenance'. In this conventional system, the entire track was through packed at a fixed cycle of time after opening each and every sleeper irrespective of the fact whether the whole length of track required such attention or not. There was no examination and measurement of track prior to 'Systematic Through Packing' and certain amount of infructuous works were being done by the gangmen in this type of maintenance. The pinch was, however, not so severely felt because not only the track technology including the method of measuring and recording of track geometry was not so advanced, but the labour was also comparatively cheap and the track attended to was in a reasonably good standard. With the increase in traffic density, heavier axle loads, shorter diameter of wheels and introduction of high speed trains, the need for adopting a more effective and economical method of maintenance was keenly felt; Directed Track Maintenance (D.T.M.) was possibly the answer to this problem.

4.12.2 Essentials of Directed Track Maintenance (DTM)

As the name itself suggests, Directed Track Maintenance (D.T.M.) is a method to maintain the track as directed every day and not as a prescribed routine. Directed Track Maintenance essentially consists of Need Based Maintenance rather than routine and conventional periodical maintenance. Under this system, track maintenance is done by proper identification of defects of the track geometry, rectification of these defects under close supervision by attending the track at these isolated locations and thereby maintaining the track to predetermined standards.

The features of Directed Track Maintenance are:

(i) Systematic recording of Track Geometry from one end of the maintenance unit to the other end including inspection of track to record defects which can be noticed visually.

(ii) Analysis of these records and identification of stretches, which need attention during periodic maintenance and spots needing immediate attention.

(iii) Rectification of defects and checking quality of work done.

4.12.3 Scope of work under DTM

The maintenance operations to be carried out in a section where DTM is introduced can be classified in the following three categories:

(i) Systematic maintenance

(ii) Periodical inspection and need based maintenance

(iii) Occasional maintenance

The annual programme of maintenance of track of sections covered under DTM are normally the same as manual maintenance of track.

4.12.4 Quality Control

The quality control to work done by the gang should be exercised as follows:

(i) Daily check made by Permanent Way Mistry (PWM) at the end of work

(ii) Inspection by APW/PWI/AEN and other Senior Officials ensuring that the track parameters are within permissible limits.

(iii) Track recordings should be done periodically and track records analysed carefully to ensure that the track is being maintained to the required standards. The PWI/AEN should travel with the track recording car and give a list of big defects (those exceeding 15 mm of unevenness, 10 mm of misalignment and 10 mm of twist for B.G. track) to the PWM to enable him to rectify them within next two days.

4.12.5 Organisation of DTM

1. Beat of DTM Unit
   The beat of the DTM unit should normally be 6 to 8 route kilometers
2. Supervision
   The concept of DTM requires higher degree of skill in recording of measurements and assessing the maintenance requirements. It is, therefore, desirable that the units work under the supervision of an official not lower in rank than a PWM. When the PWM is incharge of a unit, it is economical to combine two gangs, into one and place them under the charge of the PWM.
3. Training for DTM Supervisor/PWM
   PWMs in charge of DTM should be given detailed training in track structure, conventional methods of maintenance, MSP, DTM maintenance of LWR/CWR, track renewals, safety rules, etc. On satisfactory completion of the training, the PWMs will be awarded competency certificate by an authority nominated by the Chief Engineer.

4.12.6 Future Scope of DTM

DTM has reasonably good potential, if implemented in true sense, with competent and trained P. Way mistries, workable gang beats and proper quality control. This improved and need-based method of maintenance is not only economical but it also provides a higher standard of track maintenance.

4.13 MECHANISED MAINTENANCE OF TRACK

4.13.1 Introduction

The mechanized maintenance of track implies the deployment of track machines for day to day to track maintenance and track renewal works, normally being done by manual labour.

For over a century, the track has been maintained manually on the Indian Railways by "beater packing". There was a general feeling that this method of manual maintenance, which had stood the test of time, possibly required now a revision in view of the change in technological and social environments. The European Railways which were also in a similar position a few decade back, had already changed over to modern method of maintenance like mechanized tamping with Track Machines, measured shovel packing etc. to suit the requirements of modern track. Such a system of maintenance of track had given the P.Way men a better social status, requiring lesser physical strength and higher mechanical skill. The system had also enabled them to maintain the modern track more economically and effectively to cater for higher speeds and heavier axle loads. There is no doubt that for modern track structure having long welded rails and concrete sleepers, the mechanical maintenance of track is considered a technical necessity.

In view of these developments, Indian Railway also started planning for mechanized maintenance of track some where in 1960s.

4.13.2 Need for mechanised maintenance

Manual maintenance of track which has been in vogue for almost a century, had its own limitations and could not meet the requirements of modern track consisting of Long Welded Rails, Concrete Sleepers, & Elastic Fastenings. Some of the important points in this connection are:

Beater packing is a very hard and strenuous job and the labour have a tendency to shirk to carry this type of work.

It is difficult to get uniform quality of compaction under the sleeper by manual maintenance due to uncertainties associated with varying physical strength of labour, the extent of keenness of the workers to do the job, varying weather conditions and such allied factors.

The traffic densities, axle loads and speeds on the Indian Railways have considerably increased in recent past. Beater packing in not able to maintain the track geometry for long within the close tolerances prescribed. The retentivity of packing with manual maintenance is not very good and the track geometry gets distorted in a short time due to fast moving traffic.

On account of these dis-advantages of manual maintenance, the search for finding a suitable method which could replace 'beater packing' has been increasingly felt. Measured Shovel Packing has been found to be one of the alternative methods, but it has its own limitations. The disadvantages of manual maintenance and limitations of Measured Shovel Packing were responsible for evolution of mechanical maintenance of track.

The mechanised maintenance of track is done with the help of various "off Track" and "on Track" track machines.

4.13.3 Development of Track Machines

(i) Off-Track Tampers:

Off track tampers are portable tampers and can be taken off the track in a short time with the help of two men. These tampers work during the interval between trains and do not require any traffic block.

These tampers basically consist of tools driven by compressed air, electricity or petrol. The tampers are generally of two types namely 'self contained' and those, which are worked from a common power unit. The tampers may be vibratory or percussion type or combination of both. In the vibratory type the tamping is achieved by vibration as well as by self weight of the tamper while in the percussion type the blows imparted cause the tamping of the sleeper.

It is said world's first mechanical 'off track tamper' was tried out around in 1920. M/s Nordberg in USA manufacturing Company of Milwaukee Wisconsin started manufacturing Track shifting machines in the year 1927 followed by the Tie Adzer, Spike puller etc.. Mostly manufacturer in Europe and American concentrated in the manufacturing of small track machines.

Most important machines in those days were 'off track' tampers like Cobra (Petrol Driven) made by Atlas Copco, Sweden. Other important brands were Jackson 110 V-3 Phase (made by Jackson Vibrators USA), Shibaura-220V single phase (made by Shibaura Engg Works Japan), Kango- 110V single phase (made by Kango Elecrtric Germany), Robel-2 stroke engine (made by Robel Germany) Piongar 2 stroke engine (made by Berema AB Solna Sweden) and Hyd-2 Elect/Diesel (made by Shenyang China), etc.

The important off track tampers tried on Indian Railways are Cobra tampers, Jackson tampers, Shibaura tampers & Kangro tampers.

(ii) On –Track Tampers:

On-Track Tampers are heavy track machines, which remain on the track and can not be taken off the track by normal manual or mechanical method. The on-track tampers can work only under protection of traffic blocks.

A large number of 'On Track Tampers' are manufactured by Matisa, Plasser & Theurer and such other firms. Matissa of Switzerland was founded in the year 1945; Plasser and Theurer established their works at Linz in the year 1953 and produced their Ist On-Track tamping Machine for Austrian Federal Railways. Alongwith Matisa, Tamper Corporation and Kershaw were established in U.S.A. Kershaw developed Ballast Regulators.

Earlier Tamping machines were able to tamp only and no lifting and lining was possible. Lifting of track was introduced on Plasser machines during 1963 and lining during 1966-67. With this modest beginning of Mid fifties many firms have come up, a few of them are Plasser and Theurer of Austria, Matisa of Switzerland, Robel of Germany, Tamper Corporation of USA, Kershaw of USA, Geismar of France AMECA of Italy, DESEC of Finland, Lorem of USA, EPSA of Spain, Donelli of Italy, Elderomatic USA etc.

Nowadays machines are available for all types of track works. Firms are prepared to manufacture tailor made machines to meet the Railways requirements. Lot of sophistication has gone into these machines for getting correct geometry and desired high output. Present day machines are mostly microprocessor controlled with state of the art electronics and carrying out all track works like packing, aligning, leveling, consolidation etc.

4.13.4 Organisational and Technical development on Indian Railways

(i) Organisation:

In Railway Board there is a separate Directorate under the charge of Executive Director Track (MC), who is responsible to procure track machines in a planned manner and monitor their performance on regular basis and also making cost analysis of various track machines working on Zonal Railways.

Railway Board also arranges regular meeting of all Chief Engineers (track machines) to discuss all problems concerning track machines procurement of spares, technical and operational problems etc. and the experience of various Zonal railways is shared. Representatives of Plasser India, Kershaw, Cummins and other Companies are also called to answer the questions raised by Chief Engineers towards finding out their solutions.

At Zonal Railways level, there is a full fledged track machine organisation which was earlier under an Executive Engineer in the beginning since 1968 onwards. As the machines increased, Dy. Chief Engineers became incharge and now each Zonal Railways has one Chief Engineer (Track Machines) as the incharge of track machines organization, with all other officers and staff. A separate Cadre for track machine organisation has been formed.

All the Zonal Railways have a zonal workshop/depot. These workshops are responsible for maintenance and repairs of track machines apart from maintaining centralized stores. All the Railways have computerized their inventories, issues and receipts.

(ii) Training for track machines:

As the number of machines was increasing it was felt necessary to impart proper training to staff and officers connected with track machines. A centralized training institute was established at Allahabad called 'Indian Railway Track Machines Training Centre' in 1984 under the charge of a Principal.

This institute conducts initial courses for newly recruited fitters and chargeman for 3 months and 6 months respectively followed by refresher courses and special courses. Officers are also trained for one or two weeks.

Apart from its own lecturers, the Institute arrange visiting lecturers from noted field engineers and market on specialized subjects like hydraulics, engines etc.

(iii) Overhauling of track machines:

To meet the growing need of overhauling of the machines each Railway was overhauling these machines in their zonal workshops. As these workshops were not able to cope with the specialized needs of overhauling and load it was felt to establish a Central Periodic overhauling workshop for Indian Railways. Accordingly during 1985, one Central Periodic overhauling workshop was established by Railway Board in consultation with Zonal Railways which will overhaul track machines on age and condition basis. As per this programme, the machines are being overhauled in Central Periodic Overhaulic Workshop (CPOH) at Allahabad.

(iv) Fleet of track Machines on Indian Railways:

At present Indian Railways have around 430 track machines for various track works. These machines have been dealt in subsequent paras for various track works.

4.13.5 Type of Track machines

The Track machines can be broadly classified in the following types depending upon the type of use:

(i) Off-Track Tampers: These are portable track tampers which are used for packing the track. These can be 'taken off' the track in a short time and as such are called 'Off-Track tampers'. No traffic block is required to operate the same.

(ii) On-Track Tampers: These are heavy Track Tamping machines meant for packing the track and also aligning and leveling the same. These machines work under traffic block.

There are special Track machines meant for tamping the points & crossings.

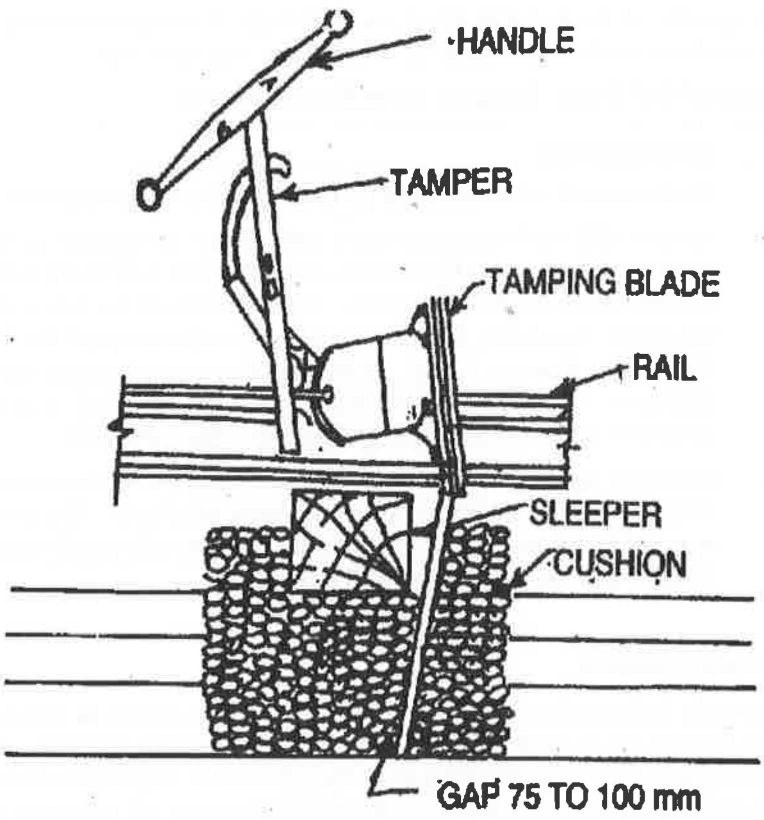
(iii) Ballast Cleaning machines & other track stabilising machine: These Track machines are meant for cleaning the ballast under the track and replenishing the track by pulling back the cleaned ballast. Then there are special track machines meant for stabilizing the track such as crib and shoulder consolidator, dynamic track stabiliser etc.

(iv) Track renewal machines: These are special type of track machines meant for track renewals such as Portal cranes, Track relaying trains etc.

All these track machines are proposed to be discussed separately with regard to their history and technical developments.

4.13.6 Use of "Off Track" Tampers

The 'off track' tampers are worked in pairs from opposite sides of the sleepers diagonally under the rail in order to have maximum consolidation of ballast. The ballast



OFF-TRACK TAMPER (Para 4.13.6)

is first loosened around the rail seat in the crib with the help of beaters for a distance of 450 mm (18") on either side of the foot of the rail. The tamper is them inserted vertically and the tamping tool blades are kept about 75 to 100 mm away from the sleeper so that enough ballast is available between the sleeper and the tamping tool blade as shown.

The average progress of achieved by off-track tampers is about 3 kms per month for one set of track tampers, taking into consideration the repairs, over-hauling etc.

(a) Limitation of Off Track Tampers

'Off Track Tampers' have been only of limited success on Indian Railways because of technical & operational problems:

(i) The tamping with 'off track' tampers is very strenuous and a worker normally gets fatigued after 30- 40 minutes. The quality of work then is likely to get deteriorated.

(ii) The transport of 'off track' tampers along with power unit to site of work in mid-section is quite difficult and this looked to be a non-practical proposition.

(iii) The quality of track maintained was not high. It was particularly not suiting the modern track. The output of work done was also less.

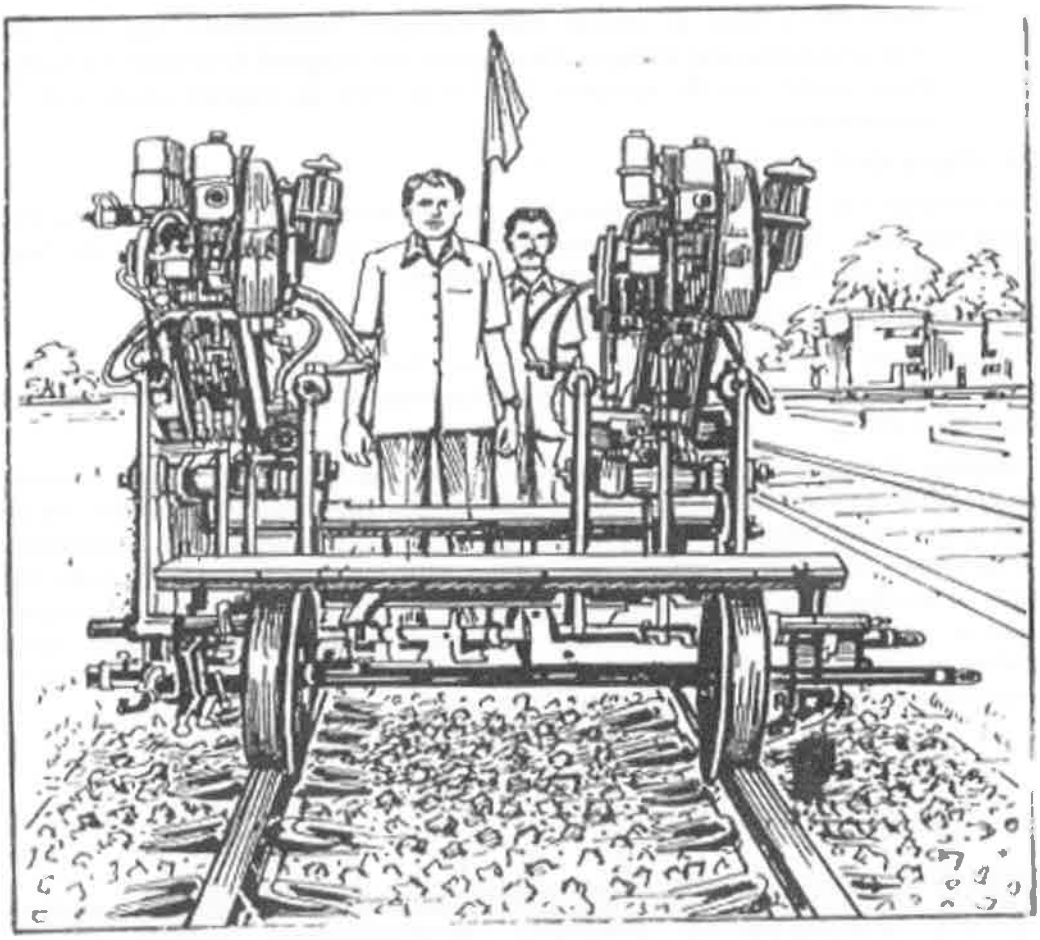
(b) Development of Off-Track Tampers on Indian Railways:

Years	**Development**
1958-60	Trials started with tamping by Cobra Off-track tampers on Delhi-Agra
1960-65 & subsequent years	Section Off track tampers were used/tried on various zonal Railways for maintaining some portions of track. The 'Off track tampers' used mostly were Cobra Tampers, (manufactured by M/s Atlas Copco Stocktlin, Sweden), Jackson Tampers (manufactured by M/s Jackson Vibratols illinnois, USA), Shibaura Tamper (manufactured by M/s Shibaura Engineering Works LTd., Japan) and Kango Tamper (manufactured by M/s Kango Electric Hammers Ltd.,
1980-onwards	Off track tampers use continued selectively on various zonal railways. With the introduction of heavy on-track machines. The use of off track was quite limited. Their utility was however felt mostly for picking up slacks and maintaining isolated locations

4.13.7 Light Track Tampers

(i) These are light on-track tampers, which have the design of being off-tracked in a minute or so and yet powerful enough to tamp concrete sleeper track and as such, fill a significant gap in the process of mechanization of track on Indian Railways between sophisticated heavy on-track tampers and manual beater packing or even off-track tampers.

(ii) During 1988-89 a large number (48) of Chinese tampers were procured by Indian Railway 50% of these were electrically driven and 50% were diesel driven. Later Indian Railways converted all of these in to diesel driven as taking generating set to site was difficult. These light tampers could be taken off the track in less than a minute. These were very good for small works and picking up slacks etc. (See Figure)



LIGHT TRACK TAMPERS (CHINESE TAMPERS) (Para 4.13.7)

(iii) The Chinese tamper had the capacity to tamp wooden, PRC and other sleepers with the help of 4 tamping tools, operated by hydraulic power. The tools can penetrate about 90 mm below the PRC sleeper and tamp about 450 mm on either side of the rail. The tamper can only pack the sleepers and other functions like levelling and aligning etc. have to be done separately by manual methods.

The light on-track tamper can work without block as it can be off-track in a time of less than a minute. While working without block protection, suitable caution order, banner flag protection and hooter arrangements have to be made in the interest of safety.

(iv) Indian Railways procured 24 Nos. Phooltas Tampers (A Subsidiary of Tamper Corporation USA) to work behind relaying or deep screening.

Since PWI's have to arrange their transport, maintenance and since the output was less and lifting and lining was also required to be done manually, these could not be accepted by P.Way men as regular equipment of maintenance.

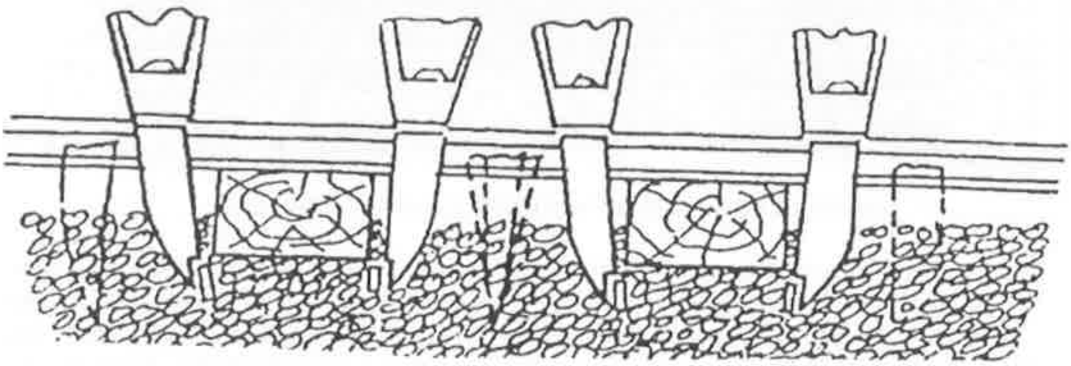
4.13.8 Heavy On-Track Tampers

These are heavy On-Track machines meant for packing the track as well as levelling and aligning the same. These Track machines have to work under traffic blocks as these cannot be off-tracked easily except in special situations.

Principle of working of 'On Track Tampers'

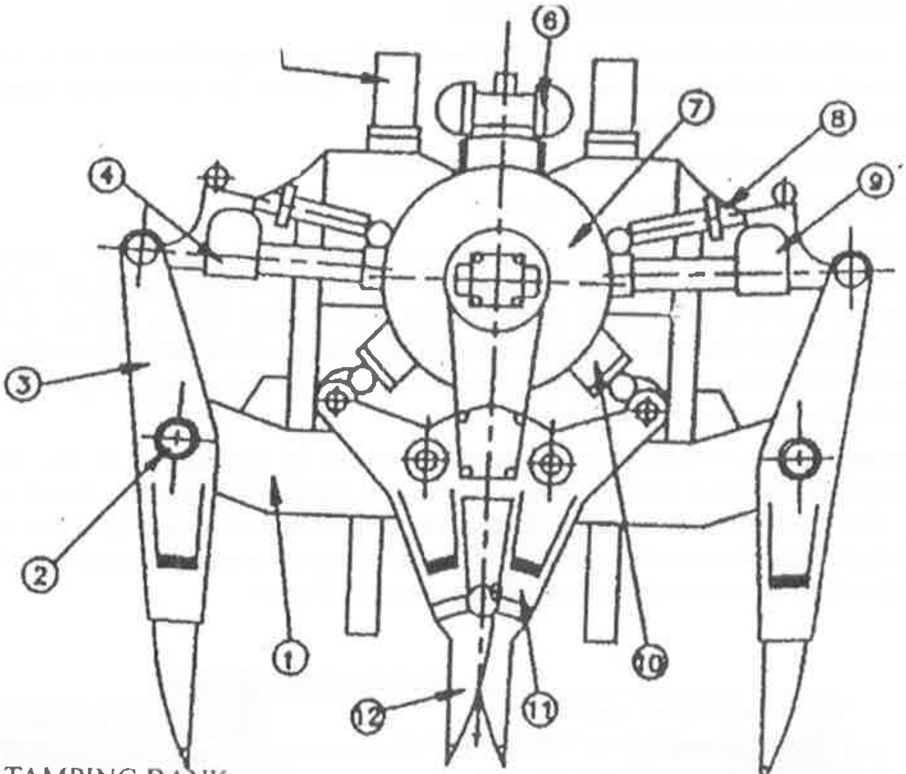
The principle on which these 'on track' tampers (Tie Tamping Machines) work are described in subsequent paragraphs. The main functions of T.T. machines are packing, lining and levelling:

1. Tamping: Tamping is the most important part of the working of the tie tamping machines. Tamping consists of packing the ballast under the sleeper. This is achieved by vibrating the ballast, thereby making it fluid and then compressing it by squeezing the same as shown in figure. The tamping is done with the help of tamping tools, the number of which can be 16 or 32 depending upon whether single or double sleepers are packed at a time. Recently quadromatic tamping machines have also been made available, which can pack even four sleepers at a time. The tamping is done either by synchronous or non synchronous system of vibration.



SQUEEZING OF BALLAST DURING TAMPING (Para 4.13.8-1)

1(a) Tamping Units: The machine has two tamping units which are situated just in front of the rear axle. The tamping units move up and down with the help of hydraulic power. The tamping is carried out by non-synchronous system of squeezing. The opening and closing of tamping tools for single and double sleepers spacing is done hydraulically with the help of pneumatic cylinder. The packing of the sleepers is done by squeezing the ballast under the sleeper with the help of tamping tools. The squeezing pressure has to be adjusted according to the condition of the track and the ballast.



1. TAMPING BANK
2. CENTRE PIN
3. BIG TAMPING ARM
4. BIG SQUEEZING CYLINDER
5. GUIDE ROD
6. OIL BATH
7. PLATE GUARD
8. CLAPPER CYLINDER
9. SECURING PLATE
10. SMALL TAMPING CYLINDER
11. SMALL TAMPING ARM
12. TAMPING TOOL

TAMPING TOOL ASSEMBLY (Para 4.13.8-1a)

2. Lining: Lining of the track is corrected by two chord system or single chord system in case of machines manufactured by M/s Plasser & Theurer. The alignment defects are corrected in two chord system to a value $1/6^{th}$ of the original fault because of the relative positions of measuring bogie and the central bogie. In case of machines manufactured by the firm Matisa, the alignment is corrected with the help of two separate chords of equal length, each in the form of a rectangle. In case the defect develops, these rectangles deform into parallelograms and rectification is done by measuring their deformations and correcting relative position.

The lining mechanism in both the types of machines is designed so that alignment is corrected to an accuracy of 1 to 2 mm.

2 (a) Single Chord System of alignment

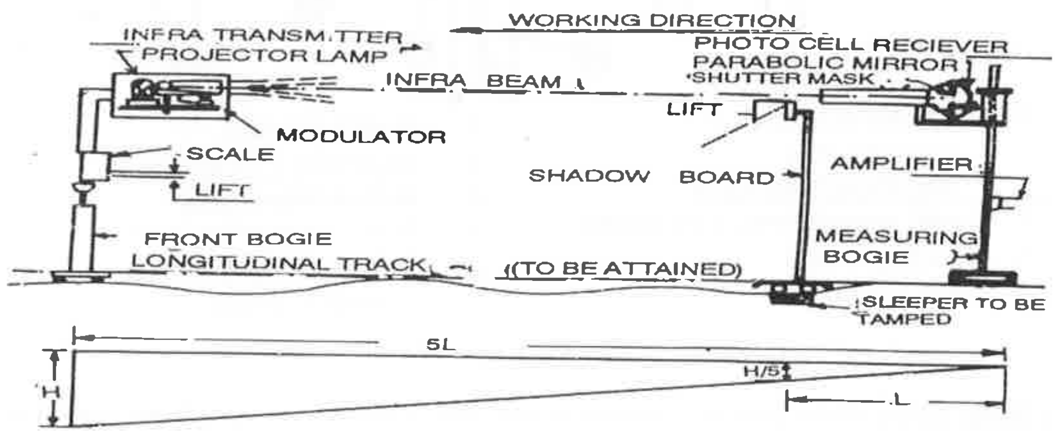
Now-a-days in latest models of Plasser track machines, single chord system of correcting alignment is used instead of two parallel chord system. In this system there are two methods of correcting alignment:

(i) Compensation procedure by 4 points method.

(ii) Precision system by 3 points method.

By using these methods, the error in alignment is reduced considerably and the riding considerably improves. The above principles of lining whether two chord, single chord, 4 point or 3 point, pertains to straight track and circular curves and do not apply to transition curves where the radius continuously changes from infinity to radius of curve, For such situations, however, corrections have to be applied which are given in the form of tables along with each machine.

3. Levelling: The longitudinal levels are corrected by the tamper on the principle of proportional leveling with the help of infra red transmitter, shadow board and photo cells. The distance between these three units is fixed and is so arranged that an error in the longitudinal level is reduced to $1/5^{th}$ of its values as would be clear from the figure. The details of the leveling equipments are given in Figure.



PRINCIPLE OF LEVELLING (Para 4.13.8-2a)

Levelling and Lining with Radio Control

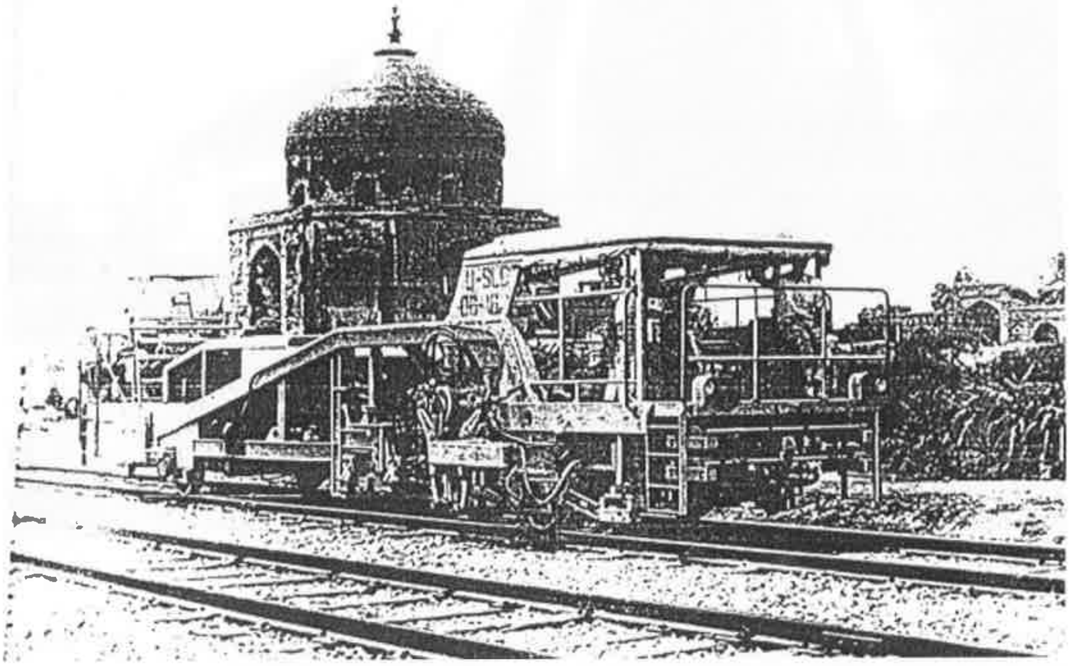
On some of the new models of Plasser on-track tie-tamping machines, radio control system of levelling and lining has been used. With this method designed levelling or smoothening, whatever required can be accurately obtained.

4.13.9 Details of some typical Track Tampers used on Indian Railways

Indian Railways have been using track-tamping machines since 1970s. It is proposed to give brief details of some of the popular track tamping machines, which have been in use on Indian Railways. These are given in subsequent paras.

4.13.10 Plassermatic 06-16-USLC Tie Tamping Machine-Universal Tamper

The earlier model of the machine was plassermatic 06-16 SLC supplied to Indian Railways. The machine was manufactured in a factory near Faridabad in 1972 using about 80% indigenous components by M/s Plasser & Theurer. The term 06 stand for 6th series of machine, 16 denotes the number of tamping tools and SLC stands for Super Lining Control. The machine was a self propelled unit and can do tamping, levelling and lining on plain track.



PLASSERMATIC 06-16 USLC TIE TAMPING MACHINE (Para 4.13.10)

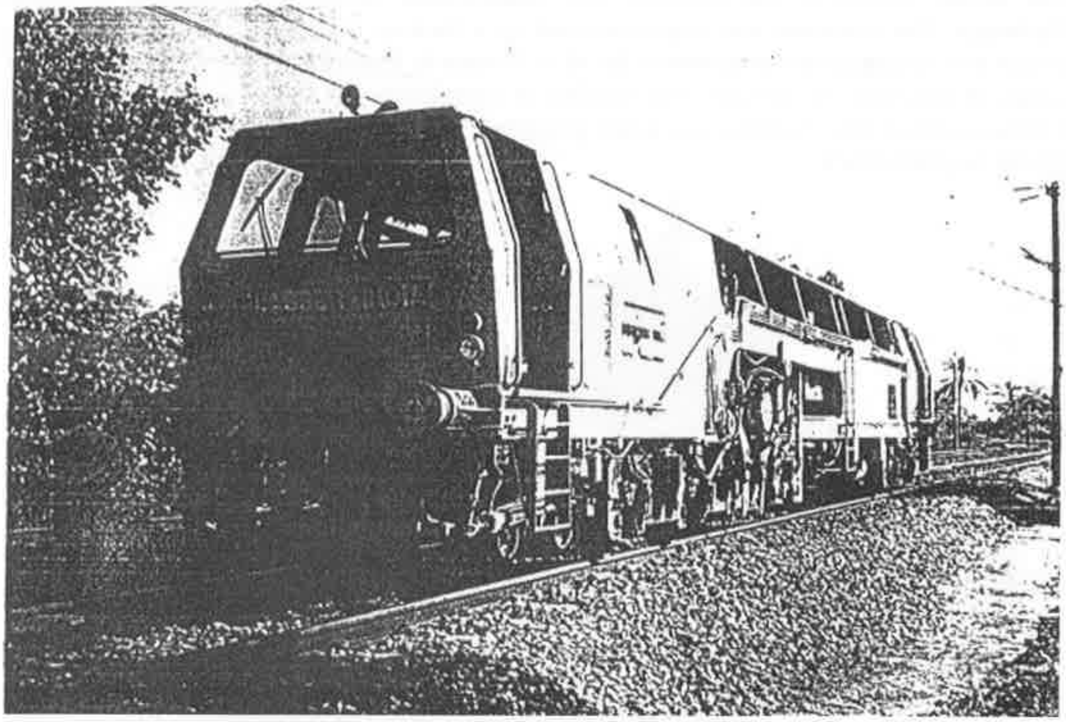
Plassermatic 06-16 USLC machine was a subsequent modified model which can carry out automatically and simultaneously various functions viz (i) Lifting (ii) Levelling (iii) Aligning (iv) Tamping (v) Sleeper and consolidation (vi) Track recording equipments for measuring cross level and versines (optional)

The T.T. machine can run upto 60 KMPH but maximum speed on Indian Railways is limited to 40 KMPH only. The machine can tamp about 500 to 600 sleepers per effective tamping hour. The average output of the machine comes about 15 to 20 Kms with 60 to 80 hours block per month taking into consideration overhauling, break downs, holidays and rests.

These machines got subsequently outdated and very few machines of this model are working on Indian Railway at present.

4.13.11 Plassermatic Unomatic 08-16

This is the subsequent development of 06 series. The machine is more productive in output.

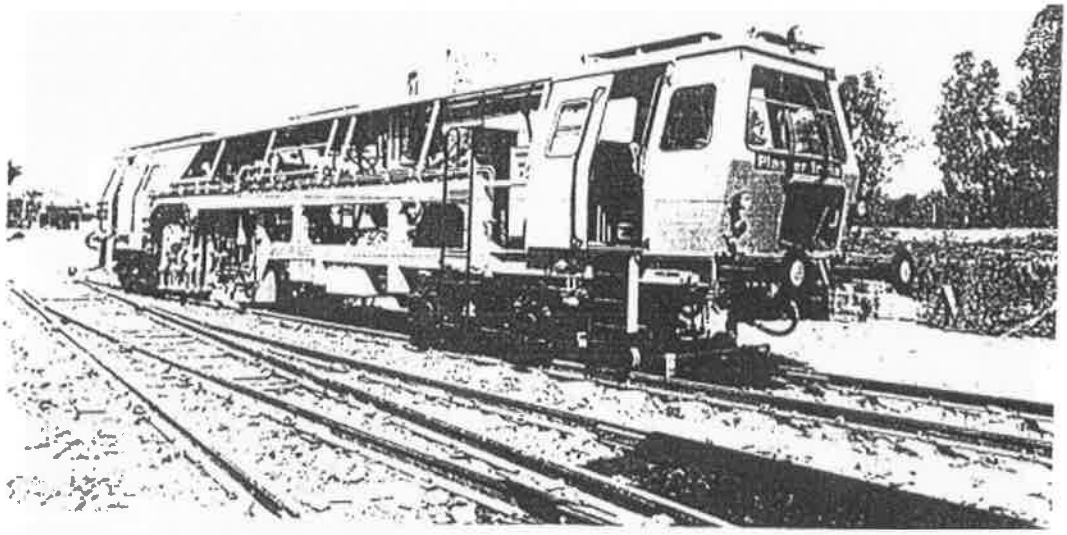


PLASSERMATIC UNOMATIC 08-16 (Para 4.13.11)

The machine has 16 tamping tools and can do tamping, leveling and lining simultaneously. The working progress is upto 1000 sleepers per hour.

4.13.12 Plasser Duomatic 08-32 machine

This is a high output tamping, levelling and lining machine for plain track. It has 32 tamping tools and can tamp 2 sleepers at a time. The working progress is upto 2000 sleepers per hour. (See Figure)



PLASSER DUOMATIC 08-32 MACHINE (Para 4.13.12)

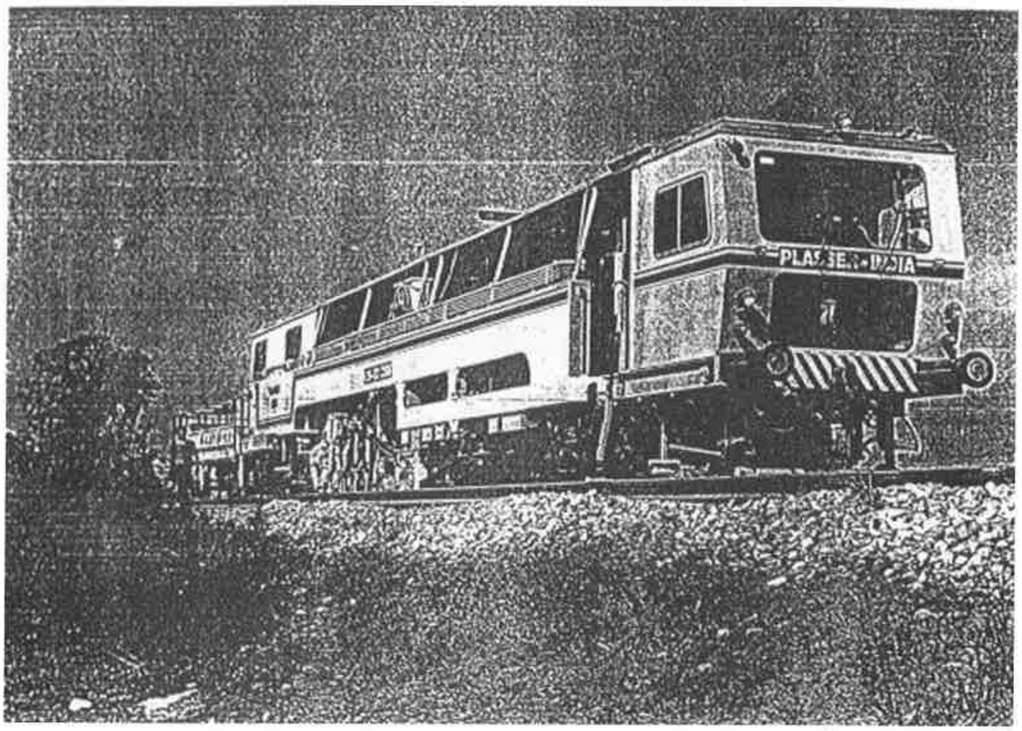
4.13.13 Plasser 09-CSM Tamping machine

A new type of continuous action 09-CSM tamping machine has been introduced in 1990s by M/s Plasser & Theurer. The main frame of the machine which carries operators cabin, power supply and drive for the entire machine moves forward continuously. The actual work units, however, which consist of tamping, lifting and lining units are positioned in a separate underframe and are moved in a work cycle from sleeper to sleeper. As the work units have only 20% mass of the total machine, these are only made to accelerate and brake and this results in lesser wear and tear to the machine and lesser strain to the operator.

(a) Details of the 09-32-CSM machine

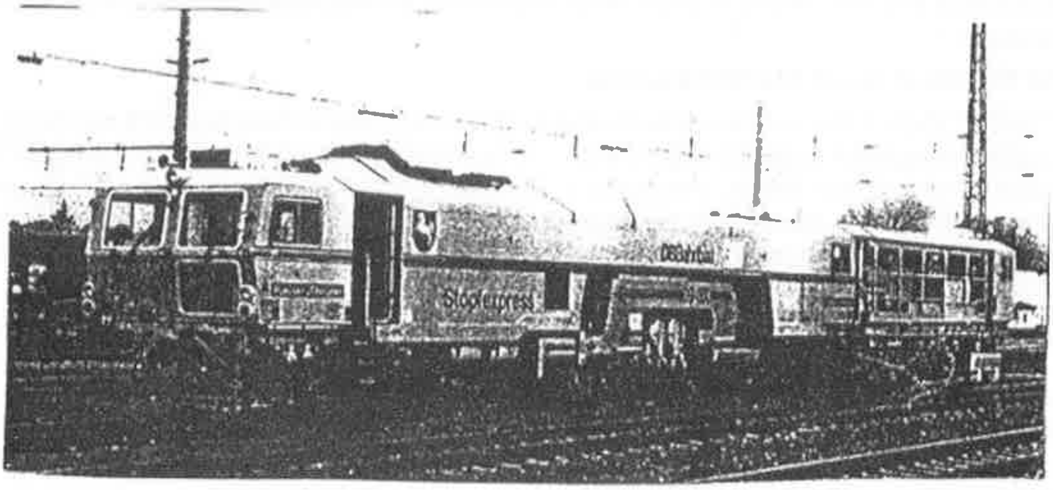
The 09-CSM is a five axle machine in standard railway vehicle designed with two bogies and an integrated material wagon with a free steering axle at the rear. A subframe is located between the bogies, connected to the main frame via a longitudinal roller guide and supported on the track at the rear on a free steering axle. The subframe carries the tamping units with a total of 32 tamping tools together with the roller lifting and lining units as shown in Figure.

During work the machine advances continuously while the subframe with the lifting and tamping units moves in work cycle from sleeper to sleeper. In contrast to conventional machines, only about 20 percent of the total mass of the machine is accelerated and braked. The non-synchronous pressure vibration tamping and the principle of "Tamping directly in front of the loaded axle" are two factors which are normally instrumental for quality tamping.



PLASSER 09-32-CSM MACHINE (Para 4.13.13a)

(b) Details of 09-3x Tamping Express



PLASSER TAMPING EXPRESS (09-3X) (Para 4.13.13b)

After 09-CSM's success story, a more productive Track tamping machine called 09-3X Tamping Express has been developed by M/s Plasser and Theuser in 2000. It is the result of experience in operation of 09-CSM tamping technology which gives further rise to output and quality. The following are its salient points:

(i) Basic design: This Tamping Express machine has got 48 tamping tools and can tamp 3 sleepers at a time with peak output of 3500 sleepers in an hour and average output of 2700 sleepers per hour. The tamping unit is in two separate parts so that it is able to tamp track with irregular spacing of sleepers. If required, one half tamping unit is lowered per rail using it single sleeper tamping Machine.

The main machine is designed as bogie vehicle with 6 axles with transfer travel drive and hydraulic working drive via power shift gear box.

(ii) System of leveling & lining: The machine utilizes proportional leveling system and 3 point lining measuring system. Recording unit with disc drive can be installed with which it is possible to record 8 parameters in digital form. In addition the machine can be equipped with laser measuring devices for longitudinal level and alignment correction.

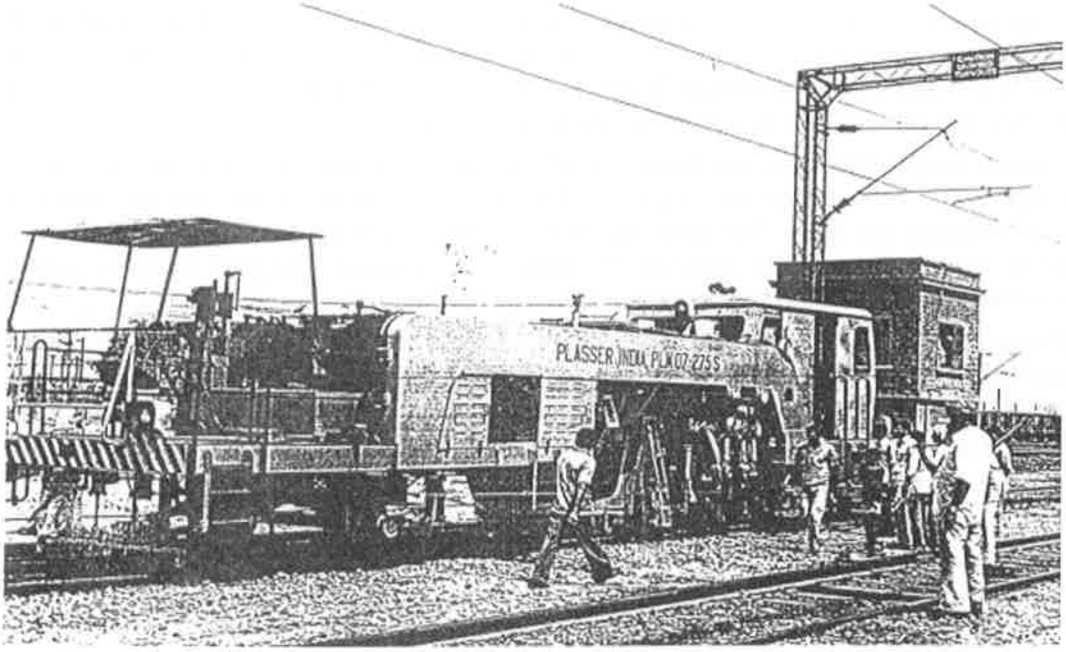
(iii) Output of the machine: With all above facilities, output of this machine (Tamping Express) is about 3500 sleepers per hour. The output gets increased by 30 to 40% compared to continuous action tamping machine; thus it proves to be cost efficient utilization even in short track possession and results in better availability of track.

4.13.14 Switch (Points & Crossing) Tamping Machines. (Fig. 4.33)

This is the machine specially designed for tamping of points and crossings. The tamping units are laterally mounted on guide columns and can be adjusted suiting to the requirements of the particular location. The machine is automatically centred in each forward block and gives a progress of about 400 sleepers per hour. Indian Railways have procured a few plassermatic 07-275 switch tamping machines. Some of the special features of this machines are:

- (i) The machine has only 8 tamping tools
- (ii) Tamping units can slide sideways. Similarly tools can also be made to slide about 150 mm.
- (iii) Tamping tools can tilt 15 degree inside and 85 degreed outside to suit the local conditions.
- (iv) Depth of tamping tools can be adjusted
- (v) Only one tool can operate and tamp at one time, if required.

The plasser 07-275 and subsequently 08-275 machines have been working on Indian Railways for some time in the past and their performance has been quite satisfactory.



SWITCH TAMPING MACHINE 07-275 S (Para 4.13.14)

4.13.15 History of Track Tamping machines on Indian Railways

Year	Type of Tamping Machines	Remarks
1963-64	Matisa B-60 (1 No.)	Matisa B-60 could do only tamping work and other works like levelling, aligning, were done separately by manual effort. The progress achieved was 150-200 sleepers per hour.
1964	Matisa BN-60 (3) Plasser VKR-05	The machines can do packing & levelling but no aligning; progress 150-200 sleepers/hour could be done.
1966-67	Plasser Super Lining Control (SLC) (12 No.)	These machines were assembled/manufactured in a factory at Faridabad by M/s Plasser & Theuser. These Machines could do tamping work as well as lining and Levelling work. The progress achieved was 400-450 sleepers per hour.Most of the parts were imported, but there was lot of stress on Indigenisation and then getting the same manufactured in India.

1972-1980	Plasser 06-16-USLC machines (12 +18)	Plasser USLC machines were improved version of SLC machines. These machines could simultaneously do tamping, levelling and aligning of track. These machines were provided with Ashok Leyland ALU-68 Engine or Communions NT 495. They could tamp 500 sleepers per effective hour.
1979-1980	Plasser 07 series	Plasser 07 series had higher production capacity and better quality of work and had ability to adhere to strict tolerances of modern track. A 16 tool machine was able to pack and align 600 sleepers per effective hour and a machine with 32 tools called Automatic was able to pack two sleepers at a time & could give higher productivity.
1980-85	Plasser 08 series (Unomatic with 16 tools & Duomatic with 32 tools)	These machines had superior performance capacity with regard to quality & output. These were microprocessor controlled machines with most of the controls being electronic. These machines had the speed potential of 80 Kmph. A 08 series machine with 16 tools (Unomatic) is able to tamp about 800 sleepers per effective hour and with 32 tools (Duomatic) can tamp about 1600 sleepers (more than a KM) per hour with better quality of track. The force available to pack the sleepers was higher due to use of longer tamping arms & increased pressure for packing, which suited concrete sleepers.
1990-95	Plasser 09 CSM (Continuous action tamping machines) (Unomatic with 16 tools & Duomatic with 32 tools)	The main feature of these machines is that they keep on moving continuously on the track at a predetermined speed and by the time they reach next set of sleepers, tamping units pack the previous set of sleepers and jump to the next set of sleepers. These machines use State of Art electronics and have many new features like GVA system, Recorders, Digital Display, Laser lining, centralized multicheck etc. The machine is 27.64 meter long, weighs 64 tonnes and has a speed potential of 95 KMPH. These machines can tamp

		1200 sleepers per effective hour through their unomatic version and 2400 sleepers per effective hour through their duomatic version.
2000	Plasser 09-3 X Tamping Express	This is the latest machine inducted on Indian Railways. This is similar to 09 CSM Machine with the difference it is heavier and can pack three sleepers at a time due to which it has a capacity to tamp maximum of 3500 sleepers in an hour and giving an average of 2700 sleepers per hour.
1981-1982	Plasser 07-275 Points & crossing tamper	This was 07 series machine called 07-275 DS. It had 8 numbers tiltable tamping tools, 4 nos on each tamping unit. This machine was tried on Northern Railway. This machine was powered with 260 BHP Cummins Engine and could tamp one turn out in one effective hour of working. Due to limited number of tools some places used to be left unpacked still the results were quite encouraging.
1984-1985	Plasser 08-275 Points and crossing tamper	This machine had 16 tiltable tools and can tamp, points and crossing more effectively and can be utilized as plain track tamping machine with the same output of 800 sleepers as other 08 series machines, with the same quality of track and efficiency. These machines utilize similar lifting and aligning system as other 08 series machines, however hook blocks are used for lifting, as rollers cannot work on Points and Crossings.
1985-1990	Plasser 08-275-35 tamper	The tamper had 16 tools and can be utilized to tamp either points and crossing or plain track. Due to better maneuverability of its tamping units it can tamp the turn- out sleepers more effectively. This machine has arrangement to lift turnout side rail also. These machines need two operators while working on Plain track, one on front tower and the other in working cabin, but while tamping turnout 3 operators are needed- one on front tower and two in the working cabin, to take care of different situations of rails on the turnout.

4.13.16 Ballast Cleaning Machine

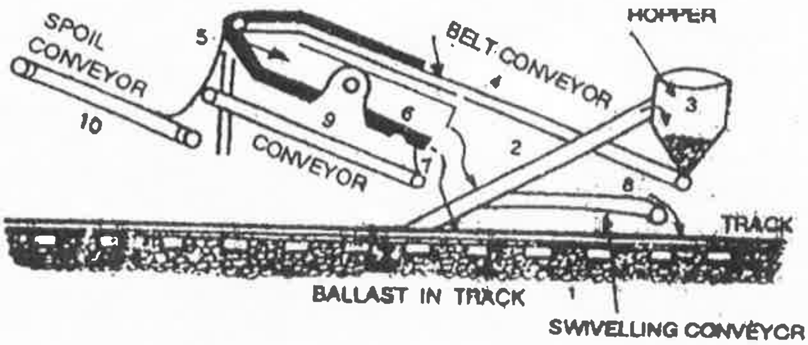
Need for Ballast Cleaning:

Due to heavy dynamic load of moving trains, track ballast gets pulverized and dust is formed. This results in clogging of ballast, thereby effecting the drainage of ballast.

Clean ballast is necessary to distribute load from wheel to rail and to sub grade; this can be done if there is enough ballast and if too many fine particles are not there.

Ballast cleaning earlier used to be done by manual efforts. In order to improve the quality of cleared ballast and to get the work done expeditiously Ballast cleaning is presently being done mechanically by Ballast Cleaning machines.

1 Ballast Cleaning machine



1 BALLAST IN TRACK	6 SCREENS
2. ASCENDING TROUGH	7 DISTRIBUTION CLUTCHES
3 HOPPER	8 SWIVELLING CONVEYOR
4 BELT CONVEYOR	9 CONVEYOR UNDER THE SCREEN
5 SCREEN HOPPER	10 SPOIL CONVEYOR

BALLAST CLEANING SYSTEM (FLOW DIAGRAM) (Para 4.13.16-1)

Ballast Cleaning Machine is a self propelled machine powered by a diesel electric generator and is used for cleaning the ballast under the track. The machine can perform the following functions automatically.

(i) Screen the ballast under the track to a desired depth without dismantling track.

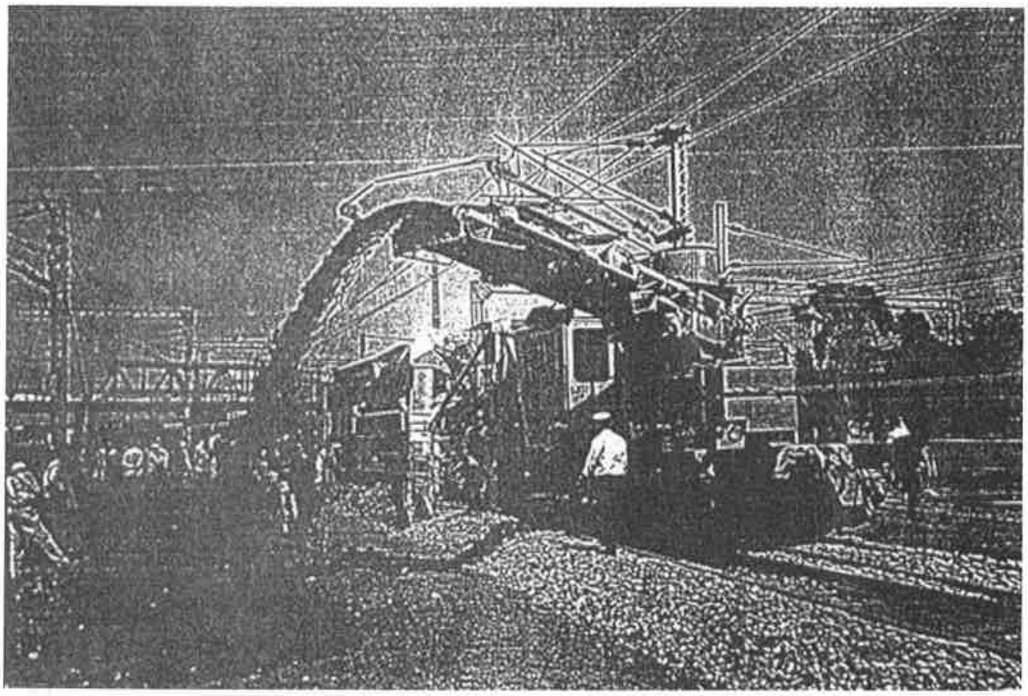
(ii) Distribute the screened ballast inside and outside the track

(iii) Discharge the spoil to a nearby convenient location.

(iv) Indian Railways inducted one No. Matisa Ballast Cleaning Machine Model 10 CB5 around 1968 for trial purposes. This was worked for Eastern Railway, later around 1974 it was transferred to Northern Railway where it worked up to 1985 when it was taken out of service. It is still being used as a model for training purposes in Indian Railway Track Machine Training Centre at

Allahabad. This machine has capacity of cleaning 300 Cublic meters of ballast in an effective hour. This was subsequently replaced by later models which are more productive and efficient such as plasser RM-76 UHR and RM-80 etc.

2 Ballast Cleaning machine-Plasser RM-76-UHR



BALLAST CLEANING MACHINE-PLASSER RM-76 UHR (Para 4.13.16-2)

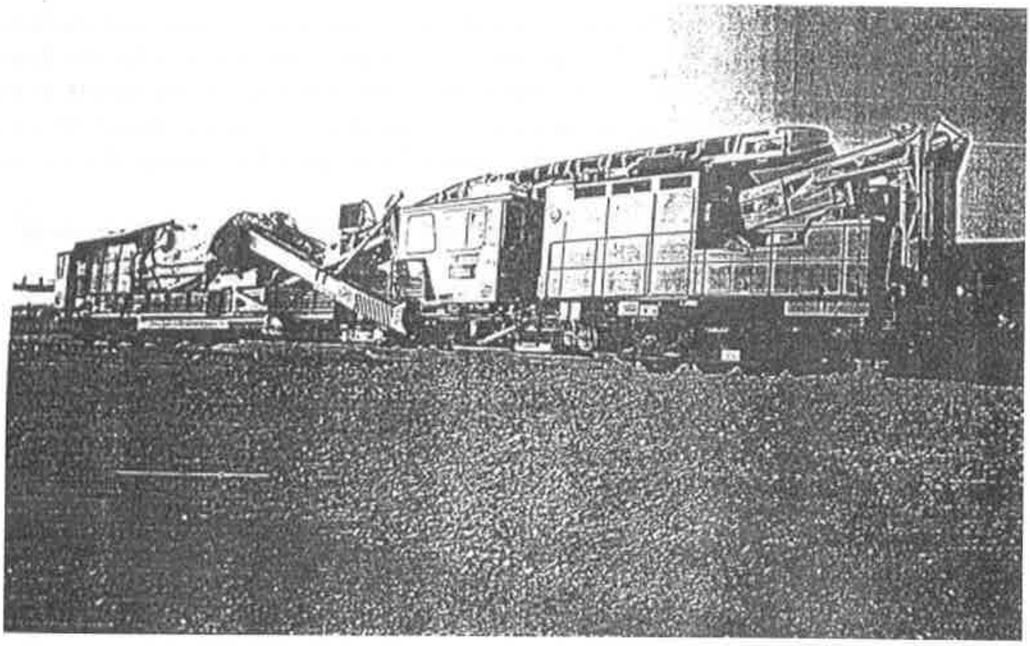
This was an earlier model of Ballast cleaning machine manufactured by M/s Plasser & Theurer.

This was Ballast Cleaner-cum-undercutter for plain track as well as for point & crossing. The cleaning progress was about 350 cum of ballast per hour.

3 Ballast Cleaning machine RM 80-92U

Ballast cleaning machine RM 80 manufactured by M/s Plasser & Theurer was procured in the year during 1989-90, The machine can perform the following functions:

(i) The machine is designed to clean ballast at an output of 650 cum per hour after collecting it from the track. The cleaned ballast is fed into the track and the spoil is discharged away from the track or loaded in a wagon standing on an adjacent track.



RM-80-92 U BALLAST CLEANING MACHINE (Para 4.13.16-3)

(ii) The machine can be extended for an excavation width on both sides. It can thus clean embankment and shoulder material brought by track mounted excavators.

(iii) The machine has storage capacity and can regulate the ballast section.

(iv) The machine has an optional Track lifting and slewing device which can lift the track for 250 mm and can align the track for 200 mm side slew.

(v) The machine can work in conjunction with a Wastage loading unit with capacity of about 1000 tonnes.

(vi) The machine can check & record important work parameters with optional Recording and monitoring instruments.

(vii) The machine can be followed immediately after work by suitable track tamping and track consolidating machines.

(viii) Progress of work: The working progress is cleaning of ballast upto 550 cum per hour of plain track & 1 turnout in 1.5 hours.

4.13.17 Crib & Shoulder Consolidating Machine

The shoulder consolidating machine consolidates the cribs and shoulder of the ballast section. The machine is normally utilized immediately following the tamping work. The main advantages of the consolidating machine are:

(i) The consolidating machine increases the lateral stability of the track and helps in maintaining good alignment.

(ii) The retentively of packing is considerably improved if cribs and shoulders are fully compacted. The experience of European Railways is that the lateral strength of the track is only about 40% after tamping. If the ballast is also consolidated in crib and shoulder the resistance increases to about 70%. Full strength of the track is, however, attained only after the passage of 2 to 3 lacs tons of traffic.

(iii) The number of loose sleepers gets considerably decreased because of consolidation of cribs and shoulders.

(iv) The speeds on the newly laid tracks are restored much quicker.

The examples of these consolidating machines are Plassermatic VDM 800 and Matisa compactor D-9.

The Indian Railways have already purchased Plassermatic VDM-800 consolidating machines and PTV-800 machines for use on its system.

4.13.18 Ballast Regulator

This is a machine used after leveling and tamping work. The ballast profile is regulated by this machine by transfer of ballast in all directions. The surplus ballast is collected and spread at locations where the same is deficient. The examples of such machine are Matisa R-7 Ballast Regulator and Universal Ballast Regulator UPS-300.

4.13.19 Dynamic track stabliser DGS 62 N

Dynamic track stabliser is a self propelled vehicle having a weight of about 57 tonnes and can run at a max. speed of 80 kmph under its own power. The machine is designed to carry out stabilization of ballast bed on order to give better maintainability of track

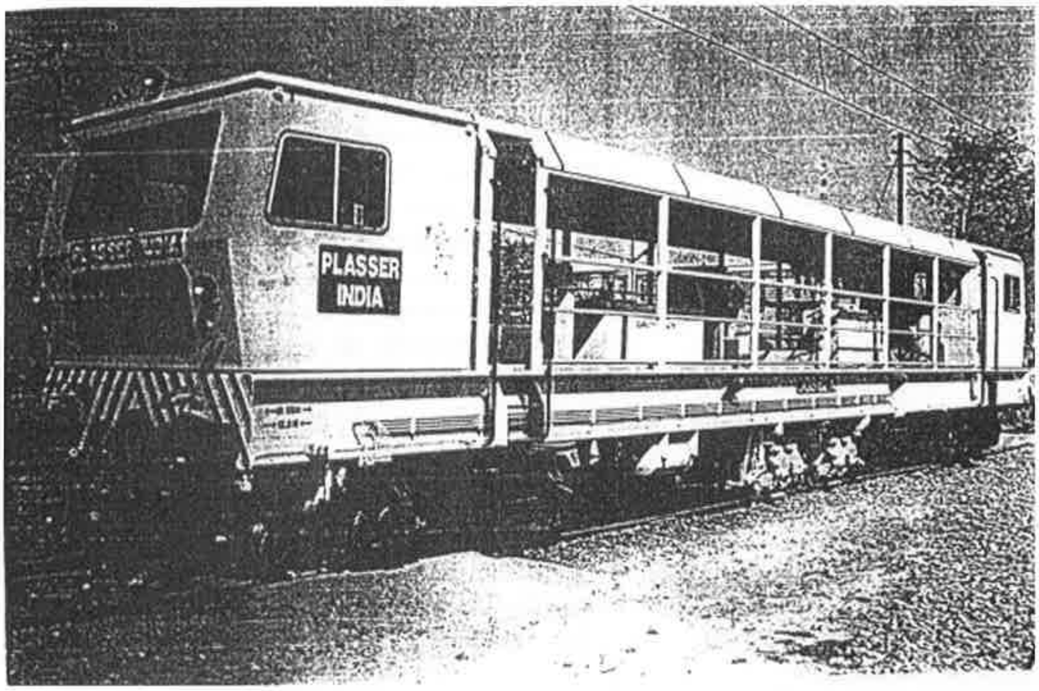
DGS-62N machine has all the facilities that a modern track man can think of. The main features are as under:

1. It stabilizes the track with the help of two Synchronous Stabilizing Units. Earlier machines use to vibrate ballast for its settlement. This machine vibrates the track itself by holding the rails and imparts vibrations horizontally which are passed to ballast also for settlement. The purpose of holding rail is to keep cross levels and longitudinal levels under control, while the track settles down, through chord leveling device provided on the machine.

2. The machine decides vertical load to be applied for achieving desired settlement. Its systems monitor work speeds, vibration, frequency amplitude of vibration and degree of settlement on the left and right side of track. It can record cross levels, twist and versine before and after stabilization.

   The machine is able to eliminate undulations caused due to uneven settlement which is caused after passing of first few trains. The ballast grains are more closely packed with broader contact surface reducing specific compression strains under load.

   Indian Railways procured first stabilizer during 1990 followed by 8 nos. between 1998-1999.



DYNAMIC TRACK STABLISER DGS –62 N (Para 4.13.19)

SALIENT FEATURES

The machine has a overall length of 17.25 meters. Total weight is 57 tonnes and has a speed potential of 80 KMPH.

The machine can stabilize around 1 to 1.5 Km in one hour thus it can match progress of 09-CSM tamper and can be deployed behind these tampers.

4.13.20 History of Ballast Cleaners and other Track Stabilising machines

Year	Track Machine	Details
1968-74	Matisa 10-CB-5 Ballast Cleaning machine	Output 300 cum in an effective hour. Being the Ist BCM; lot of teething troubles.
1989-90	Plasser Ballast Cleaning machine RM-80	These are comparatively heavier machines with a capacity to clean about 600 cum/hour of ballast; The average output being 450-500 cum/hour and about 250 linear metres.
1993-94	Plasser Ballast cleaning machine RM-76	The BCM can clean ballast for plain track as well as for Points & Crossing. The capacity of machine is about 500 cum of ballast/hour.

1968	Plasser Ballast compact ors VDM-800	These machines consolidate cribs and shoulders of ballast by way of vibrating ballast and providing static load. These machines were utilized behind tamping machines. VDM-800 and PTV 800 machines were developed by M/s Plasser & Theurer around 1968. Indian Railways purchased 8 Nos. VDM-800 and 2 No.s PTV-800 machines during 1968 for working these behind Tie Tampers. Due to certain drawbacks in their performance all these machines have been withdrawn from service around 1990.
1995-96	Plasser Shoulder BCM (FRM-80)	The excavating mechanism works on the principle of elevator chairs. The machines are micro processor controlled & can run at 80 Kmph.
1978	Plasser crib consolidating machine	The machine consolidates crib of the ballast. The capacity is 500 cum per hour.
1985	Kershaw Ballast Cleaning Machine KSC-800	Machine is designed to give clean ballast @ 600 cum per hour.
1990-99	Plasser Dynamic Track stabilizer	The machine has a capacity to do work @ 1.4 km/hour.

4.14 TRACK RENEWALS

Heavy track renewals are carried out on Indian Railways every year to keep the track safe and in good running condition and also to bring down the maintenance cost. The annual cost of track renewals carried out on Indian Railways runs in several hundred crores. These track renewals consist of Complete Track Renewals, Through Sleeper Renewal and Through Rail Renewals etc. As track renewals are costly proposals, lot of thought and planning is done to get the same executed.

For over a century, track renewal (or popularly called Track relaying) was done by manual efforts. About 10 to 15 gang of 20 labour each were collected and track relaying works executed accordingly. The main items of work were:

- (i) Unloading of track materials viz rail, sleepers & fittings.
- (ii) Arranging traffic blocks of 2-3 hours each.
- (iii) Dismarkling old track.
- (iv) Linking the new track after cleaning & spreading the ballast to proper profile.
- (v) Packing the new track manually and making it to fit for the trains to run.

Progress & Output

An average progress of complete track renewal of about 0.4 km (0.25 mile) can be achieved with 15 to 30 gangs and with 3 to 4 hours block. Deep screening work should however, proceed in advance of relaying work.

Speed Restrictions

As a new bed of ballast is provided under the sleepers, it is necessary to restrict the speed till proper consolidation of the ballast takes places. The portion deep screened today is relaid on the 4^{th} day to enable the screening party to be ahead by 1 to 2 days work. In between, the deep screened portion of track is attended to the extent necessary to keep the traffic moving. A speed restriction of 15 kmph is imposed on the day of deep screening.

The speed is relaxed to maximum sectional speed on 21^{st} day in case of manual packing.

4.14.1 Necessity for Mechanised Relaying

A concrete sleeper weighs more than 250 kg. and therefore cannot be easily handled by manual labour unlike wooden or metal sleepers. Apart from being heavy, the concrete sleeper is brittle in nature and is likely to be damaged, if dropped from a height or handled roughly. The progress of conventional method or relaying has been quite slow and the quality of the work is also not very high. On account of these technical considerations, and other social reasons the need for mechanized relaying has been increasingly felt particularly in view of the concrete sleepers being adopted in a big way on the Indian Railways.

Indian Railways were in search of track relaying machines for their track renewal works mainly due to introduction of concrete sleepers.

Generally two types of track relaying systems were available in the world market, Portal Cranes and track relaying trains. Portal cranes are semi mechanized system of track relaying while track relaying train is a fully mechanized system of track relaying.

4.14.2 Description of PQRS Equipment

Indian Railways have procured in year 1972, sets of mechanical relaying equipment called P.Q.R.S. (Plasser Quick Relaying System) at a cost of approximately Rs. 15 lacs each. These equipments have been manufactured by M/s Plasser & Theurer at a factory near Faridabad with 60% indigenous materials. Each P.Q.R.S. equipment consists of :

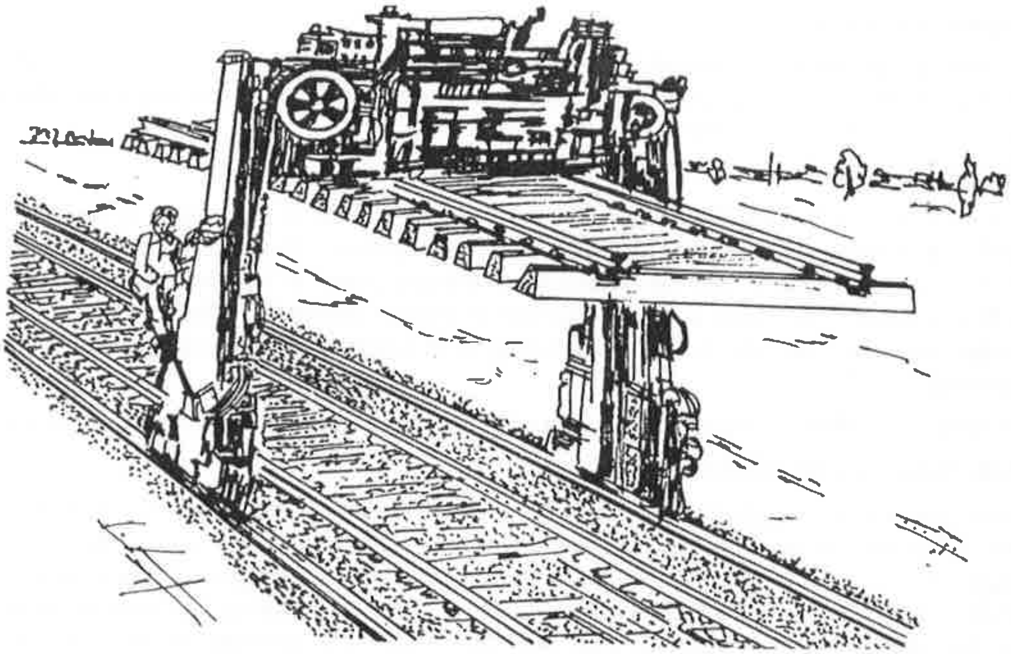
(i) Four portal cranes

(ii) One sleeper layer

(iii) Ten hand gantries

(iv) Forty track jacks

The portal cranes and the sleeper layer operate on an auxiliary track which 3.4 metre (11'-2") gauge. The auxiliary track is supported on the wooden blocks or C.I. Pots placed at 2 metre distance.



PORTAL CRANE LIFTING CONCRETE SLEEPER PANEL (Para 4.14.2)

The portal crane is a hydraulically driven 4 wheeled machine and is mean for carrying sleepers or track panels.

Initially 5 tonne portals were purchased which could left an assembled panel of 13 metres track laid on CST-9 sleepers: The portals with 9 tonne capacity were subsequently inducted to be able to handle full complete track panel with concrete sleepers. These portal cranes can run with load at a speed of 10 to 12 kms per hour. These portal cranes are loaded on a Railway flat wagon called BFR and can self load and unload on auxiliary track with their own power.

These are used for fabrication of track panels in base depot and removing old panels from track and placing new track panels in their place. 5 tonne capacity portals are used by using 9.1 meter concrete sleeper panels while 9 tonne portals can handle complete track panel of 13 meters.

4.14.3 Composition of Rake - A complete train with the following composition is utilized for carrying new panels to site and bringing old panels from site. The BFRS are to be endless and without side supports.

1. Engine
2. Crew Rest Van
3. Brake Van
4. Mobile Workshop/Rest Van for Staff

5. BFR loaded with Portal Cranes
6. 6 to 8 BFRs loaded with concrete sleeper panels.
7. 2 Nos. empty BFT for loading released panels at the time of starting work.

PROGRESS

The output of PQRS reduces in longer block sections due to increase in lead. In first one hour two portal cranes can lay around 16 panel. In 2nd hour around 12 to 14 panels and in 3rd hour around 10 to 12 panels.

BASE DEPOT

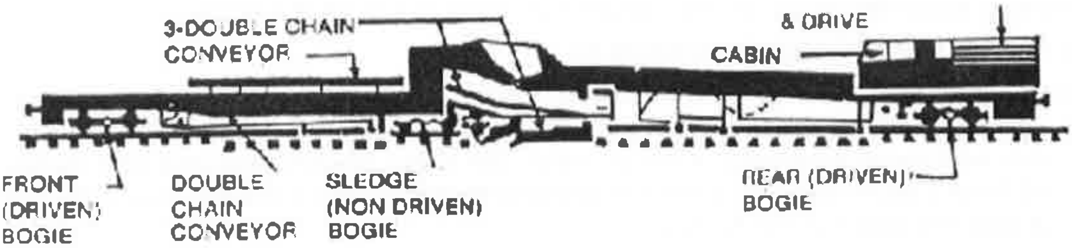
A Base Depot with 2-3 lines with Auxiliary track has to be created which is utilized for fabrication of track panels, loading unloading of material to prepare train for next days' working and dispatch of materials.

SALIENT FEATURES OF PQRS PORTALS

The portals are 2.920 meters long 3860 meters wide having a height of 4.4 meters above rail top weighting 10 tonnes each with an engine of 90 HP.

Indian Railways have procured from 1972 up to 1989 100 Nos. portals. Out of these a few were for meter gauge but all these have been concerted to BG. Now about 77 Nos. are still in use and giving good service.

4.14.5 Track Relaying Train



TRACK RELAYING TRAIN (Para 4.14.5)

The track relaying train is designed to replace simultaneously and continuously all operations involving replacement of rails and sleepers. The train is designed to carry out various multifarious functions such as removal of old rails, removal and stacking of old sleepers, leveling and compacting of ballast bed, placing new sleepers in position, laying of new rails and removal of released rails.

For complete mechanization of track renewal work track relaying trains are at present available mainly from M/s Plasser and Theurer, M/s Tamper Corporation, USA, Matisa of Switzerland, and Russian Track Relaying Train. Indian Railways have purchased two Nos. track relaying trains model P-811-S from M/s Tamper Corporation Corporation USA and one Russian Model UKE/25-18 from Russia in the year 1992-93. One more Track Relaying Train has been ordered on M/s Tamper Corporation, USA.

TRACK RELAYING TRAIN P-811-S

Track Relaying Train P-811-S consists of track relaying train with 12-15 modified flat wagon called BRH with running Rails on either side for running 2 Nos. Gantry Cranes. With this machine service track and fabrication of rack panel are not required. New rails are unloaded at site and placed near shoulders (Sides). These are joined with fishplates as required before starting work. New concrete sleepers are taken in the train duly stacked with battens in between to facilitate easy lifting of these sleepers by Gantry cranes. Two gantries run on the entire length of train.

TRT does the following works

(i) Removal of old Sleepers

(ii) ii Levels and compacts the ballast bed

(iii) iii Threads out Old Rails

(iv) iv Threads in New Rails

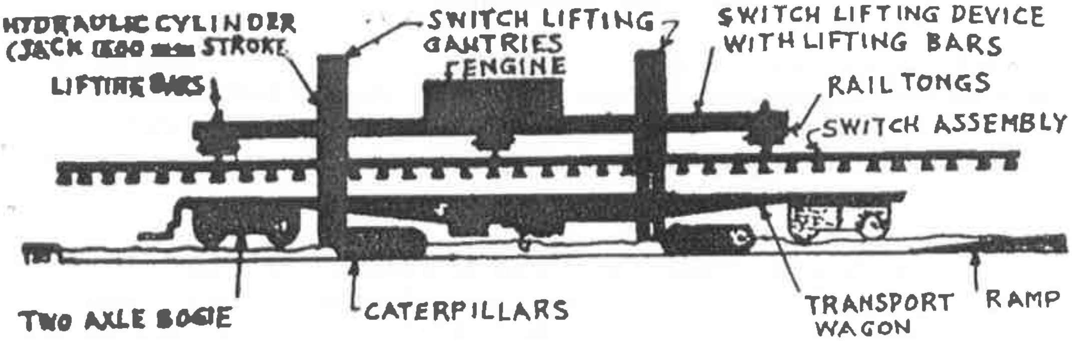
COMPLETE TRAIN RAKE

A complete train with the following composition is utilized for carrying new panels to site and bringing old panels from site. The BFRS are to be endless and without side supports. The train rake consists of Engine, Crew Rest Van, Brake Van, Mobile Workshop/Rest Van for Staff, BFR loaded with Portal Cranes, 6 to 8 BFRs loaded with concrete sleeper panels, 2 Nos. empty BFT for loading released panels at the time of starting work. This train can relay about 1 km track in a block of 4 hours.

TRACK RELAYING TRAIN UKE/25-18

This track Relaying train is from Russia. Unlike Track Relaying Train from Tamper Corporation, USA it replaces the track, panel by panel, Therefore, track panel fabrication has to be done in a base depot before hand. The above machine was procured during 1992-93 on Eastern Railway. Later it was transferred to South Central Railway from 1997 and now it is with Central Railway.

4.14.6 POINTS AND CROSSING RELAYING CRANES



POINTS & CROSSING RELAYING CRANES (Para 4.14.6)

Indian Railways started relaying plain track with concrete sleepers starting from 1972. Up to 1985, points and crossings were still continuing on wooden, or steel sleepers, for complete change over to concrete sleepers, I.R. started carrying out experiments to lay points and crossing on concrete sleepers during 1987-88.

Points and crossing sleepers are longer than ordinary sleepers. Their handling manually was not possible. Therefore need of points and crossing relaying cranes came up. Machines are available for this application from M/s Plasser & Theurer, M/s AMECA of Italy, M/s Geismer of France and M/s Desec of Finland.

SWITCH RELAYING MACHINE WM 22

The switch relaying machine WM22 manufactured by M/s Plasser & Theurer is so designed that it can relay complete set or part assembly of points and crossing. One machine unit can remove and install a section of a point or crossing whereas two machine units can relay a complete assembly.

Year	Track Machine	Remarks
1972-1988	Plasser PQRS System.	Progress of track renewal 200 m/hour. Man works to be done manually.
1990-1995	Track Relaying train	Progress of complete Track renewal 360 m/hour
1990-1995	Points & crossing relaying system T-28 (Amec)	1 to 2 Turnout per hour
1996-1997	Sleeper Exchanging machine & the crane	Progress 30 sleepers/hour

4.15 3-TIER SYSTEM OF TRACK MAINTENANCE

With the introduction of concrete sleepers and on track tamping machines, 3-tier system of track maintenance is being adopted on Indian Railways for the sections nominated for mechanized maintenance. This consist of the following 3 tiers of track maintenance

4.16 CONCLUDING REMARKS

1. Indian Railways during last 150 years have progressively switched over from Manual Maintenance to Mechanized Maintenance of track due to operational & technical considerations.
2. In between Measured Shovel Packing was adopted for about two decades, but the same was also replaced eventually by mechanized maintenance.
3. Indian Railways have presently starting from a humble beginning of 16 track machines in 1963, a fleet of about 350 Track machines consisting of Track Tampers, Track Stabilizing machines, Ballast Cleaning machines, Portal Cranes & Track relaying Trains etc.

Tier-1: On-track machines unit (OMU)

The work of systematic mechanized maintenance of track will be done with help of heavy on-track machines which include Tie-tamping machines for plain track and Points and Crossings, Shoulder ballast cleaning machines, Ballast cleaning machines, Ballast regulating machines and Dynamic track stabilizers. These machines shall be deployed to carry out the following jobs:

(a) Systematic tamping of plain track as well as Points & Crossings;

(b) Intermediate tamping of plain track as well as Points & Crossings;

(c) Shoulder ballast cleaning, ballast profiling/redistribution, track stabilization, periodical deep screening.

Tier-2: Mobile Maintenance Units (MMU)

The work of picking up of slacks and other related works will be done with the help of Mobile Maintenance Units (MMU). **Tier-3: Track maintenance by Sectional Gangs:**

The sectional gangs under 3-tier system of track maintenance will perform the following functions:

(a) Patrolling of track viz keyman's daily patrol, Hot/cold weather patrolling; Monsoon patrolling; Watching vulnerable location.

(b) Attention to emergencies viz temporary repairs of fractures.

(c) Need based attention to bridges, turnouts, SEJs and approaches of level crossings and just after miscellaneous work

CHAPTER-V

RAILWAY BRIDGES & CIVIL ENGINEERING WORKSHOPS

5.1 GENERAL

5.1.1 Construction of railway network started in India around 1850 and onwards. Although road network to a certain extent was available at that time, but not a single bridge spanning over any major river was constructed till then. This was restricting movement drastically during the monsoon season. In other seasons also rivers were crossed with the help of boats for passenger as well as goods movement. Constructions of the bridges were necessary to achieve all weather through communication avoiding trans-shipment. Railway engineers took this hurdle as a challenge and started planning for construction of bridges so that all weather communication becomes possible.

5.1.2 Problems Associated With Bridge Construction

For establishing a railway network, India was a difficult country. Natural difficulties were in the form of mountains, wide rivers, challenging ghat sections, marshy land, regions of heavy rainfall, areas infected by malarial mosquitoes and wild animals, vast deserts, undulating grounds, etc. Mighty rivers like Ganga, Yamuna, Brahmaputra, Hoogli, Narmada, Mahanadi, Godawari, Ghaghra, Gandak, Kosi, etc. in monsoon season carry voluminous flow, causing breaches in banks at times. Some rivers are notorious for changing their course and outflanking the bridge making it redundant. River Kosi of north Bihar has shifted over 122 km from east to west over a period of 200 years. In coastal areas, creeks and straits posed difficult problems in bridge construction.

5.1.3 Materials of Construction

- During middle of the nineteenth century material science was not so developed. Lime surkhi was the only known mortar. The same was used extensively. A base concrete of lime mixed with surkhi was used.
- Timber was used as a beam in smaller bridges. In case of breaches, as a temporary restoration work, the same was extensively used. Timber ballies were used as pile foundation.
- Stone was used as stone top bridges particularly for smaller bridges.
- During the middle of nineteenth century, iron came up very fast for multipurpose use. It proved to be the strongest material. Iron became one of the most important construction materials in superstructure of the major bridges.

- Reinforced cement concrete (R.C.C.) became popular in twentieth century. First pre-stressed concrete bridge in India was built as a railway bridge. Now days, most of the railway bridges are constructed either as R.C.C. or pre-stressed concrete (P.R.C) bridges except for very large spans of more than 100 m.

5.1.4 Type of Bridge Structures

- Most of the bridges constructed in the past are arch bridges, some of them are spanning up to 18 m. A large number of such bridges are still existing and performing well.
- For smaller openings stone top slab and timber structures have been adopted. Life and performance of such bridges are not very satisfactory. Most of them have however been replaced.
- Steel was the most favoured material used in bridges, particularly in super structure. For spans varying from 9 m to 30 m., Plate Girder Bridge was adopted. For 30 m and longer spans triangulated girder type of structures were adopted. In some small spans rail cluster bridge or trough type of bridge has been used.
- For smaller discharge, masonry or steel pipe bridges were adopted. Initially steel corrugated pipes of adequate thickness manufactured by M/s Armco Ltd. and M/s Lysagld Ltd. were used.
- **Irish bridge or causeway is a dip in the railway track, and allows flood water to pass over it. These are in the process of being phased out but many causeways still exist. The stream is usually in dry condition for most of the year. In flood season too the depth of water is not much. When the causeway is flooded and the velocity and depth of water is low, the train could be allowed to pass under special instructions.**
- For sub structure of a bridge mostly open type of foundations were used. Well foundations were used for major river bridges. For pile foundation cast iron screw pile or timber piles were used. Cast iron screw piles are still available in some of the bridges. Timber pile bridges are now almost phased out and not available.

5.1.5 Methods of Construction

- Most of the important bridges on Indian Railways were constructed having well foundations for sub-structure and steel open web triangulated girders as super-structure. Examples of such important bridges are Yamuna Bridge at Allahabad commissioned for rail traffic in 1864 and Yamuna Bridge at Delhi commissioned in 1887. Similarly Railway Bridge at Varanasi over mighty river Ganga was constructed between 1888 to 1894 with well foundations and steel triangulated girders.
- The practice adopted for construction of well foundations in olden days is still being followed with minor modifications. In the bottom most portion, sharp

cutting edge of steel section is used to ensure cutting of soil and well sinking. Cutting edge was filled up with lime concrete and then brick masonry was started raising it upto a suitable height for sinking work. Sinking of the well was initially done by removing (dredging) the soil from inside the well. Removal of inside soil was creating empty space inside. In this way building up of well steining and sinking of well went on. When water was reached it was bailed out. Sinking process was facilitated by putting heavy weight on the top of well steining till suitable depth or the rocky strata were reached.

- For construction of super-structure of early triangulated type of bridges, initially, bottom chord members were connected after giving proper support at the panel points. Vertical, diagonal, and top members were then added one after another. Accuracy was checked at each stage for correct configuration. Construction work was labour intensive and time consuming. Now-a-days, specialised machinery is available for execution of these important bridges. Similarly, launching schemes are developed to suit the peculiarities of site. Such types of know-how and expertise were not available in early days.
- Hilly areas had totally different problems. Deep gorges were required to be bridged. The different methods adopted are explained briefly in two typical examples:-
    - (a) In the Thal ghat section, while proceeding from Kalyan towards Igatpuri, Ehegaon gorge was to be bridged. The gorge had a gap of 225 m and a height of 55m. Each end was found suitable to build arches. Problem remained with the central spans of girder bridges. For this piers of suitable height in stone masonry were built. Girders were fabricated, assembled at the bottom and lifted step by step with the help of jacks upto the whole height.
    - (b) Bridging of the deep gorges on Kalka – Simla section was done by arch bridges in multiple tiers. First tier of arch bridges was built up to a suitable height. For 2nd tier, piers were raised in the same vertical alignment and 2nd tier of arches was built and so on and the deep gorge was bridged till the desired level was reached.
- Construction of foundation over creeks where water is available in the bed throughout the year with a tidal variation of 3 to 5 m was done by adopting cast iron screw piles as in the case of Vasai Creek Bridge on Western Railway.

5.2 SOME SPECIFIC RAILWAY BRIDGES

Some selected examples of bridges on IR are briefly described under following groups:

(i) Bridges in the plain region of the Northern India,

(ii) Bridges in the North-Eastern region of India,

(iii) Bridges in the Southern region of India,

(iv) Bridges in the Hilly regions of India,

(v) Viaducts of the Ghat sections,

(vi) Bridges in the Coastal regions of India,

(vii) Other Bridges of interest,

5.2.1 Bridges in the plain region of the Northern India

Indo-Gangetic plain is spread over major part of the Northern India. These rivers are mostly perennial in nature. Many prestigious railway bridges had been constructed over these major rivers, some of which are described below:

5.2.1.1 Bridges over river Ganga

(a) Malviya Bridge:

Malviya Bridge, originally known as Dufferin Bridge, numbered No.11 on the Mughalsarai-Varanasi section of Lucknow Division of Northern Railway is one of the most important bridges over river Ganga. This was the first bridge of its type constructed in Indian sub-continent by the engineers of Oudh and Rohilkhand Railway in 1885.

This bridge has 7 main spans of 111.5 m each and 9 other spans of 35m each. The bridge is having well foundations in brick masonry, ranging from a depth of 22.3m to 50.9m for the main spans and from19.1m to 35m for secondary spans. Originally, the bridge was constructed as a single line rail bridge with provision for road vehicular traffic at the same level.

Lord Dufferin, the then Viceroy of India, inaugurated the bridge on 16th December,1887. In his speech he remarked: "...I imagine, I am right in saying that no where in India has a more difficult engineering task been performed than that whose triumphant accomplishment, we celebrate today. Nor in connection with it can I resist the temptation of offering my humble admiration and my best congratulations to those eminent gentlemen, whose knowledge of their profession, whose practical skill and whose fertility of resource have enabled them to triumph over every impediment and to master and enthrall the gigantic forces of nature with which they were contending....".

Mac. George observed this bridge as "splendid work". He further commented, "Undoubtedly, in many respects, this is the most perfect specimen of Railway Bridge Engineering in India". Over the years the need for regirdering was felt in 1925.

Work was sanctioned in 1939 for Rs.78 lakh. Design work was assigned to M/s Rendell, Palmer and Tritton. Fabrication work was assigned to M/s Braithwaite, Burn and Jessop Construction Company(M/s. B B J). Due to Second World War and other priority works assigned to M/s BBJ, regirdering was suspended and restarted in May, 1945. Erection work was assigned to M/s Sham Singh and Company. For single line, it was opened in September, 1947 and for the double line in December, 1947. After regirdering, the bridge was renamed as Malviya Bridge. No protection work either on the upstream side or on the down stream side has been provided. The bridge is performing well.

Malviya Bridge over Ganga, Varanasi

(b) Balawali Bridge:

Balawali Bridge (Bridge No.1248) is the first railway bridge over river Ganga located on Moradabad-Laksar section of the Northern Railway. It had 11 × 76.2 m. spans of through open web girders on deep well foundations.

This was an early steel single line girder bridge commissioned in 1887 at the cost of Rs.27.94 lakh. The bridge was strengthened in 1914 and again in 1934. Its replacement with a new bridge became necessary on condition basis. The new bridge was commissioned in March 2000.

The new bridge consists of 22 spans of 36 m with clear waterway of 830 m. The girders are prestressed concrete box shaped girders. Foundations are circular wells of 9.0 m diameter and going up to 27 m deep. The piers are twin circular piers each of 2.5 m diameter and 7.81 m in height.

Old Balawali Bridge No. 1248

(c) Ganga Bridge at Rajghat, Narora:

Bridge No.101 near Rajghat, Narora, is located on the Chandausi-Aligarh section of Moradabad Division of the Northern Railway. Construction of the bridge started in 1872 and was completed on 5.6.1874 at a cost of Rs. 8.2 lakh.

The bridge is having 33 spans of 24 m. each. Sub-structure of the bridge is on well foundations in brick masonry with lime mortar.

The river has been changing its flow pattern, causing problems and endangering the safety of the bridge. Some important developments are briefly outlined below:

(i) Originally no guide bund was provided and main flow of the river was towards the left bank. During 1899, a 220m long left guide bund was constructed for protection. Subsequently, during 1913, the same was extended to 550m. Flow pattern remained the same till 1915.

(ii) After the flood of 1915, the main current swung to the right bank. The situation remained the same till 1949, after which the main flow again turned towards left upto 240m. To control the course of the river, a 160m long repelling spur at 18m up stream of the river was constructed. Left guide bund was also strengthened.

(d) Rajendra Pul at Mokameh:

Between Malviya Bridge at Kashi and Hardinge Bridge at Sara, now in Bangladesh, there was no bridge over river Ganga. Necessity of one bridge at suitable location near Patna was felt since 1907. It was only after 1947 and formation of East Pakistan (now Bangladesh), when rail traffic to Assam which earlier went via Hardinge bridge, was disrupted. This necessitated construction of a new bridge near Mokame. The new bridge was sanctioned in 1953 and construction was completed in 1959.

This was the first important bridge constructed by railway engineers after Independence. It has played a vital role in socio-economic development of the Country and of Bihar in particular.

The bridge caters for a catchment area of 7,50,000 square kms. and a discharge of 72,000 cusecs. The bridge has 14 spans of 119 m. and 4 spans of 31 m, two on either side. On north side a guide bund of 1600 m on upstream side and 300 m. on down stream side were constructed. Bridge consists of double-D well foundations of 16m × 9.5m.

Super-structure is for a single BG line at lower level and two lanes for road traffic on the upper portion. Girders are double decker Warren type with a girder depth of 18m.

Girders were designed by Freeman Fox and Partners of London. Fabrication work was assigned to M/s BBJ of Calcutta. Total steel work was 13,287 tonnes out of which 6,819 tonnes were High Tensile steel and balance mild steel.

Rajendra Pul at Mokameh

5.2.1.2 Bridges over river Yamuna

(a) Yamuna bridge at Delhi:

Site for the bridge at Delhi was finalised in 1859 and construction completed in 1866. This bridge is a peculiar one, foundations resting mostly over rock at shallow depth. Sub-structure was constructed for double line, although initially superstructure was provided for single line only. At the bridge site, river course was stable and hence no protection works are provided. Super structure of the bridge is double decker, serving as rail cum road bridge. It is of triangulated through girders. Unusual to most other rail cum road bridges, rail traffic here is on the top and provision for road traffic is made on the bottom portion of the bridge. Second bridge was placed on the same substructure by the side of the first bridge in1913. The girders of the first bridge constructed in 1866 were of early steel type and replaced in 1933.

Shallow foundation of the bridge posed repeated problems in the past resulting in temporary closure of the bridge. During high flood, water reaches above danger level, and touches the bearings. At such time, the bridge is closed for traffic. The work of a new bridge has been recently sanctioned at a cost of 72 crore to replace the old one and the work on the same has commenced in 2004.

Yamuna Bridge, Delhi

(b) Bridge No. 30 at Allahabad:

This bridge is located on Mughalsarai- Allahabad section of the Northern Railway. Location of the bridge was decided in 1855 but actual work started in 1859. The first train ran over the bridge on 15th July, 1865.

Yamuna Bridge at Allahabad

The bridge has 14 spans of 61m triangulated girders + 2 spans of 8.8m plate girders + 1 span of 9.18m arch bridge. Bridge has double decker triangulated girders for rail cum road traffic, with railway track on the upper portion. Discharge at the bridge site is estimated at 15 lakh cusecs with maximum velocity of 3.5 m. per second. Sub structure is on well foundations in brick masonry with lime mortar having depth varying from 12.8 m to 7 m.. By August, 1862, all the wells were almost completed except well for pier No.13. It gave trouble and coffer dam had to be built for rectification. The water was lowered 3 m below the low water level, the well cut down and a flooring of large ashlar stones was laid. On this was sprung an arch of stone masonry, 16.5 m in diameter, over which the pier was built. About 2.5 million cubic feet of masonry and brickwork was used on this bridge.

5.2.1.3 Bridges over river Sone

(a) Koilwar bridge :

The first bridge over river Sone was constructed at Koilwar numbered as bridge No.200 and located on the Patna-Mughalsarai section of Eastern Railway. Site of this bridge was selected long back. Due to wide Khadir widths, engineers of EIR were discouraged from constructing a bridge. Initially, they proposed ferry services for the river portion with railway stations on the either side. However, due to higher cost of ferry services a decision was finally taken to construct a bridge. Work commenced in 1856 and the construction was completed in 1862 at a cost of Rs.43 lakh.

The bridge has 28 main spans of 45.72 m and 2 shore spans of 14.173m. It is a double decker under slung bridge where rail traffic is passing on the top and vehicular traffic on the bottom. Substructure of the bridge consists of 6 m dia masonaary wells upto a depth of 10 m below the river bed.

Lord Elgin, the then Governor General of India, while performing the opening ceremony in February, 1863 declared that "this magnificent bridge was exceeded in magnitude by only one bridge in the world!"

(b) Bridge No.531 near Sone Nagar

This bridge, the longest Railway Bridge in India and perhaps the fourth longest in the world, is located on Dhanbad - Mughalsarai section of Eastern Railway. It is having 93 spans of 30 m. The bridge is located near Dehri-on- Sone, between Sone Nagar and Dehri-on-Sone railway stations.

The work for constructing the bridge was started in 1897 and completed on 22.2.1900 at a cost of Rs. 32.32 lakh. The bridge is having trough and ballasted deck on the top. Over the years troughs have corroded on both up and down lines and are being replaced on condition basis. Sub- structures have well foundations in brick masonry with lime mortar. Two wells have been sunk side by side. Piers are placed over the rails supported by the two wells. Super-structure is under slung triangulated girders of early steel type. The old early steel type girders were strengthened during 1926.

Super-structure work for the second bridge started in 1923 and completed on 6.3.1925.

(c) Bridge No.399 near Chopan

The bridge is located on Chunar-Chopan section of the Northern Railway having 14 spans of 76.2m +2 spans of 30.48m., totaling 1183m. It was decided to cross the river down stream of the confluence of rivers Sone and Rihand. Bridge is designed for a discharge of 16 lakh cusecs and maximum velocity of 3.56m per second. Waterway available at the proposed site is around 1050 m with stable banks and straight alignment. Sub-structure for the abutments consists of double-D type of wells, 7.315m × 12.19m. Pier wells are double-D 8.534 m × 14.63m.

M/s Hindustan Construction Company, the contractors, started work in December, 1959 and completed the sub-structure in May, 1962. Girders of the bridge were fabricated and erected by M/s. BBJ.

5.2.1.4 Bridges over River Ghaghra

(a) Elgin bridge:

Elgin Bridge bearing No.391 is located on Gonda-Lucknow section of the North Eastern Railway between Ghaghra ghat and Chauka ghat stations. Construction of the bridge started in 1895 and was completed in 1898 as a meter gauge bridge. In 1977, regirdering of the bridge was done for broad gauge.

The bridge has 17 spans of 61m triangulated through girders. Sub-structure consists of well foundations in brick masonry having a depth of 27 m. Guide bunds are constructed on both sides. Catchment area of the river at the bridge site is 33,633 sq. km. with a maximum discharge of 8.5 lakh cusecs.

This bridge witnessed recurring problems due to the changing course of the river. Almost every year huge damages to the bridge either to guide bunds or to piers or to both took place with possibilities of outflanking of the bridge. Modifications in the guide bunds and provision of some other protective arrangements like spurs were made. Provision of silt bar made in consultation with Uttar Pradesh Irrigation Research Institute proved effective and brought a lot of improvement. The bridge is now behaving properly.

5.2.2 Bridges in North-Eastern region of the country

This is the region where river Brahmaputra and its tributaries are flowing. The region is geologically infant in nature. Lot of disturbance due to changing and shifting nature of rivers is prevalent in this area. Many prestigious bridges have been constructed in this region. Some of these are described below:

5.2.2.1 Bridges over river Brahmputra

Till about forty-five years back, the Brahmaputra was considered as an unbridgeable river on account of its mighty extent, tendency for swift flow and changing course, and shorter working period due to long spell of rainy season. In most places, width of river Brahmaputra varies from 5 to 15 km. In some places it spreads upto 23 km. After the rainy season, river meanders in the khadar width. As far as carriage of sediments is concerned it is second in the world, after Yellow river of China. At Dibrugarh between 1950-61, bed level of the river rose by 1.2m. Another peculiarity of the river is that its flow is rolling (instead of flowing down as a sheet) like that of river Yangtze of China. Rolling action produces vertical eddies churning up enormous silt. This behaviour causes formation of shallow shoals.

(a) Bridge at Saraighat :

Saraighat site was selected for construction of first bridge over Brahmaputra due to banks being relatively stable and minimum river width. Bridge was located where waterway available was equivalent to Lacey's waterway i.e. about 1200m. Brahmaputra is used as navigational channel also, for which a clearance of 12m was required.

Bridge is designed for 2 lines of MG track convertible to a single line of BG with BGML loading. At present this has been converted to a single line BG bridge with MG track in between the BG rails. For roadway, 7.2m wide road width with 1.8m width of cantilevered footpath on either side was adopted and designed for loading for 2 Class A lanes or a single class AA lane. Double Warren type high tensile steel girders with sub verticals having 18.30 m of depth have been provided. Salient features of the bridge are: -

Span	(10 × 122.95m + 2 × 33.2m)	
	Total weight of girders	11,115 tonnes

Foundation

a. Main wells Double-D type 16.31m × 9.75m with steining thickness of 2.75m.

b. Shore wells Twin circular of 6.1m diameter well with steining thickness of 1.52m.

Saraighat Bridge over Brahmaputra

Girder work including supply, fabrication and erection was assigned to M/s Braithwaite Burn and Jessop of Calcutta. Erection of girders was done by cantilevering out one bay at a time from an anchor span. The construction of the main bridge was started in 1950s. The erection of girders was started in January, 1961 and was completed by October, 1962.

(b) Jogighopa Bridge :

The bridge falls on the railway line on the south bank of the river Brahmputra connecting New Bongaigaon – Jogighopa with Guwahati. The bridge has been completed recently in 1999. At the bridge site available waterway is 3100m. Main members of the truss are of high tensile steel while secondary members are of mild steel. Total 10,345 metric tonnes of mild steel and 18,640 metric tonnes of high tensile steel were used. Girder erection was done by cantilevering method starting from abutment. 1, 80,000 cubic meter of concreting, 1250 meter of well sinking, 240m of drilling of 1.5m diameter piles in hard rock were involved in the work.

Salient Features are:

Length of the main bridge:	2.284 kms
Length of road viaduct:	1.082 kms
Span	1 × 32.6m + 14 × 125m + 1 × 94.6m + 3 × 125m, 1 × 32.6m
Guide bunds	(i) North Bank-850m
	(ii) South Bank-478m
Maximum design discharge	90,400 cumecs
Maximum Velocity	5m per second
Navigational clearance	12.5m above HFL
Foundation	Double – D, 11m × 17m.

5.2.2.2 Some other major and important bridges of the North East Frontier Railway

NF Railway covers north-east Bihar, north Bengal and north-eastern regions of the country i.e. Assam, Meghalaya, Manipur, Tripura, Mizoram, Nagaland, and Arunachal Pradesh. This area has the heaviest rainfall in the world. Annual rainfall of 5000 mm is common. Intensity upto 900mm in 24 hrs. occurs repeatedly. Rivers are devastating in nature having heavy silt load and are notorious for changing their course. These result in increasing of the waterway year after year. Some of the important bridges of this region, other than those on the Brahamaputra are described below:

(a) Bridge No.448 over river Aie:

This bridge is located on Siliguri Junction-Saraighat Bridge section of NF Railway having 8 spans of 30.48 m. Sub-structure consists of well foundations of 6 m to 6.5m. diameter with depth varying from 55 to 66 feet. Super- structure is steel girder, two spans through triangulated girders, next five semi through triangulated girders and the last span being semi through plate girder. Bridge was originally constructed in the year 1905 as 2 × 12.2 m + 5 × 30.5 m. and modified/extended in 1938 and 1958. River flows parallel to Railway bank on western approach and a number of spurs have been built to keep the course. In 1983 the right guide bund was washed away and rebuilt after raising the top level by 2m. There is a marginal bund on the left bank of about 3 km length. This was breached in 1983 and 1984 and part flow of the river found its way to Dolani which has a much lower bed level. Marginal bund was rebuilt in 1985. It continues as a constant challenge to railway engineers.

(b) Bridge No.52 over river Tista:

The bridge is situated on Siliguri junction – Saraighat bridge section of the NF Railway having one span of 75 m + 7 spans of 45 m. Sub-structure consists of well foundations in cement concrete with 6.67 m dia and 14.5 m depth. Super-structure consists of through type triangulated girders to MGML standard. Originally the bridge was constructed in 1949 as 4 × 45 m + 1 × 75 m spans with through type girders as a part of the Assam Rail Link Project. During 1951, due to unprecedented flood in Tista, the eastern approach was washed away and the bridge was extended by 3 additional spans of 45 m. In 1968 there were again heavy floods. Location of the bridge is at a place where the river emerges from a mountainous gorge and fans out in the plains. Velocity of the floodwater is very high and due to excessive sediment load in the river continuous process of silting and changing of channel takes place down stream of the bridge. It is a continuous challenge to railways engineers.

(c) Bridge No.227 over river Torsa:

The bridge is located on Siliguri Junction – Alipur duar junction section of the NF Railway having 9 spans of 45 m each. Sub-structure of the bridge consists of well foundations in cement concrete with 6.67 m dia wells and 20 m depth. The bridge was constructed in 1948 as a part of the Assam Rail Link Project. The right bank has a guide bund of 3240 feet long on the upstream and 872 feet on the down stream. On the left bank, there are elaborate protection works i.e. a marginal bund and 15 spurs emerging from the bund. During the past, Torsa used to overflow its left bank and cause widespread damages to railway bank on west approach. The marginal bund and the spurs now prevent the flood overflow.

(d) Bridge No.415 over river Dhanuk:

The bridge is located on Lumding-Badarpur section of the NF Railway. It has 1 span of 6 m + 1 span of 12 m + 1 span of 106 m Bow String girder. Originally the bridge was having 2 spans of 12.2 m + 1 span of 20.5 m + 5 spans of 12.2 m on 10 degree curve. The piers that carried 5 × 12.2 m spans and the Northern end of 30.5 m. span were built on the bridge of a spur, which projected into the valley crossed by the bridge. During the monsoon of 1915, the spur moved towards the bed of the stream, more or less diagonal to the alignment of the bridge. All the piers on the spur were displaced by about 2 m and were leaning heavily to one side when the movement ceased. A 106 m span girder has been provided due to uncertainty of obtaining stable foundations for shorter spans. The design and working drawings of the girder were provided by consulting Engineers M/s Randel, Palmer and Tritton of England. Erection of the 106 m girder was completed during the year 1920-21.

5.2.3 Bridges in the Southern Region of India

Many major rivers like Godavari, Kaveri, Krishna, Mahanadi, Narmada are flowing in this region. Some of these are described below:

5.2.3.1 Bridges over river Godavari

(a) Bridge near Rajahmundry:

Mr. F.T.G Watson, Engineer in chief, constructed the first bridge over the river between Rajahmundri and Kovvur in 1900. Bridge has 56 spans of 45 m (under string girders) and one span of 12.2 m (on Kovvur end) with an overall length of 2772 m. The bridge has been designed for a maximum flow of 42860 cumecs (15 lakh cusecs).

Left abutment is on open foundations on the hard gravel rock. Right abutment is a group of six rectangular wells driven into hard black clayey strata. All other foundations are well foundations. Some wells are double - D of 10 × 6m, some are circular ones with external dia of 7.5m. All wells were sunk by dredging and sinking except pier well nos.1 and 2, which were sunk by pneumatic method.

Work started on 11th Nov.1897 and the first train passed on 6.10.1900. Work was completed at a cost of Rs.46.9 lakh. After commissioning of the third Godavari Bridge in 1997, this bridge is not in use.

(b) Second Godavari Bridge:

The second Godavari Bridge was constructed 1050m down stream of the first bridge in 1963, with 27 spans of 91.44m and 7 spans of 45.72m. K-type truss spaced at 7m. is adopted for bridge superstructure. It is a rail cum road bridge, having 2-lane road bridge on the upper deck. For main foundations, double D-wells of 12.4m × 7m size were adopted. Abutments and smaller spans are on circular wells of 9.6m dia. Piers are of 2 circular sections of 4.27m dia 7.01m apart.

Artificial shoal formation proved very successful for avoiding caissons for well sinking. Due to availability of anicut about 5km down stream the flow of the water at the bridge site was hardly 0.5m to 0.6m per second. The bridge was commissioned in 1974.

(c) Third Godavari Bridge:

It became necessary to construct a bridge in lieu of first Godawari Bridge due to age deterioration. The design offered by M/s Hindustan Construction Co. Ltd., Mumbai, consisting of bowstring type concrete arch bridge of 92.55m span with pre-stressing of the box girder seemed feasible. M/s Leonhardt, Andra and Partner of Stuttgart of West Germany were appointed as consultant. Final span arrangement for the third Godawari Bridge is 28 spans of 94.0m on double-D well foundation.

Cantilever method was used for construction. Each girder is supported on pot bearings of 1050 tonnes capacity. Initial three sets of bearings were imported from Switzerland. Remaining bearings were manufactured by BBR (India) Ltd. of Bangalore.

Third Godavari Bridge

5.2.3.2 Bridges over river Krishna

(a) Bridge No.3 is located on Vijaywada-Guddur section of Vijaywada division of S C Rly. At this location, three bridges are located side by side over the river. The first bridge for broad gauge was constructed in 1893, having 12 spans of 91.44m on well foundations. Super-structure of the bridge has through triangulated steel girders of early steel

(b) The second bridge over river Krishna was constructed at about 45m down stream of the old bridge in 1965. Sub-structure of the second bridge consists of well foundations in cement concrete and superstructure of 12 spans of 91.44m of triangulated through girders resting over roller and rocker bearings.

(c) The third Krishna Bridge in replacement of the first bridge is constructed at 45.72m from the center of old bridge on upstream side with 12 spans of 93.25m each. Double-D well foundations for double line are 16m × 8m with steining thickness of 2m. Superstructure consists of Rhomboidal type through steel girders. Imported high strength corrosion resistant steel (carbon steel) is used in the fabrication of trusses. During 1978-79 three spans i.e. span No. 1, 2 & 3 were launched. During 1979-80, span No. 4 to 9 were completed while during 1980-81 balance work was completed.

5.2.3.3 Bridges over river Mahanadi

(a) An important bridge at Km. 405/7 to 407/8 of the Howrah-Waltair-Chennai section numbered 544 is having 64 spans of 30.5 m. each specially designed plate girders. The substructure of the bridge is on well foundations in stone masonry with lime mortar. Originally girders were of early steel which were replaced by specially designed plate girders fabricated by M/s BBJ and erected departmentally. RCC jacketing to the sub structures was done for higher axle loading.

(b) Brief details of other bridges in close vicinity are :

River	Bridge No.	Kms	Spans	Remarks
Birupa	539	402/4-14	16 × 30.48m	Through triangulated girders over well foundations in stone masonry with lime mortar.
Katjuri	553	411/3 to 412/1	18 × 45.72 m	--do--
Kuakhai	557	414/2 to 415/3	20 × 45.7 m	--do---

All these bridges including bridge No. 544 over Mahanadi encountered very stiff soil strata while sinking the wells. In one of the wells, dredge hole upto 10 m depth was made and then only the well started moving. In another case kentledge of 1200 tonnes was placed on the well top to sink the same. In another case, when well refused to sink even after formation of 10 m. of dredge hole, help of explosives was taken to disturb the soil strata for further sinking.

(c) The bridge on Katni-Singrauli section on Jabalpur division (CR) was constructed in 1972 having one span of 46.72m + 3 spans of 31.48m + 1 span of 121.785m. Substructures are well foundations in cement concrete with through triangulated girders for super structure.

(d) Bridge No. 76 on Jharsuguda-Balangir section was constructed in 1963 having 25 spans of 30.48m each. Sub structures are well foundations in cement concrete and super structures are plate girders. Wells and abutments are common for rail as well as road bridge.

(e) Bridge on Kazipet-Balharshah (K.B.) section:

This bridge having 44 spans of 24.4 m. girders was constructed by Mr. R.V. Gregory, Engineer in Chief, of the then K.B. Railway. At the bridge site, bank to bank width is 1160 m. with catchment area of 101000 sq.km. The bridge is constructed for the full width.24.4 m. span was found to be overall economical. Deep wells are having 4.57 m. outer dia with 1 m. steining. Each pier is supported over twin wells placed 21 feet center to center. Shallow wells have 4.57 m.outer dia with steining 0.76 m. thick. Later on when problems occurred while sinking these wells the steining thickness was increased to 1m.

All the plate girders weighing 45.5 tonnes span were fabricated in Germany and brought to site and launched by crane. The selected erection scheme was not interfered by the flood. Construction started in 1925 and was completed in 1927.

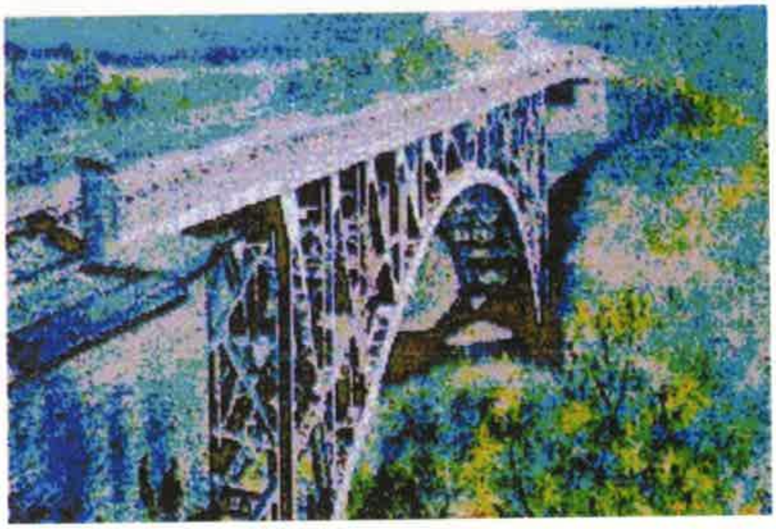
5.2.4 Bridges in the Hilly Regions of India

Many challenging bridges have been constructed on the hill railways. Brief details of some of them are given below:

5.2.4.1 Bridges on Pathankot-Joginder Nagar Section of Northern Railway

(a) Reyond Khud Bridge No.459 :

Reyond Khud Bridge is unique, being the only steel arch bridge on IR. It was constructed in 1927. Just beyond Kangra station, the railway line crosses the Reyond Khud having a depth of more than 60 m. Spanning with steel arch required least weight of steel work and had the advantage of rapid erection and general suitability for the site. Main span is 54 m of three-pinned steel arch, while the end spans are plate girders of 12.2 m spans. Braithwaite Construction Company fabricated girders in Mumbai. Design and drawings were finalised by M/s Randell, Palmer and Tritton. A temporary ropeway and a traveller worked by hand were used for carrying and placing the members, the heaviest being 3 tonnes. The erection was completed in a very short period of six weeks.



Reyond Bridge, Kangra Valley

(b) Gaj Bridge:

Bridge was originally constructed in 1927-28 as 8 spans of 30.5 m on shallow foundations of depth varying from 4 m to 7 m. During the severe flood of 1947, pier no.1 was washed away. A new pier was located at a new site and spans were increased by adding one span of 45 m and another span of 18.3 m. The present bridge is having 7 spans of 100 feet and one span of 45 m + one span of 18.3 m. The bridge was designed for a discharge of 5457 cumecs.

5.2.4.2 Arch Gallery type of bridges of Kalka-Simla section

Kalka-Simla section is one of the most difficult section

ns of the hill railways. Main beauty of some of the bridges is regarding the arrangements by which the tapering deep valleys are bridged intelligently dividing the whole height into tiers to overcome the slenderness problem. Variations in width of the valley are catered by increasing the number of arch openings for the increasing width of the valley with the increasing height. These bridges are a rich heritage for their beauty and for having served the purpose over a long period of time with simple structure.

Some features of three of these bridges are given below:

Kalka-Simla Arch Bridges

Bridge No.	No.of tiers of the arches	Between Railway Stations	Total length of the bridge	Material of Construction
226	5	Sonwara-Dharampur	69.5m	Stone masonry with lime mortar.
493	3	Kandaghat-Kanda	32m	-do-
541	4		54.8m	-do-

5.2.4.3 Viaducts of the Ghat Sections on Mumbai-Pune Section of C.Railway

(a) Ehegaon viaduct:

Ehegaon viaduct on Kalyan-Igatpuri section was opened on 1.1.1861. The viaduct consists of three spans of 42.76 m each totaling 130m. and is situated in a steep valley nestling in a midst of hills that skirt around it in the form of a horseshoe and is 55.5 m above ground. Sub-structure is stone masonry in lime mortar. Super-structure is steel girders. Originally there were three pin truss deck spans and three 12.2m masonry arches at either end. The girders were fabricated on the ground and jacked up to 55.5m height. In 1899 these girders were replaced. In 1949, the viaduct was converted from a double line into a single line bridge to pass wider rolling stock. Cross girders were strengthened. Traffic for the second line was transferred to a separate bridge completed in 1951.

(b) Mhowke-Mullee viaduct :

The viaduct on Kalyan-Pune section (CR) consisting of 8 spans of 15.24m arches with rail level 41.15m above ground level was completed in 1856. It does not exist now. Soon after construction, rumors spread regarding rumbling noises arising from the ravine from the base of the viaduct. This created scare among the villagers. Slight cracks were noticed, but a careful watch showed that they were not extending. A few days previous to the fateful date of 19th July, 1867, Chief Engineer and Dy. Consulting Engineer inspected the viaduct and could not find any cause of anxiety. At 6.30 am on 19th July, 1867 the last train passed over the viaduct. A platelayer, who was tightening the keys in the track on the bridge, suddenly felt the ground giving way under him. He ran as fast as he could to the end of the bridge. Turning around, he discovered that the viaduct had collapsed. Mhowke-Mullee is no longer a viaduct. The entire length has been filled up and there is now a continuous embankment.

5.2.5 Bridges in the Coastal Regions of India

(a) Pamban viaduct:

It is bridging Palk Strait between main land and Rameswaram Island. Pamban railway bridge popularly known as Pamban viaduct was constructed from 1911 to December, 1913 and commissioned in Feb.1914. The viaduct is 2067m long and consists of 146 spans plategirders - 143 of 12.2m and two of 12.1m. and one lift span known as Scherzer span with two leaves of total 65.27m length. Of other spans, The first 19 spans from Mandapam end are pre-stressed concrete girders and the rest are steel girders.

On the night of 22nd/23rd Dec.1964, an unprecedented cyclone swept through the Palk Strait. The cyclone hit Pamban viaduct and washed away 124 spans leaving behind pre-stressed concrete girder spans on the Madapam end and Scherzer span only. Restoration work started immediately. Regirdering work and restoration the traffic on the viaduct was done in a short period of two and a quarter months on 1.3.1965. The viaduct is in the coastal area and needs frequent maintenance due to corrosive atmosphere. An anemometer has been provided on the bridge to monitor the wind velocity. When the wind blows above 58 kmph, the train services are suspended.

Pamban Bridge –in use for trains

Pamban Bridge – in use for ships

(b) Vasai bridges No.73 and 75:

The bridges on Western Railway are near Mumbai and were initially opened in 1864. Bridge No.73 consisted of 69 of spans of 18.29m + 2 spans of 6.1m, while bridge No.75 consisted of 25 spans of 18.29m and 2 spans of 7.6m. Sub-structure consisted of single row of three cast iron screw piles of 0.615 mdia. Warren type girders were replaced in 1896. Two additional screw piles were added one on each side of the row of existing piles to add further strength. New bridges have since been commissioned; bridge no. 73 with 28 spans of 48.5m and one span of 20.6m of PSC box girders and bridge No.75 with 11 spans of 48.5m.

5.2.6 Some other bridges of interests

5.2.6.1 Bridges over river Hooghly

(a) Jubilee bridge:

Jubilee bridge, bearing No.8 is located on Bandel-Naihati section of the Eastern Railway having two end spans of 164.6 m each + one central span of 36.7m. On either end of the main bridge, there are viaducts of lengths 999.13m and 134.42m respectively constructed as masonry arch spans having a total of 141 spans varying from 3 to 15 m.

The work started in 1884. Size of the caissons used was 22.1m × 7.6m. A serious accident took place on 26th April, 1884 to caisson No.1. At that time the new moon with the strong southerly blowing breeze caused flood tide of extra-ordinary force. The caisson, 22.1m × 7.6 m, was moored ready for sinking, built up to a height of 13.4m weighing over 700 tonnes and floating with an immersion of 10m. The structure was torn away and carried half a mile upstream and grounded on the west side of the channel. As the tide lowered, it canted in east direction. The attempt next morning to haul it off did not succeed. 40 tonnes of cement brickwork was removed from the lining. The afternoon tide came in with greater force than that of the morning tide. This, together with lightening of the caisson dragged it into deep water by using additional haulage power. It was taken into a snug berth in the river with comparatively slack water and finally to the ultimate position.

The total length of cantilevering span including mid supported portion is36.6m cantilever +36.6m middle supported portion + 36.6m cantilever is 109.9 m. The central 36.6m was laid on a temporary staging strutted to the piers. The projecting portions were protruded section by section from the cantilever itself without any scaffolding. The128 m. spans weighing 1010 tonnes spans were assembled on the approach viaducts. The bridge was constructed for double line. Clearance available on the bridge and heavier train loads do not permit provision of double line movement for the new wider rolling stock. The bridge was opened in February 1887 at a cost of Rs.39 lakh.

Jubilee bridge – Kolkata

(b) Willingdon bridge:

Bridge No.13, known as Willingdon Bridge, is located on CCR section of the Eastern Railway. It is having 7 spans of 106.68m each and two spans of 25.655m. Bridge was constructed between 1927 to 1929 at a cost of the Rs. 115 lakh Waterway available at this site is 760 m. The viaduct at Bally end consists of 22 spans of 18.3 m. girders on masonry piers on RCC piles 12 m to 15 m long. The 8 main piers are founded over well foundations, which are octagonal steel caissons, 21 m × 11 m.. A unique feature of the bridge was that a caisson 21m × 11 m had been sunk in a tidal river in 1.2 m. of water with a current velocity of 10 kms an hour.

Willingdon bridge

5.2.6.2 Bridges over river Roopnarain

The first bridge over river Roopnarain bearing No.57 was commissioned in April, 1900, having 7 spans of 91.5 m plus 4 spans of 30.5 m. Sub-structure of the bridge consists of well foundations with brick masonry in lime mortar. Smaller spans have a super-structure of under slung triangulated girders and the bigger spans are through triangulated steel girders with roller and rocker bearings. Another parallel bridge was completed with the same span arrangement and super-structure on 23.3.1933.

The third bridge was constructed 200 m down stream for the third line. For launching of the cassions, mid period between full and new moon was chosen as the water rise is comparatively low at that time. 16 m × 10 m double-D wells with dredge holes of 4 m × 4 m and steining thickness of 2.67 m are provided for new Roopnarain Bridge. For shore piers, two wells 6 m external diameter at 8.5 m center to center are provided. Super-structure is K-type triangulated through girders with main members of high tensile steel and other members of mild steel. Construction started in October, 1963 and completed in December, 1966.

5.2.6.3 Coleroon Bridge

Bridge No.687 over river Coleroon is located on Villupuram-Tiruchirapalli section of the Southern Railway. Maximum discharge at the bridge site is 3.86 lac cusecs. Bridge consists of 14 spans of 45.72m, originally constructed in 1879 as 14 × 46.94m. Regirdering was done in 1922 to new spans. Sub-structure of the bridge is well foundations in brick masonry with lime mortar. Super-structure has triangulated through steel girders. The original bridge was not having end cross girders and was designed in a way that stringers were resting directly on the bed block.

5.2.6.4 Palar Bridge

Bridge No.211 over river Palar is located on Chennai-Egmore-Villupuram section of the Southern Railway and consists of 18 spans of 36.6m each. Originally constructed in 1876.

Sub-structure of the bridge consists of double-D well foundations in brick masonry with lime mortar mainly resting on sandy soil mixed with clay, kankar and mooram. Super-structure consists of open web triangulated girders having a clear span of 36.6m. During 1991, cross girders and stringers were changed. Stringers are directly resting on the bed blocks as end cross girders are not provided.

5.2.7 Masonry Arch Bridges

Initially popular type of bridges were arch bridges limited by practicability of arch design. Some of the arch bridges having spans more than 20m are mentioned below:

Bridge No.	Section	Span	Remarks
278	Kanpur-Tundla 1 × 21.34 Brick masonry with lime mortar		
86	Kanpur-Tundla	1 × 24.4	Brick masonry with lime mortar
13	Tundla-Agra bridge	1 × 27.43	Brick masonry with lime mortar

5.3 CIVIL ENGINEERING WORKSHOPS INCLUDING BRIDGE WORKSHOPS

5.3.1 To meet the urgent requirements of steel structures for new constructions and other maintenance needs, workshops were set up over the years at different locations on the railways. These workshops were to manufacture foot over bridges, roof trusses for workshops and sheds, bridge girders of different spans, flood lighting towers, christ church cribs, other steel structures, and do upkeep of tools, plants and machinery etc. The workshops were set up at: Manmad on the Central Railway, Mugalsarai on the Eastern Railway, Lucknow and Jallundhar on the Northern Railway, Gorakhpur on the North Eastern Railway, Bongaingaon on the North East Frontier Railway, Sini on the South Eastern Railway, Arkonam, on the Southern Railway, Lallaguda, on South Central Railway and Sabarmati on the Western Railway

5.3.2 The earliest workshops were at Manmad, Sabarmati and Mugalsarai. Such work-shops had capacity to fabricate up to 1800 tons of steelwork in a year.

The number of persons engaged varied from 300 to1200. An output of 0.5 tons per man per month was kept as a yardstick of monthly production eventually. Initially only small span bridge girders were manufactured, major spans being imported from U. K. Gradually longer spans were manufactured, up to 30m spans. These were riveted structures. The manufacture of riveted structures required first making a full size drawing on the shop floor, then cutting individual pieces as per measurement and joining them by riveting. The steel used was conforming to present IS 2601, and was not of weldable quality as welding was not intended. Welding was gradually introduced in these workshops. Some workshops had a foundry. Manufacture of track items such as Switch Expansion Joints (SEJ), Tie Bars, Concrete items such as Bridge Slabs etc were added to keep up workload in the workshops. Most workshops also keep reserve of bridge girders and erecting equipment like CC Cribs, stanchions etc. to be used if required in case of accidents, breaches, to restore through rail communication quickly.

5.3.4 Engineering Workshop at Manmad (Central Railway)

5.3.4.1 Manmad Engineering Workshop came into existence in the year 1906 as a small unit for assembly of imported bridge components for the then Great Indian Peninsular Railway (GIPR) and was initially known as Girder Shop. After 1929 the Workshop started modification and reconditioning of released girders from major bridges.

Subsequently, Smithy, Carpentry, Mechanical, Foundry and Bolts Nuts-Rivets shops were also added to Girder Shop. From the year 1939 during Second World War, the Workshop was engaged in production of war materials. After the war, normal activities were resumed. Due to massive regirdering programme on Central Railway in the year 1958, some remodeling of the Workshop was undertaken. A new Template Shop for fabrication of 76.2 m span Open Web Girders and a Points & Crossing shop were added. The Workshop was functioning in a very small shed till 1993. The new covered accommodation was provided during the year 1994. The total covered area of the Workshop is now about 21,000 sq. m.

In the year 1981-82, the fabrication of welded plate girders of 12.2 m span was started. The Workshop is now engaged in the regular production of welded girders up to 24.4m spans. Modernization of Workshop was started in 1989 and completed in 1994 during which the entire handling system of Workshop has been switched over from ordinary rail mounted cranes to electric overhead cranes.

The workshop obtained ISO-9002 Certification in December 2000. The Workshop has facilities for metallising the steel bridge components & Girders which provide much greater protection against corrosion.

5.3.5 Bridge Workshop Lucknow (Northern Railway)

5.3.5.1 This workshop was set up during the year 1955 as a field workshop for fabrication & erection of workshop sheds for planned Mechanical Workshop at Charbagh, Lucknow. After the completion of the mechanical workshop, this workshop switched over to other fabrication works to covers the gap in workload. In the year 1963, the workshop was converted into a regular Bridge Workshop on permanent basis.

This workshop is continuously engaged in fabrication of riveted and welded steel structure as per requirement of railways.

In course of time, this workshop gained expertise in manufacturing of track items such as SEJs, Crossings, Tie Bars, Cotters, M&P equipments, Thermit welding equipments, steel channel sleepers etc.

In 2001, this workshop got ISO-9000 certification. The workshop has manufactured girders for rehabilitation of old bridges and is continuing its best possible efforts in this direction.

5.3.6 Engineering Work Shops, Arakkonam (Southern Railway)

The present Engineering Workshops, Southern Railway originally started as a Points and Crossings repair shop at Royapuram near Chennai by the earst- while Mysore and South Maratha (MSM) Railway around the year 1885. Subsequently, it was shifted to more spacious surroundings in Arakkonam. This Workshop is mainly intended to cater to the needs of Civil Engineering department of Southern Railway. The important items manufactured are standard and specific crossings, curved switches, switch expansion joint, steel bridge girder – welded & riveted, foot over bridge, passenger platform shelter, lifting barrier gate, motor trolley, dip lorry, track Jack, push trolley, glued insulated rail joint, flash butt welded rail panel and miscellaneous components like keying hammer, Joggled fish plate & Hand signal lamps. ISO-9002 certification was taken in July, 2000.

First Welded Type Girder was successfully fabricated in this Workshop during the year 1982. Glued joints were successfully manufactured since the year 1990. Steel channel sleeper for replacing bridge timber were manufactured from the year 2000. Curved switches 60 kg. & 52 kg. both 1 in 12 and 1 in 8½ for fan shaped layout have been successfully manufactured since 2000-2001.

The Welding plant was installed during 1986 and is producing welds on 90 UTS rails. The welded joints are ultrasonically tested. During the year 2005-06, the plant has produced 57,700 joints.

5.3.7 Engineering Workshop at Bongaigaon,(N.F. Railway)

The Bridge Workshop of N.F. Railway also known as Engineering Workshop/ Bongaigaon (EWS/BNGN) is situated at Bongaigaon in Rangiya Division in the state of Assam. The workshop came in to existence after partition of 1947. Earlier the requirement of Northeast Frontier Railway was met by Assam Bengal Engineering workshop at Saidpur presently situated in Bangladesh. A need was felt for fabrication of steel structures and bridge girder components within the Railway and it was decided to have bridge workshop at Bongaigaon. The workshop commenced in the year 1950-51 in a few temporary sheds erected for this purpose. Subsequently, in the year 1957-58, two sheds of 61 × 20 m. width of light column were constructed.

Presently the items which are fabricated in the Engineering workshop/Bongaigaon are

- Fabrication of riveted plate girder up-to 18.3 m span.
- Fabrication of light welded structures such as Foot Over Bridge, Road Over Bridge, Platform Shelter, sheds for heavy load etc.
- Steel channel sleepers, Glued joints, RCC slabs, CC Crib and other ancillary works of bridge girder components, packing plates for bridge components, packing plates for bridge girders etc.
- Wooden pile driving is done and steel spans erected by workshop staff where emergency bringing is involved.

After closing of Foundry Shop in 1985, staff of Foundry Shop were re-engaged for fabrication of Glued Joints. The fabrication of glued joints were started after due training of staff and procurement of materials.

5.3.8 Engineering Workshop Lallaguda (S.C.R)

This workshop was initially a small reclamation depot wherein conversion of class III BG steel sleepers into M G & N G sleepers was being done. In 1964, due to heavy workload in the Bridge Workshop, Manmad on the C. Railway, a part work was diverted to this workshop. Consequently it became a small-scale feeding depot to the Engineering workshop, Manmad to undertake light fabrication work such as platform shelters, trusses, 6.1m girders, water tanks etc. When South Central Railway was formed in 1966, this workshop got transformed into Engineering Workshop, since Engineering Workshop, Manmad was not able to cater to the requirements of South Central Railway. It was also felt necessary to repair and maintain various assets of the Railway like lorries, trucks, compressors, concrete mixers etc. in this workshop. With this plan, facility to carry out mechanical repairs was added.

The main activities being carried out presently in the Engineering Workshop are:-

- Fabrication of riveted /welded, standard and non-standard plate girders up to 30 M span
- Fabrication of FOBs
- Fabrication of Glued Joints
- Fabrication of steel channel sleepers, rail dollies, dip lorries, speed indicator boards, nuts and washers, saddle plates, packing plates, motor trolleys etc.

To ensure sufficient workload for the staff and machinery constant endeavor is made to do some bridge girder fabrication departmentally. A target of 200 MTs per annum has been kept for production of girders.

Flash Butt Welding unit, Moula-Ali:

Commissioned on	:	25/02/1987
Manufactured by	:	ESAB-SWEDEN
Type	:	SFR11GC3T
Total Number of Joints Welded	:	572190 (Till 31/03/2006)
Major Over Hauling Done	:	1999
Major Repairs carried out	:	2002

Flash Butt Welding Plant was commissioned in the year 1987. The initial completion cost of the plant is Rs. 2.8 crores. In the initial stage the plant has started working in one shift of 8.00 hrs. a day. Subsequently two shifts were introduced which consists of 8.00 hrs. in day shift and 8.00 hrs. in night shift. The Flash Butt Welding Plant Installed at Moula Ali is of ESAB make supplied by Swedish firm. The plant operates on 440 Volts power supply with a separate feeder from M/s A.P. Transco. Sub-station is equipped with transformers for voltage regulations. The capacity of the plant is 72 joints per shift.

5.3.9 Bridge Workshop Gorakhpur Cantt. (N.E.R.)

Bridge Workshop Gorakhpur Cantt. was set up in the year 1954 with an initial investment of Rs. One Lakh. Over a period of 50 years, it has evolved into a full-fledged steel fabrication & pre-cast concrete manufacturing workshop, catering to the requirement of the steel structures and pre-cast concrete items.

The annual capacity of workshop is to fabricate 1400 MT Steel Structures and 1500 Cum. Pre-cast concrete items. Presently annual productivity of 0.47 MT of steel fabrication & 1.62 Cum. of concrete per man-month is being achieved.

The workshop is broadly grouped into following sub-units:-

i)	Steel Fabrication unit	It has 7 Fabrication shops, one for light structure, three for heavy structure, one machine shop, one painting shop & one cutting shop.
ii)	Concrete Yard	It has a slab casting unit and a concrete sleeper casting unit.
iii)	Plant unit	It is for maintenance and break down repair of plant & machinery.

Prototype Erection Of 150 Feet Girder

5.3.10 Bridge Workshop Jalandhar Cantt. (N.R.)

Bridge workshop originally existed at Jhelum in Pakistan, which was shifted to Ludhiana in 1947 after partition of the country. There was problem of adequate space and electric power to accommodate this workshop in Ludhiana which necessitated shifting it finally to Jalandhar Cantt. in the year 1949. The workshop is having an area of 10.28 Hectares.

The workshop was established to meet the requirement of fabrication of various types of girders, platform shelters, workshop sheds, foot over bridges and road over bridges. To cope with the changed requirements technology, casting of reinforced concrete and prestressed concrete bridge slabs was also added.

This workshop has been carrying out the fabrication work of 100' Open Web Girder (Riveted Type); 45 m Open Web Girder (Welded Type); Riveted plate girders of different spans from 6 m to 24m ; Welded girders of 12.2 m & 18.3 m span.; Girders of Road Over Bridges and other miscellaneous works.

In addition it also undertakes making of glued joints, Joggling of Fish Plates; Stress Benches & Moulds; Modification of BFR's for carrying Long welded rails; Metalising of vital components of Open Web Girder to increase their life; Casting of RCC Slabs for bridges and Casting of PSC Slabs of 20', 15' 12' and 10' spans for bridges.

In the year 2005-06 workshop achieved total fabrication of 2950 MT.

Temporary bridge using Calendar – Hamilton griders

The Workshop launched 67 m Calendar – Hamilton (CH) span and 30.48 m CH Span on Bridge No. 7 on Sambalpur-Jharsuguda Section in Orissa. CH Span of 67 m was launched by assembling on embankment and puling by 172.5 m over plate girders.

5.3.11 Engineering Workshop Sabarmati (W.R.)

The bridge workshop was originally set up before independence at Vashi. It had staff strength of about 500 with annual production amounting to Rs. 30 lakh only. The workshop was shifted to Sabarmati in June 1958 to cater to the requirements of fabricating steelwork for both Broad Gauge and Meter Gauge. With increasing demands for more output, the capacity of existing shops had been increased over a period of time and new shops like foundry, flash-butt welding and smithy have been added. Manpower employed was 1300 in1985 and output was Ra. 3.50 crore. At present manpower is 750 numbers and annual turnover is Rs. 26 crores.The workshop is spread over an area of 76 acres and is located at a distance of 4 km from Sabarmati Railway station.

At present capacity is to fabricate 150 T of riveted bridge girders and 75 T of other steel work, totaling 225 T per month. The workshop started manufacturing open web girders in 1979. Open web under slung type 30.5.m span was manufactured first and subsequently 45.7 m spans were manufactured. The Metalising of plate girders and flooring system of open web girders to keep away corrosion has been out sourced.

Flash Butt welding plant was set up in 1964. The plant was supplied by A I welders of U K. It can weld 90 R and 52 kg 72UTS rails. The butting force applied is 37 T. Panels of 10 rails (130 m) can be welded. A second shift working was introduced in 1983. Due to increasing workload and ageing of the plant a second plant was procured in 1983 from M/s ESAB of Sweden. This plant can weld 52 kg and 60 kg 90 UTS rails and layout permits making 20 rail (260 m) panels. The butting force of this plant is79 T. Both plants are working, the A I plant was overhauled in 2004 at a cost of Rs. 26 lakh by M/s Mechlonic Engineers, Mumbai. The overhauling of the ESAB plant is also due shortly. The power supply to the plants was augmented in 2002 to permit parallel functioning of both the plants. Presently 6000 joints are being welded in a month.

5.3.12 Engineering Plant Depot- Mugalsarai (E.C.R)

The Engineering plant depot, Mugalsarai was set up in 1929 for storage and maintenance of all tools and plants of the then East Indian Railway (EIR) in the premises of the then Bechupur railway station of erstwhile Awadh Rohilkhand Railway. The old abandoned Loco shed, Tran shipment shed and the station yard were utilized. The premises are spread over an area of 125 acres and 13 acres are covered. At present it has 8 units and employs 1080 staff.

In 1932, precasting of some concrete items like bridge slabs were started in this depot. Fabrication of steel structures (other than bridge girders) and renovating points and crossings were started in 1935.

After independence, sequel to the 5 year plans, there was a large demand for plate girders for bridges. The workshop was expanded, new machinery was procured and manufacture of plate girders was started in 1957 and of open web girders in 1965.

A **mobile** flash Butt rail welding plant was transferred to this workshop from Northern Railway in 1970(K-355 APT). This is a low capacity old plant and is used for welding 52 kg rail to 3 rail panels. In 1995 a regular welding plant (AI Welders – UK) was installed which can weld 60 kg rails and 20 rail panels are being made.

The structural yard has capacity to manufacture Open web girders of 30.5; 45.7 and 61.0 meter spans; Plate girders both riveted and welded of 9.15m; 12.2m; 18.3m; and

24.4m.spans; Steel channel sleepers for bridges and other miscellaneous items. The production is about 250 T per month. The workshop also maintains calendar Hamilton spans for emergency bridging.

CHAPTER-VI

RAILWAY CONSTRUCTION PROJECTS AND HILL RAILWAYS

6.1 GENERAL

Transport is an important sector, where Civil engineers have played an important role in development of civilisation and making the life comfortable by transporting men and materials to meet the daily needs and providing a suitable livelihood to the mankind. In India, Rails and roads are the principal modes of surface transport which have made significant contribution in national development. The Indian Railways (IR) have been the principal mode of transport in the country for common men and have played a key role in social and economic development of the country; IR have kept pace with advancements in technology and have successfully adopted appropriate technology for moving large volumes of passenger and freight traffic.

6.2 CONSTRUCTION OF FIRST RAIL-ROADS IN THE WORLD

Efforts were made in 1820s all over the world to develop railway system after a number of inventors like Murdoch, Richard Trevithick and George Stephenson developed steam locomotives for traction on railway tracks.

6.2.1 Construction of the world's first commercial railway was started in 1821 in UK from Stockton to Darlington by George Stephenson and took four years to complete. This line was commissioned on 27th September, 1825.

6.2.2 1830s saw the extensive growth of Railways in Europe and U.S.A. In France, Railways started in 1829, in Germany in 1835, in Holland and Italy in 1839. The construction of the first Railway from St. Petersburg, to the suburbs of Pavlovask was completed by a private company in 1837. The first Railway in the United States was opened on a section of 15 miles of the Baltimore-Ohio line in May 1830.

6.3 PREJUDICE AND OPPOSITION

In early stages, the first Railways all over the world had to face severe prejudice, opposition and criticism as would be indicated from the following comments :

6.3.1 Louis Phillip of France, as late as 1848, was practically forbidden to endanger his life by travelling on the Railway. "Le commerce" tells the story;

"When the king was intending to go with the Royal family to his Chateau at Bizy, he proposed to be carried by a special train on the Railways as far as Rouen and orders were given to this effect. But the Council of Ministers on being acquainted with His Majesty's project, held a sitting, and came to the resolution that this mode of travelling by Railway was not sufficiently secure to admit of its being used by the king and consequently His Majesty went to Bizy by post-horses."

6.3.2 In England in 1842, 17 years after the opening of the first Railway in U.K., the Queen Victoria was advised not to travel by train. Even at this time the hazardous adventure of Her Majesty was looked upon with apprehension and critical disapproval by some of her "Loyal subjects". The Atlas while complimenting the Queen for her courage apprehended that:

"A long Regency in this country would be so fearful and tremendous an evil that we cannot but desire, in common with many others, that these Royal excursions should be, if possible either wholly abandoned or only occasionally resorted to. There is danger by the Railway, and therefore, the queen should be occasionally exposed to it."

6.3.3 In India in 1850s, when the Railways were about to be introduced in the country, there was a similar reaction and introduction of Railways was considered as "hazardous and dangerous venture". Doubts were expressed by many Britishers. "Whether people in India would be attracted from bullock cart to the Rail and whether religious medicants, fakirs and agricultural labours and other more or less destitute folks who did not possess an anna could be persuaded to pay a train fare other than prefer to meander without any sense of time".

Ramesh Chandra Dutt, the great Indian economist, was among many Indians who considered Railways as "a wasteful expenditure" and at best deserving of secondary priority next to roads and canals. Shri R.C. Dutt wrote, "Englishmen in their own country, were more familiar with railroads than with canals, and they made the mistake of judging the needs of Indians accordingly."

6.3.4 There were, however, many persons, who had a positive thinking about Railways. Lord Dalhousie, who played a very important part in shaping the early policy of Railway construction in India, wrote in a historic minute in July 1850 from the hill station of Chini in Himalayas:

"He had doubts as indeed every one at that time as to whether the Railways could be made to pay in India. He was most anxious that this so called experimental line of constructing a line from Calcutta to Rajamahal would prove a success. Its object is to prove, not only that it is practicable to construct Railways in India as engineering works, but that such Railways, when constructed, will, as a commercial undertaking, offer a fair remunerative return on the money which has been expended on their construction".

The initial doubts, prejudices and opposition about Railways slowly vanished. The Railways played a major role in development of civilisation everywhere in the world. On the Indian scene, thanks to the pioneering efforts of some farsighted men, the construction of Railways came in a big way in 20th century, which helped tremendous development of the country and its potentialities.

6.4 THE FIRST RAILWAY CONSTRUCTIONS IN INDIA

6.4.1 The Railway was conceived

1831-1840: The first idea of Railways in India was conceived in 1831 in the Presidency of Madras. Later in 1836, Captain A. P. Cotton, a Civil Engineer of Madras, advocated the desirability of railways in India emphasising their superiority over other means of communication. The proposed railway line, however, could not be started at that time and the proposal lingered on.

6.4.2 The first Railway line was commissioned

The idea of having Railway line to connect Bombay with Thana, Kalyan and with the Thal and Bhore Ghats incline first occurred in 1843 to Mr. George Clark, the Chief Engineer of the Bombay Government. A meeting of prominent citizens was later held at Bombay on 13th July, 1844, to consider advisability of a Railway line in accordance with Mr. Clark's scheme. At the same time a company was formed in England called the Great Indian Penninsula Railway Company (G.I.P.).

On 31st October, 1850, the work of constructing Railway line from Bombay to Kalyan was started under the banner of G.I.P. Railway. The ceremony of starting this work was done by Hon'ble Mr. J.P. Willoughby, Chief Justice of Bombay, at a place near Sion. In 1851, a contract was awarded to M/s. Faviell and Fowler, an English firm for construction of Railway line from Bombay to Thana. The construction work was completed in about two years' time employing about 10,000 workers, the formal inauguration ceremony of the first train in India was performed on 16th April, 1853.

6.4.3 Railways in Eastern India

In 1844, Mr. Rowland Macdonald Stepehenson who became the first agent of the East Indian Railway Company, brought the company into being in London. In 1845-46, a trial survey was made by him from Calcutta to Delhi. After three years the construction of Railway line from Howrah to Raniganj was sanctioned as an experimental measure. By the middle of 1853, through the efforts of Macdonald Stephenson, the line was ready upto Pundooah 60.8 km (38 miles).

Two serious mishaps prevented the commissioning of this line, which could have otherwise become India's first Railway line. It so happened that the ship bringing the first models of railway carriages HMS Goodwin sank in deep sea at Sandheads. Also the ship bringing the first locomotives was accidentally misdirected to Australia and could not reach India in time. The locomotive any how reached Calcutta via Australia by HMS Dakegree in 1854, and soon afterwards on 28th June was taken on a trial trip by Mr. Hodgson from Howrah to Pundooah. The Railway line was opened as far as Hooghly, a distance of 38.4 km (24 miles), on 15th August, 1854 and up to Pundooah on 1st September 1854. On Saturday 3rd, February 1855, the line was opened to Raniganj as originally planned.

6.5 CONSTRUCTION PROJECTS IN INDIAN RAILWAYS

The construction projects on Railways can be broadly classified into following sub-groups:

(i) Construction of New lines: Construction of new lines including construction of mountain railways and construction of metro railways. Some of the constructions are highly enterprising and technical in nature.

(ii) Gauge conversion projects: Conversion of the Metre/Narrow Gauge to Broad Gauge railway system. These activities mainly started in the present decade to streamline the working of Railways.

(iii) Construction of station buildings: There have been specialised designs for construction of station buildings depending on the period of construction and architecture available. In most of the station buildings, the type of construction has been integrated with local environment and culture and also to combine the prestige and elegance of railway travel, using new concepts and innovations of engineering.

Some station buildings constructed in India are magnificent and can be compared with the best of stations anywhere in the world like Chhatrapati Shivaji Terminus (Bombay VT), Howrah station, Delhi Main Station, Madras station, Lucknow Station etc.

6.6 NEW RAILWAY LINE PROJECTS

Some specially interesting Railway construction projects are described in some detail in following paragraphs.

6.6.1 Konkan Railway

6.6.1.1 Historical Background

The history of the Konkan Railway goes back more than 100 years. Ever since 1853, when the railways began in the sub-continent, the people of the region were keen to have a railway line for efficient and dependable mode of transportation of goods and passengers. For decades, the only means of transport here was sea, and this route was severely limited by the fact that it could not be used during the monsoon. The road connecting coastal towns came up only recently. The area remained largely undeveloped, though it was rich in natural resources and was inhabited by enterprising and hard working people.

The absence of a quick and reliable infrastructure was felt mainly for two reasons. Industrial growth was considerably hampered resulting in a high level of unemployment. Secondly, though the region receives bountiful rain and is very fertile, farmers had traditionally been unable to find the wide markets that their agricultural produce should have had.

Proposals for a railway line in the Konkan to connect Bombay were investigated from time to time, the first being examined in 1894 by the then Southern Maratha Railway

Company. In 1896, Mr. H. Scott Russel submitted an application to Bombay Government for a concession for the construction and working of a railway with a steam ferry to connect Bombay and Karad via Chiplon. The project was not pursued further. In 1918 M/s Tata Sons wrote to the Railway Board, outlining a scheme for the development of water power resources of the Koyna river in the Western Ghats for which a railway line was necessary from Chiplon to Bombay Harbour to cater to a number of hydro-electric projects near Chiplon. The Railway Board approved a detailed survey for a line from Karad to Ulva via Chiplon which was carried out during 1919-1921 for a Metre Gauge line. The project proved to be expensive and unremunerative. The Railway Board suggested that instead a BG line should be proposed, which should take off from Thane or Mumbra on the existing BG line and terminate at Mahad. This survey was carried out in 1926-27, and it was found that the most suitable point for take-off was Diva and not Mumbra. This is considered as a forerunner of the scheme for a railway line upto Chiplon.

The Railway Board finally approved the construction of the 69 km Mangalore-Udupi line in 1989-90 as the first phase of the Konkan Railway at a cost of Rs.62.64 crore. The outlay required for the balance portion i.e. Udupi-Roha section was to the tune of Rs.1000 crore. An innovative approach for financing this project was evolved in which a corporation was set up to construct the line and operate it for ten years. The equity capital of the company was contributed by Central Government and the beneficiary States, and the balance was to be raised by floating tax-free bonds. The Konkan Railway Corporation was incorporated on 19th July 1990. The work was sanctioned and the construction started by the Corporation in October 1990.

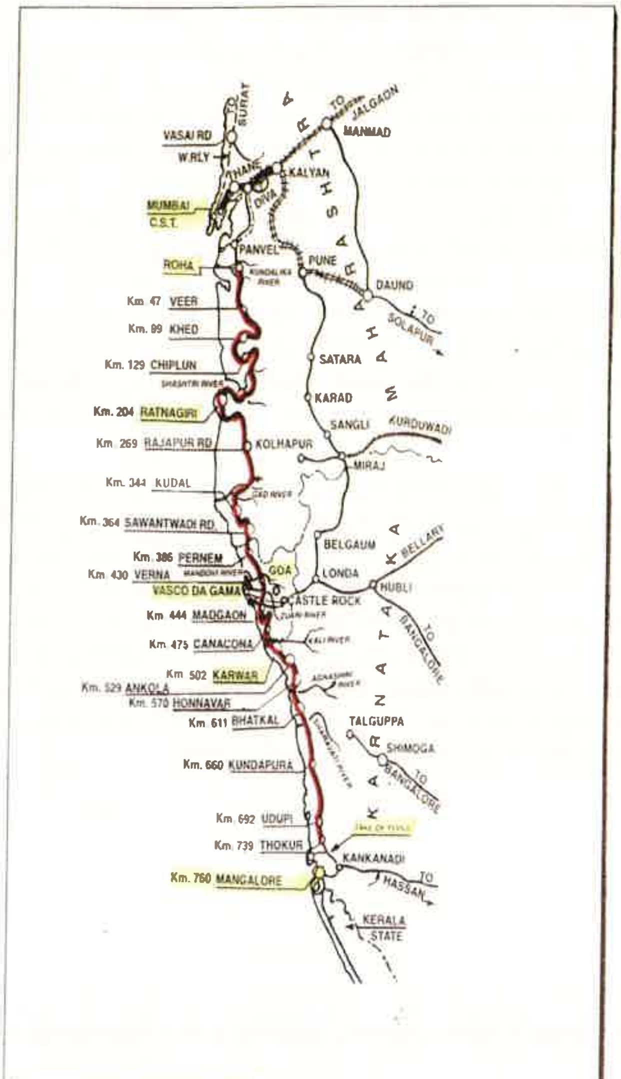


FIG6.1 MAP OF KONKAN RAILWAY

Fig.6.6.1

6.6.1.2 Construction

Karlis Goppers pointed out in his Swedish International Development Cooperation Agency (SIDA) report in July 1997 : "With a total number of 2000 bridges and 92 tunnels to be built through this mountaineous terrain containing many rivers, the project is the biggest and perhaps most difficult-railway undertaking during this century, at least in this part of the world". The rocky Sahyadris had to be bored through, 1500 rivers had to be forded, a railway line had to be built out of nowhere.

Starting from the word `go', the project took little over 7 years for completion although the railway line passes through very difficult terrain. The tunnel dimensions are provided for future electrification. Land required for future doubling has been acquired and minor bridges had been built with doubling in view.

With the opening of last section i.e Sawantwadi- Pernem the entire Konkan Railway system came into operation on 26th, January 1998.

6.6.1.3 Ventilation in Tunnels

Konkan Railway has some of the longest tunnels in the country. All the aspects and provisions on various world railway systems were studied and finally following recommendations were made:

(i) Unlined tunnels upto approximately two km. length and lined tunnels upto three km. length be allowed without any ventilation arrangements such as shaft/forced ventilation.

(ii) In all other tunnels, it is necessary to provide either shafts to reduce the length of tunnel segments or a forced ventilation arrangement provided.

It was decided to provide shafts in five out of nine long tunnels on the Konkan Railway. It was also considered necessary to provide forced ventilation system, mechanical dampers, air curtains, adequate lighting arrangements and uninterrupted power supply were planned.

6.6.1.4 Salient features

Gauge	:	B.G. (1676 mm)
Route Kilometrage	:	760 km.
Ruling Gradient	:	1 : 150 (compensated)
Bridges	:	1998 nos.
Longest Bridge	:	2.0658 km.
Length of bridged track	:	27.23 km.
Tallest viaduct	:	64 m. high on Panval Nadi.
Tunnels	:	92 nos.
Longest tunnel	:	6.506 km.
Length of tunnel track	:	84.8 km
Ballastless track	:	22.642 km. (in 6 tunnels)
Curves	:	342 nos.
Longest curve	:	41.211 km.
Length of curved track	:	249.301 km.
No. of road crossings	:	300 (road over/under bridges)

Max. height of embankment	:	25 m.
Deepest cutting	:	28 m.
No. of stations	:	59 nos.
Track	:	52 kg, welded rails on PRCsleeper
Speed potential	:	160 kmph

6.6.2 Dandakaranya-Balangir-Kiriburu(Dbk) Project

6.6.2.1 Background

Dandakaranya area covering around 80,000 square km and extending through Andhra, Orissa and Madhya Pradesh states is quite rich in mineral resources. However, no mining activity could take place at large scale due to lack of proper transport facilities. Towards the end of 19^{th} century, iron ore was discovered in Bailadila range of hills which is around 32 kms in length and 4 kms in width. Mr. Crookshank of the Geological Survey of India mapped this area geologically for the first time in 1934-35 and identified 14 distinct outcrops of iron ore deposits and numbered them serially.

Japanese were looking for reliable and high grade sources of iron ore in 1950s for their steel plants. Professor Eumeura of Tokyo University, who was studying the iron ore deposits in various parts of India, drew attention of Japanese in 1957. An agreement was signed between the Government of India and the Japanese Steel Mill Association in March, 1960 for export of 2 million tonnes of lump ore from Kiriburu and 4 million tonnes of sized iron ore from Bailadila. This necessitated construction of three new railway lines:

- 41 km long Kiriburu- Bimlagarh link to connect Kiriburu with Bimlagarh on South Eastern Railway's main line.
- 182 km long Sambalpur –Titlagarh line for transporting the ore from Kiriburu and thus providing a shorter route from the mines to Visakhapatnam port, reducing the distance as compared to the previous route via Jharsuguda and Raipur by about 280 km.
- 448 km long Kottavalasa – Kirandul line(K.K.Line) connecting the Bailadila mines at Kirandul with the South Eastern Railway's main line at Kottavalasa, 27 kms from Waltair, the port head.

A separate construction organization was set up by Indian Railways in the name of "The Dandakarnya-Balangir –Kiriburu Railway Project" in the year 1960 for taking up the construction activity of these lines.

6.6.2.2 Surveys done in the past

During the years 1945-46, 1946-47 and 1947-48 preliminary engineering surveys on different sections for a possible through route between Nagpur and Viskhapatnam were carried out by Ex.Bengal Nagpur Railway in connection with the railway construction plan for the Post-war period.

The different surveys ordered by the Board and carried out are mentioned below:-

- Jaypur-Jagdalpur Survey was carried out in 1946 as per Board's letter No.831/WW/P dated 15.11.1945.
- Jagdalpur-Bhairamgarh Preliminary Survey was carried out in 1947 as per Board's letter No. E/46C/136 dated 15.9.1946 to join Jagdalpur to the Ramagundam-Bailadila alignment (which was surveyed by the ex. Nizam's State Railway) at Bhairamgarh to establish a through route to the erstwhile State of Hyderabad.
- Tumnar-Bacheli Survey was carried out in 1947-48 as per Board's letter No. P.46C/188 dated 28.2.1947 to link Tumnar-Jagdalpur-Bhairamgarh route to the east face of the Bailadila range.
- Jaypur-Kottavalasa Preliminary Survey was carried out in 1947-48 as per Board's letter No. P.40C/188 dated 6.8.1947.

The underlying principle of the above mentioned surveys was to construct a through route from Nagpur to Visakhapatnam by the shortest possible distance consistent with the development of mineral resources of Bastar and other districts en route.

KK-Line Goods train with four locomotives negotiating a sharp curve

6.6.2.3 Special features

6.6.2.3.1 The alternative routes, with different ruling gradients were surveyed in 1947-48 for the descent from the 1000 ft. high plateau through the Ananthagiri Ghats to the plains, one adopting 2% steam pusher gradient and the other adopting 3% compensated gradient with electric traction. As 2% gradient was considered to be too severe for braking heavy freight trains hauling iron ore traffic down the ghat section, a ruling gradient of 1 in 100 (compensated against load) was considered the steepest gradient that could be allowed. A fresh survey was undertaken in 1959-60. During this survey it was found, that although a route with a 1 in 100 gradient on the Ananthagiri ghat section was possible, the cost was extremely high and considerable difficulties of construction were anticipated due to the much greater length of track over viaduct and tunnels in very difficult and inaccessible areas.

A further review of the ruling gradient was, therefore, made and it was decided to adopt a gradient of 1 in 70 effective for descending loaded trains and 1 in 50 compensated return grade for ascending empty trains. The preliminary survey with the modified ruling gradient in the Ananthagiri was taken up in November, 1960 and completed in January, 1961.

KK-Line- A Passenger Train entering into a tunnel

6.6.2.3.2 The distance from Bailadila to Visakhapatnam, as the crow flies, is 240 km. However, due to geological features in the intervening area, it was not possible to lay a direct line. The base of Bailadila hill is at an elevation of around 600 m above the sea level. The alignment has to descend by about 170 m to Dantewara before it rises to 750 m to cross Kodenar range and again descends Raikot and reaches Jagdalpur, the administrative headquarters of Bastarpur district on the southern bank of Indravati river. The area between Jagdalpur and Jaypur is relatively easy plateau country. From Jaypur the alignment rises to about 880 m to reach Koraput plateau through difficult hill and forest country. From Koraput, the alignment passes through Padua and reaches Araku after crossing Orissa - Andhra boundary over undulating table and before commencing to descend at Shimiliguda at an elevation of 1,000 m the highest point. The alignment descends for next 66 km through Anantgiri ghats, the most difficult hill and forest country, over high banks and deep cuttings to reach Shrungavarapukota (S.Kota) in the coastal plans of Andhra Pradesh. From S.Kota the alignment finally joins the east coast main line at Kottavalasa, a station on Howrah-Chennai route, about 32 km short of Visakhapatnam.

6.6.2.3.3 The line was constructed to BG ML standard, with a ruling gradient of 1 in 100 compensated for curves where loaded trains ascend the grade and 1 in 100 without compensation and 1 in 80 un-compensated where loaded trains descend the grade. In the Ananthagiri Ghats, the gradient is 1 in 60 uncompensated with 8° curves to keep down the cost. Elsewhere the curvature is limited to 6 ½° except in a few sections where 8° curves have been laid.

KK-Line Goods train over a bia duct

6.6.2.4 Salient features of the Project

Length:

(a)	Andhra Pradesh	=	117 kms
(b)	Orissa	=	158 kms
(c)	Chattisgarh	=	170 kms.
		Total =	445 kms

Ruling Gradients:

(a)	S.Kota-Shimiliguda (km.25.950-93.123)	1 in 60 uncompensated in favour of loaded trains.
(b)	Koraput-Jaypur (km.189.907-231.388)	1 in 100 compensated against loaded trains.
(c)	Tokapal-silakjhori (km.312.992-341.266)	1 in 80 uncompensated in favour of loaded trains

(d) Silakjhori-Dantewara (km.341.266-402.128)		1 in 100 compensated against loaded trains
(e) Lantewara-Kirandul(km.402.128-444.789)		1 in 80 uncompensated in favour of loaded trains.

Curves:

(a) Total number of curves	=	589
(b) Number and length of 8° curves	=	232 (63.88 km)
(c) Number and length of 5° to 7 1/2° curves	=	165 (63.52 km)

Major Bridges:

(a) No. of major bridges	=	84
(b) Longest Bridge	=	Bridge No. 543 (10x45.7 m)
(c) No. of major bridges on 8° curves	=	23
(d) Highest Pier	=	41.46^{m} (Bridge No. 669)

Tunnels:

(a) No. of tunnels	=	58
(b) Total length of tunnels	=	14.1 km.
(c) Longest tunnel	=	T.No.35 & 36 = 8.96 km.

6.6.2.5 Project Completion

Construction work on the K.K.Line started in early 1962 and completed in about 4 ½ years, the line opened to departmental traffic on 18.5.1966 and the first goods strain rolled on 3.5.1967. The passenger traffic started on the line on 1st Sept.1976. The electrification of the line was completed during 1980-82. Cost of the completed project excluding electrification was Rs.55 crore. Cost of electrification was Rs.150 crore.

6.6.3 Jammu-Udhampur Rail Link (Jurl) Project

6.6.3.1 Background

At the instance of Ministry of Defence, an engineering appreciation for extending Pathankot- Kathua BG rail link to Udhampur was carried out in the year 1964. The engineering appreciation suggested 93 km long route from Kathua to Udhampur running behind the Sundri Kot Dhar (hill range) with the alignment following the Dhar-Udhampur road. But this route was bye-passing Jammu, which could be brought on Railway map only by constructing a 35 km long leg from Manwal (a village on Dhar-Udhampur road).

A preliminary engineering survey of Kathua to Jammu rail link was also carried out earlier in the year 1962. Subsequently, after studying both the aforesaid routes, the Railway Board ordered, in the year 1967, the final location engineering survey from Kathua to Jammu, the construction of which was sanctioned and then taken up. Jammu, the winter capital of the state of Jammu & Kashmir, was connected to the Indian Railway system in Oct' 1972

The report of the Kathua-Jammu final location survey suggested the extension of the rail link from Jammu to Udhampur along the left bank of Tawi river upto Kishanpur Nagrota and, thereafter, on the right bank of Tawi along the Dhar-Udhampur road upto Udhampur. As per this survey, the cost of this railway line covering a distance of 39.64 km was Rs.40.45 crore with a ruling gradient of 1 in 50. Railway Board vide its letter dated 16.9.1981 desired that the project be recast with a ruling gradient of 1 in 100.

The revised survey based on ruling gradient of 1 in 100 was completed and the report submitted in 1983. As per this report the total length of the alignment was 53.2 km and the total cost Rs.68.67 crore.

6.6.3.2 Salient features of alignment

The alignment passes through rugged terrain intercepted by deep gorges, valleys, high precipices and numerous torrential khads. Geologically, it passes through hills having unconsolidated to poorly consolidated deposits of recent to sub-recent rocks in the Sivalik and Murree Groups.

Biaduct on JURL Project

Out of the total length of 53.6 km of the proposed line, 10.28 km (20 %) lies in tunnels and 5.16 km (10 %) on bridges. The elevation difference between Jammu and Udhampur is 290 m. This brings out the ruggedness of the terrain traversed by the alignment.

Portal of a tunnel on JURL Project

6.6.3.3 Important Features of the Project

JURL incorporates various modern features and with this project various firsts of Indian Railways are associated, such as:

(i) Fully compacted embankment 42 meters in height, which is the highest on the Indian Railways. Reinforced earth has been provided at identified sites.

(ii) Ballasted track provided on bridges and ballast-less track in long tunnels for better riding quality, and easier maintainability.

(iii) From earthquake considerations, hollow Reinforced Concrete piers constructed on all viaducts/bridges

(iv) Highest bridge (77 meters) constructed, which is taller than Qutub Minar (72.5 meters).

(v) Pre-stressed concrete girder of 102 meters span cast at site, longest on the Indian Railways so far.

(vi) Fforced ventilation has been provided in long tunnels.

A view of Sardhan Bridge on JURL Project

Salient features of the project

Year of sanction	1981-82
Initial estimated cost	50 crore
Actual cost	510 crore
Maximum curvature	5 degree
Alignment on curve	32.25%
Alignment on ruling gradient	73.2%
Maximum height of bank	42 m
Maximum depth of cutting	24.5 m
Maximum height of bridge	68 m
Ruling grade	1 in 100 (Compensated)
Longest span	102 m PSC over Tawi
Longest tunnel	2.445 km
No. of tunnels	20
Total length of tunnels	10 km
Percentage of track in tunnels	19%
Bridging length	5.14 km
%age of total length in bridges	9.6%

A view of Tawi Bridge and Viaduct E-18 on JURL Project

6.6.3.5 Technical problems

This project had its share of technical problems, which also delayed the project execution. Some of the major ones are discussed below:

Provision of ballast-less track in tunnels. Considering the difficult terrain and the fact that track maintenance inside the tunnels would pose considerable problems, beside requiring larger excavation, it was decided to go in for ballast-less track inside the tunnels.

Additional Viaduct Bridge had to be proposed at Km 25.352 in place of embankment. Considering the high bank and the difficulty in transporting necessary filling material to site, it was decided to provide an additional viaduct in place of the embankment.

Change in design and structure of bridge across Gambhir Khad due to geological problems faced at abutment A2 location needed a change in the span arrangement. This was a major factor delaying the completion of the project. The excavation of one of the foundations was in progress when a fault was uncovered in the excavated foundation. This led to fresh geological studies, soil testing, and ultimately changes in the bridge span lengths to relocate the foundation. The change in bridge spans resulted in redesign and adoption of steel girders for which a separate contract had to be entered into. A fabrication yard was set up and the girders were assembled and launched at site. This bridge was completed in December 2003 and was on the critical path of the project.

A view of Gambhir Bridge on JURL Project

6.7 HILL RAILWAYS

Through thousands of years of India's history, the mountains have attracted saints and savants in search of peace and solitude, pilgrims seeking divine inspiration, tourists for the scenic beauty, and common man for seeking relief from the summer heat of the plains. Before the advent of railways, the hill spots could only be reached on foot, horse back, or by dolis, horse carriage or bullock cart and the journey had to be tedious, cumbersome and costly.

In the later part of the nineteenth century, proposals came for construction of rail lines to the popular hill resorts, mostly from private entrepreneurs. Franklin Prestage took the lead and in 1880, his Darjeeling Himalayan Railway, famous for its zebra reversing stations and spectacular loops was opened. It was followed by Kalka-Simla Railway, a line to the summer capital, renowned for its numerous tunnels and bridges looking like ancient Roman Arch Galleries, Nilgiri Railway the only rack line in the subcontinent, Neral Matherian Railway known for its articulated locomotives and sharp curves and Kangra Valley Railway offering scenic beauty like no other. These are described in some detail in following paragraphs.

6.7.1 Darjeeling Himalayan Railway

In 1858, Eastern Bengal Railway (EBR), a private company got concession for construction and management of railway lines commencing from the left bank of Hooghly towards the Eastern and Northern part of Bengal, including a line to Darjeeling. Construction of EBR lines commenced in April, 1859. The first section from Kolkata to Ranaghat 72 km (45 miles) was opened in September, 1862 and extension to Jagati 99 km (62 miles) was opened in November, 1862. The line was further extended to Goalundo 72 km (45 miles) in January 1871. In early 1870's good dividends were being obtained from these lines. The directors were not willing to invest money in extensions including the one to Darjeeling as that might not be profitable.

The state started owning Railways from April 1, 1868, when the 'Calcutta and South Eastern Railway' was surrendered to the Government as it had been running at a loss since its opening in 1862. In 1869, the scheme of railway extensions in Punjab and Rajputana was finalised and Secretary of State for India decided that these lines should be built by the State.

Conditions of scarcity in Bengal, owing to the failure of rains, caused urgency. Construction of a line from Ganges to Jalpaiguri was pushed forward vigorously by North Bengal Railway in November, 1873. Ganges was crossed by a steam ferry, Steam boats owned by NBR had fancy names like 'Prince Albert', 'Poppy' and 'Lily'. The complete section of 315 km (197 miles) from Sara at the left bank of Ganges, to Siliguri on metre gauge alignment was opened for traffic by June, 1878.

6.7.1.1 Franklin Prestage, the Agent of the guaranteed Eastern Bengal Railway, was fascinated by the ethereal views of Kanchenjungha mountains floating in the mists of Darjeeling. NBR had no plan to take the rails to the hills, mainly because the hills were considered a formidable sphere. Where EBR and NBR failed as corporate organisations, Prestage succeeded as an individual entrepreneur.

In 1878, Prestage submitted a detailed scheme to the Government of Bengal, which was sanctioned by the Lieutenant Governor, Sir Ashely Eden. Prestage settled for a 610 mm (2 ft.) rail gauge and formed the Darjeeling Steam Tramway Co. with capital fully subscribed in India. On September 15, 1881, title of the company was changed to Darjeeling Himalayan Railway Co. This company remained effective until the line was taken over by the Indian Government on Oct.20, 1948. All through that time the line was managed by the agency of 'Gillanders Arbuthnot & Co.'from its Calcutta office. A manager and engineer was stationed at Kurseong, while the mechanical superintendent was at Tindharia.

6.7.1.2 Estimated to cost Rs.14,00,000, the actual sum spent on DHR including rolling stock was Rs.17,00,000. By 1887, the cost of DHR shot up to Rs.28,00,000 which included diversions taken in hand from 1883 and acquisition of new rolling stock including sixteen locomotives. By 1891, total investment was Rs. 30,00,000. It is interesting to note that DHR never needed Government's financial support, and was a profitable venture till its acquisition by the State in 1948.

6.7.1.3 Darjeeling-Himalayan Railway Extensions Company (DHRE) was registered on January 20, 1913 and was authorised to construct a line from Panchanai to Kishanganj in the plains and another line to Kalimpong in the Sivok mountains. These two sections are known as Kishanganj Branch and Teesta Valley Branch respectively.

Construction of these two branch lines was entrusted to Darjeeling Himalayan Railway Company. The work progressed so well that first sections on both branches were opened even prior to the conclusion of a formal contract between the Secretary of State and DHRE on April 25, 1914. The Government provided land free of cost and gave financial assistance to make up a net return of 5% on the capital invested. 107 km (67 miles) long Kishanganj Branch was longer than the main line of DHR whereas the Teesta Valley Branch was only 42 km (26 miles) in contrast to 80 km (50 miles) of the main line.

By 1915, both lines were completed and opened for traffic. The capital outlay was Rs.51.1 lakh, the gross earnings Rs.3.3 lakh and net earnings Rs.1.6 lakh giving a return of 3.2% for the year 1916-17. The net earnings of DHRE from 1915 to 1948 varied around 5%, the highest being 8.2% in 1947-48. Government of India acquisitioned DHR as well as DHRE and amalgamated them into Assam Railway.

6.7.1.4 Loops and `Z' reversing stations are the specialty of Darjeeling Himalayan Railway. The travelers have been fascinated by this specialty. Loops help in gaining height for the rail line skirting along the mountain with a radius of curve as minimum as possible. The technique of skirting along the hillock reduced the cost of construction to a bare minimum.

6.7.1.5 Brian Reed in 'Darjeeling Tanks' gives a complete account of the 55 steam locomotives owned by DHR. His analysis covers almost all aspects of the locomotives ever used on this mountain line.

6.7.1.6 With the partition of India in 1947, the whole route from Calcutta to Siliguri had to be re-oriented, as Eastern Pakistan now Bangladesh, absorbed a large part of the direct rail route. A new metre-gauge approach was constructed by connecting the DHRE Kishanganj Branch to the network further south leading to Barsoi and converting it to metre-gauge, though mainly on a new alignment. Similarly, DHRE line to the south end of the Teesta Valley was converted to mixed 610 mm (2 ft.) and metre-gauge, and the metre-gauge was extended further east from Sivok. The Sivok-Kalimpong branch remained 2 ft. gauge until large sections of it were washed away in 1951, when it was abandoned.

Steam train negotiation a culvert

6.7.1.7 A map of Siliguri Darjeeling line is attached as figure 6.2.

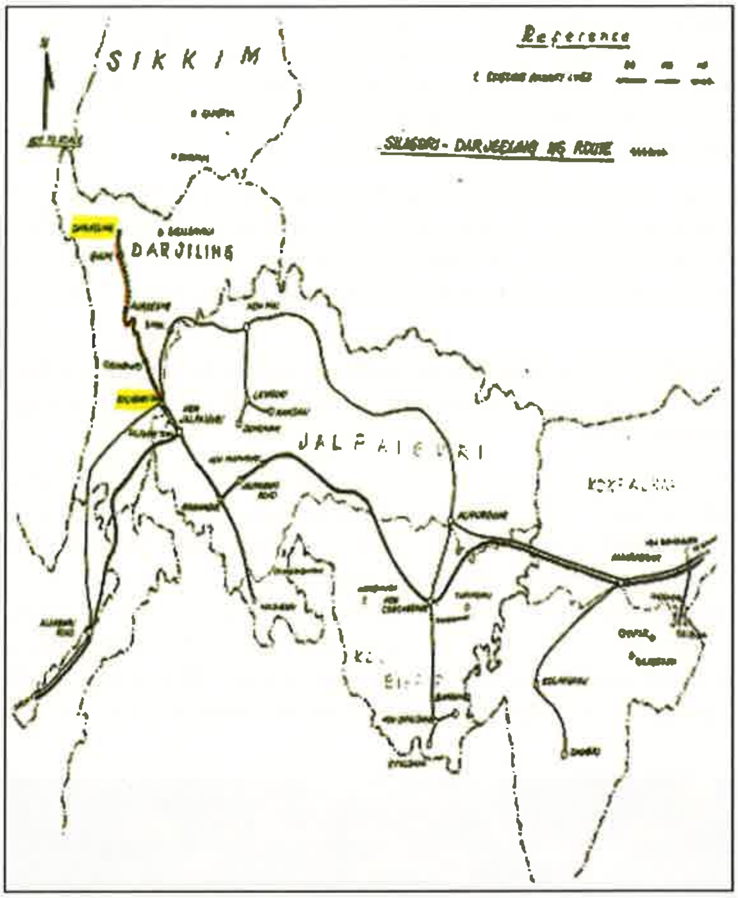


Fig. 6.2

6.7.2 Kalka-Shimla Railway

In 1827 Lord Amherest, the Governor General spent the summer at Shimla after a tour of Northern India. He found the place to his liking, and his successor, Lord William Bentinck, also liked the place and Shimla became the summer headquarters of the Government of India.

During the viceroyalty of Lord Dufferin (1884-1888) the construction of a railway line to Kalka was actively considered. It is interesting to note that the Shimla line was the most surveyed line. The earliest survey was made in 1884 followed by another survey in 1885.

On June 29, 1898, a contract was signed between the Secretary of State and the Delhi-Ambala-Kalka Company, for construction and working of a 610 mm (2ft. 0) in. gauge line from Kalka to Simla (now Shimla). The Govt. of India later yielded to the military requirements of 760 mm (2'-6") gauge. This meant change of gauge for a portion of line built in the year 1901.

6.7.2.1 The line measuring 95 km (59.44) miles from Kalka to Simla was opened to traffic on November 9, 1903. Because of peculiar working conditions –high capital cost coupled with high maintenance cost, Kalka Simla Railway was allowed to charge higher rates and fares to the then prevailing rates for other lines in the plains. Secretary of State decided to purchase the line from January 1, 1906.

6.7.2.2 The scenery along the whole route is of most magnificent character. Flanked by towering hills, the line, like twin threads of silver, cling perilously to the side of steep cliffs or ventures boldly over graceful bridges where hundreds of feet below, the little mountain streams gush and sparkle in sunlight. On leaving Kalka, 640 m (2100 ft.) high above MSL, the rail line enters the foot hills on its departure from Kalka station. Refer layout diagrame annexed. The first great difficulty met with was the huge land slide on the seventh mile of the cart road, which extends from the hill summit down to Khushallia river. 1500 feet below. As it was impossible to find a good alignment passing either below or above the slip, and construction along the face of the land slide was out of question, the only alternative was to burrow under the hill. A tunnel, nearly ½ mile long was constructed in the solid wall behind the disturbed surface strata and is known as Koti tunnel.

The main station Dharampur is at a height of 1495 m (4900 feet) and 32 km (20 miles) from Kalka. The gradient here is very steep. To achieve flatter gradients required by the railway, the development is done by three picturesque loops at Taksal, Gumman and Dharampur.

After leaving Dharampur, the railway gains on the road by taking short cuts and tunnels, so that upto Taradevi, the distance by rail from Kalka is 400 m (¼ mile) less than the distance by road, inspite of railways handicaps of grade and curvature. From Taradevi, the rail line goes round Prospect Hill to Jatog, winding in a series of graceful curves round the Summer Hill and burrows under Inveram Hill to emerge below the road on the south side of Inveram at its 59th mile and so on to the terminus near the old Dovedell Chambers. Between Dagsai and Solan the railway pierces the Barog Hill through a tunnel, 3752 feet long, situated 900 feet below the road.

6.7.2.3 Throughout its length of 96 km (60 miles) the line runs in a continuous succession of reverse curves upto 36.5 m (120 feet) radius along the valleys and spurs, flanking mountains, and finally rising to 2040 m (6800 feet) above MSL at Shimla railway station. The steepest gradient is 1 in 33.

Edward J. Buck in his book `Shimla : Past and Present writes:-

> " The work of construction involved are of vast magnitude comprising 107 tunnels, aggregating 5 miles in length, numerous lofty arched viaducts, aggregating 1 ¾ miles and innumberable cuttings and stone walls."

It appears that Kalka- Shimla Railway had 107 tunnels in the early years of operation. This fact is supported by an early photograph of Barog tunnel showing its number 34 instead of 33.The 1930 renumbering scheme of Kalka-Shimla Railway tunnels remains unchanged till date, numbers going upto 103 though tunnel No. 46 does not exist now.

6.7.2.4 In 1909, the railway line was extended from Shimla station upto the old bullock-cart office, the extension was of half a mile, but it served as an important loading point for goods traffic. With this, the total length of Kalka-Shimla Railway is 96.45 km. Most of the points and crossings used on this railway are special ones and have been designed, developed and manufactured for the particular individual situations. There is almost complete absence of girder bridges. Multi-arched galleries like ancient Roman aquaducts being the most common means of carrying the line over the ravines between the hill spurs. There is only one 18.3 m (60 ft.) plate girder span at Dharampur, and a steel trestle viaduct which replaced a stone gallery in 1935 out of the 869 bridges representing about 3 % of the line.

Passenger train on a roman arch multi tier bridge

6.7.2.5 A map of Kalka-Simla is attached as figure 6.3.

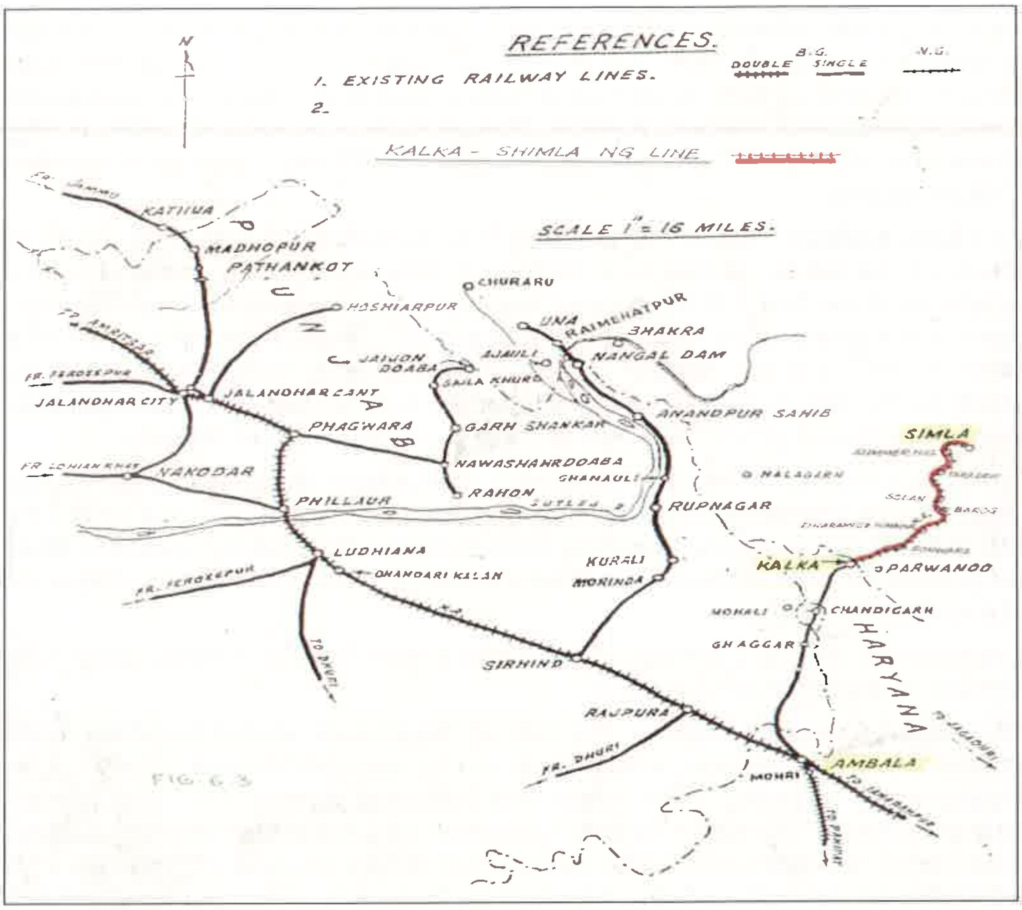


Fig. 6.3

6.7.3 Nilgiri Railway

Udagamandalam, Ootacamund or popularly known Ooty is situated in Nilgiri mountains near the trijunction of the states of Tamilnadu, Kerala and Karnataka. Ootacamund is corrupted version of Utaka-Mand a mand or collection of quaint huts in which the aboriginal tribe of Todas lived. Nilgiris or the anglicised Blue Mountains have a soft, subtle and persistent spirit of peaceful countryside serenity.

6.7.3.1 The original Nilgiri Railway Company was registered on September 30, 1885 with nominal capital of Rs. 2.5 million and a contract was executed between the Secretary of State and that Company on February 26, 1886. The original company went into liquidation in April 1894 and a new company was formed in February 1896 to purchase the line from the former company to construct the proposed extension from Mettupalayam to Ootacamund. The line to Coonoor was completed by the new company and opened for traffic on June 15, 1899. It was purchased by the Government for Pound 235,000 on January 1, 1903 and the extension to Ootacamund was constructed and opened for traffic in 1908. Till 1929-30, the Nilgiri Railway was a profit making system. From April 14, 1951, South Indian Railway and Nilgiri Railway formed a part of the newly constituted Southern Railway. Though there is no separate entity as Nilgiri Railway since 1951, the hill line maintains its individuality and continues to be referred as `Nilgiri Railway'.

6.7.3.2 Rack Railway: Major T.F. Dowden, R.E., published the first article on the Rigi Railway on the ladder system rack railway in 1874, mainly by translation from the descriptions of one Prof. I.H. Kronauer. The most ardent supporter of a rack-railway for Nilgiris was Captain (later Major) J.L.L. Morant, R.E., District Engineer of the Nilgiri District. In 1877 Captain Morant gave a detailed analysis with the title `Mountain Railway for the Nilgiri Hills'. The estimate for the rack-rail line from Mettupalayam to Coonoor was Pound 197,237 (Rigi System) and Pound 302,452 (Fell System).

In 1877 the Governor of Madras Presidency, the Duke of Buckingham, got estimates prepared for an alternate proposal, a railway line from Mettupalayam to a point 2 miles north of Kallar and an inclined ropeway from there to Lady Canning's seat and another rail-line from the head of ropeway to Coonoor. This proposal was considered hazardous and therefore dropped.

Incidentally the first rack railway in India was a short section of broad gauge Upper Bolan line on the North West Frontier

6.7.3.3 Nilgiri Railway Company : In 1882, M. Riggenback, started preparing detailed estimates for a rack railway, which came out to cost only Pound 132,000. A local company under the name " The Nilgiri Rigi Railway Company Ltd." was formed to construct the line. " The Nilgiri Railway Company" was formed in 1885 with a capital of Rs. 2.5 million and the proposal for construction of rack line was dropped for a short while in favour of an adhesion line, similar to the Darjeeling railway on a gradient of 1 in 30. However, very soon, the rack principle came to be favoured again. The original intention to have a direct rack railway on the Riggenback system had by this time been dropped in favour of somewhat longer and more substantial line, using the Abt type of rack rail. Rigi system uses a ladder type of central rail with the toothed wheel engaging the rungs of the ladder, the Abt system has two adjacent rails in the centre of the track with the teeth on the top out of step with each other. The choice was made for the Abt system due to the recommendations made by Sir Guilford L. Molesworth, Consulting Engineer to the Government of India for the State Railways. A new company with the same title was formed in February 1896. The Government purchased this line in January 1903, for Rs. 35 lakh. The line was extended to Ootacamund from Coonoor in 1908 on the same gauge over a distance of .... km (11-3/4 miles) at a cost of Rs.244 lakh. The terminal station is Udagamandalam (Ooty).

PROGRESS OF CONSTRUCTION

Section		Date of opening		Kilometres
Mettupalayam to Coonoor	-	15.06.1899	-	27.34
Coonoor to Fernhill	-	15.09.1908	-	17.48
Fernhill to Ootacamund	-	15.10.1908	-	1.79
Total			-	46.61

6.7.3.4 Alignment : Mettupalayam is at the foot of the hills (Elevation of about 330 m) and Udagamandalam on the plateau (Elevation of 2200 m), the average gradient being about 1 in 24.5. The line is laid to Meter gauge. The ruling gradient is 1 in 40 on the section between Mettupalayam and Kallar, and 1 in 12.28 from Kallar to Coonoor and 1 in 23 from Coonoor to Udagamandalam. The rack section begins at KM 7/8-9 beyond Kallar Down Top point and ends at KM 26/8-9, a little before the Coonoor Up home signal. The average gradient on the rack section is 1 in 15. The sharpest curve on the section is of 17.5 degrees. There are about 208 curves on the section, out of which 180 curves are of 10 to 17.5 degrees. The track consists of 50 lb rails. On the rack section, wooden and steel trough sleepers are laid alternately. There are 250 bridges on the section and 16 tunnels (mostly unlined) between Kallar and Udagamandalam.

It was originally proposed to locate the terminal station in Ootacamund at Charing Cross, but it was eventually decided in 1904 to construct it at the present place in St.Mary's Hill. This involved the re-alignment of the latter part of the line and the construction of an embankment across the Ooty Lake near Willowbund.

The rack rails consist of two toothed steel bars laid in a double row at 44 mm apart and 64 mm above the running rails so that the tooth of one is directly opposite to the cap of the other to ensure that the engine pinions do not work off the racks when negotiating curves. This gave it a common nomenclature of alternating biting teeth with acronym Abt, also the family name of the originator of Abt system. The rack bars are of two standard lengths i.e., full bars with 26 teeth of length 3.12 m and half bars with 13 teeth of length 1.56 m. The pitch of rack teeth is 120 mm. The racks are laid at a constant distance of 455 mm from the inner rails (152 mm in the case of 25 mm thick rack bars) and are screwed by bolting to cast iron chairs fixed to the sleepers with fang bolts.

Today the rack system consists of 50 % of old imported high tensile steel 22 mm thick rack bars and 50 % indigenous 25 mm thick mild steel rack bars, obtained from the Railway Engineering Workshop at Arakonam.

6.7.3.5 Rolling Stock : The train composition normally consists of a first class coach at the front, followed by a first/second composite, three second and a van, with the locomotive pushing at the rear. At the "uphill" end of each coach there is a small open platform on which a brakesman stands; as the train approaches each station the man on the leading coach holds out a red or green flag to indicate the position of the signal arm and this gesture is repeated from coach to coach until acknowledged by a blast on the whistle from the engine driver in the rear in pushing mode who cannot see the actual signal because of the sharp curvatures of the line.

6.7.3.6 The coaches and wagons are bogie stock. Initially, the coaches were wooden bodied, with canvas roof and windows. Subsequently, the roof and windows were also changed over to wood. In the last few years, twelve coaches have been converted to steel body, similar to bus body construction. One of these coaches has been converted as luxury tourist coach with 12 seats. There were 31 coaches, plying on Nilgiri Railway at the turn of the century, mostly built in 1931-32 and rebuilt subsequently. The coaches have no toilets. At the leading end of the coach, there is a verandah. The hand brake wheels for adhesion brakes and pinion brakes are located here. The brakes-man stands on this verandah and operates the hand brakes as required by the driver. The coaches are provided with 24 volts lighting, connected to batteries in the Guard's brake van. Whenever the train is entering the tunnels, the guard of the train switches on the lights.

6.7.3.7 Locomotives: Hugh C. Hughes has described in his article `Ascent to Ooty" in November 1967 as under:

First engines to work on Nilgiri Railway were small 2-4-OT Beyer Peacock ones with 4 cyclinders-2 normal and 2 working cogwheels. Powerful engines were needed for the steep gradients and as a 50 lb. per yard rail was used, the government relaxed the rules for MG railways and allowed an axle load of 12 tons on this but restricted the gross weight to 35 tons.

In due course the larger class "S" appeared, followed in 1910 by the "P"Class with eight coupled wheels, the maximum load being increased to 65 and 70 tons respectively for these two types. In 1913 orders were placed with the Swiss Locomotive & Machine Works, Winterthur (SLM), for a new series of 48 Ton engines to be known as Class "X". This class has been very successful.

There are suggestions and also offers for replacing steam locomotives by diesel or electric locos. While speaking of a railway with a partly touristique function, the attraction of steam must not be forgotten ; it is capable of attracting passengers. Some people believe that IR has the capacity and capability to design and build their own locomotives for Nilgiri Railway at a cost comparable to the foreign offers.

Steam train negotiating a bridge on curve

6.7.3.8 A map of Nilgiri Railway line is attached as figure 6.7.3.3

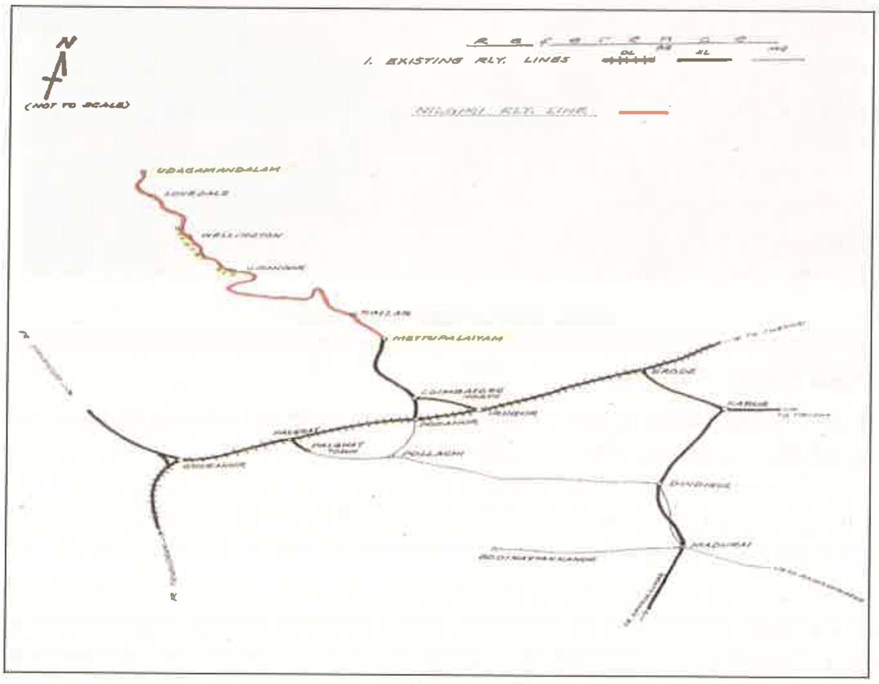


Fig. 6.7.3.3

6.7.4 Neral Matheran Railway

This is a 19 km long narrow gauge 610 mm (2′) gauge section taking off from Neral at about 96 km away from Mumbai on Mumbai-Pune mainline and terminating at the hill station of Matheron. Matheron hill is about 800 metres high above the mean sea level providing a refuge to Bombayites from their sultry weather and noisy and polluted environment in metropolis. It derives its name which means "wooded head". Sir Adamjee Peerbhoy built the line in 1905 as an enterprising venture. There is a small permanent resident community at Matheron, otherwise it is a tourist place. To maintain the place pollution free from motorists, it has been ensured that the pucca road access to Matheron is kept about two kilometres away from the tourist town. The narrow gauge railway itself is of tourist interest with very sharp curves and grades. The section operates in day time only.

Steam train chugging up the hill

6.7.5 Kangra Valley Railway

Kangra Valley is the name given to the conglomeration of valleys and plateaus of the Himalayas on the north and the last of the foot hillls on the south. For shear allurement for the magnificence of its scenery, for the majesty of its northern mountain barrier, the beauty of its glens and the grandeur of its streams, it is a vale which can surely compare on terms of equality with the loveliest of mountain resorts in Europe and America.

Kangra valley, famous for its natural beauty also had a number of ancient Hindu Shrines visited regularly by thousands of pilgrims. The European settlers converted it into a rich tea growing district and established a large European colony at Dharamsala. Shortly after the construction of Kalka-Shimla Railway was started, in 1900, a scheme was worked out to link Shimla with Dalhousie via Kalka. The proposal was revised in 1925, when the Punjab Government finalised the Uhl hydro-electric scheme. The Railway Board, found it desirable to construct a 760 mm (2'-6") narrow- gauge line from Pathankot to Shanan. Pathankot was chosen as the take-off point instead of Mukerian and the alignment included easy connections to a number of pilgrim places as well as the European settlements.

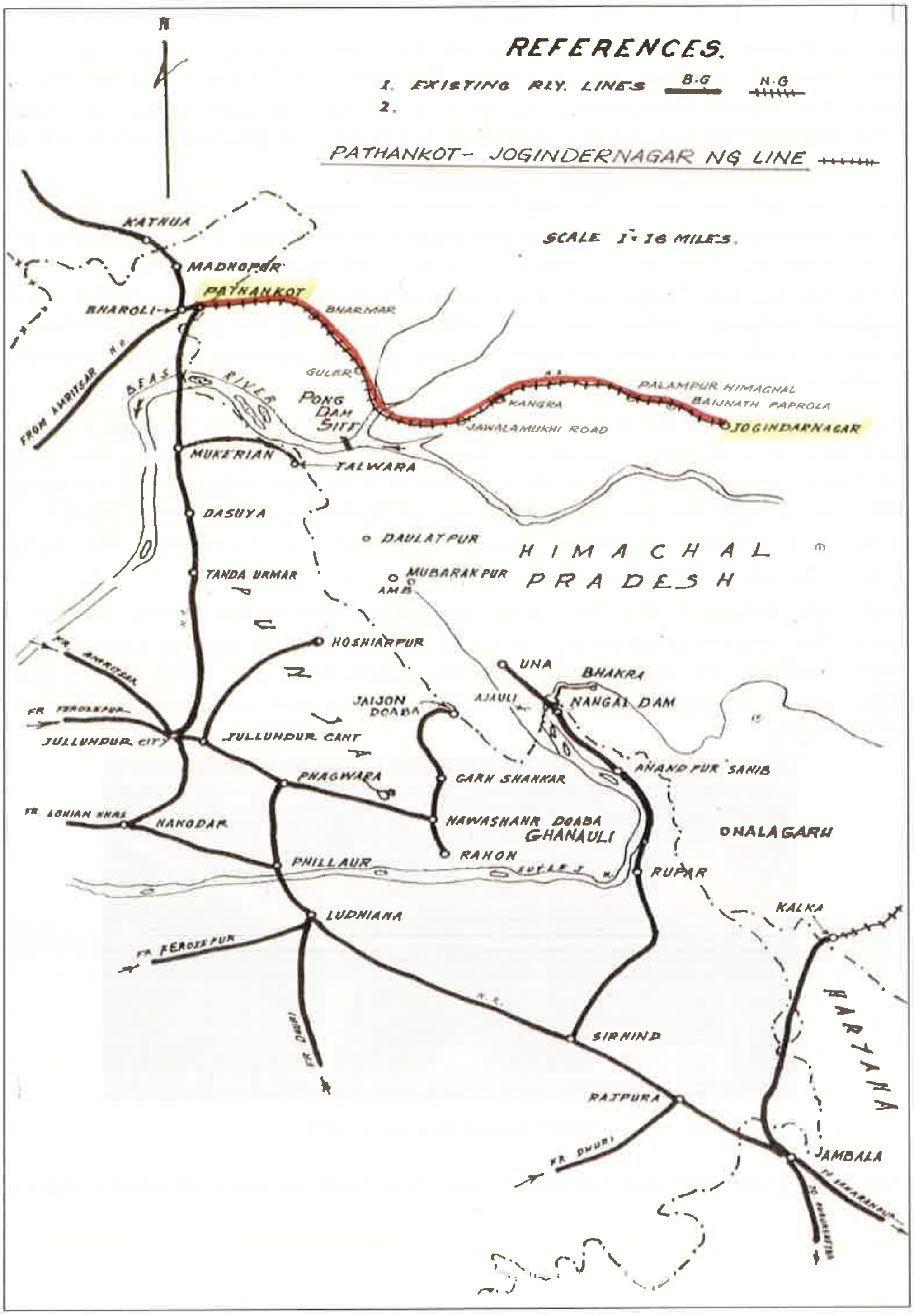
6.7.5.1 The first sod was cut by the Governor of Punjab on 2.5.1926, and the hundred mile line constructed in rough terrain and hostile weather was opened for traffic in less than 3 years time. Pathankot to Nagrota section (109.5 km.) was opened on 1.12.1928. and Nagrota-Joginder Nagar section was opened 4 months later on 1.4.1929. This section was closed in April, 1942 and the track material sent to aid the British war efforts. The restoration work was taken in hand shortly after Independence and reopened on 15.4.1954 i.e. after a lapse of 12 years.

6.7.5.2 As a result of the Indus water treaty between India and Pakistan in 1960, the construction of a multipurpose dam across the river Beas near Talwara was taken in hand. Due to ponding of water in the reservoir of Pong Dam it threatened submergence of the existing track, the line beyond Jawanwala Shahar was closed from April 11, 1973 and the track between Jawanwala Shahar and Guler was dismantled. The realigned portion of the line, 24.87 km long, was opened in 1976.

6.7.5.3 On Kangra Valley the curves are comparatively easy. There are only two tunnels. The steepest gradient is 1 in 19 for a length of 214 m (700 feet). This is the steepest gradient, for any adhesion line on Indian Railways. There are 20 crossing stations. Due to steep gradients, 11 slip sidings are provided on 10 stations. There are in all 971 bridges.

Diesel hauled train on a curve

6.7.5.4 A map of Pathan Kot-Joginder Nagar, N.G. Railway line is attached as figure 6.5.



REFERENCES.
1. EXISTING RLY. LINES B.G N.G
2.
PATHANKOT- JOGINDERNAGAR NG LINE
SCALE 1" = 16 MILES.
KATHUA
MADHOPUR
PATHANKOT
BHAROLI
FROM AMRITSAR
BEAS RIVER
GULER
PONG DAM SITE
KANGRA
PALAMPUR HIMACHAL
BAIJNATH PAPROLA
JAWALAMUKHI ROAD
JOGINDARNAGAR
MUKERIAN
TALWARA
DASUYA
DAULATPUR
HIMACHAL PRADESH
MUBARAKPUR
AMB
TANDA URMAR
HOSHIARPUR
UNA
BHAKRA
NANGAL DAM
JAIJON DOABA
AJAULI
JULLUNDUR CITY
JULLUNDUR CANT
ANANDPUR SAHIB
PHAGWARA
GARH SHANKAR
NAWASHAHR DOABA
GHANAULI
NAKODAR
RAHON
NALAGARH
PHILLAUR
SUTLEJ
RUPAR
LUDHIANA
KALKA
FR. FEROZEPUR
HARYANA
SIRHIND
FR. DHURI
RAJPURA
AMBALA

CHAPTER-VII

RAILWAY LOCOMOTIVES AND OTHER ROLLING STOCK

7.1 STEAM LOCOMOTIVES

7.1.1 It would be appropriate to start with George Stephenson, the inventor/builder/ father of the steam engine to truly appreciate and enjoy the history of the steam locomotive and the railways. George Stephenson (b.1781), had a strong practical bent of mind even though lacking formal education. He maintained pumps and engines of local collieries, made several experiments and improvements and was appointed by a consortium of Tyneside coal-owners to take over the chief responsibility of all their machinery. By 1813 he was already an engineer of repute. Stephenson built the first locomotive, Blucher, which ran in 1814 and between 1814 to 1826, Stephenson was the only engineer in Britain building steam locomotives.

7.1.2 The Stockton and Darlington railway achieved historic distinction when George Stephenson was appointed its engineer in 1821 and laid out its 22 miles main line for locomotive haulage. At the time of its opening Stockton & Darlington was worked by a mixture of steam and horsepower. The first public passenger train ran hauled by the locomotive "Locomotion" on 27th September 1825. In 1827, the railway claimed a saving of 30 % in the haulage cost per ton-mile with locomotives in comparison to that by horses. Thus the future of locomotive haulage was established.

7.1.3 Another railway, Liverpool and Manchester, started in 1826 and had heavier double tracks throughout. It was the world's first line intended to form a link between two large cities for all classes of traffic. The company decided to experiment to prove whether steam power could be used in the form of locomotive engines. The company advertised during 1829 that they would give a prize to the builder of the locomotive which would meet their difficult conditions. Several locomotive builders competed with their products. "Rocket," built by father and son, Stephensons, was simpler, more robust, more efficient, meeting all the conditions and won the prize and proved the triumph of the steam locomotive.

Soon Railways caught the imagination of Europe and USA. The imperialist countries particularly the Britain quickly spread railway network in all their colonies. The first steam locomotive that came to India was called "Thomason" named after a dynamic administrator and later principal, Thomason College of Engineering of Roorkee. This locomotive was for 4'-8 ½"gauge and it was used for starting earthwork near Roorkee on 22nd Dec.1851 for constructing the Ganges canal. It is said that she was first example of a "lemon" having been palmed off abroad for failing to live up to her promise at home. Alas, "Thomason" proved to be more of a hindrance. The working men were said to have rejoiced when she accidentally blew up her boiler within six months during a cyclonic storm. The second locomotive that came to India, again of 4'-8 1/2" gauge, worked for construction of the first railway line in India from Bori Bunder (Mumbai).

7.1.4 G.I.P. Company ran the first passenger train in India and indeed in Asia, on Indian standard gauge (5'-6") from Bori Bunder at 15-35 hrs, on 16th April,1853 with 14 carriages and 400 guests hauled by three steam locomotives Sindh, Sultan and Sahib, (probably so named after the event.) The second most important train ran on 15th Aug. 1854 from Howrah to Hooghly and later extended to Pundooah with an unnamed and now forgotten locomotive. However, two locomotives "Fairy Queen" and "Express", of a slightly later vintage, built in 1855, have become very famous, not only in India, but throughout the locomotive world. The Fairy Queen is still (2006 AD) running a tourist train on Indian railways, and the sister engine "Express" is preserved majestically on a pedestal in the famous first locomotive P.O.H workshop at Jamalpur, India.

7.1.5 The first engineer, in our civilisation was a weapons engineer, commonly called a military engineer. A military engineer was succeeded by a Royal Engineer, who carried out Kings' commands of building all that was required viz forts, palaces, roads, bridges, dams, canals, buildings etc. In course of time, someone rightly politely began to call them " civil engineers" because they carried out all construction building work.

7.1.6 For the growing civilised society, George Stephenson, an ordinary practical creative mechanic through maintenance and manufacture of pumps, became the head of a coal mine to maintain its machinery. He became Chief Engineer of a railway and laid over 20 miles of railway lines/track. It is interesting that one day, sitting in a permanent way inspector's hut along the railway line, Stephenson decided to apply to his seniors to become an accepted qualified civil engineer. His request was turned down, because he had not built any conventional civil engineering works. On hearing this, Stephenson and his tribe, decided to call themselves "Mechanical Engineers," but continued to work under the control and direction of civil engineers, who built and ran the Railways in UK. Same or similar groups of persons came to India to build, maintain and operate the railways. A similar pattern of organisation got transferred to IR also. All mechanical engineers, in one company or a railway system, came under the control of a Locomotive Superintendent, or later a Chief Mechanical Engineer, who became responsible for design, manufacture, maintenance of locomotives, rolling stock, and all machinery in workshops and loco sheds, carriage and wagon depots. All chief Mechanical Engineers, however, continued to report to and be directed and controlled by the highest authority of a civil engineer, called Member Engineering, of the Railway Board. Member Engineering was assisted by a mechanical engineer, called Director, Mechanical Engineering, till 1947. In view of increasing complexity, volume and specialisation of mechanical engineering work, Director, Mechanical Engineering was elevated to become an additional Member Mechanical, Railway Board. Finally, in 1952, a full fledged Member Mechanical, took charge of the Mechanical and Electrical departments, relieving the existing Member Engineering of these responsibilities.

7.1.7 Again, in 1987 due to increasing general electrical engineering work and electrification of the railways, another member, designated Member Electrical took independent charge of the Electrical Department. Member Engineering who was orginally responsible for all engineering disciplines was gradually relieved of all disciplines except Civil Engineering. The signalling department was also transferred under the control of Member Electrical from Member Engineering because of professional back ground of Member Electrical.

7.1.8 The first problem the Indian Railways presented before railway builders for Indian railway system was the selection of a `gauge' from multifarious gauges prevalent in the world. The next problem that was thrown up was that of standardisation of moving dimensions, sizes and types of locomotives and boilers suitable for inferior quality of coal available in India in contrast to high quality coal available in UK. The following extract from administrative report on the railways in India-for the year 1902 by Bremerton, Secretary to the Govt. of India, PWD (Railways) dated 23rd May,1903 is interesting.

"Mr. C.W. Hodson, Director of Railway construction was deputed while in England, by his Majesty's Secretary of State, India to consult the English authorities in regard to :-

(I) the relaxation of existing standard dimensions for Indian Railways as regards fixed and moving dimensions and regulations regarding the strength of bridges and axle loads and weight of rolling stock and

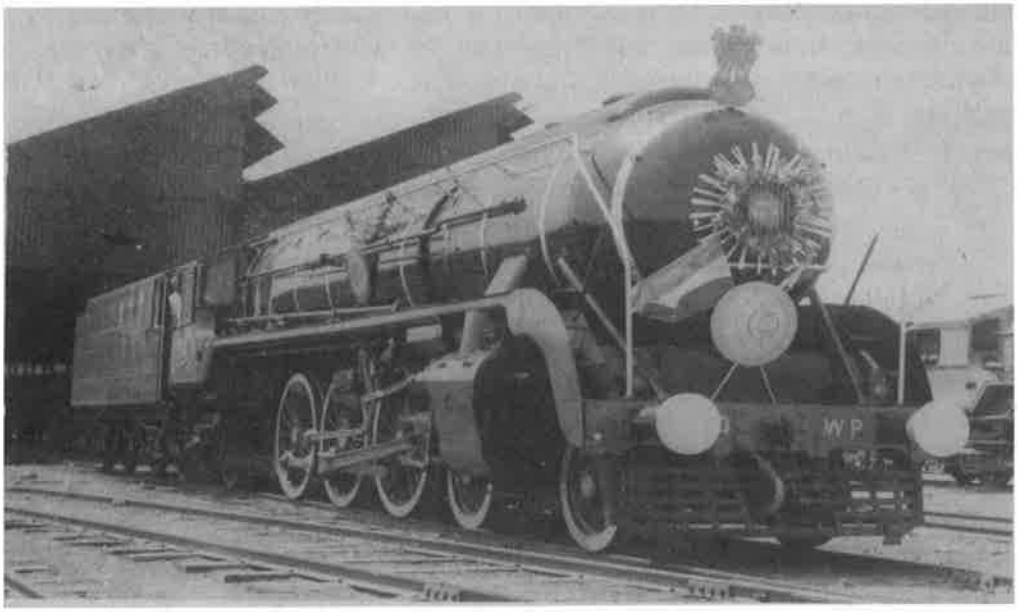
(II) the placing of orders for rolling stock in advance"

7.1.9 The policy of Standardisation of locomotives in India started about 1901. It was felt that if standardisation could be adopted (in place of each Railway Administration developing its own locos) it would admit of exchange of power between different railways, limit the number of spare parts and enable manufacturers to deliver engines in less time and at less cost.

Accordingly in 1903, the Secretary of State approached the British Standards Association (B.E.S.A.) and a committee was set up representing all interests. It included a member with first hand knowledge of Indian conditions-namely a representative of Indian Loco Superintendents Committee of Indian Railway Conference Association. As a result, B.E.S.A. design was completed for seven BG types and three MG types. Designs made provision for maximum degree of interchangibility of various parts and components between the various types. By 1910, orders had been placed for 840 BG and 470 MG standard B.E.S.A. engines.

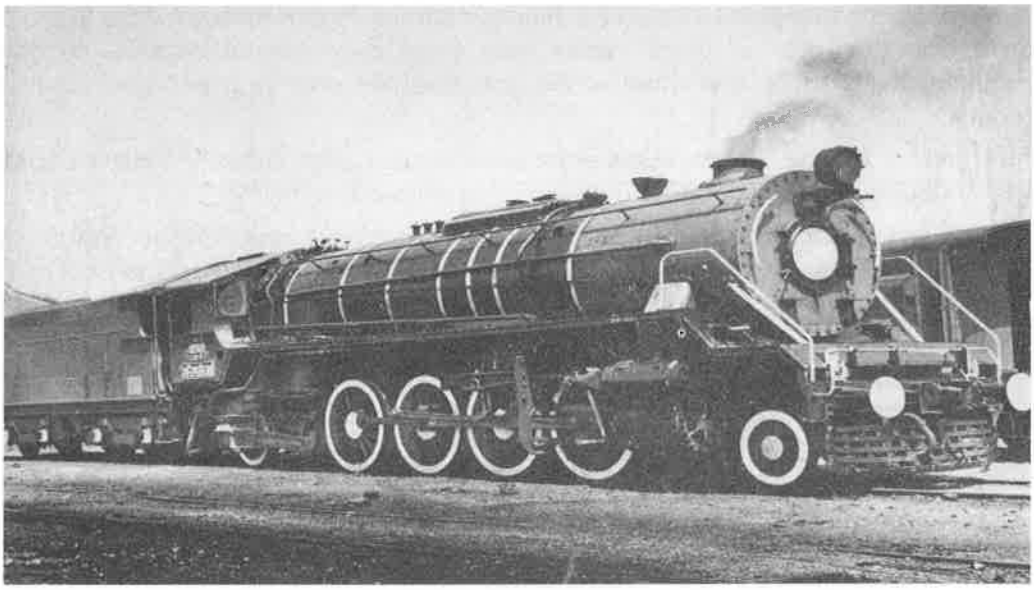
7.1.10 The Great War (1914 to 1919) forced the system to degenerate and further development work almost stopped. The War also resulted in an increase of the cost of first grade Indian coal as judged by the average cost increase from 1913-14 to 1922-23. The Board and Railway Companies particularly B.B.C.I. and E.I.R were greatly concerned and felt an urgent need for economy in the fuel bill. They pursued standardisation as a further measure of economy.

7.1.11 Another way of effecting economy was by extending the use of second grade coal, supplies of which were ample particularly in certain collieries acquired by the Railway Board. Investigations into boiler ratios of existing types of locos indicated that existing locos would be unsuitable for economic use of this (Second grade) coal and to obtain necessary boiler horse power, wide fireboxes were essential. There was a demand for the wheel arrangement of the Pacific type (4-6-2) in place of existing narrow 4-6-0 type to obtain sufficient power to meet anticipated need for heavier loads. The B.B.C.I initiated certain experiments on MG engines in 1919. It was proposed to introduce new types of engines (Pacific wide Fire box Type), boilers of goods and passenger engines being interchangeable. The cylinders and moving parts with the exception of connecting, coupling and eccentric rods were also interchangeable.



1st WP STEAM LOCOMOTIVE 'VIVEKANANDA'

7.1.12 The success of the trials, with extra wide fireboxes, encouraged the adoption of a similar arrangement for BG. Although BBCI administration requested for sanction of 20 locomotives, the Railway Board agreed to two engines of each type (MG & BG) to be tried thoroughly in running, at least for one year. In 1922 the agents reported no objection to the running of these engines and also obtained the sanction of Govt. Inspector. Another six Pacifics arrived in 1924. After sufficient running of these engines, the I.R.S. designs for series of engines (XA.XB.XC.XD.XE. & XF) were finalised. A large number of these new IRS design locos., XA,XB,XC, arrived from 1928 onwards and continued in service. One of these locomotives, XB, working a passenger train, at about 45 miles an hour derailed in mid section near BIHTA railway station in Bihar in July,1937. The cause of the accident could not be easily ascertained. A high level inquiry committee called Pacific Locomotive Committee, consisting of locomotive engineers of international standing was constituted by the Govt. of India. The committee findings highlighted little known but important factors of vibrations, oscillations, hunting and nosing of this type of locomotives. These findings substantially influenced design and manufacture of future locomotives. I.R evolved the new designs of W Series (WP, WG, WT, WL, CWD for BG & YP, YG, YL, YT for MG) of IRS locomotives. These Indian locomotive designs were the last to be manufactured in India, indeed in the world, and put into service on IR. These faithful warriors served IR from 1940 onwards till 1995, when the last of them became cold in saddle and they disappeared from BG & MG systems of Indian Railways.



WG LOCOMOTIVE

7.1.13 In Oct.1923, Railway Board decided in consultation with the Agents that a Committee (known as Loco Standards Committee) be constituted to give effect to the Board's policy of "progressive standardisation as a continous process." The Loco Standards Committee (L.S.C.) continued to function till 1930, up to which time the technical work of the committee, in the way of design and preparation of drawings, etc. had been carried out by the Consulting Engineers and by a Technical section of the Railway Board's office. The object of forming the Central Standards Office in 1930 under the Chief Controller of Standardisation was to standardise all equipment commonly in use on Railways and to provide means whereby "standardisation could be progressively effected in accordance with changing conditions and as a result of practical experience". On the Mechanical side, the office appears to have confined its attention until 1936-37 almost exclusively to I.R.S. designs of rolling stock. In 1937, a decision was taken that part-drawings system should be extended to all the standard types of locomotives. As a beginning, the Consulting Engineers were asked to arrange with the builders for the preparation of drawings as a part of fulfilment of current contracts. As brought out in Chapter II, the organisation later became R. D. S.O. in 1957 to serve all the needs of IR in Research, Design, Testing and Standardisation.

7.2 DIESEL LOCOMOTIVES AND DIESEL MULTIPLE UNITS

7.2.1 The history of dieselisation of Indian Railways starts as far back as 1911 when a few low horse power diesel locos were obtained by the tea plantations. After a good gap of 19 years, i.e. 1930, two broad gauge 350 hp BO-BO diesel locos were procured for North western Railway. In 1936, one broad gauge 330 hp Armstrong-Sulzer diesel electric shunting loco was obtained for Bombay Baroda Indian Railway. This loco gave service for a number of years. Apart from these experimental engines, no other procurement was done and dieselisation was confined only to a few diesel rail car services.

The company owned Railways and subsequently the Government of India went into more and more bulk purchases of diesel locos as enumerated below -

(i) In 1945, sixteen WDS1 diesel shunters powered by twin caterpillar engines (2 x 193HP) and manufactured by International General electric company of USA were purchased. Most of them were utilized in the BBCIR.

(ii) In 1954, another installation of 30 diesel Hydraulic shunters (400 hp) WDS2 manufactured by M/s KRAUSS & MAFFEI of West Germany arrived. These locos were powered by MAN engines and were allotted to Western Railway and are now stationed at Kurla Diesel shed of Central railway.

(iii) The year 1955-56 saw 20 YDM1 Meter gauge main line locos supplied by North British Locomotive Company. These locos had five 634 hp Paxman Engines and with hydraulic transmission. These locomotives were allotted to the Western railway and stationed at Gandhidham for operation on Palanpur-Deesa-Kendla section.

(iv) In the same year, i.e. 1955-56, eight numbers of N/ZDM1 locos were received from M/s ARJUNG & Co of West Germany. Out of these locos, 5 were ZDM1 to suit 762 mm gauge for operation in Kalka-Simla Section of Northern Railway. The balance three locos were meant for 610 mm gauge for operation in Neral-Matheran Section of the Central Railway. These locomotives, which were powered by NWM engines developing 125 hp were specifically designed for hilly section for negotiation of steep grade up to 1 in 20 and sharp curves up to 15 meter radius.

7.2.2 All these procurements were sporadic and not based on any planning and coordinated policy. In the meantime, the five year plans and the consequent rapid industrial development in the country started having its impact and demanded much larger transport capacity from the Railways. In order to meet the challenge, the Railway Ministry had to arrange immediate procurement of 100 Broad Gauge 1950 hp locomotives manufactured by M/s American Locomotive Co (ALCO). These locos were temporarily stationed at Gaya of Eastern Railway and Chakradharpur of South Eastern Railway in the year 1958-59. These locos can claim the credit of rescuing these two railways from severe transport crisis between 1958 to 1962. The locos were subsequently transferred to newly built sheds at Patratu and Bondamunda. The Railway Ministry simultaneously embarked on a world wide survey for large scale procurement of diesel locomotives for the Indian Railways network both broad and meter gauge. Indigenous manufacture of diesel locos was also kept clearly in view. As a result, between 1958 and 1973, various types of diesel locos were procured from different countries particularly from the USA and West Germany.

(i) 7 numbers of WDS3 broad Gauge shunting locos powered by 618 hp Maybak engines were imported from West Germany and put on line in year 1961. The locos were manufactured by M/s HENSCHEL on the basis of RDSO's design and incorporated novel features like SURI transmission and SURI reverse Governor. These locos were allotted to the Northern Railway.

(ii) In 1962, 30 numbers of Metre Guage main line YDM3 locomotives were imported from the USA. These locos were manufactured by General Motors and were powered by 12 cylinder two stroke cycle engines developing 1390 hp. These were based on Western Railway, Abu Rroad shed.

(iii) Next to this between 1962-63, 72 WDM4 locos manufactured by General Motors, USA for utilization for mixed traffic service were procured. These locos were powered by 16 cylinder 2 stroke cycle VEE engines. They were originally allotted to S. E. Railway and subsequently transferred to N. Railway and are at present based in MGS Diesel shed.

7.2.3 Major step in bulk purchase was taken in 1962, when 40 BG main line WDM2 locos powered by 16 cylinder 4 stroke cycle VEE engines producing 2600 hp were purchased from American Locomotive Company followed by purchase of another 212 locos. Along with this purchase, contract collaboration for setting a Diesel Loco manufacturing shop was signed for manufacture of the Broad Gauge and Meter Gauge locos to ALCO design in India. Altogether, 252 locos including 12 in knocked down condition were purchased between 1962 and 1965. Simultaneously, the manufacturing facilities for diesel locos and components were set up at Diesel Loco Works, at Varanasi.

(i) In the same period, i.e. in 1962, 30 numbers of YDM-4 Meter Gauge main line locos with electric transmission were supplied by M/s ALCOs. Subsequent to this in 1964 another 25 locos were imported. From 1967 to 1971, 170 locos of the type were manufactured by DLW.

(ii) 25 numbers of General Motors, USA built YDM5 locos were put in line in Western Railway and stationed in Abu road Shed. These locos have 12 cylinder two stroke engines developing 1390 hp and have electric transmission.

(iii) In 1964-65, 25 numbers of ZDM2 locos built by MAK of West Germany and powered by 700 hp Maybak engine were put online. These locos have SURI transmission with Brock-house converter coupling and were based at Motibagh Shed of Nagpur, S.E. Railway.

(iv) Between 1964-69, 99 numbers of YDM4A locos were imported from M/s M.L.W. Canada. These locomotives were similar to ALCO locomotives YDM4 and distributed to be based in Meter Gauge main line sheds, Golden Rock (TPJ) and Guntakal Shad of Southern Railway.

(v) In 1967-68, 31 WDS5 broad gauge shunting locos were imported from M/s ALCOs. These locos were powered by 6 cylinder 4 stroke cycle "in line" engines developing 1050 hp. The transmission of these locos is electrical.

(vi) Between 1979 and 1972, 28 WDS4 locomotives were manufactured in Chittaranjan Locomotive Works and put on line. These locomotives are the improved version of WDS3 locomotives of RDSO design. These are powered by 6 cylinder "in line" engines manufactured by MAK producing 600hp at 1000 RPM and are provided with SURI hydro-mechanical transmission.

7.2.4 Chittaranjam Locomotive Works next built 5 WDS-4A These locos are similar to WDS4 except that:

(i) Engine is capable of producing 660 hp at 960 RPM.

(ii) Voith transmission is fitted in place of SURI hydro-mechanical transmission.

7.2.5 From 1972 onwards, CLW went into regular production of WDS 4B locos which have similar features as WDS 4A locos with following changes incorporated:

(i) Engine rating 700 hp at 1000 RPM

(ii) SURI transmission has been provided, later versions of these locos are simplified SURI transmission WDS-4, 4A and 4B and the locos are distributed all over Indian Railways BG sheds attached to major yards.

7.2.6 Last type of diesel loco taken in for indigenous production in CLW/CRJ was ZDM-3 locos. Ten number of these locos were manufactured in 1970-71. These locos were powered by 6 cylinder in-line engines developing 700 hp same as MAK design engines fitted on WDS-4 locos. The major equipment/ assemblies/ components are inter-changeable with WDS -4 locos. They have hydro-mechanical SURI transmission. These locos are being utilized on Kalka-Simla Hill Section of Northern Railway.

7.2.7 In the last 10 years, the following new designs of locomotives developed by RDSO have been manufactured by DLW. These locomotives are now performing very satisfactorily on Indian Railways.

(i) 3100 hp MIXED traffic Locomotive – WDM2C

(ii) 3100 hp freight locomotive-WDG2

(iii) 3100 hp High Speed Passenger Locomotive-WDP2

(iv) 2300 hp High Speed Passenger Locomotive-WDP1

7.2.8 With the renewed thrust to tap export market new locomotive designs were developed during 1995-2002 as under -

(i) 2600 hp BG locomotive for Bangladesh Railways

(ii) 2300 hp BG locomotive for Sri Lankan Railways

(iii) Full width 2300 hp Meter Gauge/ Cape guage Diesel electric locomotive

(iv) 2300 hp meter Gauge locomotive for Malaysian railways

(v) YDM4 locomotive for Vietnam Railways.

7.2.9 To give further impetus to the development of diesel locomotives, 4000 hp locomotives both for freight (WDG4) and passenger (WDP4) operations were imported from General Motors, USA during 1999-2001. DLW has already started manufacturing both WDG4 and WDP4 locomotives indigenously.

7.2.10 Diesel Multiple Units (DMU) and Rail Bus

DMU's were developed for meeting the needs of the fast growing population centers to reap the following benefits:

- Fast and frequent services
- No need for reversal facilities
- Low capital & maintenance cost
- Minimum damage to environment
- Efficient use of rolling stock.

(i) BG DMU : Two types of stock were conceptualized : Diesel electric (DEMU) and Diesel hydraulic (DHMU).

- DEMU : This is a three coach unit consisting of one power car, one trailer car and one trailer cum drive unit. The manufacture was undertaken by ICF. After oscillation trials, the prototype was commissioned in October' 94. Up to 2002, 56 sets of DEMUs (each consisting of 3 coaches) had been manufactured. Combination of diesel engine model VTA 17102/INTAC 3412 TA and electrics supplied by NGEF/BHEL/KEC were used. The DEMUs were earlier cleared for operation upto 80 km/h. Later they were suitably modified for operation upto 100 km/h.
- DHMUs:DHMU incorporates in underslung power pack and transmission for 3 coach set unit. After oscillation trials, the prototype was put to commercial use in July' 97. Uptil 2002, 3 sets of DHMUs each having 3 coaches had been made. The DHMU is powered by twin underslung power pack, each consisting of engine NTA 855R and Voith transmission T 211lrz. The DHMUs were cleared for operation upto 95 km/h.

1400 HP high power DEMU : It was decided to develop a high horse power diesel multiple unit for suburban sections on Indian Railways. A feasibility study brought out immense potential of such stock for non electrified sections of IR. The prototype 1400 HP DMU was manufactured at ICF/Chennai & cleared for operation upto 100 km/h. Later, more than 20 nos of these DEMU, were manufactured.

The DEMU incorporates the following equipments:

(a) One Cummins KTA 3067 L fuel efficient diesel engine capable of producing 1400 hp under standard conditions along with accessories and excitation control & speed governing LCC system.

(b) One BHEL make traction alternator model TA 7003 AZ.

(c) One BHEL Make three phase bridge type rectifier.

(d) Four BHEL Make 4303 AZ model traction motors.

(e) One Kerala Electrics Make Auxiliary alternator with voltage regulator.

(f) One complete set of BHEL Make propulsion control equipment.

The operating requirements were :

(a)	Maximum operating speed	100 km/h
(b)	Gear ratio	20.91
(c)	Motor Grouping	4 P Permanent
(d)	Maxim tractive efforts at start	15,000 kg.
(e)	Continuous rating tractive effort.	7100 kg.
(f)	Installed power (standard condition)	1400 hp.
(g)	Installed power (site)	1370 hp.
(h)	Power input to traction (site)	1250 hp.

(ii) MG DMU : The following types were conceptualized :

- On board electric transmission version.
- Underslung hydraulic transmission version.
- It was also decided to convert MG coaches to DMU in Izatnagar Workshop of N.E.Railway. Railway Board directed that initially only one MG DMU set of 3 coaches should be manufactured and based on field performance two more sets of DMU will be ordered. The prototype DMU was manufactured and cleared for operation at a speed of 55 km/h.
- MG DEMU : Development of 350 HP MG diesel Electric Multiple Unit was also done.

(iii) Railbus

Rail Bus was developed for sparsely populated areas with requirement of frequent service to have the following benefits :

- Low capital investment.
- Minimum facilities for maintenance.
- Low operation & maintenance cost.
- Low axle load & track friendly.
- Frequent and efficient service.
- Use of indigenous equipment with easy interchangeability.
- For BG, these were conceptualized as 2 axle light weight vehicles, with assistance from RDSO. Development work was taken up by M/s BEML, Bangalore for 5 G railbuses. After oscillation trial, the prototype was put to commercial service in Oct.'94. The remaining 4 railbuses were commissioned subsequently. The railbuses were cleared for operation up 60 km/h.

  Later, another order was placed for 5 nos. more to the same specification. The manufacturer was completed & the same were commissioned.

  - With the experience gained in the working of railbuses, development for an upgraded version calling for an operating speed of 70 km/h was taken up for 10 nos. of railbuses.
  - For MG, two designs were developed one consisting of two axled vehicle with new design body and another by conversion of 4 axled MG steel bodied coach. For the 2 axle design, a development order was placed on M/s Phooltas Tampers, Patna for 5 nos. of railbuses. After oscillation trials the prototype was commissioned in Oct.'97. The railbuses were cleared for operation upto 55 km/h. For the 4 axle design, a decision was taken in 1995 to convert some surplus MG coaches to railbuses. The first railbus was commissioned in mid 96. Later, 10 such railbuses have been manufactured by NE Railway. After oscillation trials, these railbuses were cleared for operation upto 55 km/h.

7.3 ELECTRIC LOCOMOTIVES AND EMUs

7.3.1 Direct Current (D.C.) Locomotives

M/s Merz & Mclellan, who were appointed as consultants for the first ever Railway Electrification in India, were confident of the success of 1500 V DC system in India with main equipments available from British manufacturers. However for a suitable design of locomotive for operation of heavy goods and passenger trains on the 1 in 37 gradient ghat (hilly) sections (even 1 in 34 at some places), they looked to the Swiss experience of St.Gothard line having similar grades.

7.3.1.1 EF/1 Freight Locomotives

The first locomotive type IC-CI (be 6/8) introduced in regular service in 1926 for haulage of freight trains on Gothard line was of rod drive type. The loco weighing 126 tons, which was operating at a maximum speed of 65 kmph, also operated satisfactorily at slo speeds. These locomotives which came to be known as "KROKODIL" (Crocodile) in Switzerland were upgraded for operation at 75 kmph after midlife overhaul in 1950.

Merz & Mclellan adoped this concept for freight locomotives for operation on Bombay-Igatpuri section. 41 (EF/I) freight locomotives required for both main line freight train operation and banking duty on the Thull and Bhore Ghat sections were acquired, which also came to be known as "crpcpdo;es" by railway men. The EF/I locomotive bogie carried 2 traction motors which worked the two herring bone gears fitted to the driving axle through 2 jact shafts and the gudgeon pin. The driving axle in turn was connected to the other two wheels with 2 side rods. The 2610 HP locomotive weighing 126 tons could exert a starting tractive effort of 30,500 kg. (305 KN) under ideal dry rail conditions, with a little sanding.

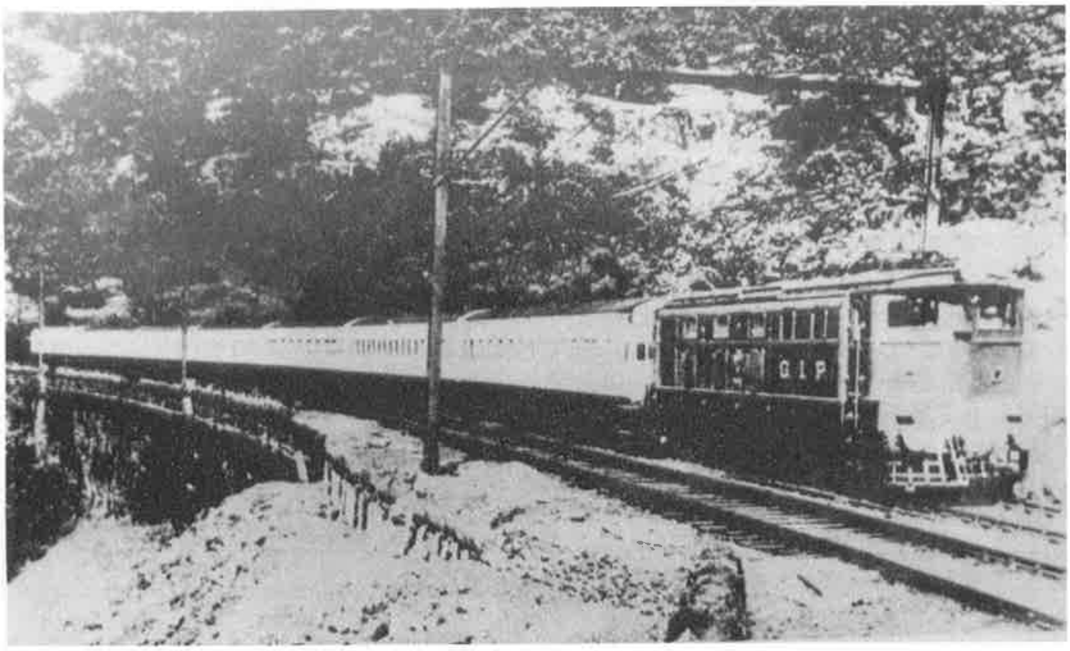
Freight locomotive on GIPR, Known as 'Crocodile'

The mechanical design was obtained from Swiss Locomotive Works who supplied first ten locomotive sets, balance 31 being manufactured by Vulcan Foundries (UK). EF/1 was the most powerful engine on the IR in 1932. It was fitted with regenerative equipment, which performed well.

7.3.1.2 EA/1 Passenger Locomotive

For Passenger locomotives, 3 different design prototypes were field tested. EA/1 type with mechanical design obtained from Swiss Locomotive Works was found most suitable for the ghat section operations. These, locomotives performed well till the Second World War, when ability to obtain spare parts from the manufacturers virtually dried up.

These 41 goods and 24 passenger engines moved all the traffic for the next forty years including war time military goods, petrol & oil and passenger traffic.



"Decean Queen" 1930

7.3.1.3 Main Technical Specifications

Sl. No.	Particulars	Frieght Loco	Passenger Loco
1	Class of Loco	EF/1	EA/1
2	Builder	M.V.ELEC.CO.	M.V. ELEC.Co.
3	Type	C-C	1 Co 2
4	Line Voltage	1500 V D.C.	1500 V D.C.
5	Weight	124.82 t	103.33 t.
6	Axle Load	21.23 t.	20.63 t
7	Max. Speed	72.5 kmph	136.5 kmph

8	Max. T.E.	42800 kg. @ 25% Ad	15241 kg @ 25% Ad.
9	Loco Brakes	Air, Hand, Regen.	Air, Hand
10	Train Brake	Vacuum	Vacuum
11	No. of Traction Motors	4	6
12	T.M. Suspension	Frame Mounted	Frame Mounted
13	T.M. Voltage Rating	1400 V.	700 V.
14	Motor Coupling	S-SP-P	S-SP-P
15	Gear Ratio	1:4.15	1:3.66

7.3.1.4 Mixed Traffic Locomotives (Imported)

Soon after independence, with increase in traffic, there was need for augmentation of locomotive fleet. It was decided to acquire Mixed Traffic Locomotives which could be used for both the Passenger as well as Freight traffic, and the first lot of Mixed Traffic Locomotives was imported from M/s English Electric Company, U.K. These are known as WCM/1 type.

In the mean time electrification at 3000 V D.C. had started in Eastern region around Kolkata and Locomotives were required. Once again it was decided to go in for mixed traffic locomotives. Subsequently, with conversion of traction system in Kolkata area to 25 KV A.C., these locomotives were converted to 1500 V D.C. and shifted to Central Railway.

Details of different types of locomotives imported are given below:

S. No.	PARTICULARS	CLASS OF LOCOMOTIVE			
		WCM/1	WCM/2	WCM/3	WCM/4
1	Builder	English Electric Co. U.K.	English Electric Co. U.K.	Hitachi, Japan	Hitachi, Japan
2	Type	Co – Co	Co – Co	Co – Co	Co – Co
3	Year Put on Line	1955	1957	1958	1961
4	System – Voltage	1500V DC	3000 V DC	3000 V DC	1500 V DC
5	Nos. Ordered	7	12	3	7
6	Adhesive Weight	123.98 t	112.8 t	113 t	125 t
7	Axle Load	20.83 t	18.8 t	19.11 t	20.83
8	Max Speed	120.5 kmph	120.5 kmph	65 kmph	120.5 kmph

9	Max T.E.at 25% Adhesion	31000 kg	31298 kg	28200 kg	31250 kg
10	Loco Brake	Air, Hand, Regen	Air, Hand	Air, Hand	Air, Hand, Regen
11	Train Brake	Vacuum	Vacuum	Vacuum	Vacuum
12	No. of Traction Motors	6	6	6	6
13	Suspention	Axle Hung Nose suspended	Axle Hung Nose suspended	Axle Hung Nose suspended	Axle Hung Nose suspended
14	Railway	Central	Eastern. Subsequently transferred to Central Railway and converted to 1500 V DC	Eastern. Subsequentl y transferred to Central Railway and converted to 1500 V DC	Central

7.3.1.4 CLW Built DC and Dual Voltage Locomotives

WCM/5 Locomotives:

By late fifties it was decided to convert Chittranjan Locomotive Works of Indian Railways to manufacture Electric Locomotives. The first electric locomotive turned out from CLW in 1961 was a WCM/5 class DC locomotive meant for 1500 V DC operation on Central Railway. 21 of these were built with electrics imported from English Electric.

WCG/2 Locomotives: By late sixties it was time to start retiring the EF/1 locomotives, the old work horse of heavily graded section of Central Railway. By that time, both RDSO and CLW had acquired fairly good expertise in design and manufacture of Co – Co bogies and Indian industries, particularly HEIL (later renamed as BHEL) were ready to supply the Electrics. Combining all these capabilities, a new DC loco of WCG/2 class was designed and fifty seven of them manufactured at CLW.

WCAM/1 Locomotives:

With the extension of electrification on Western Railway from Virar (near Mumbai) to Sabarmati (a suburb of Ahemdabad), electric locos were needed. As this electrification was on 25 KV AC and the existing DC section was too small to support fleet of DC locos, it was decided to go in for dual voltage locomotives, which could work on both the systems – 1500 V DC as well as 25 KV AC. This gave rise to a new hybrid design loco of WCAM series. Initially 34 WCAM/1 locos were built by CLW and put in service in 1975, which was subsequently increased to 53.

WCAM/2 Locomotives:

As electrification got extended from Vadodara to Mathura and to Delhi, requirement of dual voltage locomotives kept increasing. With CLW's hands being full for meeting Indian railways' increasing need of AC locomotives, it was decided to collaborate with the Public Sector giant BHEL, for manufacture of additional dual voltage locomotives. Order was placed on BHEL in 1994 for 20 WCAM/2 class locomotives to almost WCAM/1 design, with fabricated bogie.

Salient features of CLW built DC and dual voltage locomotives are given below:

S. No.	PARTICULARS	CLASS OF LOCOMOTIVE			
		WCM/5	WCG/2	WCAM/1	WCAM/2
1	Builder	CLW	CLW	CLW	BHEL
2	Type	Co – Co	Co – Co	Co – Co	Co – Co
3	Year Put on Line	1961	1971	1975	1995-96
4	System – Voltage	1500V DC	1500 V DC	1500 V DC / 25KV AC	1500 V DC / 25 KV AC
5	Nos. Ordered	21	57	53	20
6	Adhesive Weight	124.0 t	132.0 t	112.8 t	112.8 t
7	Axle Load	20.6 t	22.5 t	18.8 t	18.8 t
8	Max Speed	120.5 kmph	80 kmph	120 kmph	120 kmph
9	Max T.E	31000 kg at 25% Adhesion	35600 kg at 27 % Adhesion	33840 kg at 30% Adhesion	33800 kg at 30% Adhesion
10	Loco Brake	Air, Hand, Regen	Air, Hand, Regen	Air, Hand	Air, Hand
11	Train Brake	Vacuum	Vacuum	Vacuum	Dual
12	No. of Traction Motors	6	6	6	6
13	Suspension	Axle Hung Nose suspended	Axle Hung Nose suspended	Axle Hung Nose suspended	Axle Hung Nose suspended
14	Railway	Central	Central	Western	Western

7.3.2 A.C. Locomotives

It was in 1957 that Indian Railways took the decision to adopt 25 KV,50 cycles, single phase AC system for Railway Electrification. As electrification work started simultaneously on Eastern and South Eastern Railways, process for acquiring AC locomotives was also started the same year (1957). The progress of AC locomotives on Indian Railways can be divided into following three distinct phases:

(i) Imported Design

(ii) RDSO Design

(iii) Modern Three Phase Technology

7.3.2.1 Imported Design

Initially two makes of the mixed traffic of locomotives were imported for the newly electrified lines, 100 (WAM 1) from the European Group – called The 50 Cycles Group, and 10 (WAM 2) from the Japanese Group – led by Mitsubishi. The first WAM1 loco, then designated as BBM1 arrived at Kolkata harbor on 30th November 1959. Both the types were fitted with ignitron type mercury arc rectifies. Subsequently another 26 WAM2 and two WAM3 locos were imported from Japan.

Later, for haulage of heavy goods trains, need was felt for a higher tractive effort locomotive with higher adhesion coefficient, dedicated only for goods traffic. Again, three types of such locos were imported, with an option for transfer of technology (TOT) with intention to take up their manufacture by CLW. These consisted of WAG1 class from the 50 cycles European Group (42 Nos), WAG2 class from Japanese Group (45 Nos.) and WAG3 class (10 Nos) also from European Group. All of them were fitted with 'Monomotor' type bogies. WAG3 was similar to WAG1 but was fitted with dc auxiliaries instead of 3 phase auxiliaries. Ultimately WAG1 class was selected in preference to the other two for series production in India at CLW. First loco was turned out in 1963.

Since the locomotive power fell short of the requirement, the traction motor was subsequently upgraded from MG-1420 (1420 KW) to MG –1580 (1580 KW). This is the maximum power which could be fixed within the existing monomotor bogie of WAG1. The rating of the transformer was also suitably increased from 3000 KVA to 3460 KVA.

On WAG-1 locomotives, excitrons with regeneration were used as rectifier devices. At this time, rapid developments started taking place in the field of solid state electronics and silicon rectifiers came into being and in due course the excitrons were replaced with solid state silicon rectifiers. With these changes, CLW started producing WAG4 class of locomotives, an upgraded version of WAG-1 locomotive. The first WAG-4 locomotive was turned out in 1967.

As part of the indigenization process, CLW started in-house-production of major assemblies and sub-assemblies of electric locomotives, like smoothing reactors, master controllers, bogies, wheel set assemblies, E.P. contactors, E.M. contactors, reversers, etc. Some other major equipment like transformers, Arno converters, auxiliary machines, blowers, compressors, exhausters, circuit breakers, pantographs and tap changers etc. were developed through Indian industries.

Both the WAG1 and the successor WAG4 Locomotives suffered from serious inadequacies in the context of Indian requirements. Transmission of tractive effort through the coupling of the axles by gears, driven by one traction motor per two axle bogie, inevitably led to "Juddering" under conditions of slippage with high tractive effort demands and marginal adhesion. This phenomenon led to fatigue failures of transmission components – gears, couplings and shafts. The manufacture and maintenance of Monomotor bogies needed precision and highly trained and skilled staff – which, in switch over from steam era, was grossly inadequate. The components, especially the rubber elements, had to be of exacting standards – the so called indigenization efforts working adversely in this respect. All this, and more, led to unsatisfactory performance of the locomotives in the field. Though, a large number of these 'Imported Design Locomotives' with monomotor bogie were manufactured, soon there was thinking for alternative design and give a go bye to the monomotor bogie locomotives

Salient features of the imported design locomotives are given in table below:.

S. No.	PARTICU-LARS	CLASS OF LOCOMOTIVE						
		WAM1	WAM2	WAM3	WAG1	WAG2	WAG3	WAG4
1	Builder	GROUP	MITSUBISHI	MITSUBISHI	GROUP/CLW	HITACHI	GROUP	CLW
2	Type	B-B	B-B	B-B	B-B	B-B	B-B	B-B
3	Year First Put on Line	1960	1961-64	1964	1963	1964	1965	1967
4	System – Voltage	25 KV AC	25 KV AC	25 KV AC	25 KV AC	25 KV AC	25 KV AC	25 KV AC
5	Nos. Ordered	100	10+26	2	30+82	45	10	186
6	Adhesive Weight	74 t	76.03 t	76 t	85.2 t	85.2 t	87.32 t	87.6 t
7	Axle Load	18.64 t	19.17 t	18.8 t	21.3 t	21.3 t	21.83 t	21.9 t
8	Max Speed, KMPH	112.6	112.6	112.6	80	80	80	80
9	Max T.E	25000 kg at 33.3% Adhesion	25242 kg at 33.2% Ad	25242 kg	30000 kg at 35% Ad	30000 kg at 37 % Ad	30000 kg at 34.4% Ad	30000 kg at 34.4% Ad
10	Loco Brake	Air, Hand	Air, Hand	Air, Hand, Rheostatic	Air, Hand, Regen	Air, Hand, Rheostatic	Air, Hand, Rheostatic	Air, Hand, Rheostatic

11	Train Brake	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum
12	No. of Traction Motors	4	4	4	2	2	2	2
13	Suspension	Pendular, with Equiliser beams	Pendular, with Equiliser beams	Pendular, with Equiliser beams	Pendular, with Equiliser beams	Pendular, with Equiliser beams	Pendular, with Equiliser beams	Pendular, with Equiliser beams
14	Control	Tap Changer	Tap Changer	Tap Changer	Tap Changer	Tap Changer	Tap Changer	Tap Changer

7.3.2.2 RDSO Design

WAM/4 Locomotive:

The period of sixties and seventies was accompanied by development of heavy industry like steel plants and super thermal power stations etc in the Industrial Ruhr of India – the Coal-Steel belt of the present Jharkand state, Bengal and Orissa which gave rise to rapid growth of bulk movement of industrial raw materials – Coal, Iron ore etc and finished products like steel. The rapid increase in rail traffic was ahead of development of railway infrastructure – track, bridges and even length of loops to accommodate freight trains. Call of the time was to increase throughput with existing infrastructure. The motive power was called upon to give higher tractive effort with higher balancing speeds and reliability. AC locomotives of 'Imported Design' fell far short of such requirements. This was also the period when foreign exchange was extremely scarce and the country could ill afford another import of locomotives from developed world. Though tenders were called for import of six axle locomotives with TOT, the only acceptable offer from SKODA, Czechoslovakia was found to be unaffordable. It is at this time that RDSO, who had so far not gone beyond writing simple performance specifications, landed with the task of designing an AC Electric loco, that could meet the stringent performance requirements. Thus, started the evolution of six axle AC locomotives on Indian Railways.

It was recognized that the problem was essentially one of working to high limits of every parameter – mechanical strength, technical aptitudes in manufacture and maintenance, adhesion between wheel and rail etc. The axle loads had already been pushed to the limits possible – 22 tonnes and the maximum tractive effort was falling short of the actual requirements of unit loads of the wagon fleet, without operating too near adhesion margins causing juddering. There was no alternative but to go in for more driving axles on the Locomotive.

In order to obtain quick changeover to the new design, it was decided to use the Trimount Bogie of the WDM2 Diesel Locomotives, already under mass manufacture. This was by no means an optimal design for electric locomotive, having poor adhesion and comparatively restrictive space to accommodate the more powerful traction motors needed. Though, these bogies gave lot of cracking problems due to higher average tractive efforts and speeds possible with the new locomotive designs, the choice of this bogie gave a much needed relief in mechanical construction beneficial both for manufacture and maintenance. Another feature adopted was that the new locomotive would be of the mixed traffic type – suitable for both freight and passenger haulage. This concept, though superficially attractive, as virtually any locomotive could haul any train, it resulted in another constraint – the size and weight of the traction motor.

The choice of the Bogie and Mixed Traffic concepts though based on the tried and proved diesel locomotives, forced a number of design compromises such as using a wrong voltage transformer with lower than required power ratings, with series and series-parallel groupings of the traction motors, increasing costs due to higher circuit voltages to earth, higher insulation levels than needed on the equipments lower performance both on tractive efforts and balancing speeds on the gradients etc. The change of lcomotive design thus was not an unmixed blessing – but certainly gave a much needed relief to maintenance sheds. As the old four axle WAG series of locomotives was unsuitable for express trains being limited in speed to 75 KMPH only, the new Mixed Traffic locomotives designated as WAM4 were found very useful for haulage of long trains (with 22 plus bogies) which became quite common with successive routes being electrified from the apex cities like Bombay, Calcutta, Delhi and Madras. The earlier imported WAM1 and WAM2 Locomotives were already inadequate for such purposes and their performance in graded sections was inadequate, being a compromise for freight and passenger operation.

The compulsion of events and performance requirements soon made Indian Railways the Mixed Traffic concept and series connection of traction motors and brought in how designs optimized by freight and passenger/express haulage – the former with better all weather sustained tractive efforts and higher power levels giving higher train haulage performance, and the latter giving superior balancing speeds on grades for very long express trains. The basic decision to go in for a six axle design was thus found to be sound.

Further evolution of six axle locos

WAG5 Locomotive

The Railway felt the need for higher HP and more reliable freight locomotives. Major equipment such as transformers, smoothing reactors etc. were identified to be upgraded. Therefore, with the efforts of CLW, BHEL and NGEF developed HETT-3900 transformers replacing the earlier version of BOT-3460. CLW, with their own effort, also developed Smoothing Reactors (SL-30) in place of the earlier SL-42. The comparative technical parameters of SL-42 and SL-30 are given in Table below:

Type of SL	Rated voltage (U)	Rated current (I)	Inductance (mH)	Resistance (ohm)	Class of insulation	Weight (Kgs)
SL-42	1270	1000A	7.00	0.00707	F/H	1385
SL-30	1270	1350A	3.35	0.00359	H	1400

With this development 3900 HP WAG5 locomotives came into existence. On this locomotive, all the traction motors are connected in parallel thus improving the reliability of motors and adhesion. Loco HP rose from 3460 to 3900.

Along with the production of WAM4 locos, TAO-659 traction motors were developed through technology transfer from M/s Alsthom, France after global tendering. Indigenous production of these motors commenced in 1971.

Ultimately CLW entered into another technology transfer agreement with M/s Hitachi, Japan in 1974 for manufacture of HS-1050 traction motors. The initial lot was imported. Subsequently in 1983, the agreement was amended to manufacture superior version of the traction motors HS – 15250. Indigenous manufacture of this motor started in 1990 and production of TAO 659 motor was stopped.

WAG7 Locomotive:

With the change over from TAO 659 motor to HS 15250A motor spare power margin was available to make a more powerful locomotive for haulage of 4500 tonne train, giving rise to evolvement of a new locomotive of 5000HP designated as WAG7.

This locomotive is capable of running at maximum speed of 100 KMPH which was the anticipated future needs of the freight services, on the Railways. For this high adhesion fabricated bogies designed by CLW in association with RDSO and manufactured in-house were used. On these bogies, the traction motors are facing in one direction and load transfer at the time of loco starting is minimal. Problems of bogie cracks which were the cause of failure in service were totally eliminated.

Additional power is drawn through a new transformer designated as HETT-5400 developed by BHEL, CGL and NGFF. The comparative ratings of the transformers are indicated in Table below:

Loco Transformers

	3460 KVA BOT	3900 KVA HETT 3900	5400 KVA HETT 5400
Primary Voltage	22500V	22500V	22500V
Secondary Voltage (no load)	1700V	865V	1000V
Auxiliary voltage	1 × 389V	2 × 415V	2 × 415V
Primary current	166.0A	185.0A	252.0A

Secondary current	2 × 2000A	2 × 2254A	2 ×2700A
Auxiliary current	694A	650A	650A

Passenger Electric Locos:

WAP1 Locomotive

As mentioned earlier, CLW had initially manufactured WAM4 type of electric locomotives to haul passenger trains upto a maximum speed of 100 kmph. However, these locos were not suitable for working other high speed trains like Rajdhani Express and Shatabdi Express. Indian Railways seriously started feeling the need for some high speed passenger electric locomotives. CLW in association with RDSO developed 3900 HP WAP1 locomotive in 1980, using a double suspension flexi coil high speed bogies. The shell is also specifically manufactured giving it an aerodynamic shape to reduce air resistance.

WAP3, WAP4 and WAP5 Locomotives

Later, an improved version of this locomotive, designated as WAP3, was produced to haul longer passenger trains up to a maximum speed of 160 KMPH. The WAP3 type is 3900 HP locomotive having Mark II fabricated bogies. Later on these bogies were further improved and Mark IV version and used on 5000 HP WAP 6 locomotives. In the meantime, 5000 HP WAP4 locos were also produced by using flexi coil cast bogies. After gaining service experience and feedback from the user Railways, CLW has started series production of WAP4 type of passenger locomotives. Comparative parameters of passenger electric locomotives are given in Table III.

Type of Loco	Type of Bogie	Type of TM	HP	TE	Max. Speed (KMPH)	Axle Weight (tonnes)	Total Weight in (tonnes)
WAP-1	Co-Co (cast) Flexi Coil	TAO-659	3900	13.8	130	18.80	112.8
WAP-3	Co-Co (fab) MK-IV	TAO-659	3900	13.8	140	18.88	112.8
WAP-4	Co-Co (cast) Flexi coil	HS-15250	5000	19.0	140	18.80	112.8
WAP-6	Co-Co (fab) MK-IV	HS-15250	5000	19.0	160	18.87	113.2

High Horse Power Electric Locomotives:

By mid eighties, railways were facing the prospect of a quantum jump in traffic offering and it was recognized that the available infrastructure can be put to optimum use by introducing higher HP locomotives, which will enable hauling of higher loads at higher average speeds. As packing the higher power in a single locomotive would not have been feasible with existing design of tap changer technology, it was decided to obtain higher hrose power locomotives with modern and upgraded technology.

6000 HP Thyrister Locomotives:

WAG6 Locomotives

Indian Railways considered the then modern and proven Thyrister Technology for inducting High HP locomotives. With a view to select an appropriate and tried design, 18 locomotives of 6000 HP rating of three different designs (six of each design) were imported. It was the intention to try them extensively and select one for taking up manufacture in CLW, through Transfer of Technology. Essentially these locomotives used DC Traction Motors with voltage control through microprocessor controlled Thyristers. Salient features of these locomotives are as under:

S. No.	Type	Manufacturer	Nos. Ordered	Wheel Arrangement	Year of Order	Year of Commi-ssioning
1	WAG/6A	Asea Brown Bovery, Sweden	6	Bo-Bo-Bo	1985	1988
2	WAG/6B	Hitachi Japan	6	Bo-Bo-Bo	1985	1988
3	WAG/6C	Hitachi Japan	6	Co-Co	1985	1988

However even before the locomotives arrived in India and commissioned, decision was taken to not to proceed with this technology, and instead adopt the Three Phase Technology which had been fully developed by that time. In fact, these Thyrister locomotives also failed to deliver the specified performance parameters in respect of Harmonic Levels and have been confined to an isolated section of K-K line of South Eastern Railway.

Three Phase Locomotives:

With the commercial development of high power rated Gate Turn Off (GTO) Thyristers, advanced countries had started switching over to Three Phase Induction Motor as Traction Motor. This became possible by converting the single phase power received from catenary, on board, to three phase, through GTO based Converter –Inverter. Indian Railways also decided to go in for the Three Phase Technology for up-gradation and modernizing the electric locomotive technology. In July 1993, a contract was placed on ABB, Switzerland (now Bombardier), to procure 30 nos. 6000 HP 'State of the Art' energy efficient, microprocessor controlled, three phase electric locomotives, together with Transfer of Technology (TOT) for eventually manufacturing them at CLW. The three phase technology was adjudged to be overwhelmingly superior on account of :

- High energy efficiency,
- Unity power factor,

- Regenerative braking upto almost zero speed,
- Use of the more reliable and sturdy three phase induction motor as traction motor,
- Signal system compatibility (acceptable harmonic level)

Two versions of such locos were ordered, consisting of

Ten nos. of WAP/5 locos, for passenger operation upto 160 kmph speeds (with capability of up-gradation to 200 kmph), having four axles with four fully suspended traction motors and

Twenty nos. of WAG/9 locos, for freight operation, with speed capability of 100 kmph, having six axles with six axle hung / nose suspended traction motors.

Indian Railways were quickly able to absorb the new state of the art technology, both for maintenance and manufacture. With this development, India became first developing country, second in Asia (after Japan) and fifth in the world (after Switzerland, Germany, France and Japan) to have acquired this capability in the field of three phase GTO technology locomotives.

CLW have further developed another version - WAP/7 – for hauling longer passenger trains at speeds of 130 kmph.

7.3.3 EMUs AND MEMUs

7.3.3.1 DC EMUs

Railway Electrification in India was started in Mumbai region of the erstwhile GIPR (now Central Railway) and BBCR (now Western Railway) at 1500V DC and both decided to run commuter train suburban services based on Electrical Multiple Units (EMUs). The first service ran on 3rd February 1925, from Victoria Terminus to Kurla via Harbour Line.

While choosing the EMU stock, width of the stock became an important parameter. It was decided that 12′ wide coaches would be used instead of 10′8″ wide coaches which was the all India standard moving dimension. The 12′ wide coaches provided over 22 % more passenger carrying capacity under dense crush peak hour loading condition. A 4-car unit could carry almost 250 more passengers. The wide bodied 12′ stock was not provided with foot boards at all as it sails over the platform by a few inches.

For the Harbour Branch (HB), a steep fly over of 500 meters with a gradient of 1/33 had to be built to cross over the quadruple main lines at V.T. This became a bench mark section for testing all new generation of EMU stock for Bombay area.

With no earlier experience of working with suburban electric stock under harsh tropical conditions and almost 100 % humidity, the stock had remarkably a fine debut. The master plan envisaged that infringements to running of 12′ stock would be taken up in phases on the main line as well, but the financial restrictions imposed due to the worldwide recession put this work back by over two decades. The main line electrification continued as planned. Since infringements remained, the later stock was forced to be the standard 10′8″ wide. The track beyond Kurla was easier to tackle. All infringements were removed on the quadruple tracks up to Thana. The 12′ stock could run up to Thana by 1950 by which time all infringements to running of 12′ wide stock were removed from entire Bombay Division (GIPR). All postwar stock imported or built in India were of 12 feet width only.

The design and specification for both 12′ stock and 10′8″ stocks were prepared by M/s Rendele Palmer & Tritton for the mechanical equipment and M/s Merz Mcllelan for the electrical equipment. This stock was designated as WCU1. Some significant details are given below:

(a) Suppliers

(i) Electrical Equipment

- M/s English Electric & Metropolitan Vickers for GIP Railway.
- M/s British Thompson Houston for BB & CI Railway.

(ii) Mechanical Equipment

Coach Bodies	- 12′ Stock	- M/s Cammel Laird
Part	- 10′8″ Stock	- M/s Cammel Laird
Part	- 10′8″ Stock	- M/s Isenbahnen Gemeinschaft

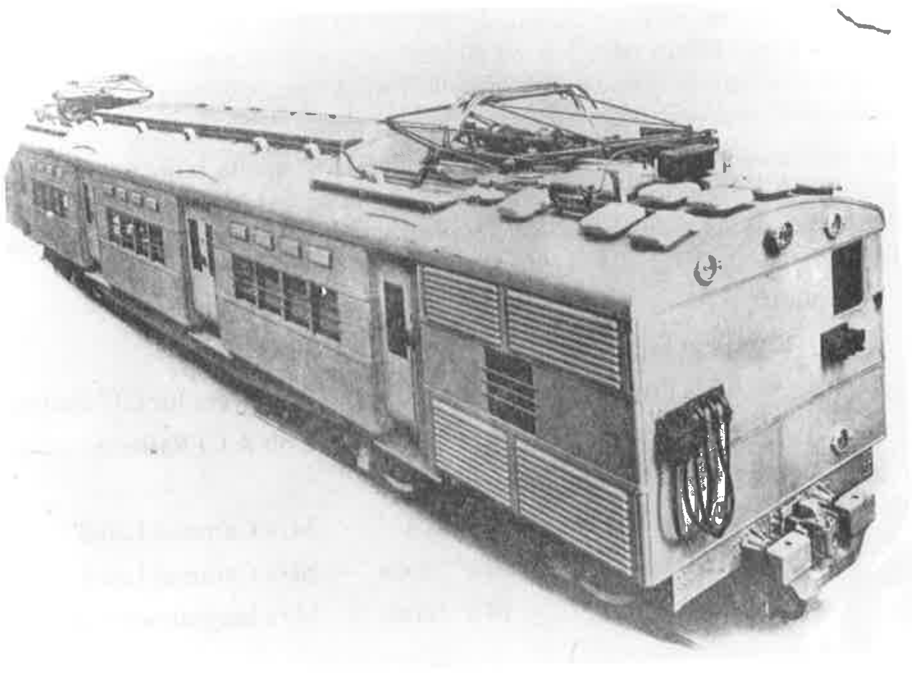
Bogies

Part	- M/s Cammel Laird
Part	- M/s Societe Franco Belge de Materiel

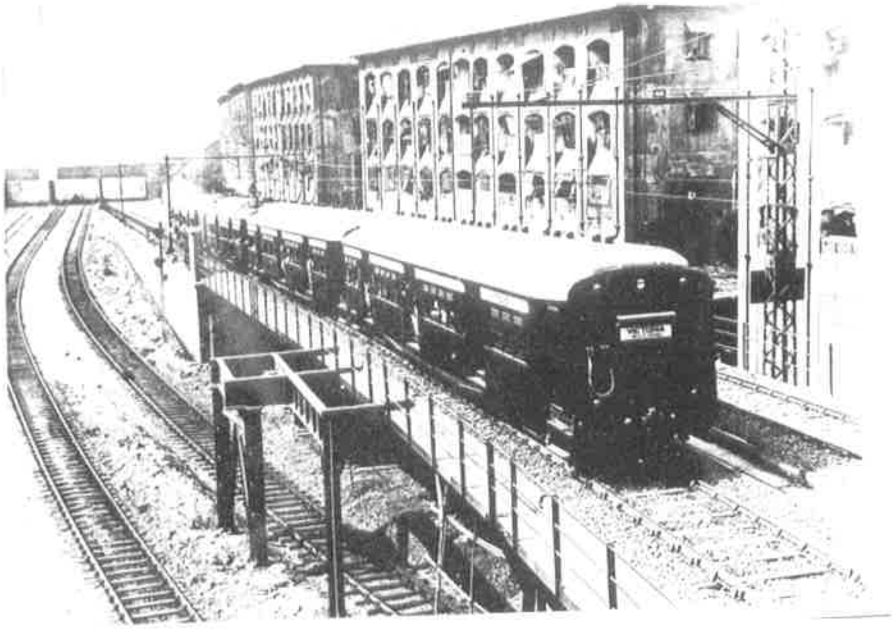
(b) Technical particulars:

	Type of Stock	12′ Stock	10′-8″ Stock
(1)	Tare weight of motor coach	70.1 Tons	62 Tons
(2)	Tare weight of 4-coach unit	196 Tons	169 Tons
(3)	Seating capacity 4-coach unit	441	361
(4)	Length of coach over buffers	70′6″	71′ 6″
(5)	Number of motors per motor coach	4	4

The consultants had recommended 3 coach units comprising 1 motor & 2 trailer coaches. However GIP/BBCI Railways chose a unit composition of 1 motor & 3 trailer coaches. In subsequent years, due to frequent traction motor failures, the composition was altered to 1 motor & 2 trailer coaches.



First EMU Motor Coach-1925 (GIP)



B.T.H, EMU for BB & CI Railway

With the increased traffic requirements other important stocks were introduced from 1951 onwards. While the earlier units were with vacuum brakes, all further stock was with pneumatic brakes. Initially all the stock was imported from Europe. However, subsequently imports of the entire stock or the electrics were made from Japan also. In due course manufacture of EMUs was started in India, including the electrics.

7.3.3.2 A.C. and A.C./D.C. EMUs

By mid fifties electrification had started in Eastern region, first on 3000 V DC system and then on 25 KV AC. To meet the requirements of suburban system, in 1958-59 Railways purchased 16 nos. 3- coach units with one spare motor coach of 3000 V DC/ 25KV BG EMU stock from M/s Machison Fabric Augsburg Nuraberg (MAN). The electric for this stock were supplied by Allgeneine Electricitats Gesellschaft (AEG). This stock designated as WCU8 was put in service on the Eastern Railway.

In the same year (1958-59) another 16 three coach units with one spare motor coach of 3000 V DC BG EMU stock was purchased from M/s SIG Switzerland and put into service on the Eastern Railway This stock is designated as WCU9-WCAU2. One such unit was later converted to1500 V DC operation and put into service on Western railway in 1960-61. Twelve of these units were also converted to dual voltage (3000 V DC / 25 KV) system at Kanchrapara workshop of Eastern Railway. The conversion equipments were supplied by M /s Scheron Switzerland and installed in two new compartments. The motor is powered by 4 Oerlikon type TM – 500 traction motor of 212 HP each.

By this time (1959), M/S Jessop & Co based at Calcutta were ready to build coaches for EMU stock. Sixteen three- Coach units with one spare motor coach were purchased from them in 1959-60. Electrics for this stock were imported from AEI. These 3000 V DC units were later converted to dual voltage operation (3000 V DC/25 Kv AC) at Kanchrapara works shop, with the conversion equipment obtained from AEI.

By the end sixties Indian public sector giant, Bharat Heavy Electrcals Ltd. (BHEL) started manufacturing electrical equipment for EMUs and with coach manufacture by M/S Jessops, totally indigenous EMUs started entering Indian Railways.

In the mean time Integral Coach Factory (ICF) of Indian Railways, situated at Madras also established capabilities to manufacture EMU coaches. It was in 1970 that ICF supplied the first lot of totally indigenous EMUs consisting of 45 nos.3-coach units with 2 spare motor coaches for Central & Western Railway with unit formation of NDT-MC-TC. Electrics were supplied by M/s BHEL. The motor coaches were powered by 182 hp BHEL make 133AY traction motor, while the Electro Pneumatic brake system was manufactured by M/s Escorts which was developed as indigenous version of Westing House / Knorr Bremse equipment. This stock is designated as WCU15.

In the year 1981 Railways purchased 43 nos. complete sets of Electric Traction equipments for 1500 V DC BG EMU coaches from M/s TDK Japan with coaches supplied by M/s Jessops. Each motor coach is powered by four 187 Kw, Type TDK 5620 A DC series traction motors. The units are provided with Westing House, Saxby and Former and M/s Escorts Electro Pneumatic brakes. This stock is designated as WCU16.

It is worth mentioning that 59-60 vintage stock (3000 V DC/25 Kv AC) was in house converted to 25 KV system at Kanchrapara works shop and put into service in June 1964 on Eastern Railway. These units are now operated only on 25 KV AC. This stock is designated as WAU1.

By 1966 ICF also started building 25 KV AC EMUs. They built 31 nos. 4-coach units for Eastern Railways, with electrical equipments supplied by M/s Hitachi Ltd. Japan. The unit formation was DT-MC-TC-DT (driving trailer-motor coach-trailer coach-driving trailer) and each motor coach powered by 215 HP, Hitachi type BF20-H60 traction motor.

7.3.3.3 MG EMUs

With the conversion of Sothern Railwa's Meter Gauge suburban section at Madras to 25 KV AC system, ICF supplied the required MG EMUs. 19 nos. complete 4-coach EMUs and 26 motor coaches were built by ICF with the Electrical equipments supplied by Nichimen Co. Ltd. Japan and were introduced in service during 1967. This stock is designated as YAU1 25 KV AC MG EMUs.The unit formation was MC-NDT-NDT-DT. Each motor coach is powered by 172 hp Nichmen type TDK 5442 A traction motors. The units are provided with Saxby & Farmer vacuum brakes.

In 1989-90 ICF built another 25 nos complete 4-coach, Thyrister controlled, 25KV AC MG EMUs, with the Electrical equipments supplied by GEC / BHEL, and unit formation of DMC-NDT-NDT-DTC. Each motor coach is powered by four 120 hp GEC-320 type traction motors. The units are provided with Saxby & Farmer vacuum brakes and designated as YAU2.

7.3.3.4 Three Phase EMUs

By mid nineties, Indian Railways had taken two important decisions:

1. To upgrade the technology of EMUs to the energy efficient and maintenance friendly Three Phase Drive, and
2. To convert the 1500V DC system of electric traction in Mumbai area, to 25 KV AC system, in uniformity with the entire Indian Railway system.
3. The process of conversion to 25 KV system necessitated induction of dual voltage (1500V/25 KV) EMUs for the period of conversion. Technologically the three phase drive was ideally suited for dual voltage EMUs.
4. Thus, it was decided to procure three phase drive kits to be used for retro fitment in the existing DC stock and also for manufacturing new EMUs at ICF. In 1998, Western Railway placed an order on M/s ALSTOM for supply of equipment for retro fitment on 50 no. existing motor coaches and 33 no. Driving Trailer Coaches. At the same time another order was placed on M/s BHEL for supply of equipment for fitment on 50 no. new motor coaches and 33 Driving Trailer Coaches to be built by ICF. These orders were subsequently increased to 62 nos. motor coaches and 42 nos. DTCs for BHEL and 38 nos. motor coaches and 24 nos. Driving Trailer Coaches for M/S ALSTOM. The unit formation is DTC+MC+TC. Normally 3/4 such units form a rake.

7.3.3.5 Main Line EMUs (MEMUs)

Apart from metropolitan areas of Mumbai, Kolkata, Delhi and Chennai, Indian Railways run a large number of short distance commuter trains around other important towns. As these trains stop at all stations and run on the same track as long distance passenger and freight trains, they cause considerable wastage of line capacity. It was felt that EMU type trains, with their characteristic fast acceleration and braking, could be used for such services. However traditional EMU stock posed severe limitations as high level platforms are required at every station and major structural modifications are required to run the 12 feet EMU stock as against the clearances being available only for the traditional 10 ft. 8 inches stock.

Thus came up the idea to develop a new type of stock, incorporating the required features of both the main line coaches and EMU type drive. This stock has been named as Main Line EMUs, MEMUs in short.

The 10'-8"or 3250 mm wide 25 Kv AC BG stock designed by RDSO was manufactured by ICF during the last quarter of 1993-94. It was initially commissioned by the Eastern Railway on Bardhman- Asansol section in Septembr1994. The bogies of these coaches are similar to existing AC EMU stock, while the shell is 3250 mm wide, similar to main line coaches with the provision of stairs and vestibule. The four-coach unit formation is DMC-TC-TC-TC. All electrics on MEMUs are supplied by M/s BHEL similar to 12ft AC BG EMUs. The units are provided with M/s WSF / Escort Electro- Pneumatic brakes similar to existing EMUs.

The MEMU services are fast becoming very popular on all electrified sections and have already been introduced on East Central, Western, Northern, Eastern, South Eastern, South Central, and Southern Railways.

SALIENT FEATURES AND IMPORTANT DATA FOR EMUs AND MEMUs.

Salient features of all EMUs and MEMUs of Indian Railways are given in the table on following pages:

ELECTRICAL MULTIPLE UNIT DATA

S. No.	Type	Coach builder	Supplier of electrics	Imp / Ind	**Year**	Unit formation	Train formation	Total tare weight / unit in tonne	Working voltage	HP / MC	Average accele. up to speed of 40 kmph	Average Decele. from 96 kmph	Energy Regene ration
1.	WCU1	Metro politan vickers	The English Electric Company	Imp	1925	DT-NDT-MC-DT	2 Units	-	1500 V DC	840/ 864	1.83	3.20 Kmph/ sec	Nil
2.	WCU2	British Thompson Huston &Metro Cammel	British Thompson Huston	Imp	1928	DT-MC-NDT-DT	2 Units	-	1500 V DC	840	-	-	Nil
3.	WCU3	British Thompson Huston &Metro Cammel	British Thompson Huston	Imp	1951	MC-NDT-NDT-MC	2 Units+ 1spl TC	160.88	1500 V DC	600	2.08 Kmph/ sec	3.20 Kmph/ sec	Nil
4.	WCU4	Metro Cammel	The English Electric Company	Imp	1951	MC-NDT-NDT-MC	2 Units+ 1spl TC	161.49	1500 V DC	540	2.08 Kmph/ sec	3.20 Kmph/ sec	Nil
5.	WCU5	Breda ferroviaria SPAMilano	The English Electric Company	Imp	1956	MC-NDT-NDT-MC	2 Units+ 1spl TC	170.86	1500 V DC	560	1.735 Kmph/ sec	3.20 Kmph/ sec	Nil
6.	WCU6	Hitachi	Hitachi	Imp	1957	MC-NDT-NDT-DMC	2 Units+ 1spl TC	177.86	1500 V DC	560	1.92 Kmph/se c	3.65 Kmph / sec	Nil

S. No.	Type	Coach builder	Supplier of electrics	Imp / Ind	**Year**	Unit formation	Train formation	Total tare weight / unit in tonne	Working voltage	HP / MC	Average accele. up to speed of 40 kmph	Average Decele. from 96 kmph	Energy Regene ration
7.	WCU7	Nippon sharyo SeizoKaisha Japan	Hitachi	Imp	1958-59	MC-NDT-NDT-MC	2 Units+ 1spl TC	174.90	1500 V DC	560	1.92 Kmph / sec	3.65 Kmph / sec	Nil
8.	WCU8	Machison Fabrik Augsburg Nuraberg (MAN)	Allgeneine electricitats Gesellschaft (AGE)	Imp	1958-59	DT-MC-DT	3 Units	120.90	3000V DC Converted to1500V DC	732	1.92 Kmph / sec	3.2 Kmph / sec	Nil
9.	WAU2/ WCAU2	SIG	Secheron Switzerland	Imp	1958-59	DT- -MC-DT	2 /3 Units	117.00	3000V DC / 25KV AC	848	1.92	3.20	Nil
10.	WCU9/ WCAU2	SIG	Secheron Switzerland	Imp	1958-59	DT- -MC-DT	2 /3 Units	117.00	3000V DC/25KV AC Converted to 1500V DC	848	1.92	3.20	Nil
11.	WCU10	Breada FerroviariSPA Milano & Arisaldo Gerogia	SERAS	Imp	1959	MC-NDT-NDT-MC	2 Units+ 1spl TC	166.20	1500 V DC	548	1.896	3.48	Nil
12.	WAU/WCAU	Jessop & Co.	AEI	Imp	1959-60	DT- -MC-DT	2 /3 Units	141.23	3000V DC / 25KV AC Converted to 1500V DC	840	1.92	3.2	Nil

S. No.	Type	Coach builder	Supplier of electrics	Imp / Ind	**Year**	Unit formation	Train formation	Total tare weight / unit in tonne	Working voltage	HP / MC	Average accele. up to speed of 40 kmph	Average Decele. from 96 kmph	Energy Regene ration
13.	WCU11/ WCAU1	Jessop & Co.	AEI	Imp	1959-60	DT- -MC-DT	2 /3 Units	141.23	3000V DC / 25KV AÇ Con-verted to 1500V DC	840	1.92	3.20	Nil
14.	WCU12	Jessop & Co.	Metro Vick	Imp	1961	DT- -MC-DT	3 Units	141.23	1500 V DC	840	1.92	3.2	Nil
15.	WCU13	Jessop & Co.	AEI	Imp	1964	NDT –MC-DT	3 Units	133.64	1500 V DC	860	1.92	2.74	Nil
16.	WCU14 WCU8	Jessop & Co.	BHEL	Imp	1969	NDT –MC-DT	3 / 4 Units	122.25	1500 V DC	744/ 1000	1.94	2.74	Nil
17.	WCU15	ICF	BHEL	Ind	1970	DT-MC-NDT	3 / 4 Units	113.80	1500 V DC	744/ 1000	1.94 c	2.74	Nil
18.	WCU16	ICF	TDK	Ind	1981	DTC-MC-TC	3 Units	126.7	1500 V DC	1002	2.00	2.74	Nil
19.	YAU1	ICF	NICHIMEN	Ind	1967	MC-NDT-NDT-DT	2 Units	112.00	25 KV AC	688	1.8	1.8	Nil
20.	YAU2	ICF	GEC/BHEL	Ind	1989-90	MC-NDT-NDT-DT	2 Units+ IDMC+ ITC	112.00	25 KV AC (Thyris-tor)	483	1.62	1.70	Nil
21.	WAU3	ICF	Hitachi	Ind	1966	DT-MC-TC-DT	2 Units+ 1spl. TC	146.73	25 KV AC	860	1.62	2.73	Nil

S. No.	Type	Coach builder	Supplier of electrics	Imp / Ind	**Year**	Unit formation	Train formation	Total tare weight / unit in tonne	Working voltage	HP / MC	Average accele. up to speed of 40 kmph	Average Decele. from 96 kmph	Energy Regene ration
22.	WAU4 (EMU)	ICF	HEIL	Ind	1967-69	DT-MC-TC-DT	2 Units+ 1spl. TC	152.38	25 KV AC	896	1.6	2.74	Nil
23.	WAU4 MEMU	ICF	HEIL	Ind	1994	DMC+TC+TC +TC	3 Units	160.45	25 KV AC	896	1.6	2.74	Nil
24.	AC-DC (EMU)	Retro-fitment on existing Coaches at W.R.	ALSTOM	Imp / Ind	2001	DTC-MC-TC	3 or 4 Units	200	25 KV AC / 1500 V DC	1286	1.95	2.88	More than 30%
25.	AC-DC (EMU)	ICF	BHEL/ Traxis	Imp / Ind	2003	DTC-MC-TC	3 or 4 Units	200	25 KV AC / 1500 V DC	1303	1.95	2.88 c	More than 30%

7.4 COACHING STOCK

7.4.1 Prior to 1955,only wooden bodied coaches were manufactured in Railway Workshops.In 1955,the Integral Coach Factory was set up at Perambur, Madras (now Chennai) to manufacture steel bodied coaches in collaboration with M/S Schlieren of Switzerland.

7.4.2 These coaches had integral coach shell construction which ensures increased safety for passengers in the event of an accident. The coaches had fabricated bogies with laminated springs in secondary & coil springs in primary suspension and a speed potential of 96 kmph. Since then the steel body integral coach shell became the standard coach design on I.R and even the new coach factory at Kapurthala adopted this design.

7.4.3 Major modifications were subsequently carried out to the original Schlieren design to make them suitable for Indian operating conditions. Some of these were:

(i) Corrosion control- Low alloy steel IRSM-41 was adopted to minimize corrosion. Thickness of structural was optimized to achieve weight reduction. Floor construction was changed through use of 2mm PVC floor laid with adhesive over 12mm compreg (compressed ply) boards. Stainless steel & FRP lavatory inlays and epoxy resin bonded floor were adopted to eliminate water seepage in lavatories. Use of ferritic stainless steel/austenitic steel in critical areas has also been adopted.

(ii) Weight Reduction-This was achieved through adoption of IRSM-41 steel, use of composites for coach furnishing, use of PVC flooring and changeover from 24V to 110V DC for lighting.

The weight reductions enabled improvement to passenger amenities like provision of gangways, higher capacity water tanks, cushioned berths in second class coaches, additional fans etc.

(iii) Safety-Twin pipe compressed air graduated release air brake system was adopted in place of original vacuum brake system. Capacity of couplers & draft gear was enhanced to arrest head stock damages and enable train lengths upto 24 coaches followed by the recent development to gradually shift to Centre Buffer Couplers. Wear adapted wheel profile was adopted to improve wheel life.

(iv) Speed Potential-Speed potential of the coach was gradually enhanced from original 96 kmph to 110 kmph on mainline standard track through the following major changes:-

(a) The secondary stage laminated springs were replaced with helical springs.

(b) Side bearers were provided to transfer the coach body weight in place of earlier arrangement of transferring the load through center pivot.

(c) The length of bolster hanger was increased to 410mm in place of 286mm.

(d) Vacuum brakes were replaced with air brakes.

(e) Bogie frame of AC coaches was redesigned to take up the higher load(16.25 t axle load)

Improved track condition (Rajdhani standard) further enabled the above coaches to be operated at speeds upto 140kmph & introduction of Rajdhani Express trains to connect the capital of India with important metropolitan towns followed by fully airconditioned inter-city trains with chair car formation.

7.4.4 High Speed Coach –IRX Shell & IR –15 Bogie :Following major changes were carried out to achieve the speed potential of 160 kmph:

(i) Secondary suspension made softer.

(ii) Dash pots of ICF coaches were a major area of weakness. These were replaced by shock absorbers to provide necessary damping. Besides shock absorbers were provided in the secondary stage.

(iii) Bolster hanger length was increased further to 630 mm to achieve lower frequency of oscillation.

(iv) Wheel web was machined to reduce imbalance. Maximum diameter was reduced from 915mm to 865 mm & this reduced the unsprung mass.

(v) Bogie was fitted with taper roller bearings.

(vi) IRX shell was designed with straight side walls & no corrosion pockets. Body bolster was modified to take up IR-15 bogies.

The prototype coach had cleared the oscillation trials satisfactorily but commercial production was not taken up due to the more promising design of IRY shell with IR 20 bogie for same operating speed.

7.4.5 High Speed coach with IRY Shell & IR20 Bogie : Limitations of ICF bogie design led IR to evolve a new bogie design later designated as IR-20.The important features are enumerated below:

(i) The axle guidance was designed in such a way that its flexibilities in longitudinal & lateral directions may be optimized independently.

(ii) A different transverse suspension concept using flexicoil secondary springs was adopted.

(iii) Bogie frames were designed without headstocks & with shorter wheel base.

(iv) Diameter of wheels was reduced from 915mm to 890mm.This improved curving & reduced the unsprung mass by about 142 kg per bogie which in turn reduces stresses on the track structure.

(v) Axle mounted disc brakes with wheel slide protection were provided. Two brake discs of 610mm dia. per axle were provided without tread brakes.

IRY COACH

7.4.6 IRY Coach Shell: A new coach with lesser propensity to corrosion & improved interior was designed to accommodate IR-20 bogies and with a speed potential of 160 kmph. The salient features of this coach design were :

- (i) IRY bare coach shell is 2.5 t lighter than ICF coach shell.Completely furnished coach is 1.5 t lighter than ICF coach shell.
- (ii) The coach was provided with roof mounted AC package units at either end.
- (iii) UIC type vestibules were provided.
- (iv) The underframe consisted of 2 sole bars fabricated out of two folded pressed sections of IRSM-41 steel in 4mm & 5mm thickness.The sole bar has no corrosion pockets & is ideally suited for easy fixing of side walls & cross members.

Success of two new coach designs with speed potential of 160 kmph gave IR enormous confidence in designing new coaches.

7.4.7 Some recent developments in coach technology have been as follows:-

- (i) Fitment of Centre Buffer Couplers on main line coaches instead of screw couplings which had several limitations.
- (ii) Bogie mounted brake system and adoption of composite brake blocks.
- (iii) Development of hygienic and aesthetically pleasing modular toilets of FRP.
- (iv) Designing of ten variants of the LHB coach imported from Germany.
- (v) Provision of fire retardant upholstery and curtains in AC coaches.
- (vi) Modifications in ICF coach design to minimize injury in case of accidents.

LHB VARIANT

7.5 WAGON STOCK

7.5.1 Pre-Independence Period

Indian Railway had appointed a British firm, M/s Rendol, Palmer and Tritton as consulting engineers to obtain designs of wagons for Indian Railways from this firm besides other areas of consultancy provided by them.

As the Railways in India prior to independence were company managed, there was need for co-ordination and standardization in technical matters. Central Standards Office was therefore set up in 1930 for purpose of preparing specifications, standards, tender documents etc.

7.5.2 Post-Independence

In 1952, "Railway Testing and Research Centre (RTRC)" was set up for undertaking applied research, providing basic design criteria, producing new designs, validating new concepts of designs, testing prototypes for their performance characteristics and to eliminate bottlenecks in the full utilization of the existing assets.

Soon thereafter, it became possible to dispense with the foreign consultancy and the contract with M/s Rendol, Palmer & Tritton was terminated in 1955. In 1957, CSO and RTRC were merged into a single organization called "Research, Designs and Standards Organisation (RDSO)". Eversince, Indian Railway have acquired high capability to undertake designs of wagons, not only for Indian Railways requirements, but also for use of private and public sector undertakings within the country under consultancy terms. Designs of wagons have been also been evolved by RDSO for manufacture in India for export to foreign countries.

7.5.3 Broad Gauge Wagons

Designs of the following types of BG wagons were obtained from M/s Rendal, Palmer & Tritton :

S. No.	Code	Type of Wagon
1.	O	4-Wheeled Open Wagon
2.	OX	4-Wheeled Open Wagon, Heavy
3.	OH	4 – Wheeled Open High Sided Wagon
4.	OS	4 – Wheeled Open Wagon – Special
5.	OM	4 – Wheeled Open Wagon – Military
6.	BO	Bogie Open Wagon
7.	BOC	Bogies Open Wagon – Coal
8.	CR	4 – Wheeled Covered Wagon
9.	CX	4 – Wheeled Covered Wagon –Heavy
10.	CJ	4 – Wheeled Covered Wagon – Jute
11.	CMR	4 – Wheeled Covered Cattle Wagon
12.	CE	4 – Wheeled Covered Explosive Wagon
13.	BCR	Bogie Covered Wagon
14.	BR	Bogie Rail Wagon
15.	BOB	Bogie Hopper Wagon
16.	BOBC	Bogie Hopper Wagon
17.	BOBX	Bogie Hopper Wagon
18.	BW	Bogie Well Wagon
19.	BWX	Bogie Well Wagon
20.	BWL	Bogie Well Wagon
21.	BWH	Bogie Well Wagon
22.	TO	4 – Wheeled Oil Tank Wagon
23.	TP	4 – Wheeled Petrol Tank Wagon
24.	TM	4 – Wheeled Molasses Tank Wagon
25.	BVG	4 – Wheeled Goods Brake Van

In the following instances, detailed designs were prepared and submitted by various firms, to meet the Schedule of Technical Requirements prepared by CSO/RDSO :

S. No.	Types of Wagon	Designed By
1.	BOBS – Bogie Hopper Wagon Special	M/s ISW & M/s TALBOT, Germany
2.	BWS – Bogie Well Wagon (132t)	M/s Swiss CAR Elevator & M/s Hitachi, Japan
3.	Bogie Well Wagon	M/s Deutsher, East Germany
4.	TSA – 4 – Wheeled Sulphuric Acid Tank Wagon	M/s Teikoku, Japan
5.	THA – 4 – Wheeled Liquid Ammonia Tank Wagon	M/s Hitachi, Japan
6.	TCS – 4 – Wheeled Caustic Soda Tank Wagon	M/s CRDA, Italy
7.	TAL – 4 – Wheeled Liquid Ammonia Tank Wagon	M/s Hitachi, Japan
8.	TCL – 4 – Wheeled Liquid Ammonia Tank Wagon	M/s M & W Graze Brook Ltd. London.
9.	TBT – 4 – Wheeled Bitumen Tank Wagon.	M/s CRDA, Italy.

7.5.4 Broad Gauge Wagons Designed By CSO/RDSO

(i) TPR – 4 – Wheeled Petrol Tank Wagon

This revised version of TP was designed by CSO in 1951. Capacity of barrel was slightly increased and the pump & piping arrangement for suction discharge of petrol was modified to top filling and bottom discharge arrangement.

(ii) TOH – 4 – Wheeled Heavy Oil Tank Wagon

This wagon was designed in] 956 for transporting commodities like fuel oil, furnace oil, creosote, pitch etc. which _ become more viscous in cold weather. The design provides for steam heating of the contents. No master valve is provided and the diameter of the bottom discharge pipe is bigger than TPR/TORX wagons.

(iii) BOX- Bogie Open Wagon

The first major design undertaken by RDSO in 1957-58 was broad gauge Bogie Open Wagon type BOX. This design was developed for the bulk movement of commodities, especially coal, and incorporates special features, which were not provided in the older design, viz. higher axle load of 20.3t. as against 16.3t, roller bearing in place of plain bearings, high capacity semi-automatic centre buffer coupler, improved suspension system with a speed potential of 100 km/h., use of weld-fabricated techniques in the construction of bogies and wagon body and improved braking system incorporating clasp brakes and provision of slack adjuster and empty load box.

(iv) BVM-4-Wheeled Goods Brake van Match Truck

This modified version of 'BVG' was designed in 1958 with provision of transition centre buffer coupling to make it suitable to be used as a match truck between the older wagon stock with screw coupling and side buffers and new stock with centre buffer coupling.

(v) BWT/A- Bogie Well Wagon

This modified version of BWT was designed in] 958-59. Wooden floor was removed & track guides were provided. The floor height of the well was maintained as that of BWT by making the girder deeper.

(vi) BRH-Bogie Rail Wagon Heavy

This wagon was designed in 1960 with 20.3t axle load and plate fabricated bogie of BOX type for transportation of rails and heavy steel sections.

(vii) BWX/A- Bogie Well Wagon

This modified version of BWX was designed in 1960-61. The well length was increased from 3.96 meters in BWX to 5.94 meters by raising the height of the floor of the well to meet the special requirement of defence movement.

(viii) BOI- Bogie Open Gondola Wagon

This open wagon was designed in 1961, especially for the movement of high-density items like iron and manganese ore. The height of the body was reduced thereby increasing the payload by about 30%. Both AVB equipped and air brake equipped versions of BOI wagons have been built for KK line of Southern Eastern Railway.

(ix) TPGL, TPGLR- 4-Wheeled LPG Tank Wagons

This wagon was designed in 1962 for-transportation of LPG at a ressure of up to 15 bar. The designed axle load was 16.31. It used standard IRS suspension. The design incorporates an insulated barrel fabricated from cryogenic steel with filling and discharge arrangements at the top. Revised version of this wagon, known as TPGLR, was developed in 1974 without insulation on the barrel and with a higher carrying capacity.

(x) BCX- Bogie Covered Wagon

This design was evolved in 1963 for bulk movement of commodities requiring protection from rain etc. This design includes all the special features of BOX wagon and in addition has provision of swing-cum-flap doors.

(xi) BHS- Bogie Well Hole wagon

Designed in 1965, this well hole wagon provides for a clear hole of 6250 ×

2440 mm in between two girders. With 92t pay load, this wagon was specially designed for transport of transformers manufactured by M/s. Bharat Heavy Electricals Ltd.

(xii) BOY- Heavy Duty Bogie Open Gondola Wagon

A successor to BOI wagon, this was especially designed in 1967 for transportation of minerals/ore in closed circuit. With an axle load of 22.9t and payload of 71t,the wagon tare weight was 20t. This design included all improved features of welded construction and sub-systems. The design permits full utilisation of track loading density and is suitable for haulage of a gross trailing load of up to 4500t in the existing loop length. The wagon is provided with modern high-speed cast steel bogies with speed potential of 100 km/h and air brakes.

(xiii) BWZ- Bogie Special Well Wagon

This 182t capacity special purpose heavy duty well wagon was designed in 1968 for transport of turbo-generator stators from BHEL/Hardwar. This all welded design incorporates four 6-wheeled 22.91 axle load bogies coupled together through intermediate bridges.

(xiv) CRT (4-wheeled covered wagon)

The utility of an improved design of 4-wheeler wagon was established from the commercial consideration. Hence, a new design of covered wagon type CRT was developed in 1971. This design incorporates improvements over the conventional 4-wheeler wagon by increasing axle load from 16.3t to 20.3t, increased volumetric capacity, strengthened body structure, use of light weight centre buffer coupler and roller bearings and increase in the payload by about 26%.

(xv) BVZT (4-wheeied goods brake van)

Improved design of brake van type BVZT was designed in 1973 to meet requirements of higher speed of goods trains. This incorporates s0fter suspension with longer links and was designed to have a speed potential of 100 Km/h. The design also provided for better facilities and environment to the Train Guard.

(xvi) BOXN (New bogie open wagon)

For meeting the increased demand for the bulk movement of commodities like coal during the Corporate Plan period, a new design of bogie open wagon was evolved in 1976. This design is a radical improvement over the earlier BOX wagon in terms of payload capacity, efficiency, reliability and ease of maintenance. The design uses cast steel bogies. By striking a judicious balance of various constraints and requirements, it was possible to obtain the maximum utilisation of track loading density and the design is also suitable for running trains with gross trailing of 4500t. Now BOXN wagon fitted with

Casnub 22HS bogie have been designated as BOXNHS wagon, which are suitable for 100 km/h operation.

(xvii) **BOBS Mk.-II (Bogie hopper Wagon special)**

This hopper wagon with provision of side discharge is a modification to the older BOBS design. The design was completed in 1976. It uses 22.9t axle load cast steel snubbed bogies.

(xviii) **BOGIE HOPPER WAGON FOR BALLAST 'BOBY'**

This hopper wagon was designed in 1977 to meet the transportation requirements of ballast for the Railway's track maintenance. The wagon has a special feature for regulating discharge of ballast in between and/or outside the track and thereby eliminating manual re-distribution.

(xix) **BCN. BCNA Covered Wagons**

BCN wagon similar to BCX Mk.-II type wagons, was designed in the year 1984.Casnub 22 NLB 'type bogie and air brakes were.fitted. BCNA wagon was designed in the year 1990 by reducing the length of the wagon and increasing the width and height to achieve similar volumetric capacity. This new design resulted in 7.5% increase in throughput BCNA wagon fitted with Casnub 22 HS bogie.have been redesignated as BCNAHS fit for operation at 100 km/h.

(xx) **BFNS type Wagon**

BFNS wagon, suitable for 100 km/ph operation was designed in the year 1998 for transporting HR/CR coils, plates etc. The design incorporates Casnub 22 HSbogies, non-transition CBC and air brake.

(xxi) **BOXNHA Wagon**

A landmark thrust towards higher axle loads in IR was made in 1998 with the design of BOXNHA wagon with higher axle load of 22.1t & with a view to increase throughput per train by 11%. The design incorporates Cast Steel IRF108 HS bogie, non-transition CBC and air brake. However, axle load has since been reduced to 20.32t for regular operation at 100 km/h speed until track upgradation works are completed.

(xxii) **BVZI Brake Van**

BVZI brake van was designed in the year 2000. The design incorporates fitment of ICF type bogie, non-transition CBC and air brake. This brake van is fit for operation at 100 km/ph & has better ride comfort.

The above designs clearly establish IR's capability to meet all its needs of wagon stock.

CHAPTER-VIII

MECHANICAL WORKSHOPS

8.1 From 1853 onwards, railway lines were built by about 40 companies. Each built a mechanical workshop of its own. In 1952, when the Indian Railways decided to re-organise the entire railway system, existing 37 railways were rationalised to form six zonal railways. Similarly, their railway workshops were rationalised and reduced. The rest were gradually closed.

With modern rolling stock and increase in the holding, the modernisation of Railway Workshops became imperative for their proper upkeep and operation besides achieving efficient use of rolling stock by reducing their down time during maintenance schedules. A Central Organisation for Modernisation of Workshops (COFMOW) was established in 1979 for this special task to be done in phases covering replacement of old outmoded machinery, and equipment by sophisticated, computer controlled units, improved handling and inventory systems to drastically reduce the wastage of time and space in criss-cross unplanned movements. In phase I, Chittaranjan Locomotive Works, Kancharapara workshops (ER), Kharagpur workshops (SER), Matunga workshops (CR) and Lower Parel workshops (WR) were taken up. Later in Phase II seven other shops were selected. Historical development of some important Railway workshops is given in following paragraphs.

8.2 JAMALPUR WORKSHOPS (EIR)

8.2.1 East Indian Railway Co. started the first passenger train on its line from Howrah to Hooghly, on 15th Aug, 1854 which was extended to Pundooah on 1st September, 1854. This was the start of the railway line to connect Calcutta with Delhi via Burdwan, Sahibgung, Jamalpur, Kiul and Allahabad. After completion of a tunnel the line reached Jamalpur on 8th Feb.1862.With the opening of the line a workshop was started at Howrah to commission imported locomotives and rolling stock. The need for a bigger and better place for the main workshop for POH of locomotives was soon felt and a search was therefore started while the construction of the line to Kiul was in progress. The choice of Jamalpur as a site for the locomotive workshop was due to its proximity to Munger, which had come to be known as "Birmingham of the East" and was expected to be a ready source of supply of skilled labour as the inhabitants of Munger had for several generations been gun makers of local nawabs and established a high reputation as silversmiths and high precision workers. The place was also known for its bracing climate and had enough area for future expansions.

8.2.2 The move to shift the locomotive portion of the workshop from Howrah to Jamalpur was started in 1862 itself. Soon Jamalpur was made an engine changing station and a loco shed for carrying out loco running repairs was also constructed. Within a year of the inception of the workshop, 247 locomotives were based at Jamalpur for periodical overhaul (POH). The workshop then covered an area of 50 acres and employed 3112 men. In 1870 a rolling mill was setup – first mill on the railways and probably in the Country, to turn out standard flats, rounds, hexagonals, angles, channels and fish plates for rails. Spring plates were rolled for manufacture of locomotive springs. An iron foundry was set up in 1893.

8.2.3 In 1896-97, the first major expansion and remodelling of the workshop took place for the manufacture of new locomotives from workshop-made components and boilers. A steam power house (capacity 2600 hp) based on coal burning stationary boilers, was installed in 1901. In 1898, a steel foundry was started along with a new iron foundry making the workshop self sufficient in respect of all iron and steel castings. The workshop undertook mass production of cast iron chairs required for permanent way. Several other shops like machine shop, tool room, die sinking shop, pattern shop, etc. were also set up, making it a complete workshop having all the basic engineering trades, skills and manufacturing activities. The workshop manufactured over 300 locomotives of several types, mostly for shunting duties. Mr. Huddleston CIE, Chief Superintendent, EIR said, "There are, of course, large railway shops existing in Europe and not few are more self contained or better equipped with modern electrically driven machinery than these works". With the expansion of the shops from 1896-97, workmen's trains were started in three directions to Sultangunj, Kajra and Munger to bring workmen from several kilometers away.

8.2.4 Gradually, a well laid out township developed around the workshop. Water was obtained from fresh streams flowing down through Arravali hills, reservoirs and wells. In 1912 steam pumps were installed in two boats in the river Ganges, near Munger. A pipe line (approx. 11 Kms) was laid and a waterworks complete with filtration facilities was set up on top of a hill on the east of the township. The waterworks, at the end of a pretty winding road from the open maidan along the side of a water reservoir, in lovely surroundings, makes a pretty sight and gives a commanding view of the township. The layout after remodelling remained largely the same until the great earthquake of 1934.

8.2.5 The year 1902 was another year in the history of Jamalpur. In that year, for the first time in India, the manufacture of 30 ton weighbridges was started at Jamalpur. In 1956, Jamalpur foundry shop made a record performance by manufacturing a 60 ton Anvil Block, for the Chittaranjan Locomotive Workshops, which was under construction. Jamalpur also made a large number of horizontal boring and horizontal milling machines for the Machine Tool Controller, India. Jamalpur made a valuable contribution to the country's development and growth by manufacturing 21 Nos. "Sluice Gate Shafts" for the Damodar Valley Corporation. Jamalpur, made the first steam and then diesel Rail Mounted Cranes in India, designed by Indian engineers at RDSO, Lucknow for Accident Relief Trains on I R. This activity developed to the manufacture of giant 140 ton state-of-the-art design breakdown cranes in collaboration with Gottwald of Germany. After assembling 12 cranes from semi-knocked down components, the first fully Indian made crane, called "Ashok Samrat" was turned out on 14.02.1999.

8.2.6 Jamalpur workshop has played a unique role in the history of IR by starting the training of trade apprentices for filling the posts of skilled artisans. Evening classes were started in 1888 to impart necessary theoretical training to complement the practical training being imparted in the workshop itself. A technical school was started in 1905 to impart academic training to a higher category, Apprentice Mechanics, who after training became the supervisors in different railway departments. To meet the country's demands for Indianisation of superior establishment of Mechanical and Electrical engineers, this technical school was upgraded by increasing facilities by bringing in English trained Professors and other staff. A Principal was appointed in 1925. A scheme for training young lads, selected by the Federal Public Service Commission, was started in 1927 to train future class I Mechanical and Electrical Engineering Officers. The Institute has expanded training facilities to cater to training of Indian Railway and foreign railway working engineers and administrators. Over the years, the institute has trained a large number of artisans, an equally large number of supervisors, special class apprentices, Indian and foreign railway officers and administrators. It was upgraded in 1967 and renamed Indian Railway Institute of Mechanical and Electrical Engineering.

8.3 LOCOMOTIVE WORKSHOP, PAREL, BOMBAY (GIP)

The first train on IR was run between Bombay and Thane in 1853 by the then Great Indian Peninsular Railway Co. renamed as Central Railway in 1952. As the number of locomotives increased, Parel loco workshop, situated at 8 kms from Bombay VT, was set up in 1879 as a steam locomotive shed. Parel workshop is close to the terminal station and situated in the heart of Bombay metropolis. With continuous increase in traffic and attendant increase in loco holding, Parel workshop had a peak outurn of POH repairs of 32 steam locos per month.

8.3.1 With the passage of time and tapering off of steam traction the shop was upgraded to take up the work of WDM_2 loco POH from 1974-75 onwards with a monthly out turn of 4 locomotives. Steam loco activity was further reduced and completely wound up by March 1988 and Diesel loco POH capacity was enhanced to 9 locos per month w.e.f. June 1987. It is a full fledged self contained unit. As on 31.12.88, the workshop had a total land area of 1.9 sq. km., covered shed area of 81251 sqm., track (P.way) length inside shops of 11 kms, roads and pathways 14 kms, 1186 machinery and plants, with a wage bill of about Rs.11 million per month and 650 thousand units of energy consumption.

8.3.2 Set up in 1879, Parel workshop is amongst the oldest large size workshops on IR. With the complete change-over in traction from steam to diesel and electric, Parel workshop was considered for total conversion from steam loco repair and POH to similar work for diesel locos. The conversion and modernisation was started under workshop modernisation plan on IR to achieve the following objectives:-

(i) Diesel POH for an outurn of 150 diesel loco units per annum.

(ii) Reduce POH time from 45 to 25 days for WDS locos by planning uni-directional movement of materials, and better material handling methods, use of gravity cranes etc. and state of the art machines and equipment.

(iii) Undertaking manufacture of insulated coils for 212 traction machine sets per annum to achieve reliability and independence from trade.

8.4 KHARAGPUR WORKSHOP

Established in 1998. as a small workshop of Bengal Nagpur Railway, Kheragpur workshop evolved a grew over the years to become the largest maintained workshop of the Indian Railways.It has the unique distinction of being the only workshop of IR which deals with all types of Rolling Stock viz.coaches, EMU's, Wagons, Diesel Locomotives, Electric Locomotives, Electric Locomotives, Diesel and Stream Cranes etc.

The BNR board of Directors recorded their sanction for construction of an integrated workshop at kharagpur in 1900 and the workshop came into operation in 1904. Earlier this workshop undertook periodic overhaul of steam locomotives, timber bodied passenger cars, fitted with plain bearing and freight cars comprising mainly of covered four-wheeler wagons with plain bearing and screw coupling. With changes in modes of traction and types of rolling stock, the workshop had progressively diversified its working. Main features of diversification include:

(i) Periodic overhaul of Diesel Electric Locomotives,

(ii) Periodic overhaul of Electric Locos,

(iii) Periodic overhaul of EMU Trailer and Motor Coaches,

(iv) Periodic Overhaul of new types of freight cars fitted with roller bearing and centre buffer couplers,

(v) Periodic overhaul of all steel coaches fitted with roller bearings and advanced designs of suspension,

(vi) Corrosion repairs to all steel coaches,

(vii) Periodic overhaul of Diesel Rail and Road Cranes,

(viii) Rewinding of traction generators and traction motors,

(ix) Manufacture of sophisticated components of Diesel Electric, Diesel-Hydraulic and Electric Locomotives.

The first phase of Modernisation of Kharagpur Workshop was approved by the Ministry of Railways in September, 1979 with a project outlay of Rs. 132.69 million. The project has been completed. The major objectives covered by the project are-

- Reduction in the number of days taken for POH of Diesel Electric Locomotives from 21 days to 15 days per locomotive.

- Reduction in the number of days taken for POH of Coaches from 18.5 days per coach to 17 days.
- Reduction of POH cycle time for freight cars from 4.2 days per freight car to 4 days.
- Replacement of low-production machine tools.

Second phase of modernisation of Kharagpur workshop has been approved by the Ministry of Railways in September, 1985 with an outlay of Rs. 261.15 million.

This phase of modernisation covered the following major objectives:-

- Periodic overhaul of Electric Locomotives taking advantage of the infrastructure already set up for the POH of Diesel Electric Locomotives and released covered accommodation from Steam Loco POH belt @ 4 locomotives per month.
- Periodical overhaul of EMU motor coaches @ 7 per month.
- Reduction in the number of days taken for POH of coaching stock by 1 day per coach.
- Increase in corrosion repairs to coaching stock from 17 to 24 per month.
- Installation of self-contained coil spring shop.

8.5 PERAMBUR CARRIAGE WORKSHOP

Established in the year 1856, it is the oldest BG mechanical workshop in the Southern Railway System. Initially the workshop carried out periodic overhaul of Steam locomotives, coaches and wagons belonging to the erstwhile Madras Railway and later Madras & Southern Maratha Railways Company. In 1932, the loco maintenance work was transferred to loco works, Perambur with the creation of Southern Railway in 1951. This workshop became an important part of the system as it was the only BG wagon POH shop on Southern Railway. Till 1963, the Carriage workshop was rendering assistance to ICF by furnishing the newly manufactured shells. Being close to the mega Coaching depot at Basin Bridge, this workshop undertakes periodic overhaul of coaches belonging to most of the prestigious trains of Southern India.

8.6 GOLDEN ROCK WORKSHOP/TIRUCHIRAPALLI

The erstwhile South Indian Railway Company Ltd. had its major workshop located at Nagapettinam, a port town on the East Coast. In order to cater to the increasing work load, the workshop at Nagapettinam was moved to Golden Rock near Tiruchrapalli, a central location. Workshop construction started in 1926 and it was commissioned in 1928 for Steam Loco and C&W POH activities. The workshop was designed and constructed with mixed gauge tracks to tackle both BG and MG rolling stock. The workshop has a proud history and even assisted the Royal Air Force in repairing Fighter Bombers during the Second World War.

8.7 LILUAH WORKSHOP

Carriage a wagon Workshop Eastern Railway, Liluah was set up in 1900.The saga of this workshop is inextricably linked with that of Eastern Railways and its precursor, the East Indian Railway (EIR).

The earlier history of non timely supply of imported materials led to the thinking that rolling stock should also be manufactured in India. Accordingly the first workshop was set up at Howrah, upgraded to a Carriage and wagon workshop in 1863 and the facility shifted to Liluah in 1900 by setting up a modern Carriage & Wagon workshop.

Liluah was primarily assigned the task of manufacturing of Coaches and Wagon. 3000 coaches were manufactured upto 1972. Wagon manufacturing was also undertaken but discontinued in the post independence era. Apart from rolling stock required for the military, the workshop produced hundreds of ambulances, water cars, tanks, armoured vehicles, lorries and ammunition.

The workshop constantly witnessed upgrading and modernisation in order to be able to tackle modernisation of rolling stock like introduction of all steel coach shells in lieu of wooden bodied coaches, roller bearings instead of plain bearing, air brakes in lieu of vacuum brakes, bogie wagon instead of 4-wheelers.

The workshop has to its credit conversion of 6 AC Coaches for 'Great Indian Rover', rehabilitation of condemned EMU coaches, manufacture of first Diesel Multiple Unit 'Push-Pull' type trains for non-electrified sub-urban sections (total 29 rakes made), upgrading and refurnishing Raj. Saloon no. ER-2377 in which noble laureate Tagore made his last journey.

8.8 DAHOD WORKSHOPS (BB & CI)

8.8.1 Dahod is situated on Mumbai New Delhi trunk route almost mid-way between Vadodara and Ratlam. It is the district headquarters of Dahod district of Gujarat state. This is a tribal area and the home of Bhil community. It has a long history, origin dating back to the epic of Mahabharata.

The repairs to steam locos of of BB & CI Rly. were done at Lower Parel workshops. A separate shop became necessary when workload became heavy. The foundation stone for Dahod workshop was laid on 14th January 1926 by Sir Clement Hindley, Chief Commissioner for Railways. The shop started functioning in 1931. It was originally planned for an outturn of out 8 to 10 locomotives, but gradually the load increased upto 20 locos/month. Addition of some shops was made like separate Wheel shop & facilities for manufacturing loco duplicates. In June'92 all activities connected with steam loco repairs were closed.

8.8.2 Alternative work undertaken by the shop are :-

(a) All types of steam cranes of WR are repaired and spares made in this shop.

(b) Rehabilitation of Cat`C' damaged Box wagons was started in June'92 with an initial out-turn of five wagons and since enhanced to 25 wagons per month. In

Jan'95 the damaged Box C wagons were converted to container flats. This was done upto March '97.

(c) Electric loco POH and rehabilitation is done here. The first loco No.23427WAG-5 was received on 1st Sept.`1996 and turned out in Jan.`1997. The present output is four locos per month.

(d) Since Jan.1997, POH of MEMU Coaches has been started.

(e) After 1965 war, repair to Arms of Railway Protection Force department was undertaken. These included rifles, muskets, stenguns and small arms.

(f) Rehabilitation of some electric locos resulting in considerable saving.

8.8.3 The shop made valuable contribution in maintenance of rolling stock for BB & CI and later WR in critical periods.

8.9 LOCOMOTIVE WORKSHOP CHARBAGH, LUCKNOW (NR)

The Railways came to Lucknow on 23 April 1867 under the banner of Indian Branch Railway Company as part of Oudh & Rohilkhand Railway (O & R R). For maintenance of Rolling Stock (Locos, Carriages & Wagons) the Railway set up a workshop south of its Charbagh station. The workshop was set up in the orchards owned by the Farooqui family around Fatehli Talab in Charbagh. They were offered land at Dalmau in lieu, at the scale of 3 acres of land at Dalmau for every one acre surrendered at Charbagh.

8.9.1 The workshop is known to have started with almost all its workforce coming from Britain. By 1870, the Charbagh Workshop was successfully employing native labour, a large number of people being brought from loyal princely states of Bihar. These immigrants came to be known as "Bhojpurias"and their presence was predominant in the Blacksmith Shop. There was a parallel strength of Muslim artisans. In the mid 1870, low pay and poor conditions experienced by the low level workers led the Anglo Indian employees to form India's first Railway Union, (The Amalgamated Society of Railway Workmen).

8.9.2 The first locomotives of the O & RR came from M/s Neilson. Till 1950 all the locomotives were imported from Britain. For every 20 locomotives imported in the assembled condition, one locomotive was imported in knocked down condition to provide vital spare parts. They were of the orthodox 0-6-0 and the strange looking 0-8-0 class.

8.9.3 One of the 0-8-0 class locos, after withdrawal from service was displayed for many years outside steam shed in the Workshop. A 0-6-0 is preserved at the Railway Transport Museum at New Delhi. The workshop did the POH of locomotives. In absence of the industry which could manufacture and provide components, broken or damaged in accidents, these were made in the workshops. POH shops had the basic engineering facilities of Blacksmithy, Foundry and Machine, where iron/ steel would be cast, formed and manipulated to produce components for the powerful steam locomotives. This needed skilled local workers. Mr. H.R. Neville, ICS writing in 1904 Gazetteer of United Provinces of Agra and Oudh reported :-

" The workshops of the Oudh and Rohilkhand Railway to the south of the Charbagh station, employ many hundreds of hands; including several pupils from the Martiniere school as well as many other Europeans and Eurasians."

8.9.4 The shops were taken over by EIR in 1925, and rationalised in regard to distribution of workload in their other shops like Jamalpur etc. During the First & Second World Wars ammunitions were produced in the workshops, particularly hand grenades. Workshop Administrative office itself was used as an Armoury. There was a small Ordnance factory next to the Charbagh Shops.

8.9.5 In 1947, a number of Muslim staff gave final options for going to Pakistan. Many however, could not adjust and returned back. Since their options had been final they were not taken back by the Government of India. They sat at home for 5 to 6 years. Later as a gracious gesture most were absorbed back into Railway service. Over 1000 artisans came to Charbagh Locoshops from Punjab, specially Moghalpura and Sukkhur Workshops. They had a tradition of hard work and great skill. All of them were successfully amalgamated into these shops.

8.9.6 Charbagh shops became a part of N. Rly. in the 1952 regrouping. This Railway did not have any loco POH shop. A major effort was mounted to develop the shops and increasing its manufacturing as well as overhaul capabilities. Manufacturing activity continued and reached its peak in the 1960's losing way in the 1970's when Indian industries developed and steam began to be slowly replaced by diesel locomotives. The shop was modified to undertake POH of diesel electric locomotives in 1975 beginning with one or two locomotives and gradually increasing to ten locomotives per month. The shops have POHed over 1000 Diesel locomotives. POH of Electric locomotives was started in 1986.

8.10 COFMOW (Central Organisation for Modernisation of Workshop)

8.10.1 At the time of integration of the Indian Railways system in 1952, there were 41 major repair workshops dealing with the periodic overhaul of coaches, wagons and locomotives. Most of these were set up in the latter half of the 19th and early 20th centuries to cater to the maintenance needs of the individual railway companies. Day to day repairs were handled in over 300 locomotives repair depots and 400 carriage and wagon sicklines.

Over the last 50 years, Indian Railways witnessed extensive changes in the mode of traction as well as in the design technology of new coaches and wagons and the size of the rolling stock fleet more than doubled. Financial constraints, however, did not permit development of facilities to meet the enhanced requirements of expenditure on workshops. Upto the 5th Plan Period, the expenditure on M&P was restricted to around 1.4% of the total plan outlay of the Railways. About 45% of these funds were, utilized in creating additional manufacturing facilities.

As a result, the workshops at one point of time were facing multifarious problems on account-of obsolescence of machinery and plant, diverse product mix and layout deficiencies due to piecemeal additions over the years. The situation in respect of machinery and plant had become a major concern. Because of inadequate inputs the proportion of over aged machine in 1977 rose to approximately 77% as against 47% in 1952.

The deteriorating workshop facilities in turn were adversely affecting the availability of rolling stock for transportation. World Bank Mission, in the year 1977 identified Workshop Modernization Project with IDA aid. This project was to support the improvement of selected workshops of Indian Railways through acquisition of modern machinery and plant. For this purpose, the Central Organization For Modernization of Workshops viz. COFMOW, was set up in the year 1979 to monitor this project and procure the required machinery and plant under this Program. COFMOW deserves due credit in the contribution made towards restoring the manufacturing and maintenance capability of Railway Workshops.

The first phase of Workshop Modernization Project was implemented during the period 1980-84 with the World Bank support of IDA Credit 844-IN of US $ 88 million. In this phase, the repair workshops at Matunga, Kanchrapara, Lower Parel and the Locomotive Production Unit at Chittaranjan were taken up for modernization: The first phase of Workshop Modernization Project was essentially a 'holding-on' operation to arrest the deteriorating trend in maintenance of locomotives and rolling stock due to insufficient investment earlier in the maintenance infrastructure.

The second phase of workshop modernization started in 1985 and covered the repair workshops at Parel, Liluah, Jagadhri, Golden Rock, Kharagpur, Ajmer and the Integral Coach Factory at Chennai and selected maintenance depots. The World Bank had provided support of $ 132.5 million for this phase under IBRD loan 2417 -IN. The second phase of the project enabled Indian Railways to consolidate the gains of the first phase. The World Bank credits were fully utilized by 1990.

8.10.2 Present Role of COFMOW

After completion of the World Bank project, COFMOW assumed the role of a centralized agency responsible for induction of high technology machine tools for the railway workshops and Production Units. COFMOW has been fulfilling this unique function for the last, 25 years and. has become a specialized organization dealing in sophisticated technology required for upgradation of machinery and plant.

COFMOW also realized that while procurement of the M&P is complex and a specialized task by itself, the scope for improvement in the process of planning and upgradation of technology is immense in which COFMOW has been playing an active and a decisive role.

COFMOW has been constantly attempting to upgrade the machine tool specifications by incorporating latest developments in the industry for M&P sanctioned by the Railway Board. However, in the last few years a bold initiative was taken to widen the scope of COFMOW activities so that in addition to its traditionally defined role of inducting new technology, COFMOW undertook integrated system studies to help the railways find "total solutions". Some important high value M&P indents received at COFMOW were selected as "Test Cases" for detailed studies, and studies were successfully conducted for DLW Gear Line and axle production line at Wheel and Axle Plant' Bangalore resulting in substantial savings.

8.10.3 Core Competencies of COFMOW

COFMOW has been assisting Indian Railways in -

(i) Conversion of metre gauge machines for use on broad gauge in view of "unigauge" policy of IR. MG Surface Wheel Lathes at Jodhpur and Gorakhpur Workshops are getting converted into BG.

(ii) Planned rebuilding/reconditioning of older machines to avoid procurement of new machines. Several Surface Wheel lathes and Under Floor Wheel Lathes have already been re-conditioned and some more are in advanced stages.

(iii) Retro fitment of modern CNC controls on the older machines for improving productivity. Vertical Turret Lathes at Kharagpur, Raipur, Liluah, Kanchrapara & Jagadhari Workshops were retrofitted with CNC Controls resulting in a savings of Rs. 6.2 crores and also increased productivity.

(iv) COFMOW was also designated Central Procurement Agency of the Ministry of Human Resource Development for their World Bank Aided Technical Education Projects. COFMOW was required to specify, procure and commission equipments in Polytechnics spread across the length and breadth of the country. COFMOW procured a total of 6362 machines valued at Rs. 147 crores within the time frame given.

(v) Providing various industrial engineering inputs to Railway Workshops and Production Units.

(vi) Preparation of technical specifications, procurement, delivery and commissioning of machinery & plant. So far COFMOW has prepared about 800 specifications. Some of the technical specifications prepared by COFMOW have not only been utilized by RITES in their international bids but were favorably commented upon by the World Bank The total no. of machines procured till date (31st March 2003) is 6944 valued at Rs. 1119.8 crores. The M&P ordered in terms of value showed a steadily increasing trend over the years. The highlight was procurement of highest ever number of machines totaling 418 at a total value of Rs. 254.4 crores in the year 2002-03.

(vii) Training of Workshop Personnel in operation and maintenance of machines.

(viii) Organizing Seminars on New Technologies.

(ix) Assisting Indian Railways through Workshop Management Group as Secretary of Group.

(x) Prepare standard Workshop layout for overhaul and maintenance of sub-assemblies.

(xi) Development of indigenous suppliers for manufacture of sophisticated and special purpose machines resulting in savings of foreign exchange. Wheel Lathes, Cam Milling, Cam Grinding, Honing and Gun Drilling machines have been procured indigenously.

(xii) Centralised platform for user-manufacturer interface.

(xiii) Study of technological developments in machine tool industry to assess their suitability for Indian Railways.

(xiv) Contract management for procurement, commissioning training, warranty and post warranty support for machinery & plant.

(xv) Providing technological support in terms of M&P for implementing rolling stock technology transfer projects viz. ABB 6000 HP Electric Locomotives for CLW, GM 4000 HP Diesel Locomotive for DLW & LHB Coach project for RCF.

(xvi) Undertaking turnkey works and inclusion of Annual Maintenance Contract of machines in the technical specifications to ensure their reliability & availability.

CHAPTER IX

PRODUCTION UNITS

9.1 HISTORY

From 1853 to 1947, almost all important equipments e.g. rails, locomotives, rolling stock, workshop machinery were imported from England, in CKD or later in SKD condition. During the war years (1939 to 1944) due to despatch of some locos & rolling stock to war zones in the Middle East and intensive utilisation in India, the railway assets were badly run down and in poor condition. The division of all types of assets with the partition of the country made the situation worse almost to a crisis situation. Therefore, IR took a decision to start setting up production units, one by one, to meet the railways immediate requirements as well as to make IR gradually self-sufficient for meeting its growing requirements for the country's developing economy. Chittaranjan Locomotive Works (CLW) at Chittaranjan for loco building was set up first. This was followed by setting up of Integral Coach Factory (ICF), Perambur for building coaches. Wagon manufacture was largely left to the private sector. When diesel locos proved themselves in India and their requirement grew, Diesel Loco Works (DLW) was set up at Varanasi followed by setting up of a Wheel and Axle Plant (WAP), at Bangalore, as a large amount of foreign exchange was getting drained out in importing wheels and axles for the rolling stock. As the diesel loco fleet grew, the demands of repairs and reconditioning of diesel locos could not be met by DLW and diesel loco sheds. Another production unit called Diesel Components Works (DCW) was set up at Patiala. Last in the series of Production Units has been Rail Coach Factory (RCF) at Kapurthala for meeting increased demand of rail coaches beyond the capacity of ICF.

9.2 CHITTARANJAN LOCOMOTIVE WORKS, CHITTARANJAN

The unit was initially set up for production of Steam Locomotives and started production in 1950. CLW had produced a total of 2351 steam locomotives. Production of steam locomotives was stopped in 1972.

9.2.1 CLW commenced production of Electric Locomotives in 1961 and Diesel Locomotives in 1967-68. Production of diesel locomotives was stopped in 1993-94. A total of 842 diesel locomotives, including YDM and ZDM type of locomotives were manufactured by CLW. The unit is now manufacturing only Electric Locomotives. Till March, 2006 a total of 3380 Electric Locomotives have been manufactured by CLW.

9.2.2 Using improved technology through indigenous sources, CLW has developed 5000 HP WAG-7 Electric locomotives having high adhesion bogies with a maximum speed potential of 80 KMPH. 638 such locomotives have been manufactured upto March, 2002. CLW turned out the prototype state-of-art, 6000 HP freight locomotive in November, 1998 in collaboration with Asea Brown Boweri. (ABB)

CLW achieved ISO-9001 certification in July,1996. The CLW Steel foundry achieved ISO-9002 Certification in October 1996.

The target Vs. actual production of CLW in the last five years is indicated below:-

YEAR	TARGET	ACTUAL
2000-01	120	120
2001-02	73	82
2002-03	69	69
2003-04	86	86
2004-05	90	90

9.3 DIESEL LOCOMOTIVE WORKS,VARANASI

After the second World War, it was apparent that steam locomotives would not be able to meet the ever growing traffic arisings. Diesel locomotives were fast replacing steam locomotives all over the world. IR imported a few diesel electric locomotives in fifties for trial operation. These locomotives proved more efficient, required less maintenance and were more cost effective. To make the Railways and the country self-sufficient for future requirements, it was decided to set up a new production unit named Diesel Locomotive Works (DLW). An available site of the erstwhile Locomotive Component Works at Varanasi was selected. The unit including a model township was set up, in 1961 at a cost of Rs.20 crores.

9.3.1 IR entered into a technical collaboration with ALCO Prod. Inc. of USA for machinery and plant required, training of staff and complete transfer of know-how. The first diesel locomotive, with all imported components assembled at Varanasi was inaugurated by the Prime Minister, Shri Lal Bahadur Shastri on 3rd, Jan. 64. DLW was planned for producing 150 locomotives per annum, with maximum indigenous content. DLW has surpassed its target of production and also achieved 98 % indigenisation. Till Sept. 1999, DLW has produced a total of 4072 diesel locos, including 49 locomotives exported to Vietnam, Bangladesh and Sri Lanka.

9.3.2 The collaborators provided designs and know-how for the first ALCO 2600 HP BG WDM2 and 1350 HP MG YDM4 locomotives. These original design ALCO locomotives developed a number of serious problems, which RDSO, DLW, and Indian engineers patiently eliminated by improvements in design, substitute materials, new assemblies and by carrying out modifications in running sheds and workshops. By 2000, RDSO & DLW had developed six new designs of locomotives, to meet IR's varied requirements. The latest design is WDP2-3100 HP high speed passenger locomotive.

9.3.3 The ALCO diesel locomotive technology was fully utilised for 35 years and need for the latest was felt. IR signed with General Motors (USA) a new 10 year technology transfer agreement in 1996. IR obtained full manufacturing rights to EMD's GT 46 MAC locomotive and its passenger equivalent GT 46 PAC, both of which are powered by EMD's 300 KW 16 cylinder 710 G3B engine. The new generation, first micro-processor technology 4000 HP diesel electric locomotive WDG4 manufactured from partially knocked down locomotive from GM, USA, and assembled and tested to collaborator's standards rolled out from DLW on 14th, Aug. 1999. India is the first country outside North America to have AC-AC technology diesel electric locomotives. DLW is the only manufacturing unit, outside EMD's Chicago plant, to manufacture family of 710 series engines of 3000, 4000, and 5000 horsepower. DLW, is certified for ISO 9002.

9.3.4 The target Vs. actual production of DLW in the last five years is indicated below:-

YEAR	TARGET	ACTUAL
2000-01	103	103
2001-02	98	102
2002-03	116	116
2003-04	116	116
2004-05	124	121

9.4 INTEGRAL COACH FACTORY, MADRAS

Integral Coach Factory (ICF) was set up in 1952 as a production unit for manufacture of all-welded steel, light-weight integral coaches with anti- telescopic features in collaboration with M/s Swiss Car & Elevator Manufacturing Corporation, Switzerland. The production from the unit commenced in 1955. Later, towards the middle of the Second Five Year Plan, a separate furnishing division was set up. The division commenced production in 1962. The unit has manufactured 29,467 coaches till September, 1999 including 425 coaches exported to Tanzania, Taiwan, Vietnam, Philippines, Bangladesh, Mozambique, Thailand, Burma, Zambia, Uganda & Nigeria.

9.4.1 The factory was set up to initially manufacture 350 shells per annum. The installed capacity has been increased progressively to 750 coaches in 1979, 850 coaches in 1987 and 1000 coaches in 1991. The unit undertakes manufacture of a large variety of Broad Gauge AC and non-AC Coaches, DC and AC Electric and Diesel Multiple Units. ICF achieved the ISO-9001 Certification in December,1996. A pilot project on Total Quality Management (TQM) is presently under way.

9.4.2 To obviate the delays in dispatch of medical van to a site of accident on account of ready availability of locomotives, ICF manufactured 10 self-propelled Accident Relief Medical Vans recently.

The target Vs. actual production of ICF in the last five years is indicated below:-

YEAR	TARGET	ACTUAL
2000-01	1000	1000
2001-02	1001	1025
2002-03	900	944
2003-04	1211	1070
2004-05	1100	1119

9.5 RAIL COACH FACTORY, KAPURTHALA

Rail Coach Factory (RCF) is the youngest production unit of Indian Railways. The unit commenced production during March,1988. Full capacity to manufacture 1,000 coaches per year was attained towards the end of 1991-92. The unit has manufactured 11714 coaches till December, 2001.

9.5.1 RCF developed and manufactured 3 tier AC coaches in 1993-94 which have been popular with the traveling public. A total of 1240 such coaches have so far been manufactured by RCF. It has also undertaken detailed design and manufacture of new designs of shells and bogies with increased speed potential. 18 such coaches employing IRY shell on IR-20 bogies with a speed potential of 160 KMPH were so far been manufactured by RCF which are successfully running on Shatabadi trains. In future, RCF would be manufacturing state-of the-art, light- weight, high speed coaches under a TOT agreement with M/s LHB, Germany. RCF achieved the ISO-9001 certification for its Shell & Painting division in Jan'1997 and for Furnishing division in July'1997. RCF has also achieved ISO-14001 certification on environment.

The target Vs. actual production of RCF in the last five years is indicated below :-

YEAR	TARGET	ACTUAL
2000-01	1090	1090
2001-02	1204	1204
2002-03	941	944
2003-04	1201	1201
2004-05	1250	1201

9.6 RAIL WHEEL FACTORY, YELAHANKA, BANGALORE (RWF)

This production unit of IRWO was previously known as Wheel Axles Plant (WAP). Wheels, axles and wheel sets are required in large quantities for the manufacture & maintenance of the large fleet of rolling stock on IR. The indigenous capacity for production of these wheels & axles was inadequate. Over 50 % of the total requirement was met by imports involving heavy drain of valuable foreign exchange in early seventies. Durgapur Steel Plant & Tata Iron & Steel Co. were the only two plants in the country manufacturing wheels, axles and tyres. They had old outdated M&P and had limited scope for physical expansion. Being non-automated plants, labour and cost inputs were high. In order to achieve the self-sufficiency in this area, IR set up the plant at Yelahanka, Bangalore commissioned on September 15th, 1984. The Plant spread over 291 acres was built at a cost of Rs. 146 crores with the assistance from the World Bank through IDA for USD 56.5 millions and incorporates state-of-art developments in wheel & axle technology. The plant has an annual capacity to manufacture approx. 1,00,000 wheels & 50,000 axles.

9.6.1 Construction: The structures of the workshops are mainly of RCC members with pre-cast, pre-stressed concrete roof girders, pre-cast roof elements, cast-in-situ folded plate roofs (6 metre width & span of 15 metres), shell/flat roofs etc., which were the state-of-art technology adopted for its low cost and maintenance apart from durability. The basement roof is a composite structure involving RCC slab with top supported on steel work. The design of these structures provides good ventilation/illumination. Other administrative, laboratory and service buildings have been specially designed with economic and architecturally unique features.

9.6.2 Manufacturing Techniques: The wheels are produced by casting process as against the conventional forging process by adopting the controlled pressure pouring technique developed by M/s Griffin Wheel Co., USA. The advantage is that the scrap steel from all over IR could be used as the raw material. The manufacturing process is automatised for achieving high productivity. The axles are produced using high precision long forging machine of M/s GFM, Austria capable of forging the heaviest axles required on IR. In conjunction, specialised machining centres and semi automatic handling equipments have been provided resulting in a high output of machined axles. The final pressing of the wheels onto the axles is undertaken by an automatic machine with pre-set controls precisely engineered.

9.6.3 In its 15 year life till 1999, RWF has achieved the following landmarks :-

November,1994	Accreditation of ISO 9002 certification by M/s BVQI.
November,1995	W & AP certified as a manufacturer of Wheels and Axles for supply to US Railroads by Association of American Railroads.
February,1998	Re-certification of ISO 9002 by M/s BVQI and Accreditation of ISO 14001 certification by them for environmental standards in June 1999.

The plant surpassed its installed and rated annual capacity as below:

1998-99	Production of Wheels (99,688 Nos.)
1997-98	Production of Axles (52,249 Nos.)
1998-99	Production of Wheelsets (38,624 Nos.)

RWF has implemented TQM including the essential aspects like energy conservation, environmental friendliness, welfare of the employees, vendor development etc.

9.6.4 Technical developments: Some recent important developments made in regard to the engineering products, processes and services are given in Appendix 9.6.4 at Page IX-9.

9.6.6 Technical Innovations

(i) Wheel Shop: Initially the Electric arc furnace was relined at every 500 heats using 15 T of wet ramming mass. WAP has now resorted to condition based relining. The lining serves on an average of 4500 heats giving reduced furnace down time and savings in costs.

(ii) RWF has developed a second stage slag making without increasing the cycle time saving about 20-25 minutes time.

(iii) RWF has designed and developed suitable roller bearings for conveyor assembly using indigenous resources. These are giving reliable service and overcome the need to import.

9.7 DIESEL LOCO MODERNISATION WORKS

Previously known as Diesel Components Works (DCW), DMW, a production unit of Indian Railways was set up at Patiala to extend maintenance support for the WDM_2 locomotive fleet of Indian Railways by providing high precision components & sub assemblies. The foundation stone for DCW, Patiala was laid on 24.10.1981 by the then Minister for Railways Shri Kedar Pandey. The facilities were expanded later in the second phase & rebuilding of Diesel Electric Locomotive & Power Packs was started in 1989. Approximately Rs. 170 crores was invested in this project including US $ 30 million provided by the World Bank.

9.7.1 Important Milestones

• Foundation Stone of the project laid	Oct.' 81
• Component manufacture started	Jan.' 86
• First Rebuilt Locomotive Turned out	Nov.' 89
• First Fuel Efficient (26W HP) Locomotive Turned out	Apr.' 94
• First Export Order executed for Vietnam Railways	Oct.' 94
• First WDM_{3A} (3100 HP) Locomotive turned out	Jan.' 00
• First WDM3C (3300 HP) Locomotive turned out	Nov.'02
• First Rail cum Road vehicle turned out	July' 03

9.7.2 Technological Innovations

In order to remain competitive, DMW has strategically focused on Technological aspects while rebuilding locomotives. Some of the technological innovations undertaken by DMW are highlighted below.

9.7.2.1 Manufacture of Stiffer Unit Camshaft

Manufacture of Stiffer Unit Camshafts commenced at DMW for fitment while upgrading the existing 2600 HP WDM2 locomotive to 3300 HP WDM3C locomotive during rebuilding. The use of Stiffer Unit Camshafts makes the ALCO engines more maintenance friendly, reliable and is expected to give fuel saving of approximately 2%.

9.7.2.2 Conversion of Plain Bearing Traction Motors.

Conversion of conventional magnet frame of 4906-BZ type traction motor of WDM_2 (with plain suspension bearings) to 4907-AZ type traction motor with roller bearing suitable for WDM_{3c} locomotives by incoprating suspension tube etc. was started at DMW. The conversion involves substantial in-house inputs by way of welding, precision machining etc. for which the requisite drawings and processes were evolved.

The converted Traction motor is functionally similar to the new roller bearing traction motor as regards quality and life and also very cost effective resulting in savings of over Rs. 4 lacs per locomotive.

9.7.2.3 Locomotive Turning Manipulator

DMW successfully designed and fabricated a Locomotive Turning Manipulator, to rotate the Diesel Electric locomotive under-frame by 360^0 on its longitudinal axis. This manipulator facilitates down-hand welding at locations which are otherwise difficult to access.

9.7.2.4 Auxiliary Machines Rehabilitation

Indian Railways changed over from DC-DC to AC-DC transmission on the Diesel Electric locomotive in a big way. The alternators and associated Auxiliary Machines now require comprehensive repairs. DMW accordingly started reconditioning of AC-DC loco-specific auxiliary machines as well.

9.7.2.5 Load Test Facility for Traction Alternators

DMW established the capability of undertaking rewinding of traction alternators and a number of alternators awaiting repairs were successfully rewound for the Zonal Railways. However, load test facility for repaired alternators was lacking and setting up the same involved major financial investment. After detailed innovative engineering, the existing DC Traction Generator test facility was been modified for testing of traction alternators as well.

9.7.2.6 Up-gradation of Insulation Scheme

An upgraded "Class 200 Insulation Scheme" was applied during rewinding of old Traction Motor interpoles to make them fit for use on 4907 BZ type Traction Motors with roller suspension bearing for WDM_{3c} Locomotives. Earlier, new inter-poles had to be procured from M/s. BHEL. This resulted in a saving of Rs. 1.4 lacs per traction motor.

9.7.2.7 Fitment of Microprocessor Control Based Governor

DMW fitted BHEL make Microprocessor control based governor on rebuilt locomotive No. 18712 of Vatva shed, Western Railway. This is the first such governor fitted on any rebuilt locomotive and commissioned successfully. The governor is totally maintenance free and offers improved fuel efficiency due to faster response.

9.7.2.8 Modification of Lube Oil Circuit

Lube oil inlet circuit for GE Turbo Charger was modified to arrest the drop in pressure that was taking place in the earlier design. The modification resulted in increase of Lube Oil Pressure by 1.0 kg/cm^2 at turbo inlet, leading to a higher circuit reliability.

9.7.2.9 Testing of Traction Machines

A Hopkinsons Test bed was installed in TMS to test the Traction Machines on load. DMW was the First unit of Indian Railways to have such a facility for testing of Traction Motors. This helped in improving the reliability of TMs.

9.7.2.10 Modification of Old Magnet Frames

The Heavy Machine Shop converted 370 old 165 M type Magnet Frames to 4907 type Traction Machines suitable for 3100HP locomotives. These frames were earlier procured from BHEL. A saving of more than Rs 4 Crores was thus achieved during the period.

9.7.3 The target Vs actual production of DMW for loco rebuilding in the last five years is indicated below:

Year	Target	Actual
2000-01	63	63
2001-02	70	73
2002-03	70	73
2003-04	72	74
2004-05	72	73

TECHNICAL DEVELOPMENT IN RAIL WHEEL & FACTORY: BANGALORE

(a) **Indigenisation:** The following items have been fully indigenised.

- (i) Critical imported consumables like P F Resin, Stopper heads, Gaskets etc., and spares like Thermal corridor ring, etc.
- (ii) Costly spares/consumables of GFM machine including Forging hammers, Base plates, Pressure rings, Jaws, Block cutting nozzles, Cutting torches, etc.
- (iii) Hardened bed liner at Stn-2 of the Axle machine shop, two inch cylinder of LH head movement in Station-2 and Grab crane break liners, Drive wheel, Drive pinion, Grab and Grab guide in Axle Shops.
- (iv) Chuck jaw screw rod, nuts & chip guard cyliner, a number of electrical & electronic components including thyristors, temperature/other recorders, controllers, drives, pulse transformers etc.

(b) **Wheel shop:** The following process and technique improvements have been made:-

- (i) Introduction of local area network for on-line computerisation of all core activities.
- (ii) Despatch of wheelsets in two-tiers for better wagon utilisation to get lower costs of transportation.
- (iii) Alteration of wheel manufacturing processes and use of alternate materials resulting in full exploitation of the infra-structure.
- (iv) Replacement of Pusher Beam conveyor by chain driven live roller conveyor to handle the moulds with more reliability and better speed for an outturn of 1,25,000 wheels p.a.
- (v) Adoption of CAD & Application of FEM analysis for design & development of wheels.
- (vi) Provision of parallel drive of Cope tilter to improve its availability.
- (vii) A Parallel hydraulic circuit with flow control valve developed & installed to operate the John Mohr Vessel to ensure minimum down time.

These developments enabled export of CH-36 wheels & first class axles to USA and manufacture of 1090 mm dia loco wheels & coaching wheels.

(c) **Axle shop:** The following process and technique improvement have helped in increased production and reduced unit costs.

- (i) Modification of intermediate cooling bed & hydraulic heat treatment as an alternate in the event of break-down of the tempering furnace.

(ii) Isolation of charging & discharging hydraulic line in the event of breakdown of charging side of RHF.

(iii) Conversion of mechanically operated coolant valves to electro-pneumatic valves for economy.

(iv) Spray pump in the mounting press replaced with pneumatic spray vector for better house keeping/safety and material savings.

(v) Oil cool refrigeration system to heat exchangers converted to water cooled system.

(vi) Pneumatic systems converted to hydraulic & DC Valve converted to electrical solenoid operations.

(vii) Replacement of Linseed oil by Castor oil in Mounting Press for economy.

(viii) Development of Working platform at Chip conveyor discharge end for safety

(ix) Introduction to tool sensing device at Station -2 to prevent rejection of Axles

(x) Replacement of foot operated pneumatic valves with user friendly push button system.

(xi) Introduction of Poly-high Solidur strips in place of brass liners on conveyors for better handling of Axles.

(xii) Console & tracer of Joint lathes replaced with in-house developed units.

(xiii) Grab Crane at Station-8 modified to travel upto MPT conveyor for effective use.

(xiv) Retrieval of rejected axles by converting to lower sized axles.

(xv) Provision of ultra filter systems at various machining stations to improve the effective and useful life of the coolant.

(d) **Electrical engineering:** To reduce the dependence on foreign equipment manufacturers/suppliers for spares & service and to improve availability of electronic equipment, an Electronics Lab was established in 1988 to adopt special maintenance techniques for spares/sub-assemblies/equipment including component level servicing, indigenisation of sub-assemblies preferably from local manufacturers & in-house development of sub-assemEmblies.

CHAPTER X

D.C. ELECTRIFICATION

10.0 ELECTRIFICATION ON INDIAN RAILWAYS

Electric traction started on Indian Railways with electrification of Bori Bandar-Kurla section of the erstwhile Great Indian Peninsular Railway in 1925, on 1500 volt DC system.

It would be appropriate that the history of development of electric traction world over is briefly traced before bringing out such developments on Indian Railways.

10.1 DEVELOPMENT OF ELECTRIC TRACTION ON WORLD RAILWAYS

10.1.1 Unlimited Power - the benchmark of electric traction with its driving motors drawing power from the national grid or from generating plants located far away, giving electric traction a unique advantage of its ability to draw as much power as needed without 'running out of steam'. With this inherent capability, electric traction first appeared in its primitive form in 1835, when Thomas Devenport, a blacksmith and electrical inventor from Vermont in USA successfully demonstrated a small toy like circular railway driven by a rotary electric motor. This is preserved in the Smithsonian Institution in Washington D.C.

Just three years later (1838), the first successful electric locomotive-though rudimentary in design- was made by Robert Davidson of Aberdeen, Scotland. This machine, weighing seven tons, was demonstrated during 1839 "Electro-Magnetic Exhibition" held in London under patronage of Royal Scottish Society of Arts. Davidson later mounted his locomotive on a two km section of the railway line between Edinburgh and Glasgow. It attained a top speed of 6 KM/H while hauling a load of six tons. Unfortunately Davidson's galvanolocomotive (as it was popularly called) met a tragic end as it was vandalized by a crowd of angry workmen of a steam railway, wanting to protect their jobs from that first competitor of the 'Iron Horse'.

Some other known attempts, towards use of electric motor in rail transportation, are:

- In 1840, Pinkus obtained a patent in which use of rails for conveying electric current was indicated.
- In 1847, Farmer operated an experimental electric model car at Dover USA.
- In the same year Lilley and Cotton constructed a small locomotive at Pittsburg that ran on a circular track with the current being conveyed from a battery through track rails.

- In 1850, Hall exhibited in Boston a small car on rails through which current was supplied from a battery.
- About the same time Page, aided by a special grant from Congress, constructed a larger electric locomotive fitted with 100 Grove cells. This vehicle was tried on a railway at Washington.

10.1.2 Siemen's Railway

The first generator powered railway to operate with any degree of success was built by German electrician and inventor Dr. Wemer von Siemens, for Berlin Industrial Exhibition in1879. (He was also the founder of the company which eventually grew into present giant electrical machinery manufacturer known worldwide by the family name.) The train was made up of a small four wheeled locomotive hauling three cars, each having seats for six passengers. The current, generated by a Siemens dynamo coupled to a rotary steam engine, was conveyed to the locomotive by means of a central rail while the track rails were used for the return current.

The first commercial electric railway was operated in Germany in 1881, by Dr. Siemens, between Berlin and Litcherfeld with twin rail tracks insulated and carrying current.

10.1.3 Edison's Locomotive

Almost at the same time (1880), the prolific American inventor Thomas Alpha Edison demonstrated a small generator powered locomotive hauling two small carriages at 40 MPH (65 KMPH) speed over a 1400 feet track laid out in his Menolo Park laboratories in New Jersey. A few months later Edison and Henry Vallard built two curious looking electric locomotives which resembled small steam engines. In 1883 Edison's experimental locomotive "THE JUDGE" transported some 26,000 visitors to the Chicago Railway Exposition, in which the engine drew power from third rail and worked at a top speed of 12 MPH (19 KMPH).

10.1.4 Another landmark in the history of electric traction was reached in 1884 when French engineer Lucien Gaulard successfully operated an overhead power system which fed 2 KV alternating current (AC) to locomotives operated on the Turin-Lanzo section in Italy. This opened the door to include electric traction as an option before management of railways.

10.2 INDIAN RAILWAYS - ELECTRIFICATION STARTS FROM BOMBAY

10.2.1 The inaugural run of the first electric train in India on 3rd Feb.,1925 between Bori-Bandar and Kurla via Harbour Branch (H.B) was the second most important development for IR, after the inauguration of the railway network in India on April 16, 1853. With this development India was 24th country in the world, 3rd in Asia and Ist in British Empire to adopt electric traction on its railways. Later developments proved the importance and necessity of electric traction for railway operations the world over for increase in track capacity, higher productivity, better energy efficiency, clean, comfortable, non-polluting and environment friendly transport, ability to negotiate steep gradients and regeneration of energy.

10.2.2 City of Bombay was the second largest economically and strategically important city in the British Empire, second only to London. Bombay city had a phenomenal growth in its industrial and economic activity and expansion of residential areas with fast growing population with consequent necessity for daily commutation. By 1901 the increase of suburban traffic in Bombay was so heavy that electric traction was first proposed almost only a few years later to its introduction in London in 1890 on Southern Railway Suburbs (U.K.) and main line up to Brighton. The proposal was accepted in principal in 1904. In 1912 Mr. C.H. Merz, designer of London under ground electric railway, was appointed to report on the railway electrification (RE) in India beginning from the city of Bombay. The population of Bombay city had reached a million mark in 1910 and was growing.

10.2.3 Mr. Merz based on his detailed investigations at site, study of the local conditions and discussions with officers of GIP, BB & CI. and Port Railways prepared detailed reports on the technical aspects and economics of substituting steam by electric traction on the suburban sections of GIP, BB & CI Railways and BPT lines in 1912. The study included main lines of GIP Railway- on account of capacity constraints of steam traction in negotiating the Bhore and Thull ghat sections having heavy gradients and reversing stations.

10.2.4 At about the same time, demonstration by Swiss Federal Railways (SFR) in successfully establishing electrification on the Gothard line, having a gradient of 1 in 37 and consequently increasing the line capacity, was a significant development. Services of M/s Merz & Mclellan were engaged for detailed study for the electrification of suburban services of GIP/BB & CI and Port lines besides the main line services of GIPR. They submitted two separate reports, the first in October, 1913 and the second in January, 1914.

10.2.5 Soon after submission of the reports, World War I erupted in 1914, in which U.K. was deeply involved. The electrification plans of the IR were shelved. On cessation of hostilities M/s Merz & Mclellan were asked to review their reports for any changes in costs and traffic projections and also consider main line sections beyond Igatpuri. In July 1919, Merz & Mclellan submitted revised detailed report. They recommended electrification of all suburban sections of both Railways and Port lines besides immediate steps for electrification of Bombay-Bhusaval main line section. They proposed 1500 V DC for suburban sections and 3000 V DC for the main line.

Here it would be significant to understand the logic for recommending adoption of D.C. system and the voltages. In this context relevant extracts from M/s Merz Mclellan's report are reproduced as Appendix X-2.5.-(I) to compare the advantages and shortcomings of various alternatives considered.

It would also be interesting to know the trend then obtaining in the advanced electrified railways. Appendix X-2.5-(II) titled "Significance of relevant factors of electrification on Swiss Railways" explains the far reaching developments taking place in Switzerland, who are considered to be among the pioneers in electrification of railway lines. It is not understood how the consulting engineers failed to mention the success of single phase traction on Swiss railways

10.2.6 Some of the additional factors influencing the introduction of electrification of railways in India, immediately at the end of World War I were:

- (i) Requirement of increased traffic due to export of cheap raw materials out of Bombay port.
- (ii) World wide recession and worst depression ever after the World War I in UK
- (iii) Growth of exports from UK while giant industrial rivals like France and particularly Germany lay supine and were struggling politically.
- (iv) Opportunities for British industry.

The recommendations were reviewed in 1919 after the war. The recommendation was for adoption of 3000 V DC electrification of main line from Bombay to Bhusaval at one `go' on account of handsome returns on investment (over 20%). GIPR, however, approved electrification of main line upto Igatpuri and a small stretch of 80 miles beyond on NE section of main line and accepted the original 1914 report to choose the 1500 V DC overhead system operation on heavily graded sections.

10.2.7 Power Source

It was proposed to use hydro power available from Tata hydro power system for the immediate needs of suburban electric services and to set up a dedicated thermal Power plant near Thana to use lower grade Central India coal. Exploitation of hydro power in western ghats was not even considered. Perhaps hydro generation would have meant longer time frame.

In M/s Merz and Mclellan's second report for electrification of GIPR main line for overcoming the constraints of ghat sections under steam operation, a separate thermal plant at Thakurli (Chola) together with 95 KV transmission lines both on NE & SE sections for feeding track side rotary converter substations, was proposed, which was accepted and the thermal plant commissioned in 1929. HV linkage was provided with the Tata Hydro power system at Chola power house site. Special features of the original power plant, specially designed mainly for traction supply, were:

- (a) Main generators with large short time overload capacity.
- (b) Absorption of the surplus regenerative power of heavy goods trains descending ghat sections.

Today it baffles us to think that the British consulting engineers had recommended the provision of steam power house overlooking the potential of large hydro power in western ghats.

10.2.8 The preliminary works on DC electrification started around 1922 both on Harbour Branch and Victoria Terminus (V.T.) local lines. Even in the early phases, cathodic protection against corrosion on account of electrolysis was provided. The foundation bolts and structure bases then erected still have a residual life. Care was taken to provide a very low resistance heavy return current path through fish plated copper return joints which were checked with a sensitive ductor set for maintaining a stringent joint resistance level of three microhms. All structures were bonded to the rails so that any catenary insulator failures, particularly during and after the monsoons due to frequent lightening, did not affect the foundation bolts.

By 5th Nov. 1929, the entire section from V.T. to Pune on the South East stood electrified while the North East section from Bombay to Igatpuri was opened in December, 1930. Thus came electrification of Railways in India, which in later years was to prove the backbone for handling bulk of increased traffic in most cost effective manner.

10.2.9 The main line electrification brought a sea change in operation of trains on the NE & SE ghat sections. Three reversing stations on each of the ghats were necessary to avoid negotiating heavy grades working with steam engines. By eliminating the reversing stations a new direct alignment was possible. It resulted in increasing the ruling grade to 1 in 37, the steepest for broad gauge in the world. The electric engines not only negotiated this grade but also hauled a higher load. The new alignment was provided with three catch sidings while there were 12 tunnels on NE and 26 tunnels on the SE lines.

10.2.10 Phasing Out DC

After almost exponential increase in suburban and mainline traffic for almost eight decades, the 1500V DC system is proving to be inadequate and Indian Railways have already decided to convert all dc electrified lines in Mumbai area to 25 KV AC traction. When these plans get executed, dc electrification which served a crucial role in ushering in electrification of railways in India would have been given a "good bye".

10.3 ELECTRIC TRACTION IN SOUTH INDIA (1500 V DC)

10.3.1 Soon after completing electrification in Bombay area, similar electrification was considered for suburban areas of Madras and it was decided to adopt 1500 V DC. The work of electrification of 29.1 rout KM of double track running from Madras Beach to Tambaram and 11.2 KM sidings at Madras Beach, Madras Egmore and Tambaram stations, totaling 69.4 track KMs was completed and inaugurated by the Governor of Madras on 2nd April, 1931. However, the first electric train for public was started on 11th May, 1931. Gradually, the suburban services between Madras Beach and Tambaram were all electric from 1st August, 1931.

10.3.2 Power Supply

Power at 5 KV 3 phase, 50 cycles, was supplied by means of 3 cables from the Madras Electric Supply Corporation situated at Basin Bridge, approximately 3.78 kms from Egmore Sub-station. All circuits, both for power supply and automatic electric signaling circuits, were provided in duplicate. The sub-stations had metal type mercury arc rectifiers employed for the first time in British India. These rectifiers were the latest type, water cooled by closed circuit re-cooler system. All switching operations at Sub-stations

(Minambakkam and Egmore) were carried out by the Power and Traffic Controller from Egmore by remote control.

10.3.3 Rolling Stock

The initial rolling stock consisted of 17 EMUs of three coaches each, with articulated bogies, and four electric locomotives. Two battery tenders were also provided to work the locomotives in the sidings at Madras Beach. By November, 1934 these sidings were also electrified and the battery tenders withdrawn.

10.3.4 The electrification of railways in Madras suburban areas resulted in accelerated real estate development adjacent to the Railway lines and value of property appreciated considerably in Madras - Tambaram area.

10.4. D.C. ELECTRIFICATION OF LINES IN AND AROUND CALCUTTA

10.4.1 Electrification at 3000 V DC.

At the time the electrification work of the first line in the suburbs of Bombay(at 1500V DC) was in progress, the consultants M/s Merz and Mclellan were instructed by the East Indian and the Eastern Bengal Railways to investigate the possibilities of electrification of certain lines in the neighborhood of Calcutta. The report submitted by the consultants in August, 1924 concluded that there was no financial justification for electrification of the suburban and main line sections around Calcutta mainly on account of the low cost of coal, the small volume of traffic and its division between several lines. They observed that it is only after some effective schemes by the Railways to improve access from the city have been carried out by extension of the suburban lines into and through the center of the city, that there could be a large increase in the suburban traffic. After that electrification would be necessary to solve the problem of dealing with the increased traffic, which would also be financially justified.

10.4.2 It was only in 1953 that IR again considered electrification of railway lines in Calcutta area. Based on a world study tour of a group of railway officers, 3000 volt dc system was chosen in preference to the 1500 v dc system, then in operation in the Bombay and Madras areas. Howrah-Sheoraphali-Bandel section, including Sheoraphali-Tarakeshwar branch line, was taken up for electrification, which was completed in Dec.1957 and formally inaugurated by Shri Jawahar Lal Nehru, the then Prime Minister of India. Soon thereafter, Bandel-Burdwan electrification was inaugurated by Dr. B.C. Roy, the then Chief Minister of West Bengal, on 31.8.58.

EXTRACTS FROM M/S MERZ & MCLELLAN REPORT GENERAL FEATURES OF ELECTRICAL WORKING.

1. "It is also certain that whatever be the pressure at which electricity is delivered in the coaches, the current actually used by the motors on the train must be at a moderate pressure.

   The questions for consideration, therefore, are:-

   The form in which electrical energy shall be used on the trains, i.e. a selection between the following alternatives:-

   (a) Energy transmitted and delivered to the trains in the form of high tension alternating single-phase current, transformers carried on the trains being used-for reducing the pressure to one suitable for use on the motors.

   (b) Energy transmitted as high-tension three-phase alternating current, and converted to direct current, at moderate pressures, in sub-stations located at suitable intervals alongside the track, the trains in this case using direct current and carrying no transformers.

   (c) Energy transmitted as high-tension three-phase alternating current transformed at wayside substations to three-phase alternating current at moderate pressure and distributed as such to the trains- which would, in this case, be equipped with three- phase motors".

2. "The selection can first be simplified by discussing alternative (1c)-i.e. the use of three- phase current on the trains. Several successful examples of this system are in operation on main line, and mountain railways-notably in Switzerland and Italy, but where suburban traffic is heavy and frequent and where the approaches to terminal stations involve any complications of track, the provision of at least two live wires at different pressures over each track-which are essential to this system- is a fatal objection to it.

   A further disadvantage of the system is that the characteristics of the three phase motor, while very suitable for main line operation at constant speed, are by no means the most suited to the operation of a suburban system where there are a large number of stops to be made. The special characteristic of the three phase motor is that it will run at a nearly constant speed and it is not particularly suited for variable speed work which is a feature of suburban services."

3. "We have satisfied ourselves that, in the case before us, it would not be commercially desirable to adopt the three-phase system. Moreover, it is not the cheapest of the three systems to install for suburban operation apart altogether from the question of its suitability for operating suburban traffic.

   This leaves the present choice between :-

(a) The single-phase system, and

(b) The direct current system.

The comparison of these has formed the subject of much controversy. It is, however, generally agreed, that from an engineering point of view, each is capable of dealing with heavy suburban traffic, and, in fact, is doing so successfully – the single phase system in a few, and the direct current system in a large number of instances. The broad difference between the two systems lies in the fact that whereas the single phase motor equipment on the trains is heavier and involves the use of transformers making the equipment on the trains considerably more costly, the direct current system, since it usually involves a number of substations, which are somewhat costly, involves greater cost in transmitting current to the trains. The tendency, therefore, is for the single phase system to appear to be better in relative advantage, the greater the length of track and the lower the traffic density, whereas the direct current system is seen to advantage if the traffic density is high and the lines to be equipped comparatively short."

4. "Where a heavy traffic is expected to develop, the direct current system would, generally speaking, be the correct choice. The denser the traffic becomes, the more justifiable would the choice of the direct current system."

5. "Since the direct current system is both cheaper in first cost and cheaper to operate, we recommend its adoption on the lines considered in this report, more especially as the traffic is growing, and hence the advantages which justify its choice will increase rather than the reverse. From an operating standpoint the advantages are distinctly in favour of the direct current system.

   We now have to consider the most suitable pressure and the best method for conveying the direct current to the trains."

6. "In the last few years, great advances have been made in the design of direct current motor equipments. Owing to the inherent simplicity of the series direct current motor, it has been possible to increase very much the voltage which can be used. The voltage which can now be applied to one motor is about 1,500 or even 2,000 volts. Another development has been the employment of large power upon the motor coaches, which necessitates dividing the motor equipment into four motors instead of two. Advantage has been taken of this in conjunction with the greater voltage per motor now practicable, to increase very largely the voltage at which power in the form of direct current is supplied to the trains. In fact, it is now commercially possible to adopt a line voltage of 3,000 volts giving a maximum voltage upon the motors of 1,500 volts each."

7. "We have specially investigated both the use of a 1,500 volts overhead wire and a 3,000 volts overhead wire for the lines considered in this report. The higher the voltage, the smaller is the number of substations required upon a given network of lines. While in the case of the 3,000 volt scheme, there is a considerable

reduction in the number of substations required, the converter plant in each substation is more costly both in capital outlay and operating charges. There is a saving, however, in the case of the electrical equipment of the track".

"For those of your lines under consideration the 1,500 volt scheme is nearly as cheap as the 3,000 volt scheme, and as it is more flexible for multiple units working, we recommend its adoption."

SIGNIFICANCE & RELEVANT FACTORS OF ELECTRIFICATION ON SWISS RAILWAYS

1 HISTORY

In about 1890, encouraging results obtained from the electrification of tramways and the first mountain railway as well as from the research work undertaken by E.Huber-Stockar showed technical feasibility of equipping standard gauge railways for electric traction using High voltage ac. On 16th Jan.1905, trials commenced between Seebach and Affoltern of the first single phase locomotive equipped with single phase ac/dc converter. At the same time Mr. H. Behn-Eschenburg had also successfully tried an ac single phase series motor (1903). A second locomotive was built for trials on Seebach-Wettingen line equipped with single phase series ac motors operating at 15 cycles. Loetschberg line and Engadine lines were opened for electric working in July, 1913 on single phase ac. It may be interesting to note that Loetschberg line is standard gauge 15 kv 15 cycles which was later standardized to 16 2/3cs when the surrounding SFR lines were electrified), but Engadine lines are meter gauge 11 kv 16 2/3 cycles. At about the same time Prussia (1912) Baden and Bavaria had adopted 15 kv 16 2/3 cycles ac single phase for electrification of their state railways. Austrian, Swedish and Norwegian railways also adopted the same system.

This paved the way for Swiss Federal Railways to adopt the same for the St. Gothard Line, which had reached capacity saturation with steam locomotives. World War I had erupted in 1914 and impeded all major decisions for investment on railway electrification projects. At the peak of world war I, Swiss govt. and SFR decided to go ahead with the electrification of most difficult mountainous section, Erstfeld-Bellinzona on 15 kv, 16 2/3 cycles ac single phase and to set up dedicated hydro power stations at Ritom and Amsteg for power supply to railways. Severe coal shortage (all imported) during the World War also favoured the decisions to rely on abundant own hydro power. From 1920 onwards, the mountain section of the St. Gothard Line was opened for electric working in stages. On 29th May, 1921, the whole line from Erstfeld to Bellinzona was electrified. SFR had thus concluded that for operation on the heavily graded St. Gothard line, single phase, 16 2/3 cycles, 15000v system would be the most suitable system.

CHAPTER XI

A.C. RAILWAY ELECTRIFICATION

11.0 ADOPTION OF 25 KV AC AT 50 CYCLES

With the success of the 25 KV AC 50 cycle electrification on SNCF(France) and the world wide acclaim it received, this technology was considered seriously for all future electrification programmes covering all the trunk routes on the IR. A team of SNCF experts led by Mr. F.F. Nouvion visited India in June-Sept., 1956 to study the IR plans. The SNCF team strongly recommended adoption of the 25 KV industrial frequency system. By that time, Industrial frequency AC system had already established its superior performance at considerably lower cost compared to 3000 V DC system. This system held out advantages in initial costs as well as maintenance and energy costs, while at the same time improving the locomotive haulage capacity. With the then anticipated growth of traffic the benefits were to be even higher. It was noted that the British Railways too had acknowledged industrial frequency AC as a better alternative. It was also considered necessary to have only one system for the entire railway network on Eastern & South Eastern (SE) Railways. As 3000 V DC had not been extensively installed, sections already energized could be easily converted to 25 KV AC system. **Thus it was in 1957 that Indian Railways finally took the momentous decision to adopt 25KV, 50cycles, Single Phase, AC system for electrification of the railways.**

India was the 2nd country in Asia to have opted for 50 cycles AC for electrification. Though Japan was the first to have opted for 50 cycles AC electrification, but it was at 20 KV as against 25 KV of India. Turkey and Portugal had also experimental short stretches at 25 KV 50 cycles. Hungary had 180 KM main line at 16 KV 50 cycles before World War II and Germany had an industrial railway at 6 KV 50 cycles. Many major railway systems such as British, Chinese and Russian Railways adopted 50 cycle AC electrification much later.

11.1 CONVERSION OF 3000 V DC SYSTEM TO 25 KV AC

Having decided to adopt 25 KV AC system, it was logical to convert the small section already electrified at 3000 V DC to 25 KV system.

11.1.1 Strategy For Conversion

In keeping with the proposed electrification of the Howrah-Kharagpur line and the Howrah-Burdwan Chord line at 25 KV AC, a part of Howrah Yard was energized at 25 KV AC. Electrification of the Howrah-Burdwan chord was completed by early 1965.

The change over had to be executed for the first time in India. There were no precedents elsewhere in the world for similar work. Extensive on-going work of remodeling and modernization of signaling in Howrah Yard made it impracticable to undertake the entire conversion in one `go'. Therefore the conversion was proposed to be done in two stages:

(i) First from Burdwan to Bandel by December, 1964, and

(ii) Finally from Bandel to Howrah by the end of 1965.

The items of work consisted of the following :

(1) Modifications to the overhead equipment :
- Augmentation of insulation
- Increase of clearances

(2) Provision of booster transformers and return conductors.

(3) Modifications to the power supply system and sectionalizing arrangements, the latter involving development of special heavy duty section insulator suitable both for AC and DC working.

(4) Modifications to ancillary equipment affected by induction (including signaling, telecommunication and remote control equipment), and low tension general electrical services.

(5) Modifications to electric rolling stock.

11.1.2 Execution of Work

The work on the overhead equipment, viz. augmentation of insulation, increase of clearances, replacement of section insulators, isolators and the stringing of return conductors, was carried out without disrupting the train services. Most items of work were carried out well in advance of the actual change over of the system of supply. However, there were works which had necessarily to be completed simultaneously with change in the system of supply. On Burdwan-Bandel section such critical work was to be carried out at approximately 30 locations at the time of change over. The first section between Burdwan and Memari was energized on 25 KV AC on 23rd May, '65, followed by Memari to Bandel on 27th June, '65. Once the entire section of Burdwan-Bandel was converted to AC system, AC push-pull WAM3 hauled trains started running over this section, starting from Sealdah/Naihati. After energization of Burdwan-Bandel section at 25 KV AC, it was essential to use dual system rolling stock on Howrah-Burdwan section. Out of a total of 47 DC-electrical multiple units (EMUs) in service, 31 EMUs were modified for dual voltage operation for through services. The remaining 16 EMUs were used for Howrah-Bandel main line trains, till the conversion of the entire system to 25 KV AC. These were later converted for 1500 V DC operation in the Bombay suburban area.

The additional equipment to convert 25 KV AC power into 3000 V DC power was mounted on each EMU in the luggage compartment of motor coach along with a separate pantograph. It was possible for the EMU to collect power at 25 KV AC and feed 3000 V DC to the traction motors. These EMUs were suitable for working both on 3000 V

DC and on 25 KV AC systems. An additional sensing device was provided to prevent any inadvertent operation of wrong pantograph.

11.1.3 EMU Stock for Calcutta Suburban Sections

SNCF, who were IR's Consultants for ac electrification, recommended the use of push-pull loco hauled trains for the Calcutta suburban area. Coincidentally, at the same time British Railways had transformer failures on their new EMU stock. Recommendations of SNCF were, therefore, not overruled and push-pull trains were employed for Sealdah suburbs. Since economics favoured the operation of EMU services, initiative was taken to build ac EMUs, with key design prepared by RDSO. The coaches were built by ICF with imported equipment from UK and Japan. Services on Howrah suburban section on ac traction were thus commenced with EMUs. Gradually pushpull operation was withdrawn even on Sealdah suburbs, replaced by ac EMUs. Locos were modified for main line trains.

11.2 ELECTRIFICATION IN THE INDUSTRIAL BELT

11.2.1 First Phase of 25 KV AC Electrification

AC electrification work was started almost simultaneously, both on Eastern and South Eastern Railways. 110 mixed traffic locos, i.e. 100 WAM1 from 50 cycle group from Europe and 10 WAM2 from Japanese group were ordered. The first WAM1 locomotive then designated as BBM I 20250 (first to be manufactured), arrived at Calcutta harbor on 30^{th} Nov., 1959. 25 KV installations i.e. OHE and substations were still not ready. The second loco 20251 was equipped with standard gauge bogies and underwent full test programmes on SNCF tracks for over a year before being delivered to India (See Photograph).

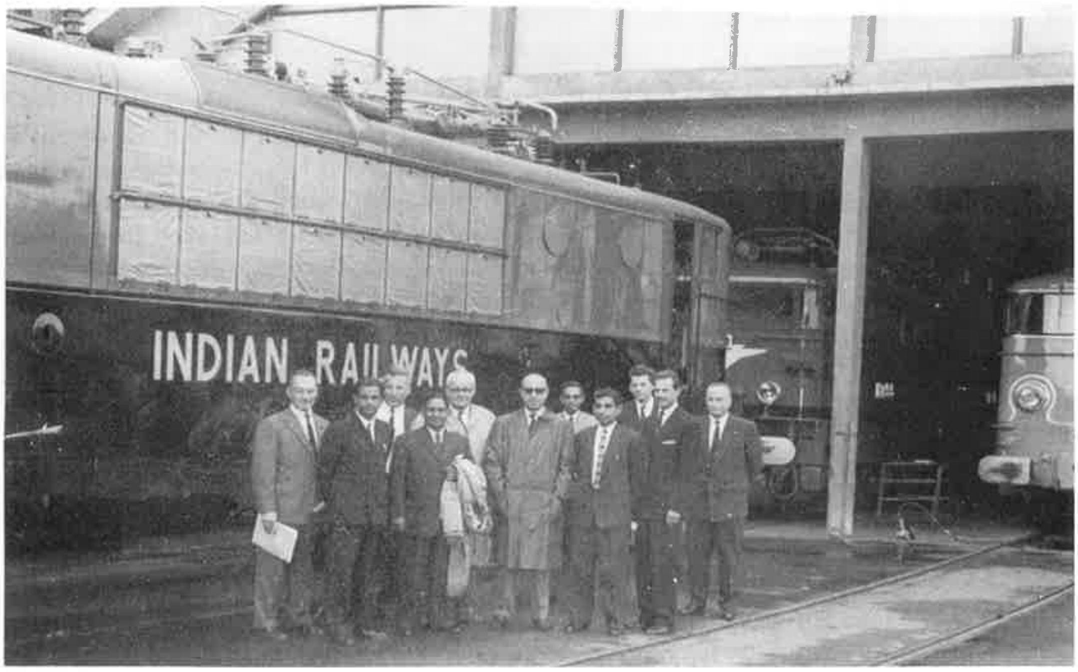


Photo: Locomotive 20251 at Strasbourg shed (SNCF) with Mr. F.F. Nouvion, Mr. H.D. Awasthy and other French and Indian Railway engineers.

The electrification work was considerably behind schedule on the fixed installation side. However as Indian Railways had committed themselves to inaugurate AC traction on 15th December, 1959, a complete sub-station with high voltage transformer and circuit breakers was obtained on loan from SNCF. This was installed in December within ten days at a site near Kendaposi (SE Railway) where an existing 66 KV power transmission line crossed the Dangoaposi-Rajkharsawan railway line. (See Photograph).

Photo: Kendaposi – First 25 KV AC substation supplied by SNCF.

Efforts were concentrated to erect quickly a stretch of OHE originating from this feeding post. On 12th December, 1959 power was switched on and loco 20250 made its first journey on IR track. On 15th December, 1959 the official inauguration ceremony took place. A special steam train and the electric loco ran parallel on a 3 KM double track stretch between the sub-station site and Kendaposi, marking the initial step of electric traction taking over from steam traction.

In the spring of 1960, Asansol electric loco shed started to function. Locomotives arriving from Calcutta harbor were unpacked and commissioned there. These were initially hauled by steam engines over 250 KMs to Dangoaposi. From March, 1960, power from 25 KV OHE was made available on 20 KMs between Dangoaposi and Kendposi and the loco commissioning could be completed. By middle of the year the AC system was gaining shape. Trains began to be hauled electrically between Dangoaposi and Banspani (38 KMs) and the entire line Rajkharsawan-Dangoaposi was inaugurated for electric traction on the 11th August, 1960. Simultaneously, electrification progressed in the Asansol area. On 10th August, Kumardubi feeding post, 19 KMs west of Asansol, was energized along with the 11 KMs line to Sitarampur. Sitarampur-Asansol electrification followed on 29th August. Later in autumn the electric loco shed at Asansol itself was wired and energized to take up normal operation. On the 25th November, the special train for the congress of ECAFE (Economic Commission for Asia and Far East) was hauled by electric loco Nos. 20202+20292 from Asansol via Pradhankhunta to Pathardih. A month later, on 22nd December, 1960 the 58 KMs Asansol-Dhanbad (Grand Chord line) and the 18 KMs Pradhankhunta-Pathardih (Branch line) were formally inaugurated by Railway Minister, Shri Jagjivan Ram, flagging off from Asansol a goods train, composed of 70 coal wagons with 2300 t trailing load hauled by the ER green locomotive No.20270.

As for locomotives, initially two makes were imported – 100 WAM1 from 50 cycles group and 10 WAM2 from Japanese group. Of the 100 WAM1 locomotives, 69(for SE Rly.) was equipped for multiple operation with hose pipes between locos for vacuum and compressed air brakes and the jumper cables for control circuits. Initially they carried screw couplings. These were later modified to centre buffer couplings gradually on SE Railway. The other 31 WAM1 locomotives (for E Railway.) had only the normal equipment for single operation. The change in driving habits for the engine drivers was quite difficult. Slow starts and excessive loads overheated and damaged the electrical traction equipment initially. The situation improved after some experience and special attention given to these aspects during drivers' training programme.

11.2.2 Progress of Energisation

In 1961, electrification was extended from Dhanbad to Gomoh (30 KMs) on Ist of February and eastwards from Asansol to Waria near Durgapur (34 KMs) on 31st March. Asansol/Kalipahari-Damodar-Chakradharpur and Kandra-Tatanagar-Sini sections were energized in two stages on 8th of June and Ist of July respectively, totalling 243 KMs. The official inauguration ceremony took place on 21st of July at Tatanagar. Thus the iron ore trains from Dangoaposi to Burnpur and Durgapur and the coal trains from Dhanbad and Asansol to Tatanagar were hauled by electric locos. The spine of the electrified industrial rail network was in place. From this time Tatanagar electric loco shed operated in parallel with Asansol and gradually took over the locomotives assigned to it.

On the ER Grand Chord line, Gomoh-Koderma section (94 KMs) was energized on 21st of August, Koderma-Gujhandi section (10 KMs) 10 days later and the remaining 69 KMs to Gaya on 13th November, 1961. The year 1962 saw completion of the remaining parts of the initial electrification schemes. On 10th of January the branch line Dhanbad-Kusunda-

Tetulmari was energized. With the inauguration of electric operation on Gaya-Sone Nagar section (76 KMs) on 30th June, Sone Nagar- Chandauli Majhwar section (105 KMs) on 7th of July and the remaining 19 KMs to Mughalsarai on 25th of July, initial steps to the future main line electrification between the capital cities had been taken. During summer the OHE reached the Durgapur Steel Plant. On South Eastern Railway, energizing Chakradharpur-Rourkela section (102 KMs) on 12th February completed the electrification of the industrial belt.

On the South Eastern Railway, the electric operation on Tatanagar-Kharagpur section (128 KMs) started on 4th of January, 1963, which can be considered as the onset to the future main line electrification. By June, 1963, electrification of some branch lines around Adra and Burnpur, totalling 26 KMs, completed the system in this industrial belt which also constituted the completion of the first phase of AC electrification on IR.

By this time the next electrification project for the suburban lines east of Calcutta radiating from Sealdah station had been finalized. Asansol loco shed contributed to the preparation work by equipping and testing a prototype push pull rake as well as commissioning of the WAM1 locomotives.

Gradually railway electrification has spread to other parts of the Indian Railways system, including Northern, Western, Southern, South Central and Central Railways. However, over the years the objective criteria for financially justifying a new electrification project has been changing. Different high level committees were set up to examine the economics of railway electrification and recommend policy directives. The list of various committees and their recommendations in brief are given in Appendix XI - 2.2.-1.

Progress of electrification on IR since its inception in 1925 till 31.3.2004 is given in Appendix-XI- 2.2.-2

11.3 TECHNOLOGY ADOPTION AND DEVELOPMENT

11.3.1 Having decided to adopt 25 KV AC system, Indian Railways obtained basic design from SNCF as 'Transfer of Technology'. An independent organization, called 'Railway Electrification Organization', was set up at Calcutta for absorbing the technology and its adoption on IR, besides working as a centralized construction organization for undertaking electrification works. Far reaching contribution was made by this organization in standardization of various designs and dissemination of newly acquired knowledge on intricacies of RE designs. A manual called 'AC Traction Manual' (ACTM) was brought out, which continues to serves as a master reference book on all matters pertaining to AC Electrification on Indian Railways.

11.3.2 Railway Electrification Organization also laid great emphasis on development of OHE (Over Head Equipment) fittings locally due to shortage of foreign exchange. With the help from RDSO and SNCF engineers based at Calcutta, local industry produced fittings, some of them in workshops rigged up under tin roofing and bamboo matting. These compared favorably with LUCEAT of France, BICC of UK and SAE of Italy. Had the local resources not been tapped, the electrification would not have progressed at a pace and cost to be economically a success.

11.3.3 It will not be out of place to mention the pioneering contribution made by electrification contractors, both foreign and Indian, whose efforts made the electrification pragramme a success. To mention a few:

BICC of U.K.,

SAE of Italy and

NICHIMEN of Japan,

Initial Indian contractors:

KAMANIS,

ECEC,

BEST & CROMPTON.

11.4 SPECIAL-FEATURES OF ELECTRIFICATION ON IR

Indian Railways adopted many innovative technologies and systems to suit local operating conditions and technological developments. Some of them are described below:

11.4.1 Provision of AC/DC Switching Yards

On WR haulage of goods and passenger trains continued with steam traction and later by diesel traction as the change of traction at Virar (terminal station for operation at 1500 V DC) was not desirable operationally. Subsequently CLW built AC/DC dual system locos were introduced for through running of trains on DC as well as AC sections.It was for the first time that dual voltage locomotives were used on IR. On CR it was economical to make use of AC locomotives beyond Igatpuri while operation on existing DC sections continued with DC locomotives. Innovative sectioning and safety devices for facility of changing locomotives in AC/DC switching yards have been employed at Igatpuri.

11.4.2 Electrification of Isolated Waltair Section

This section has long and continuous stretches of steep grades and numerous curves of 5 and 8 degrees. It was built between 1960 and 1967. The advantage of electrification is obvious mainly because of movement of loaded heavy trains in down-gradients, contributing to regeneration of electricity for light trains carrying empties on the up--gradients. A 3-electric loco consist in multiples was used, for the first time mainly for controlling the trains on the down gradients. A contact wire section of 150 sq. mm was employed as against 107 sq. mm for standard OHE.

11.4.3 OHE in Aluminium Alloy

For the first time a composite Overhead Equipment, comprising of 19/ 2.79 mm Aluminium Alloy catenary wire and standard 107 sq. mm grooved copper contract wire have been installed on a stretch of about 500 route KMs i.e. about 1250 track KMs., which after some initial minor problems, continues to give satisfactory service. The use of this composite OHE was subsequently discontinued due to comparative advantages with all copper OHE, especially for ease of maintenance and sharp fall in copper prices. This composite overhead equipment, its design and development, has been a pioneering work. It is not known if anywhere else in the world, this type of overhead equipment has been used.

Again, between 1971 and 1981, a trial of the first all Aluminium Overhead Equipment, comprising of 19/2.79 mm Aluminium Alloy catenary with two standard 107 sq.mm. grooved Aluminium contact wires and Aluminium Alloy fittings was carried out at Bamrauli station of Northern Railway. This was abandoned due to short life span and copper prices coming down in the international market

11.4.4 2 × 25 KV System

IR have introduced 2 × 25 KV auto-transformer feeding system of power supply on Bina-Katni-Bishrampur/Chirimiri coal route of Central and South Eastern Railways, as distinct from the conventional 25 KV system. This pilot project was executed in 1993-94 with the technical guidance from Japanese Railways Technical Services (JARTS). This 2 × 25 KV traction system is already in vogue on the TGV routes of France and Shinkansen routes of Japan. The system has also been adopted in Australia, Russia and China.

With this system, the advantage of high voltage transmission i.e. 50 KV AC is realized permitting at the same time inter-running of standard 25 KV AC electric locomotives. This is achieved by using an additional power conductor on top of the overhead equipment masts with 50 KV being obtained between the overhead equipment and the feeder. Use of return conductor and booster transformers gets completely eliminated. The system was intended on IR on the premise that 9000 t trains would normally run on these sections. However plans to run 9000t were abandoned and not a single such train has been run. The system has not been extended to any other section.

11.4.5 Use of Prestressed Concrete and Wooden Masts

Experimental pre-stressed concrete masts were erected on 37 track KMs at 3 KV DC during 1957 between Sheoraphali and Tarakeshwar on Eastern Railway. This line was later converted to 25 KV AC. Such masts were also erected along about 1.5 track KMs of 25 KV main line near Rourkala.

During an attempt by miscreants to steel OHE wire in 1958 between Haripal and Nalikul, structures in the whole tension length of 1.6 KM collapsed due to shock load. This prompted for the entire length of 37 KM to be later replaced by steel structures. This resulted in a set back to the use of RCC structures for 25 years.

Another experiment of using wooden poles, 7.9 m long and 250-270 mm in diameter, was tried near Rourkela. However these were not treated against white ants or dry rot but only had a steel cap to exclude moisture. These were not implanted in the ground but attached to steel or reinforced-concrete frames, embedded in concrete foundation blocks. All of them, along with the concrete masts, were later replaced by steel masts.

The use of Pre-stressed Concrete masts was again taken up in 1983 by CORE (Central Organisation for Railway Electrification), because of corrosion of steel masts in coastal areas due to aggressive environments, and consequent problems of high cost of maintenance. Spun PSC masts were used this time as they are comparatively maintenance free and cheaper.

CORE placed developmental orders on two firms in November 1983 for 1000 spun PSC masts each. The designs and drawings of required fittings were developed by RDSO.

Spun PSC masts are mainly in use in some yards, loco sheds, branch lines and private sidings on Northern, Western, Southern and South Central Railways. However following problems were experienced.

(i) Difficulty in transportation, handling and erection due to heavy weight.

(ii) Different type of fittings and separate earthing arrangements are needed.

(iii) Spun PSC masts usually get totally damaged and need replacement in case of accidents.

(iv) Some masts get broken from their top upper corners during erection/transportation, and rain water enters the mast.

(v) Wasps and honeybees make honey combs in the hollow portion of the masts, causing difficulties for maintenance staff.

(vi) Metal running inside the mast can not be seen, with the result that continuity of earthing from top to bottom can not be assured visually.

In view of these difficulties, the use of spun PSC masts has been limited.

11.5 SOUTHERN RAILWAY ADOPTS 25 KV AC

11.5.1 The erstwhile South Indian Railway drew up a scheme in 1947 for the electrification of the main line from Madras Egmore to Villupuram and the branch line from Chingleput to Arkonam in the post-war programme. This was reviewed by the Consulting Engineers Messers Merz and Mc.lellon and a revised report was prepared by S.I. Railway in 1949 with further proposals to electrify beyond Villupuram upto Tiruchchirappalli via the main and chord lines. The traffic over the Madras Beach-Tambaram suburban section was increasing rapidly. The scheme of electrifying the third track from Madras Egmore to Tambaram was sanctioned in April, 1954 on the newly regrouped Southern Railway (SR). The main line electrification up to Villupuram was approved in March, 1955. The Electric Traction Advisory Committee, however, recommended the adoption of 3000 V DC system both for this section and the third line between Madras Egmore and Tambaram. This scheme was reinvestigated for adopting the 25 KV AC system towards the end of 1956 after a study of Nouvion's Report on the Electrification of Eastern, South Eastern and Central Railways.

Considering the relative cost and economics and after detailed investigations, decision was taken in November, 1960 that Madras Egmore-Tambaram-Villupuram section should be electrified on the 25 KV AC, single phase system. Tambram- Villupuram section was energised first. (The first electrically hauled goods train ran on 26th March, 1965 and the first express train on 14th August, 1965.) This was also the first section where indigenous (BHEL built) 110 KV transformers were used for substations.

11.5.2 Conversion from Dc To AC in Record Time

The Madras Beach-Tambaram section was converted from DC to AC on 14th /15th January, 1967 (Makarsankranti) in a single operation during the night. The challenge in changing over from DC to AC traction lay in disconnecting the DC feeds and making the AC connections along with booster transformers while keeping the suburban service going with minimum disruption. With meticulous planning, training of every one involved and rehearsals this was achieved in a record time of one hour and twenty minutes. While the last service on the 14th of January ran on DC traction, the very first service on 15th January morning ran on AC traction. Not a single train was cancelled or rescheduled.

11.6 IR ADOPTS SINGLE SYSTEM FOR ELECTRIFICATION - DC TO AC CONVERSION IN MUMBAI AREA

11.6.1 By the time extension of electrification on main line on Central & Western Railways came up for consideration, decision had already been taken to adopt a unified system of 25 KV AC. The issue of converting the then existing DC system on Mumbai Divisions of CR & WR was also considered. However, the enormity of the task, with possibility of disruptions to sensitive suburban sections, deterred the decision-makers to convert this system into 25 KV AC. The changeover would have been possible in smaller sections calling for availability and deployment of dual voltage rolling stock (locos and emus) for the period of conversion. At that time, efficient and cost effective dual voltage rolling stock was not in sight and the traffic levels too were considered manageable with the DC traction. It is probable that decision makers expected that the increase in traffic in foreseeable future could be handled by laying, additional stand-alone suburban corridors which did not fructify. It was decided to keep this area as an island DC system rather than go in for conversion

11.6.2 This necessitated that certain adjoining isolated sections, though came up for new electrification, were kept on DC traction for continuity and flexibility in operation. Mumbai area remained an island of 1500 V DC traction while the contiguous sections, both on Central and Western Railways, were electrified on 25 KV AC, which will also be the system on Konkan Railway, as and when it gets electrified.

11.6.3 The traffic levels in Mumbai area continued to grow almost exponentially, demanding high amount of DC power and reduction in the inter sub-station distances. For handling higher suburban traffic more and more 12-car EMU rakes were introduced posing even higher demand on power requirement, necessitating manufacture of high capacity circuit breakers in Europe where special testing facilities had to be set up for routine tests. Inter sub-station distances were to be reduced to almost unmanageable levels of less than 500 m. It was realized that the DC traction system had reached its limitations in handling such power levels as it became increasingly difficult to discriminate between fault levels and load currents, increasing propensity of fire hazards.

On the main line, goods and passenger traffic between Mumbai and hinterland of the country has to largely pass over the two steeply graded Ghat sections. Traditionally goods trains with loads upto 1200 tonnes and passenger trains upto 12 coaches were run over these sections. With the growth of population and industrial activities loads have gradually increased, which have been handled by increasing the number of locos hauling a single train. The increased levels of traffic demanded running of goods trains with 4000 to 4500 tonnes loads and passenger trains of upto 26 coach composition, needing enormous amount of power to be fed from OHE. Overhead line conductors were already very heavy (645 sq.mm.) and could not be increased further with existing supporting structures. Nor could number of substations be increased further due to higher fault current levels as well as very high cost of substations in Ghat sections.

11.6.4 With these limitations of DC system, changeover to 25KV AC system, having following distinct features, was given a serious consideration.

- It can meet all future long term traffic requirements of Mumbai area, both for suburban as well as mainline operations.
- Haulage of longer and heavier trains resulting in increase in line capacity and rationalization of train loads to match the plain section pattern.
- Steep reduction in number of sub-stations.
- Saving in energy of about 7 % due to reduced transmission losses.
- Increased system reliability due to fast acting protection system.
- Reduction in maintenance costs arising out of reduction in assets.

Development of Gate Turn Off (GTO) thyristors, in the mean time, enabled development of efficient and cost-effective dual voltage rolling stock, which could take care of rolling stock requirements during the conversion period.

With all these considerations, it was finally in 1997-98 that IR decided to convert the island of 1500 V DC to 25 KV AC to fall in line with rest of the country.

11.6.5 Intricacies Involved and Strategy Adopted

Mumbai's total dependence on the suburban services and sensitivity of its commuters make it imperative that the conversion work is meticulously planned and carefully executed so as to avoid any interruption and the resultant chaos in the suburban traffic. Full complement of train services including those increased from time to time are to be maintained all through the long period of conversion. The conversion work has, therefore, been planned in such a way that the rolling stock, OHE, power supply and signaling are suitable for both systems. Following strategy has been adopted for this purpose:

- The entire work has been split into number of convenient phases so that each phase is self sustaining. Entire work has also been split into ON LINE and OFF LINE activities.
- On line activities like modifications required in OHE, signaling and telecom, power supply systems, civil engineering structures etc. are to be carried out during normal maintenance blocks of two to three hours daily. All the systems adopted are such that they can work both on AC as well as DC. Testing of the system is also to be completed during these blocks.
- AC substations with protection systems would be simultaneously made ready.
- Dual voltage rolling stock shall be inducted to cater to the need for each phase. Released DC rolling stock will be used in areas where DC is continuing for the time being.
- Once all these modifications are completed and tested, the changeover will be made during one power/traffic block of three to four hours. During the block AC switching and protection systems will be charged.

At the time of writing (2006), the work of conversion is already under execution, with some sections having been completed. It is expected that the entire work of conversion will get completed by 2008-2009.

LIST OF COMMITTEES WHO EXAMINED RAILWAY ELECTRIFICATION POLICY FROM TIME TO TIME AND GIST OF THEIR RECOMMENDATIONS

1. **Karnail Singh Committee on Fuel Consumption – 1958.**

   As a measure of fuel economy the pace of electrification be accelerated. Share of Electric, Diesel and Steam traction to be 50%, 25% and 25% respectively.

2. **Sahay Committee – 1963.**

   Recommended electric traction on level sections at traffic density of more than 6.9 GMT/RKM/Annum. The breakeven level of traffic on 1 in 60 gradient was worked out as 1.91 GMT/RKM/Annum.

3. **Estimates Committee of Parliament – 77th Report (1974 – 75).**

   16,000 RKM warranted electrification, to be completed by end of 7th Plan (1989-90)

4. **J.A.Raj Committee – 1978.**

   Breakeven traffic level for electrification raised to 30 GMT/RKM/Annum.

5. **Planning Commission's Working Group on Energy Policy-1979.**

   On recommendations of the Committee of Secretaries/GOI, the cabinet gave directive in 1980 to electrify at the rate of 1000 RKM per year.

6. **National Transport Policy Committee – 1980.**

   Recommended break even traffic level of 30 GMT/RKM/Annum.The main routes covering the four Metropolitan cities and high mineral carrying routes to be electrified on priority.

7. **Railway Reforms Committee – 1984.**

   Recommended electrification of at least 15,500 RKMs by the year 2000, according high priority to electrification.

8. **CORREP Report – 1989.**

   Pruned down target for three Plan periods from 1990 to 2005 to 2,510 RKMs.

9. **Khosla Committee Report – 2002.**

   Recommended break even level as 53.64 GMT/RKM/Annum.

PROGRESSIVE ELECTRIFICATION ON INDIAN RAILWAYS
(UPTO 2003-2004)

YEAR	RKM ELECTRIFIED	PROGRESSIVE TOTAL
1925-56	529	529
1956-61	216	745
1961-66 (3rd Plan)	1,678	2,423
1966-69	814	3,237
1969-74 (4th Plan)	953	4,190
1974-78 (5th Plan)	533	4,723
1978-80	195	4,918
1980-85 (6th Plan)	1,522	6,440
1985-90 (7th Plan)	2,812	9,252
1990-92	1,557	10,809
1992-97 (8th Plan)	2,708	13,517
1997-02 (9th Plan)	2,484	16,001
2002-03	455	16,456
2003-04	504	16,960

CHAPTER XII

TRAIN LIGHTING AND AIRCONDITIONED COACHES

12.1 TRAIN LIGHTING

12.1.1 Pre-Electric Era

On Indian Railways the train services commenced with all the amenities as laid down in the 'Cheap Trains Act' passed by the British parliament in 1844. Thus, the practice of lighting the carriages with oil lamps was there from day one. These oil lamps used either vegetable or mineral oil. The successful use of gas lamps on European Railways prompted some of the Indian railway companies to explore the possibilities of this system. It was East Indian Railway which went ahead and installed gas lighting in 400 carriages in the last decade of 19^{th} century, employing a system known as Pintsch's gas lighting system. This system however did not receive acceptability because of high initial investment and operating expenses.

12.1.2 Trials with Electric System (Battery Only)

12.1.2.1 International Scene

Electric train lighting was first attempted in USA in 1872 on a sleeping car of the New York Central, by Battery Only system. The first train to be entirely lit with this system was in 1887.

The Paris-Lyon-Mediterranean Railway Company of France also started experimenting with this system in 1890. Each carriage was provided with its own battery to feed the electric lamps. The batteries were charged from stationary battery charging plant located at terminal stations during the lay over period of the carriages.

12.1.2.2 Indian Scene

The first and only attempt to provide electric lighting in carriages with this system was made by the Rajputana-Malwa Railway Company in May 1901, when the lighting system of all the carriages of a rake was changed from oil lamps to electric lamps. After about 6 months of successful trials, the company decided with the consent of Government of India to extend this system of lighting to all its carriages. The cost of 1 unit of electric Candle-Power-Hour in trains was found to be actually 0.63 pies (1Rupee=192pies) and compared favorably to 0.89 pies then being charged in Bombay (Mumbai) for domestic lighting.

For terminal charging of batteries, an existing 170-amps capacity dynamo, installed in the Carriage & Wagon workshop at Ajmer was utilized. Later on, on 23rd of September 1903, a second dynamo of 80 amps capacity was also added at Bandikui.

This company summarized the experience gained over a period of 3 ½ years as under:

> **"The system has given every satisfaction, both to the public in the matter of excellent lights and to the company in effecting savings in the cost of train lighting, which has considerably come down to a little over half the cost of oil lighting. There is an additional advantage that we can now attach 'Pankhas' (fans) to the same circuit and so provide additional comfort to 1st class passengers".**

This system was used for a few more years, till a decision was taken to go in for Stone's system of self-generation. All these coaches were ultimately converted to the Stone's system in a planned manner.

12.1.3 Axle Driven System

12.1.3.1 International Scene and Origin of Stone System

Central Railroad of New Jersey installed the first axle-driven generator in 1894. However, in England, almost at the same time, the system of train lighting was invented by one Mr. A.B. Gill an employee in the firm of engineers located at Deptford in England and known as M/s J. Stone & Co. This firm then had purchased the patent rights from its employee and gave the system its own name. In this system each carriage was self-contained with its own dynamo and battery and was thus capable of generating electric energy from the motion of the train to which the carriage may be attached. It differed from the earlier systems tried in England where electric energy for the whole train was generated and stored in the Guard's brake van, which restricted the use of electric lighting to block rakes only.

The Dynamo used in the system had to satisfy the following working requirements:

- The rotational speed of the machine was widely variable, while voltage output was required to remain as steady and as close as possible to the one needed by the consuming equipment.
- The direction of rotation of machine was reversible due to change in the direction of train movement, while the polarity of electric supply had to remain the same.
- The machines had to supply a load which was highly variable, and at the same time was required to permit the two battery sets to be connected in parallel to meet the coach load during the train halts.

The design of the dynamo used initially was that of a pure dc shunt generator. The rotational speed of the dynamo and consequently its output was limited to its designed capacity through a special suspension arrangement which allowed the drive belt to slip over the dynamo pulley when the train speed exceeded beyond a certain safe limit. Later on, a design which used two fields was evolved to make the dynamo output self-regulating. In this design, the main shunt field was connected to the output terminals whereas the auxiliary field was connected to a third brush located midway between the main brushes. This auxiliary field assisted the main field at low speeds and opposed it at higher speeds. The rocking brush arrangement was used from the very beginning to maintain the polarity of the output irrespective of the direction of train movement. Initially only over voltage protection was considered necessary. This was provided by use of a fuse in the main field supply to protect the lamps, fans and the lead acid cells from over-voltages This fuse was later supplemented by an over-voltage relay and then by a single over current and over voltage relay, christened as ROB.

12.1.3.2 Indian Scene

12.1.3.2.1 Experience of Jodhpur-Bikaner State Railway

Mr. W. Home, the manager of Jodhpur-Bikaner State Railway was the 1st person to have obtained this system from Stone and Co. and had it installed in his meter gauge saloon during early 1897. He reported on 29th Jan 1898, to the Director of Railway Construction, that he had a small installation of Stone's plant working in his carriage for the last few months but it was too early to pass an opinion as to how this system would last, or what would be the cost of lighting, but opined that so far the lighting quality had been excellent. He further stated that his railway had procured during 1897 itself, an installation of Stone's lighting plant for one complete train set, The arrangement adopted was to provide dynamo and battery only in the front brake van and to work the entire train as block rake receiving electric power from front brake van. Any extra carriage if necessary could still be attached in the rear. All lamps used in this experimental train initially were of 10 candlepower. The trial train was operated for a year beginning in March 1898, between Marwar Junction and Hyderabad (Sind). After one year of successful trials the balance two rakes on this link were also taken up for conversion to Stone's system of lighting. Only 5 candle- power lamps were used, whereas 1st classes were provided with twin lamp fittings, all other classes used only single lamp fittings.

The success of the electric lighting of these three trains had encouraged them to continue the system and to extend it further.

12.1.3.2.2 Experience of South Indian Railway

This railway had also obtained in early 1897, a set of Stone's electric train lighting plant, consisting of a 25-amp dynamo and a 16 volt battery. The Agent of this railway was quite impressed with the quality of lighting obtained in the trials and engaged Sir George Bruce, a consultant, to advice on introduction of electric lighting. The consultant recommended that all the seven meter gauge rakes consisting of 91 carriages and working the Madras (Chennai) – Tuticorin mail service be provided with Stone's system of lighting.

Based on his recommendations a proposal was submitted to Government of India in December 1898 to convert in all seven rakes each having thirteen carriages, since the system was found to be cheaper than Pintsch's gas system. The proposal was approved by the Director of Railway Construction.

The plants required for these rakes were received in January 1902, and installation work completed by the year end. During the service trials conducted on the Madras (Chennai)-Tuticorin Mail, the problem of poor charging of batteries was noted. It was eventually solved by reducing the diameter of the dynamo pulleys.

Thus the honor of 1st carrying out a large scale service trial of Stone's system goes to the South Indian Railway who carried out this trial in 1903, while Jodhpur State railway carried out a similar trial a year later in 1904

12.1.3.2.3 Experience of Bengal-Nagpur Railway

The agent and Chief Engineer of this railway stated on 4th June 1900 as under; " We have now had Stone's electric lighting system fitted in a broad gauge carriage for last one year, which is in working order and lighting quality the most satisfactory".

A proposal was also formulated to provide electric lights in 35 bogie carriages under construction. **This was actually the first recorded instance of provision of fans in India in a passenger carriage.** These carriages were put in service on Howrah-Madras Mail, with inspection facilities only at Howrah. This railway also made an innovation to facilitate easy adjustment of Dynamo output by any fitter on line by fixing a quadrant to the Dynamo which had a pendulum finger that could be moved over the quadrant as the angle of suspension of the Dynamo was changed while adjusting the belt tension. The only limitation of this system was that it required calibration of each Dynamo on a test bed in the workshop at Kharagpore (now spelt as Kharagpur).

12.1.4 Role of Committees

At this stage it would be appropriate to bring out the all important role played by various committees in the creation of the Indian Train Lighting System

12.1.4.1 Locomotive Carriage and Wagon Superintendents Committee (LCWSC)

The first committee to play important role was the LCWSC set up as far back as 1889. In its 1st meeting an overview of the status of train lighting world over, as available in the proceedings of the International Railway Congress held in Milan in 1888, was presented to the members for information.

The 8th meeting considered the details of experience gained on battery only system over Rajputana-Malwa Railway as well as with Stone's system of self-generating coaches over Jodhpur-Bikaner State Railway and South Indian Railway. The concluding remarks of the chairman were as under:

> "The great attraction that there is in India for the adoption of the electric light is that it affords an opportunity of using electric fans. One is reluctant to say that a higher stage will not be reached when such difficulties as have already been encountered and are dared, will be satisfactorily overcome. In England carriages work over very short distances, compared with State and Family carriages in India. The entire conditions are different. The subject is one regarding which we must keep an open mind, merely recording that we have at present scarcely sufficient material on which to form a definite opinion. I think that by the next meeting we shall be able to collect fresh data which will be of very general

interest and may be of assistance in enabling us to form a definite opinion in the matter."

12.1.4.1.1 Final Selection of the System

This subject was taken up in the next meeting i.e. 9th meeting held in Calcutta (Kolkata) from 28th to 31st January 1907, when after consideration of all the reports and discussion, it was resolved as under:

> **"That the general feeling of the committee is that gas still holds its own as an illuminating medium, but that electricity is forced upon them in connection with the cooling of the carriages, and so far the general feeling is, that no system has as yet been tried in India which has given better results than Stone's system and it is the best available option, although the experience is that it has defects, which would like to see eliminated".**

Thus the decision to use electric lighting system was literally forced on the Indian railway companies simply because gas system then could not provide for use of fans, for which there was a pressing demand by the upper class passengers. Provision of electric lighting to third class passengers was incidental as it was found cheaper to extend electric supply from adjoining upper class carriages than to provide oil lamps. The 9th meeting gave a clear signal to railway companies to go ahead with provision of Stone's system in more and more carriages.

The decision to adopt the newly developed Stone's train lighting system was thus taken at the 9th meeting of locomotive carriage and wagon superintendent committee held at Calcutta (Kolkata) on 31st January 1907.

The LCWSC meeting held in 1916 further recommended standardization of the location of electrical couplers and sockets so that coaches owned by different railway company could be coupled together to form a single block rake.

12.1.4.2 Carriage and Wagon Standard Committee (CWSC)

In order to speed up the progress of standardization LCWSC was split up into two groups. The group, which was to deal with carriages, was called CWSC. Its first meeting was held in January 1926 when it out lined an ambitious plan for standardization activities with regard to carriages including train lighting. This committee's membership was similar to that of its predecessor committee and consisted of only mechanical engineers. The committee could however, make poor progress with regard to train lighting work without assistance from electrical engineers. The work done during this phase of first 4 years is hence designated as Phase-1 and that done in next 8 years with assistance of electrical engineers is designated as Phase-2.

12.1.4.2.1 Phase – I

The 9th CWSC meeting held in June 1929 made a very important recommendation to adopt the Parallel Block Rake Double Battery System of train lighting as standard for broad gauge (BG) and meter gauge (MG) Coaches. It was also decided that dynamo and batteries would be provided only on upper class coaches and brake vans, leaving the bulk of lower class Coaches as wired trailers with only light fittings.

The 9th CWSC meeting also recommended to the railway board to nominate two electrical engineers as members of the CWSC to deal with electrical matters. The electrical members took their new assignment very seriously and on 11th November 1929 presented to the secretary CWSC a detailed note laying down a road map to be followed to deal with the issues in a systematic manner and proposed its own agenda. The 10th CWSC meeting held in January1930 approved the agenda as proposed.

12.1.4.2.2 Phase –II

This phase started with 10th CWSC meeting held in 1930 and had full contribution by the newly nominated electrical members. This phase ended with 18th CWSC meeting held in March 1937 when Electrical Standards Committee took over this work. The important contributions in this phase were: -

1. The first IRS specification relating to train lighting dynamos was finalized and was published in 1934 as specification E –1 / 34.
2. The drafts for other IRS specifications were also prepared.

12.1.4.3 Indian Railway Conference Association (IRCA)

Almost simultaneously with the splitting of LCWSC into two separate CWSC and LSC, a separate technical committee was set up under IRCA (Indian Railway Conference Association) in 1928 and was called IRCA committee. This committee had an electrical section as well as a mechanical section, each of which dealt in detail about their respective subjects. The respective standards committee considered the recommendations made by IRCA committee and if approved, presented to Railway Board for orders.

12.1.4.4 Electrical Standards Committee (ESC)

Recognizing the contribution made by the electrical members of CWSC, Railway Board decided to set up this new committee, and also simultaneously to transfer the work of train lighting maintenance to the electrical department of various Railway Companies. It was recorded in the proceedings of the 14th CWSC meeting held in 1933 that electrical department was yet to take full charge of the train lighting maintenance and this process must have taken few more years to complete, hence the delay in setting up of ESC.

The 1st meeting of the ESC was held at Simla from 23rd September to 26th September 1935 and was attended by Chief Electrical Engineers (CEEs) of MSM, NW and EI railways only. The secretary of this committee was Deputy Chief. Controller (Standardization) Railway Board, Simla. The recommendations made by the ESC covered all aspects of train lighting. Later on, this committee took over the standardization work for Air Conditioned Coaches also.

12.1.4.5 Maintenance Study Group for Train Lighting and Air-Conditioned Coaches (MSG - TL& AC)

Initially this review group took up issues connected with air-conditioned coaches only, but later on from 1981 onwards it also started reviewing the performance of 110-VDC and 24-VDC non-air-conditioned coaches, thus relieving the ESC from its workload relating to these subjects.

12.1.5 Evolution of the Indian system

The adoption of Stone's system was preceded by a decade during which many Indian Railway Companies used this system on trial basis to gain first hand experience. The system as available from western countries was oriented towards the concept of each coach being a self-contained unit and capable of functioning independently, whereas in India there was a vast disparity in the loads of upper classes and lower classes. The load of a typical upper class was six times the load of a typical lower class coach. Also a rake then had ten coaches out of which upper classes were one or sometimes two and the rest were all of lower class. Each rake however had two brake vans. In order to save initial capital investment it was felt that there was no need to provide dynamos and batteries in all the ten coaches and it would be cheaper to provide these only in upper classes and both the brake vans. The rest of the coaches could be just wired with electric lights and connected to receive power from the few adjacent equipped coaches on the rake. Thus in India a rake was considered as a basic unit and not each coach as in Europe or U.K.

With only a few equipped coaches on a rake, a strong need was felt to evolve a system which will be very reliable and fail proof. This led to the concept of creating a common bus on the rake to which power from the three or four equipped coaches could be fed and from which all coaches could draw power for lights and fans. There was also a need to ensure charging of batteries on any coach where due to any reason the dynamo provided on the coach failed to generate power. For this purpose an additional main wire was laid which carried power at the generated voltage and which was designated Paralleling Main (PM). Further in order to avoid over loading of batteries of any particulars equipped coach it was also considered necessary to ensure simultaneous switching OFF and ON of the load on all the coaches by having a group control.

These entire requirements were met by creating a set of five through wire system on the rake. The wires were: -

Main positive called paralleling main (PM)

Main negative

Light positive

"ON" wire

"OFF" wire

All dynamos were connected to first two wires and all lights were connected to second and third wires. The last two wires were purely used as control wires to operate magnetic load switches provided on each coach. The system where a rake formed a basic unit instead of coach came to be known as:

"PARALLEL BLOCK RAKE DOUBLE BATTERY SYSTEM" and was popularly known as the Double Battery (DB) system

12.1.6 Salient Features of the System

Before proceeding further it is necessary to list out a few salient features of the system. These are: -

12.1.6.1 Kent Couplers

The use of 5-core inter-vehicular coupler cables had started sometime before 1929 as drafting of a specification for these cables was taken up for the first time by the IRCA electrical section in its 2nd meeting held in 1929

This cable had an overall diameter of 0.95inches and was required to be capable of withstanding a pull of 150 lbs without any strain being transmitted to the cores. A bending test, around drum of 11.4 inches (12 times the cable diameter) was also specified.

BG coaches till 1937 had only one set of Kent couplers at each end of the coach. The 3rd ESC meeting held in 1937 recommended the use of two sets of Kent couplers, and also specified the use of 15 way junction boxes in place of 5 way junction boxes. MG coaches however continued to use one Kent Coupler at each end of the coach.

12.1.6.2 Lamp Resistance

This resistance was introduced in Indian system of train lighting with the DB system. It was meant to maintain a voltage difference between battery-on-charge and battery floating with load. Its value could be adjusted depending on the load of the coach, so that when passing full coach load a drop of 8v was created. This facility improved the coach lighting and ensured proper charging of the battery on charge.

After introduction of the Simplified System, a Lamp Resistance Cut-in Relay was also introduced which shorted the lamp resistance automatically each time the coach came to a halt, thus restoring the lights to full brightness during the halt. These relays after few years in service went out of use mainly due to neglect, and further as it was felt that operation of these did not make appreciable difference to the quality of lighting available inside a coach.

12.1.6.3 Magnetic Switches

These switches were Guard controlled and enabled him to simultaneously operate lights and fans by use of "On" and "off" wires provided in all coaches. This was an innovation designed by Indian engineers and was only applicable to rakes, which did not have all coaches equipped. These magnetic switches had copper coils to operate heavy contactors.

12.1.6.4 Standardisation of Dynamo & Battery Capacities

As already mentioned Indian Railways started with a huge variation in the loads of upper and lower classes. The rake was thus considered a unit and was really a group of equipped and wired coaches. This led to the concept of using standard size of dynamo and battery. The standard capacities of dynamos and batteries as recommended by CWSC in 1930 were as under:

Gauge	Dynamo in Amps per equipped coach	Battery Capacity in Amp Hrs. per set	per coach
Board	120*	300	600
Meter	80**	220/250**	440/500**

* Dynamo capacity modified to 100 Amps in 1936.

** Dynamo capacity modified to 60 Amps and Battery capacity to 200 Amp. Hrs. in 1952.

For Narrow gauge the general feeling was that on N G Coaches, the size of dynamo and battery sets to be provided would depend purely upon the length and character of the particular train and as such no standardization was possible. It was only in March 1953 that 11th. ESC meeting recommended the use of 40 amps dynamo and 120 Amp Hrs. battery sets as a future standard.

12.1.7 First Efforts to Change Over to Single Battery (S.B.) System

The Double Battery (DB) System encountered its first serious challenge in 1949 when ESC recommended the adoption of Single Battery System. This system used a shunt dynamo in association with external voltage regulator. The ESC even recommended the provision of SB system in all new builds, but the Railway Board while accepting the recommendation, restricted its provision to only new light weight Schlieren coaches, which were then to be imported from Switzerland. The ESC had anticipated the likely hood of the presence of circulating currents when SB coaches were put to work in parallel with DB coaches on the same block rake. In order to limit this current ESC had even recommended the provision of a small resistance in the negative circuit of the SB coach. The recommendations of the committee were put up to DME who was not convinced of the recommendations of ESC, and put up the proposal to CRB, who passed the following orders

"I accept this. In fact the balance (economic and technical angle) is all in favour of DB system."

12.1.8 Growth of Loads

12.1.8.1 Coach Loads

Initially during the trial period up to 1907 there were no fans, but only lights in all coaches. Fans were provided in upper classes (1st & 2nd) only after 1907. The fans in inter classes were provided in 1937 and in the third classes in 1950. In 1955 additional fans were provided in 1st classes, to ensure that there was one fan for every sleeping berth. Provision of external lights was made quite early in the four-wheeled stock to augment the platform lighting at non-electrified wayside stations. External lights were introduced only in 1951 on the newly built lightweight metal body coaches at the rate of 8 lights per coach.

12.1.8.2 Coping with Increased Rake Loads

The rake loads, having increased drastically after 1949, called for urgent steps to increase the power supply capacity of the rakes. While search was going on to find a better system, as an interim measure stress was laid to equip more coaches with dynamo and battery. It was decided that:

- All new coaches placed in service up to March 1957 should be equipped with dynamos and batteries and the position should be reviewed before expiry of this period.
- Railways should take opportunity during POH (Periodical Over Haul) to improve the ratio of equipped to unequipped coaches.

From 1959 onward, all new coaches were built as equipped coaches. All the new dynamos produced indigenously were used to meet requirement of new coach building programme and large-scale reclamation was done to keep the existing dynamos in working condition.

12.1.9 Indigenous Production of Train Lighting Equipments

Even when Stone's system was installed on experimental basis in 1897/1898, practically all the train lighting equipment were imported from England. By 1951, indigenous manufacture had commenced for dynamo belting, lamps, Kent couplers, junction boxes, push button switches and carriage fans. By 1955 some more items were added including C.I. fuse junction boxes, lamp resistances, auto- cut-in switches and magnetic load switches. Different manufacturers were approved for different items, following being prominent among them:

12.1.9.1 Dynamos

- M/s Stone India for 100amp. And 60amp. Dynamos.
- M/s Beni Engineering Works for 100amp and 60amp Dynamos.
- Railway Workshop, Ajmer (In house)

12.1.9.2 Lead Acid Batteries

- M/s Associated Batteries Manufacturer (Chloride & Exide)
- M/s Standard Batteries
- M/s Amco Batteries

12.1.9.3 Dynamo Belts

- Messrs Bengal Belting
- M/s B.N. Rubber Works, Delhi
- M/s Oriental Rubber Industries, Mumbai

12.1.9.4 Carriage Fans

- M/s Jay Engineering Works (Usha Fans)

- M/s Orient
- M/s IEW
- M/s Stone India
- M/s Matchwell (Kassel)

12.1.9.5 Switchgear (including auto cut-in-cut-out, magnetic load switches, and over voltage over charge relay (ROB)

- M/s Stone India
- M/s IEW
- M/s Beni Engineering Works

12.1.10 Problem of Thefts and Vandalism

Soon after independence, theft of train lighting material from coaches in service, which were initially only nominal and restricted to dynamo belt and lamps, gradually grew to unmanageable proportions. By 1965, the thefts from cables, switch-gears and batteries located on the under frame had reached alarming proportions. Only a few Mail and Express trains, which were closely monitored, had some semblance of lights and one could see a large number of entire passenger trains passing through in total darkness at night. It forced a quest for theft proof systems.

12.1.11 Evolution of Simplified System

Based on recommendations of the XXIII ESC meeting held at Lucknow in 1966, a special duty officer was posted exclusively to deal with train lighting problems to work under the guidance of RDSO. In a short period of four months RDSO produced a very exhaustive report entitled:

> **"Evaluation and Performance of Double Battery Parallel Block 24V DC Train Lighting System on Broad Gauge"**.

This report became the basis of all future developments in train lighting system. In a way this report became a **Historic Milestone and a Bible** for Train Lighting. The significant changes that took place included:

- Introduction of silicon blockers in place of the auto-cut-in cut-out switches.
- The replacement of magnetic load switches by manually operated load switches.
- Rewinding of existing dc dynamos as alternators and use of Rectifier Bridge for conversion to DC (Direct Current). A demonstration machine was produced at Alam Bagh shops under RDSO's guidance by rewinding an existing dynamo.
- Replacement of copper wiring by aluminum wiring.
- Replacement of 15-way Junction Boxes with Metal Clad Boxes with Cartridge Fuses.
- Provision of Fuses both in positive and negative mains and light and fan distribution circuits.

- Recommendation of simple testing procedure by use of two lamps method for detection of earth on any polarity of coach wiring.
- Use of wire gauges to select correct fuse wires for use in various circuits
- Replacement of copper field coils by aluminum coils in dynamos and fans
- Segregation of Positive and Negative Mains on new builds. Railways were also advised to carry likewise during their next POH of coaches.
- Use of PVC cable instead of VIR cables and that too of nominated colors for each polarity
- Each polarity to be fixed on different wall of the coach in formed cleats of treated wood or of PVC to replace untreated parallel wooden cleats
- Wiring on coach body sidewalls to be secured by PVC insulated aluminium clips.
- Large-scale introduction of anti pilferage devices to make it difficult to remove the components targeted by the thieves.

The 24th ESC meeting held in September 1967 at Lucknow recommended that this simplified system be adopted for general application by the coach-builders, and also employed on existing coaches.

12.1.12 Impact of Implementation of RDSO Report

As a result of implementation of this report, following major systems got evolved:

12.1.12.1 Single Battery System (SB System)

The replacement of auto cut-in cut-out switch by Silicon Blocker resulted in all the coaches being converted to SB system as both batteries had to be permanently connected in parallel, and for all purposes, behaved as a single battery. This system differed from the earlier SB system, as dynamos were all inherently regulated and there were no external regulators. The lamp resistance was shifted to be in series with the load. As this resulted in dim lighting under stationary conditions, the lamp resistance were later replaced by selenium rectifier, which offered a 4 to 6 V drop in the forward direction from no load to full load. These were called the Selenium Lamp Ballasts. Only a limited number of these were put in service during the period in 1968 to 1970. The value of the lamp resistance drop at full load was adjusted to a value of 4 volts in place of existing 8 volts value in use.

12.1.12.2 Slipring Alternator

It was developed with a view to utilise the existing dynamos and to have a machine, which will need much less maintenance. In this machine the existing commutator was removed and in its place sliprings were provided. The Alternator winding was designed by using existing coils of DC machine and the Alternator Slip Rings. This alternator could give 80% additional output and the inspection covers could be sealed.

12.1.12.3 Code of Practices

To implement the recommendations Codes of Maintenance practices, laying down simplified procedures for field staff, were issued which played significant role in effective propagation and adoption of the system.

12.1.12.4 Painting "Aluminum" Wherever Employed

As the thieves were looking for only copper, the word "Aluminum" was painted on wiring, field coils of fans and Dynamos wherever it was employed. Treating it as a bluff thieves still meddled with them but ultimately gave up.

12.1.13 Aluminium Cables for Coach Wiring

In order to tide over very acute shortage of foreign exchange, the Government of India decided in 1961 to use only indigenously produced aluminium conductors in place of imported copper conductors. Equivalent cable sizes for aluminium cables to be used for wiring of new coaches and rewiring of existing coaches were decided. Simultaneously wiring layout was also revised to avoid T joints as such joint was not possible with aluminium conductors. In the mean time National Metallurgical Laboratory, Jamshedpur developed an aluminium alloy (designated as NML PM2), which was quite malleable. Its use in cables eliminated breaking of strands.

Use of aluminium cables also resulted in development of crimping process as well as full range of terminal sockets and tools for all sizes of cables up to 120sq.mm. eliminating the earlier used soldering process.

The problem of theft of coach wiring was greatly reduced The changeover to aluminium conductor for coach wiring had been so successful, that even after 40 years of this change and with easy availability of copper cables, the railways felt no need to go back to the use of copper conductors for coach wiring.

12.1.14 Electrical Fires in Coaches

12.1.14.1 Wooden Body Coaches

The wooden body coaches had never posed any serious issue in regard to fires on coaches. However, with the supply position of VIR cables becoming rather acute, PVC cables having fire resisting properties were developed for use in these coaches.

12.1.14.2 Fires in Metal Body Coaches

In 1953-54 when Indian Railway started furnishing the imported metal shell of Schlieren Coaches and later completely manufacturing these at ICF, many well established principles of wiring were overlooked, resulting in many fires. An in depth study to find out the cause of these fires was taken up by RDSO and came out with a report titled **"Fires of electrical origin on all metal coaches".** Some of the important recommendations of this report were: -

- Use of PVC insulated cables in place of VIR cables.
- Provision of fuses on the negative circuits even those of fan and light sub-circuit.

- Re-location of fuses so as to leave no part of the cable unprotected.
- Use of colour code to indicate the polarity to which a particular wire being used belonged to.
- Negative and Positive wiring mains to be separated and each fixed on two different walls of the coach and fixed with formed cleats of treated wood or of PVC to replace untreated parallel wooden cleats.
- Wiring on coach body-sidewalls to be secured by PVC insulated aluminium clips.
- PVC grommets and bushes to be used to protect the wires against abrasion when passing through metal parts of the coach or to light and fan fittings.
- PVC sheathed cables to be used exclusively on under frame wiring to give maximum protection from abrasion. In addition these cables were to be run through flexible armouring conduits or toughing. Fixed type of fans and berth light fittings to have connectors to make connection with coach wiring.
- All fan frame and light fittings were to be insulated from coach body.

In addition to the above changes in the coach wiring practices, importance of following for field maintenance was stressed: -

- Periodical checking of all coaches for Earth with Earth Fault Indicator.
- Provision of only correct sizes of fuses.
- Use of good quality PVC adhesive tape for line repair.
- Reduction in exposed area of the terminal.
- Proper methods were laid down for frequently required emergency repairs to 24 way junction boxes where all internal components have been stolen.

The earliest batches of coaches produced by ICF had provided false ceiling in the lavatory area made out of the following quality of hard boards: -

- Masonite tempered quality.
- Insulated hard board.
- Thermotaxic hard board.
- Treetex hard board.

The lavatory area of these coaches was found to be very vulnerable to electric short-circuiting than the rest of the coach. The hard board ceiling in this area was replaced by Limpet asbestos sheets.

The implementation of all these recommendations resulted in total disappearance of fire of electrical origin from the metal body coaches.

12.1.15 Review of Alternative Systems

12.1.15.1 Self-Generating Coaches at 110-VDC

Although this system was first used on Indian Railways in 1950 when the first lot of fully air-conditioned coaches were built, the idea, of using 110V DC system for train lighting in conventional coaches was considered for the first time by the 14th ESC meeting held in 1956 and again in 1967 by 24^{th} ESC which recommended changeover to 110V DC system. 6 (six) rakes were initially produced. Some salient features were as under:

Alternator Regulators: KEL (Kerala Electrical Ltd.) make 3 KW and 4.5 KW capacity and SPE (I) (Stone Platt Electrical India Ltd.) make of 3 KW capacity.

- Output Control: Magnetic amplifier for KEL machines, and Transistorised Regulators for SPE machines.
- Regulator Setting: At 130-VDC.
- No lamp resistance or Selenium lamp ballast in the lighting circuit.
- Battery: 90 Amp Hrs. capacity of 55 cells formed with 11 nos. 5-cell monoblock units.
- Lights and fans circuits controlled by miniature circuit breakers (MCB).

Based on the satisfactory performance this system has been adopted and by middle of the 1990s Indian Railway was able to eliminate 24-vdc system from its BG system.

12.1.16 Fluorescent lighting

Although fluorescent lighting in trains was first introduced on New York Central in 1938 and on Burlington in1939, it was only in 1956 that it was first considered on Indian Railways in the context of 110V dc being available in the newly built air-conditioned coaches. It was first provided in the experimental air-conditioned rake called Deluxe-express built on EOG system with 110-V AC being available inside the coaches.

During the 2nd half of sixties trails were initiated with this form of lighting for use in 24V DC coaches by employing electronic inverter ballasts of indigenous make. The experience gained did not however generate the level of confidence necessary to encourage general application.

During the 2^{nd} half of seventies the 110V DC trial rakes were provided with this form of lighting, which performed well. Fluorescent lighting has since being used in all 110-V DC as well as in EOG rakes with 110-V AC supply system.

12.1.17 Dynamo Drive

12.1.17.1 Trials with Cardan Shaft Drive

The initial trials with Cardan Shaft drive were not successful. However, when ICF was required to produce a batch of BG fully air-conditioned and BG partially air-conditioned coaches the shaft drive from centre of axle through a Hypoid Gear Box was used. These coaches required 18 kW generators for fully air-conditioned coaches and 12.5 kW generators for partially air-conditioned coaches. The generator was mounted on the under frame and the drive obtained from the centre of the axle where an axle mounted hypoid gearbox was provided. A cardan shaft linked the two. The drive was found to work satisfactorily.

12.1.17.2 V-Belt Drive with Bogie Mounted Dynamos

From the very beginning in 1897 all dynamos on Indian Railway were generally under frame mounted and driven by a flat belt. Due to poor life of belt obtained V-belt driven dynamos mounted on the bogie frame were considered, as this appears to be most promising solution to the dynamo drive problem.

After various tests and trials by different Railways trails with V-belts were extended to all Railways, particular attention being given to trials on such sections that had high incidence of theft. The trial reports were satisfactory. Interest in V-belt drive was again revived after a few years when the 24th ESC meeting held in September 1967, talked about converting the existing dynamos into alternators with slip rings and driving these with V-belts.

12.1.17.3 Use of Endless V-Belt Drive

12.1.17.3.1 Air-Conditioned Coaches

In order to pursue this idea further, fresh proposal of suspending the dynamo from the bogie transom and driving it with endless V. belts was developed. During service trials on a coach life of belt obtained was considered sufficient. This new drive arrangement was there after used in the newly produced 2-Tier Second Class Sleeper Air-Conditioned Coaches built by ICF in 1974 to drive the 18 kW brushless alternators. This arrangement thereafter had been used as a standard drive for all self- generating air-conditioned coaches.

12.1.17.3.2 Non-Air-Conditioned Coaches

The use of endless V. belt drive in ordinary coaches had to wait another 10 years till it was established that the endless V-belts provided in air-conditioned coaches could last 8 to 9 months in service and required only one change of belts from one POH to the next POH.

This drive with endless V-belts and bogie transom mounted alternator was used on trial basis in 1984 in 2nd batch of 110-VDC conventional coaches. Finally it was in February 1988 that it was decided to use transom mounted alternator with endless V- belt drive for conventional coaches with the proviso that V-belts be used in matched sets with correct marking of grade",

It was also decided to develop suitable equipment for MG coaches with the object of using bogie transom mounted alternators with endless V-belt drive for all MG coaches.

12.1.18 Brushless Machines

M/s Best & Compton, a firm based in Chennai, produced the first lot of these machines along with Transistorised Regulators, in early seventies by using reverse engineering on a Japanese imported machine received by ICF for fitment on coaches manufactured for export to Taiwan. Later on other manufactures entered this field. By 1987 following firm were manufacturing these machines in India.

a. Best & Compton (Beacon)
b. Stone India
c. Beni
d. KEL
e. Compton Greaves
f. HMTD
g. Delmot

The Beacon and Stone Regulator had used transistors, Beni regulators had used Thyristor while M/s KEL and M/s Compton Greaves Machine had used magnetic amplifier. Most of these regulators had facility to reduce the alternator output to prevent over charging of batteries.

Initially each machine had to be used with its own brand of regulator. Later on design parameter were laid down and it was made possible to work any machine with a regulator of any other make in the same voltage rating. The regulator-cum-rectifier unit had following functions to perform: -

- Rectifying 3-phase AC output to DC using full wave Rectifier Bridge.
- Regulating the voltage generated to a set value.
- Regulating the output current to a set value.
- Reducing output current of the machine depending on the state of the charge of the battery and thus preventing over charging.

12.1.19 Alkaline Batteries

These were introduced in Indian Railways in early twenties and by 1950 had formed a significant part of the total population (30% approximately) and were preferred as alternative to Lead Acid Batteries. However their use was given up, simply because their indigenous manufacture could not be organised. On the other hand, acceptable quality of lead acid cells from indigenous sources was readily available by 1957. And finally the tight foreign exchange position just prevented their import.

12.1.20 Prime Mover Based Train Lighting Systems

These systems were used in Western Countries from second half of the 19th century i.e. before the advent of axle driven self-generating system. After India gained independence in 1947, the Railway Board sought the opinion of M/s Rendel Palmer & Tritton of U.K., who were then the consulting engineers for Indian Railway; on the question of prime mover based versus axle driven train lighting systems. The consultants in their report came to the following conclusions.

- From engineering considerations, the diesel system was quite practicable, but was more expensive and its adoptions would introduce difficulties in train marshalling.

- In India, the electric loads stipulated were well within the capacity of axle driving and with the co-commitment advantage of cheaper operation, a uniform system, greater flexibility and simplicity. It was therefore advisable to adopt axle driven system.

The axle driven system had its own limitations, particularly on slow speed passenger trains. With a view to over come these limitations, trials with End-on Generation (EOG) system using 110 V were considered. However, the trials were not conclusive.

In 1958, Indian Railways introduced the first experimental air-conditioned train popularly known as Deluxe Expresses. In these rakes EOG system was used to supply power for both air-conditioning and train lighting loads. Electric power was generated in two power cars at 400V, 3 phase, 50 cycles AC located at either end of the rake. The lights and fans inside the coaches worked at 110V AC.

The 23rd ESC meeting held in March 1966 considered the satisfactory performance reports on the deluxe train and recommended its adoption. The railways, however, still faced the Herculean task of providing electric lighting to slow passenger trains. For this purpose a system of mid-on-generation (MOG) was evolved in which one of the second class general compartment located in the middle of the rake was converted as a temporary power car by provision of one diesel generating set, generating power at 110.VDC or if generating at 400 V AC 3 phase 50 cycles had a rectifier set installed to convert the power to 110V DC which supplied electrical power to coaches located on both sides of the temporary power car. This system, which came into use in early sixties, was in use till late seventies when position was eased by the replacement of the DC dynamos by brushless alternators. For BG coaches a 4.5 kW alternator was used in place of 100amp dynamos and for MG coaches a 3 kW alternator replaced the 60amp dynamo. Thus there was a very substantial increase in generation capacity of the block rake. The use of MOG system was then given up.

12.1.21 Linke Hoffmann Bosch (LHB) Coaches

In an attempt to employ the latest, state of the art, technology, Indian Railways took Transfer of Technology (TOT) from the German Firm LHB and started their manufacture at Rail Coach Factory (RCF). Initially, only air-conditioned coaches were manufactured but later also switched to self-generating (SG) type ordinary stock. Because of space restrictions, endless V belt drive has been replaced by Bevel Gear Drive of indigenous make.

Special features of these coaches are: -

- Provision of automatic constant voltage, constant current Insulated Gate Bipolar Transistorized (IGBT) based battery charger.
- Micro-controller/PLC based automatic pump control system with Opto coupler (optical based) dry run protection.
- Micro processor controlled electro-pneumatically operated brake system and anti skid devices for efficient slide free braking.

- Micro-controller based controlled discharge toilets for better sanitation, which start operation after train reaches a speed of 20 kmph.
- Modular, elegantly finished interiors with excellent coach light fittings, reading lights etc.
- Lighter coach weight by about 4.6 T in comparison to conventional ICF coaches.
- Usage of "RADOX" brand electron beam cross linked (irradiated) FRLS (fire resistant low smoke), halogen free cable with excellent resistance to extreme temperature, oil, ozone, weathering and abrasion with very low toxicity. coupler
- Riding index of LHB coaches is maximum 2.5 against 3.3 in conventional IR coaches. Thus lesser jerks/vibrations and better comfort conditions to passengers and lesser failure of equipment due to reduced vibrations.
- On line insulation monitoring in real time mode for visual indication of short circuit/partial leakage in electric supply in coach electric equipment through insulation monitoring device.

12.2 AIR-CONDITIONED COACHES

12.2.1 Introduction and Background

Being the 2nd most populous country of the world and having 63,000 route km of Railway network, the total volume of passenger traffic in India is one of the highest in the world. Bulk of this passenger transportation is by Railways due to higher cost of air travel, and inadequate road infrastructure, especially for medium and long distance routes. In general, medium and long distance passengers prefer rail travel due to higher speed, better level of comfort, and better safety & security. Summer conditions prevail for about 7 to 8 months throughout India (except in mountains). In southern and western India such summer conditions exist throughout the year. Some of these summer months in northern and central India are characterized by dusty winds, and at times with high humidity. Coastal regions are characterized by extreme humid conditions causing profuse perspiration.In contrast winter conditions prevail in North and North Western India.

12.2.1.1 Initial Steps

The first step to provide some comfort to upper classes was taken when fans were introduced in 1905. This facility was extended to Intermediate classes then popularly known as Inter Class in 1936 and to lower classes in 1949. It was only in 1936, that efforts were made to provide a very simple type of cooling facility, but only for upper classes, when ice blocks placed in metal trays were made available at selected points on payment en-route with facility of loading into the compartments of the running trains. This system of providing cooling comfort to 1st. class passengers continued in use till 1960.

12.2.1.2 Earliest Known Air Conditioning Systems

12.2.1.2.1 International Scene

Earliest known air conditioning of railroad coaches was by Pullman Company of their sleeping cars and by the Baltimore and Ohio Railroad of their coaches in 1927-29. By 1931 the latter put in operation first complete air conditioned passenger train. By 1953 there were 20,000 air conditioned coaches on US Railroads.

Heating was necessary and usual under European conditions since the early days of the railways, with individual ovens and/or steam from the locomotive. With the advent of electrification electric heating was introduced progressively. With increasing train speeds traveling with open windows was uncomfortable (air draft noise) and even dangerous. Therefore air conditioning in trains started with the introduction of first high speed train i.e. TEE train sets. Powerful electric supply was the essential requirement. European Railways never considered using Batteries for running compressors. TEE train sets fulfilled this condition by having Diesel Electric Generators for auxiliaries

With the change from steam to diesel and electric traction in the sixties, train heating changed from steam to electric. Thus air conditioning became possible in individual coaches. It was gradually extended to other intercity train sets in the beginning and to individual coaches later with electric power being drawn from locomotive, known as HOG (Head On Generation) system.

12.2.1.2.2 Indian Railways

EPR (Eastern Punjab Railway) came in possession of coaches running with Ice-activated air conditioning system probably as apart of division of assets of erstwhile NWR North Western Railway form Pakistan. In these coaches cold water was circulated in the coils located in various compartments, and a blower fan circulated cool air in the compartment. The cool water was obtained from the tank located below the coach underframe in which ice was loaded at various nominated stations. NWR served the hottest part of undivided India and such coaches were running on Lahore Karachi Mail.

Prior to 1948 some coaches were also provided with mechanical refrigeration system working at 48-V DC. There is however, no mention of such coaches in any records.

12.2.1.3 Earliest Recorded Notes of Various Committees

This subject was considered for the first time in the 14th meeting of the Electrical Section of IRCA and the recommendations made were discussed at the 28th CWSC meeting held in 1948.

The 7th Electrical Standards Committee (ESC) meeting held in 1949 reviewed these recommendations concerning air-conditioned coaches and recorded as under:

> "The committee recommends that as both ice-activated and electro-mechanical systems of air-conditioning have proved satisfactory on Indian Railways, both may be adopted as future standard. Individual railways may adopt either type to suit their particular service conditions. The committee confirms the IRCA resolution that the unit types of conditioners are suitable for MG stock.

During recent years, considerable developments have taken place in America with direct mechanical type of air-conditioning; the compressor being driven either from the carriage axle or by a diesel engine. A combination of the ice-activated system with an axle driven compressor, would offer many advantages. It is therefore recommended that trials be carried out with these equipments to gain experience in considering their suitability for use in the country. The Senior Electrical Engineer of EP Railway will act as a co-ordinating officer."

The Railway Board (RB) pended the decision on the question of selection of a standard type of equipment until it was decided as to what extent air-conditioning was to be introduced. The trials recommended by ESC with the hybrid system were however, permitted to be carried out by SEE of EP Railway provided a suitable opportunity occurred.

The 8th ESC meeting held in 1950, after discussing this subject recorded the following:

> "The committee examined the report submitted by the Senior Electrical Engineer of EPR. Since the last meeting, no opportunity has offered for installation of fresh air-conditioning equipment on coaching stock. The committee feels that until some definite programme has been laid down for the construction of air-conditioned coaches, little progress can be made with the trials proposed by the 7th ESC meeting. In view of the financial stringency and the fact that there are over 35 sets of air-conditioning equipment available with railways at present, the committee feels that it is not an opportune time to embark upon new trials for the purpose of determining a standard system for Broad Gauge (BG) coaches."

The origin of 35 sets and the type thereof is not mentioned any where.

12.2.1.3.1 Refrigerated Vans

Before 1949, Indian Railway had been using ice-cooled Refrigerated Parcel Vans for carriage of perishables such as fruits and vegetables. These vans used a straight ice system i.e. the use of wet ice only, without any equipment for pumping cold meltage, as in the case of ice-activated system described earlier. The IRCA resolution had suggested use of a system similar to that used in ice-activated coaches in these vans.

Digressing from the subject of Air conditioned coaches 7th ESC also decided as under:

> "The committee consider that the straight "ice system" is best suited for the transport of fruits, vegetables and similar commodities and that any further standard design of Refrigerated Vans shall be based on this arrangement.
>
> This system is, however, unsuitable for transporting frozen, meat, fish, etc. which require a much lower sustained inside temperature. Such temperature can only be obtained and maintained throughout the run by the provision of direct mechanical or full electro-mechanical type of refrigerating equipment, with automatic temperature control."

The RB approved this recommendation and advised the Central Standards Office (CSO) to base any further designs accordingly. During mid sixties about a dozen Fish Vans were built in various workshops of Indian Railways using diesel engine driven direct mechanical refrigerating plants.

12.2.2 Construction of Self Generating Wooden Body Air-Conditioned Coaches

Ignoring the recommendations of 8th ESC Railway Board (RB) came up with a programme to build 14 nos. BG fully air-conditioned and 36 Nos. BG & MG partially air-conditioned self-generating coaches on a priority basis

12.2.2.1 Fully Air Conditioned BG Coaches

Railway Board in 1950, and the plant required was ordered on M/S J Stone on turnkey basis, who inturn imported it from UK. The air-conditioning plants were of 5-ton capacity, used open type compressors made by Carrier of type 5F-30, and were coupled directly to a 110 V DC 8.75 HP motor. The power generating plant, rated at 18 KW at 135 V consisted of a DC generator directly coupled to a 20 KW, 400-V 3 phase AC motor and driven by a propeller shaft through an automatic centrifugal clutch combination from a Bevel gear box located on the bogie head stock. The Bevel gear box was inturn driven from coach axle using cogged V-belts. The propeller shaft had built in universal joints to take care of any lateral or vertical movement. These coaches were provided with a single battery of 56 nos. cells each of 330 Amp. Hour capacity. The entire plant was of underslung type except for the air handling unit which also carried electrical heating elements. This unit was located in the ceiling over the luggage compartment and passage space while the electrical and air-conditioning control panel was located on the coach floor and was accessible from the common passage. The power supply for the lighting circuit was taken from battery through a carbon-pile type voltage regulator, which ensured a regulated voltage to the lights irrespective of the actual lighting load. In stationary condition the 20 KW 3 phase 400 V AC motor was used to drive the plant for pre-cooling purpose from external power source.

These coaches had large underslung water tanks and an electrically driven air pressure controlled Water Raising Apparatus (WRA) to raise the water to a small service reservoir located in the roof of the lavatories.

These coaches consisted of three Coupes and two four berth compartments a common corridor into which all air-conditioned compartment doors opened. All the lavatories were located near the coach end-panels and could be accessed through common passage. The layout provided sleeping accommodation for two coach attendants.

The work of building these coaches was equally distributed between Matunga Workshop of Central Railway (CR) and Kharagpur Workshop of South Eastern Railway (SER).

It was subsequently (in 1953) decided to use 110V DC for BG fully air conditioned coaches. Since then all coaches of this type have been built using this voltage.

12.2.2.2 Partially Air-Conditioned Wooden Body BG and MG Coaches

In 1952 a decision was taken to build 36 BG and MG partially air-conditioned self-generating coaches using 24-V DC system. These coaches accommodated eight passengers in air-conditioned portion and 8 to 10 persons in non-air-conditioned 1st class portion.

These coaches were provided with a power generating system similar to the standard Train Lighting system then in use and had 540 Amp Hrs Double Batteries along with 2 dynamos. The dynamos used in BG coaches were of 120 Amp capacity and those on MG were of 60 Amp capacity. Underslung air-conditioning plant was used with Carrier compressor type 5F20 directly coupled to a 5 KW DC motor. The forced air-cooled Condenser was also underslung, with compartment type cooling units. The refrigerant used was Freon 12 (R-12). The cooling units had electrical heating elements for use in winter months. All these coaches were built in railway workshops under supervision of M/s. J Stones. These coaches had poor cooling capacity. It was only in 1960 that ESC realised that the problem of poor cooling was mainly due to poor layout of the coaches where considerable loss of cooling capacity took place due to compartment doors opening directly to outside hot air instead of opening into a common passage isolated from outside.

A new layout, with a corridor into which all air-conditioned compartments opened (instead of opening directly to outside as in the original layout), was developed. This new layout was followed in all subsequent builds of partially air-conditioned coaches. Some of the existing coaches were modified and others, which were nearing the end of their useful life, were condemned.

12.2.3 Experimental Air-Conditioned Train (Deluxe Train)

This experimental train service having air-conditioned 1st Class coaches and air-conditioned Chair Cars was conceived in mid fifties and was meant to be a very prestigious service between Delhi-Howrah, Delhi-Mumbai and Delhi-Madras (now Chennai).The turn key contract for the supply of equipment and supervision of installation including commissioning was given to M/s. J Stone. These wooden body coaches on IRS under-frames were built in railways' own workshops and involved construction of about 90 air-conditioned coaches. This service, popularly called Deluxe Expresses, was introduced in mid 1957. These trains had one air-conditioned 1st Class, five air-conditioned Chair Cars and an air-conditioned Dinning Car. All coaches were designed to receive power at 400 V AC 3 phase from two power cars carrying Diesel Generating Sets located at either end of the train. The luggage compartment and brake van were located in the power car. The only portions of these trains that were not air-conditioned were two brake vans and the Kitchen Car. Kitchen Car however carried electrical cooking appliances and refrigerating equipment. The length of train was limited because of Steam locomotives being the only tractive power available at that time.

Each Power Car had 2 nos. DG sets each of 165 KVA capacity along with its control panel, and provided sleeping accommodation for operating staff. The air-conditioned coaches had under slung plant except for control panel, which was floor mounted and Cooling/Heating units were ceiling mounted in the entrance/lavatory area. The 1st class coach had 5 ton plant with a single 5F30 type Carrier compressor directly coupled to a 10 HP 400 V AC motor. All other coaches had double plant using 5F40 Type compressors coupled to 12.5 HP 400-V AC motors. All underslung Condensers were fan cooled.

These services were very popular in spite of the fact that over-night travel in a chair car was rather uncomfortable

12.2.3.1 End-on-Generation System Standardisation

This subject was discussed by the 23rd ESC meeting held in 1966, when after discussion following recommendation was recorded:

> "The committee recommends that special rakes which work as a set rake and have more than 30 KW load, which is difficult to be satisfactorily met by the conventional train lighting system, can be adopted (selected) for end-on-generation (EOG) system with 400 V, 3 phase, 50 Hz as standard system of generation, 3 phase equipment being utilised for the various components of air conditioning plant, while 110 V AC as standard for consuming equipment inside the coach."

Adoption of this 3 phase supply enabled the use of ac induction motors. Thus use of these robust motors without any brush and totally enclosed type became a reality giving ample benefits. Having a three phase supply eliminated the limitations of starting torque for the compressors and opened up scope for use of robust sealed refrigeration compressors with higher speed, thus affording significant system benefits.

12.2.4 Air Conditioning of Metal Body Coaches

12.2.4.1 Metal Body Fully Air-Conditioned BG 1st Class Coaches

In 1967, the ICF built and turned out 24 nos. of these coaches, which were distributed to various BG railways. M/s. J Stone supplied the plant required for these coaches, and also supervised the installation and commissioning of the same in ICF. The plant used for this batch of coaches was significantly different from that used for earlier batch of wooden body coaches, as the cogged-V belt drive from coach axle was replaced by a Hypoid Gear Drive, the pre-cooling motor was replaced by a battery-charging Silicon rectifier, and the dc machine was replaced by Brushless alternator of 18 KW capacity with a transistorised automatic output regulator The fan cooled Condensers and Cooling/Heating units supplied were of indigenous manufacture, and even though there was no false ceiling as with wooden body coaches, the cooling /heating units were still ceiling mounted in the Lavatory-passage area. The compressor used was still 5F30 and the control panel was still floor-mounted type.

The new drive gave satisfactory service, and by and large this batch was trouble free.

12.2.4.2 Metal Body Partially Air-Conditioned 1st Class Coaches

The manufacture of ten of these BG coaches was taken up by ICF in 1971- 1972. These coaches were provided with 10-berths in air-conditioned 1st Class and another 10-berths in non-air-conditioned 1st Class portion.

Bulk of these coaches had air-conditioning and power supply plant supplied by M/s. J Stone, and installation carried out by ICF. These coaches had used 110 V DC system as used in the earlier batch of fully air conditioned coaches along with Hypoid Gear Drive, but the size of Alternator was scaled down to 12.5 KW. The air-conditioning plant used was also similar but a scaled down version to suit 5F20 compressor.

12.2.4.3 Metal Body 2-Tier Fully Air-Conditioned BG Coaches

So far the facility of air-condition travel was available only to those passengers who could afford to travel by the costliest class. With a view to extend this facility to passengers who could only afford to travel in non-air conditioned 1st Class, these BG coaches were developed which could accommodate passengers roughly equal to two ordinary 1st class coaches. Thus against 24 passengers carried in an ordinary 1st Class, air conditioned 2 tier BG coaches accommodated 44 passengers. This was the first time that Indian Railway undertook the responsibility of design and procurement of plant on its own as against the past practice of depending on M/s J Stone for all these functions.

Initially twenty such coaches were produced in 1975-76. The air-conditioning and power generation plant used in these coaches was similar to earlier batches of metal body coaches with following major departures:

1. For the first time these coaches were provided with Bogie Transom Mounted Brushless18 KW Alternators provided with end-less V-belt drive from the bogie axle.
2. The 18 KW Alternator along with its rectifier and transistorised output regulator was designed and built by complete indigenous effort by M/s. Best & Crompton located in Chennai under the brand name of BEACON.
3. For the first time indigenous refrigeration compressor manufactured in Ahmedabad under the brand name ACCEL was used in self-generating coaches.
4. For the first time air-conditioned self-generating coaches with two sets of underslung air-conditioning plant and two sets of power generating plants were produced.

These coaches were well received by the travelling public and seeing the good response, ICF starting producing similar coaches at the rate of 40 to 50 coaches per annum for the next 10 years.

12.2.4.4 Two Tier MG Air-Conditioned Coaches

Following the success story of BG two tier AC coaches, it was extended to MG in mid eighties. These coaches had only a single set of underslung air-conditioning plant with double set of power generating plant with endless V-belt drive, but with smaller size of alternator than their BG counterpart.

12.2.4.5 Composite Metal Body Air-Conditioned Coaches

With the concept of self generating air conditioned coaches having been stabilised, it was extended to build composite coaches having non air conditioned first class in one half and air conditioned second class sleeper or chair car in the other half. These coaches had power generating and air-conditioning plant similar to that used in 2-Tier coaches.

12.2.4.6 Metal Body 3-Tier BG Air-Conditioned Coaches

A Roof Mounted Package Unit of indigenous make was successfully developed at Rail Coach Factory (RCF) Kapurthala, in early nineties. (Details given in para 12.2.7). This could provide extra head room for a third tier berth. Thus a 3 tier AC coach got evolved. As the package units could work only from 400 V AC 3 phase supply, the initial lot of these coaches was built to work only on Rajdhani Expresses where this power supply was available from the power cars. The self-generating version of these coaches had to wait for few years more and could be produced only in mid-nineties, by which time the floor mounted version of a forced cooled inverter of 25 KVA rating was successfully produced by Indian Industry. However these coaches could accommodate only 64 passengers and it took another 5 years to produce an underslung version of the invertor when the carrying capacity of these coaches could be raised to 72 passengers.

12.2.5 Regular air-conditioned trains

12.2.5.1 Rajadhani Expresses

These trains were conceived to be completely air-conditioned, high speed (120 KMPH) services and were initially provided with only two classes for travel, namely 1st Class and Chair Cars, with fully air conditioned pantry car and brake vans. Each coach had sub pantries with hot cases and other equipment.

As in case of Deluxe trains, a mention of which has been made earlier, two power cars located at each end of the train equipped with generators supply power at 415 V three phase AC. A major improvement in these services took place in mid nineties when 3 Tier coaches replaced the existing chair cars. This improvement increased the popularity of Rajdhani Services immensely, as over-night journey in a chair was uncomfortable.

Initially this service was introduced with 14 coaches, but later the composition was raised to 22 coaches in late seventies. As the power cars generated power at 415 V, it was not possible to distribute the same to all the 22 coaches even if the generator capacity was raised to suit the new loads. As an immediate measure an additional power car was provided in the middle of train. This was followed by development of high capacity power car with 350 KW DG sets (against 250 KW in the existing ones) and generation and distribution voltage increased from 400 to 750 V.

12.2.5.2 Shatabdi Expresses

This service was conceived as a short distance intercity service with only seating arrangement. These services initially introduced in 1989 are fully air-conditioned and, like Rajdhani trains, work on EOG system with two power cars. Each coach has a small pantry with electrically operated equipment.

12.2.5.3 Super Luxury Trains

Mainly to attract foreign tourists these super luxury trains have been introduced on dedicated tourist circuits, providing lavish comfort and unmatched regal luxury. These trains have been benchmarked with the best trains of the world like Blue train of South Africa, Orient Express of Europe and Eastern and Oriental of South East Asia. The technical aspects of air conditioning and power supply have been based on systems already developed for Rajdhani Trains. Currently (2007) following three such trains are in service.

- Palace on Wheels
- Deccan Odyssey
- Heritage on Wheels (Meter Gauge)

12.2.6 Linke Hoffmann Bosch (LHB) Coaches

As already mentioned in Chapter 12 these coaches are being manufactured at RCF with TOT from the German Firm LHB. Initially AC coaches were manufactured for EOG stock of Rajdhani and Shatabdi Expresses but presently self generating type too are being manufactured. Because of space restrictions endless V belt drive has been replaced by Bevel Gear Drive of indigenous make. Roof Mounted Units on these coaches are of altogether different design

In addition to special features of these coaches mentioned in 12.1.21 additional features provided on AC Coaches are: -

1. Roof mounted Microprocessor based AC package unit for the control of AC plants. Development of roof mounted units for other stock has been discussed in the following paragraph.
2. Integrated single switchboard cabinet based on modular system incorporating complete control of train lighting, Air Conditioning, pantry etc.
3. Light weight rigid epoxy molded 60 KVA transformers.
4. For Rajdhani stock state-of-art integrated modular pantry unit

12.2.7 Development of Roof Mounted Package Units (RMPUs)

This type of units was used for the 1st time in early eighties by Hong Kong Metro. On Indian Railways, their use was considered for development of 3-Tier air-conditioned Sleepers for Rajdhani Services for replacing the existing Chair Cars. Initially specifications for these units were in 1990, which was later modified in 1999 and again in 2005. After initial trials and modifications, two Indian firms M/s Sidwal and M/s Fedder Lloyds succeeded in producing an acceptable prototype. The refrigerating medium initially used was R-12, which was later replaced by R-22, and later changed to R-134A,being environment friendly. These RMPUs initially used reciprocating compressors manufactured indigenously by M/s Kirloskar and Denfoss, but later changed to imported scroll type rotary compressors. Each compressor is rated at 3.75 tons. A RMPU consists of two sub-units, each with its independent cooling system, but mounted in the same housing. For winter months each RMPU is provided with a common heater of 6 KW capacity. Thus, each RMPU is rated at 7.5 tons and has a facility to cut-off one of the sub-units under low heat load conditions. Whereas two RMPUs are provided in each 2 or 3-Tier Sleeper or Chair Car carrying over 46 passengers, only one RMPU is provided in 1st Classes carrying 20 passengers.

12.2.8 Major Technology Developments

It is a historical coincidence that the entire development and expansion of air conditioned services to keep up with the demand and expectation of traveling public happened during the post independence period. The electrical design aspects of inter-coach transmission voltage, specification of the diesel-generators, extent of provision of standby diesel-generators, type of inter-vehicular coupler and their safety interlocking are some of the major aspects which were finalized after detailed deliberations and adequate study by of Indian Railway engineers. Some applications of these developments are mentioned hereunder: -

12.2.8.1 Endless V Belt Drive

This type of drive was developed by RDSO for bogie-transom mounted machines in late sixties and was cleared after carrying out oscillation trails. The drive was adopted for 2-Tier air-conditioned coaches built by ICF in mid seventies to drive the 18 kW brush less generator. This drive was very successful and a new set of belts was found to last 6 to 9 months of service. In some coaches the life was even as much as 12 months. These coaches used matched sets of 8 number C-section belts. Poor life of belts was however noticed when after some years of service the pullies had worn-out. This problem was overcome after standards were laid down by RDSO to detect and replace worn out pullies. This drive used all indigenous materials and proved to be much cheaper than imported Hypoid Gear drive used on the first batch of metal body air-conditioned coaches built in late sixties. The success of this drive was one of the major contributory factors for the decision to replace all old non-air-conditioned coaches with 2-Tier air-conditioned coaches.

12.2.8.2 Development of Bulk Inverters

The development of indigenous inverters to convert 110-V DC to 415-V AC 3-phases, with capacity of 25 KVA which could supply power to each RMPU was initiated in mid nineties. Initially only a floor mounted design with forced air-cooling was taken up for development Although 8 Indian firms were involved, but only M/s Siemens succeeded initially and supplied bulk of requirements. This was later followed by M/s HI-REL who supplied 75 units. This design had two significant disadvantages namely unreliability of forced air cooling system and loss of valuable floor space which reduced passenger carrying capacity.

Development of a naturally air-cooled underslung Inverter was then taken up in 2003. This development was completed in 2005, by the following three firms.

Autometers

HI-REL

Medha Sarvo

With this development railways could satisfy the demand for self-generating 3-tier air conditioned coaches for use in other trains. Future builds of air conditioned coaches only employed bulk inverters. As on 1st July 2005 there were 3054 coaches with RMPUs against a population of 1113 coaches with underslung air-conditioning plants. The production of air-conditioned coaches with underslung plant was totally given up in 1996.

12.2.8.3 Electronic regulating and rectifying units (ERRUs)

Majority of the self-generating air-conditioned coaches now use 2 nos. 18 KW alternators, along with their independent rectifier regulating units. As these machines work in parallel to meet the coach load, there is a problem of load sharing as the regulating characteristic is not designed for parallel operation. These ERRUs developed in 2003 is a combined unit for both the alternators which ensures equal loading for each alternator, and are of underslung design.

12.2.8.4 Control Units for RMPUs

These Microprocessor based units, developed in the year 2004, control the temperature of the return air from the coach by switching ON and OFF the compressors in the RMPUs in summer and switching ON and OFF the heaters in winter. They ensure that more than one compressor does not start at a time and the next compressor starts after a preset time delay from the starting of the last compressor. These units are set to maintain 19-21degrees C in summer and 17-19 degrees C in winter

12.2.8.5 Refrigeration Gas

Initially wooden body as well as metal body coaches had used R 12 gas as refrigerating medium. The RMPUs when initially developed had used R 22 gas as refrigerating medium. As both these gases are not environment friendly, the latest RMPUs built after 2004 now use R 134 A, which is environment friendly.

12.2.8.6 Electronic thermostats

These were developed by a number of Indian firms with total indigenous effort in 1987, and were put in service trials during Feb.1988. These service trail and endurance laboratory trails continued for a number of years and it was only in 2004 a decision was taken to stop procurement of mercury in glass thermostats and go in exclusively for Electronic Thermostats.

These thermostats are provided with a single summer and a single winter setting with a differential of 2-degree C. The settings adopted are;

Summer: 25 degree C cut in and 23 degree C cut out

Winter: 19 degree C cut in and 21 degree C cut out

12.2.8.7 Sealed Batteries

Stating from the year 2000, only sealed batteries are provided on all self-generating coaches, in capacities ranging from 330 Amp. Hrs. in full air conditioned 1st classes to 800 Amp. Hrs. in 2 Tier and 1100 Amp. Hrs. in 3 Tier coaches. This has considerably reduced running maintenance man-hours as need to add distilled water has reduced considerably.

CHAPTER XIII

SIGNALLING & TELECOMMUNICATION

13. THE BEGINNING

13.1 The first train which ran on September 27, 1925 between Stockton to Darlington had no signals. Initially the traffic policeman posted along the section signalled the train. In subsequent year the arms of the traffic policemen took the form of signals ushering the era of semaphore signalling in railways.

13.2 GROWTH OF RAILWAY SIGNALLING

13.2.1 In India, the first railway train started its maiden run on Bombay to Thannah (Thana) followed by another section on Howrah to Hoogly. More sections were opened in due course. The Government decided in 1869 that all trunk lines will be constructed to Broad gauge and subsidiary lines to Meter gauge. First MG line on Delhi- Rewari section along with Frauknagar branch was opened on 14th February 1873.

13.2.2 Construction of new lines picked up with formation of State Railway Directorate in 1874. The Companies who were investing in Railway network in India, had emphasis on minimum investment since the railway ventures were considered risky, the traffic was low and paying capacity of the "Natives" was poor. Under these circumstances signalling in the initial stages had the least of the equipment. Hence, the lines were opened based on practices followed at "Home".

13.2.3 The rules governing the opening of Railway were formulated under Railway Act. The Railways Act XVIII was passed in 1854 during the rule of East India Company. This Act was replaced by Indian Railways Act,1879 and subsequently superseded by The Indian Railways Act IX of 1890. The Act provided for framing of Rules for Operation of the Railways- the General Rules, Rules for Opening of Railways and Indian Railways Schedule of Dimensions. The General Rules were first issued by the Public Works Department of the Government of India as circulars in 1880 and revised in 1892 and on 12th March, 1895 (No 6-Railways). These were superseded by the Rules issued by Railway Board's circular No. R.T.49A/5 Dated 4th September, 1906 and brought into force from 1st January,1907. These were again revised to suit the changed circumstances vide Railway Board Circular Nos. 1078-T dated 18th December, 1925; 1058-T dated 30th December, 1927 and 1078-T of 9th March, 1929.

13.2.4 These rules laid down the basic principles for operation of Railways for ensuring safety of the public e.g.

(i) Stations were classified as Block and Non-block for purposes of train working and the conditions for the train to make a journey from one Block station to the next were laid down to ensure safe working.

(ii) The type of Fixed Signals/ Hand Signals to be used and their `Aspects' by day and by night were defined.

(iii) The stations were classified into four Classes, A,B,C, and D, based on the type of train movements. Various constituents of a station which were essential for safe working of trains such as Home Signal, Last Stop signal, Facing and Trailing Points, Fouling mark, Station section, Block section, the Adequate distance was defined and the rules for Opening of Railways specified the minimum complement of Signals for various classes of stations.

13.3 INITIAL SIGNALLING & TELECOMMUNICATION SYSTEMS ON THE RAILWAYS –(1853-1900)

13.3.1 While railways were initiated in India in 1853 and its mileage increased to 24,752 by 1900 but the Rules about operating and opening of Railways were issued by Railway Board in 1906 only. During this time, several Company and State managed systems grew up, based on practices followed in their parent countries. This brought about a heterogeneous growth of widely different signalling systems in the Country.

13.3.2 These signalling systems were elementary in nature as the traffic levels were low and the anticipation of more traffic in future was also lower. Thus barest minimum signalling equipment was provided. In some cases the work was managed in the early stages by "Hand Signals" only.

The fixed signals came into existence in Britain some time in 1841 followed by "disc signals" in about 1860. When the first railway line in India was opened, the signalling consisted of a flag during the day and a lamp in Station Master's office at night. These were followed by disc signals in 1862. Later semaphore signals of "Slotted Post Semaphore Signal" type were introduced with three aspects. In one of the aspects the signal arm was covered by the signal post for a "clear" indication. This led to a major accident as the arm got stuck in the post due to snow and gave wrong signal to the driver of an approaching train. In 1880 a counter balanced two aspects type signal called "Somersault Semaphore Signal" was introduced in Britain with two aspects only. It was so counter balanced that it would assume danger "ON" position on its own, should it get disconnected for any reason. The spectacle and the semaphore signal were separate. These were later on combined to make a composite semaphore signal with the spectacle. In 1892 such combined semaphore signals were introduced in India. These were the fore-runners of the type of semaphore signals we have today. The Signals operated in the lower quadrant. The night visibility was given by a kerosene lamp through the colored roundels of the semaphore arm. The night visibility was affected by weather and proper trimming of kerosene lamp wicks as well quality of kerosene.

13.3.3 The early system of signaling essentially required a "Main" signal for each direction with a single disc/arm for all the lines. This was to be erected at the center of the station in front of the Station Master's office. The signals for the two opposing directions could be mounted on the same post. One outer signal was to be provided in each direction at an "adequate distance" outside all connections referring to the `running lines' of a station. The Points were locally operated by tumbler levers and locked by a bolt and cotter during the movement of a train. The Outer signal was to be operated after the "Main" Signal had been taken "OFF". The points were provided with point indicators for showing to the Station Master and the Driver the setting of the Points. There was no interlocking between points and signals.

13.3.4 The method of working of train from one station to the next was based on "the space interval-Absolute Block system". This required that only one train at a time can travel in a "Block Section" - a portion of line between two consecutive Block stations. This was ensured in initial stages by following the Time Table system according to which the trains had to move on a fixed schedule. There was no means of communication during the first seven years for introduction of Railways in India. Later with the introduction of telegraph system in 1860, Block working was conducted by exchanging Morse messages between the two stations at either end of a "Block Section". An electric wire connecting the two stations at the ends of a Block section was provided for this purpose.

13.3.5 The Telecommunication was most primitive in the form of Morse telegraphy on a physical wire line. This was introduced in 1860, seven years after the opening of the first line. Year 1910 marked the beginning of Railway Telecommunications in the real sense when telephones were provided for voice communication between stations in conjunction with Block instruments. This was followed by introduction of group magneto telephones between stations and operating points such as cabins, loco sheds, yards etc.

13.3.6 This situation continued for many years. The signalling systems were gradually improved as the traffic grew on the lines and need for faster operations at stations became an inescapable necessity.

13.3.6.1 Key Locks were introduced in 1892 at points in place of locking with bolt, cotter and pad lock. The key locks ensured proper setting of the points with the extraction of a particular key. The signals continued to be worked separately and were not interlocked with signals. Some interlocking apparatus was installed in 1893 by M/s Saxby Farmer.

13.3.6.2 The "Main" signal was shifted to outside all connections, one in each direction to provide greater protection. These were called Home signals. Initially operation of Home signals was done locally from near the outermost point. Later the operation of all the Home signals was done from a lever frame at the station. The operation of the Outer signal continued by winches from the outer most points by the points-man after setting the points and exchanging "all right" signals with the Station Master after he had lowered the "Home". Still there was no interlocking between the Points and Signals. The system had disadvantages as the signals could be lowered by mistake before proper setting of the points or the signal may not go back to `ON' position due to contraction of the wire or by outside interference.

13.3.6.3 The Key Locks at the Points ensured correct setting in proper position before the appropriate key could be extracted. However in case the points were damaged after setting, locking and extraction of the relevant key, the concerned signal could still be lowered. This could result in a derailment. It led to installation of Detectors in 1894 by Mr. G.H. List in the wire run of the signals to prevent such instances. These detectors were mechanical devices where the slide of the Home signal engages with extension rods attached to the point switches.

13.3.6.4 List and Morse Signaling was first introduced in 1898 by M/s List and Morse on Nizam State Railway. It had a lever frame with two levers for the Home signals and two for Starters. These had push and pull movement. The relevant key was used to set the points properly thereby releasing the corresponding key for the release of the appropriate Home or Starter signal. The keys were carried to the points manually which was time consuming. Interlocking between points and signals was indirect by using the keys from the Key Locked points. The keys and locks had specials wards and levers, so that only the designated key could operate a lock. The interlocking was further extended to the Signals by providing locks on the signal operating mechanism to ensure that only proper Home signal referring to the set road could be lowered.

13.3.6.5 Various methods and designs of key locks were adopted by different railways for Key Interlocking namely:

- Standard-Key-Locking (1892)
- List and Morse Key Locking (1894)
- Saxby Farmer Key-Interlocking
- Four line Signaling Key Interlocking
- Three Line Signaling Key Interlocking

These were arrangements for locking points and releasing the signals to achieve the desired sequence of operation.

13.3.7 The single arm home signals gave way to bracketed home signals providing for each direction one arm for each passenger reception line and one combined for a group of goods reception lines. The placement of signal arms (relative height and sequence) on the post was designed to permit the driver to know the reception line on which the train was being received for greater safety.

13.3.8 Key interlocking systems were in due course found not suitable for intensive traffic that was developing over many parts of IR. The system got complicated as the number of lines in a yard increased. Besides, transport of keys manually was a time consuming and labor intensive process, not suitable for quick movement of trains. The speed of movement over points with key locked points was limited to about 20 miles an hour only which was a serious restriction.

13.4 DEVELOPMENTS IN RAILWAY SIGNALLING AND TELECOMMUNICATION DURING 1900-1947:

13.4.1 The mileage of railways in Indian became 34,656 in 1913-14 and stood at more than 40,000 miles at the time of Independence (1947). To increase the carrying capacity of trains the number of wagons in train were increased requiring longer loop lines for longer trains. The points had to be located at longer distances from the station. The operation of the Points manually took longer time as also lot of man power. The operations in case of night, rainy or foggy weather would be with increased risk of mistakes and accidents. The centralization of operation of Signals and Points from a common lever-frame became important for operation on lines where traffic had increased. At many stations the signal operation was shifted to the station from lever frames. These were still operated by single wire.

13.4.2 The points continued to be operated locally by tumbler levers placed near the points. The Keys for point operation were carried manually from the station to points and back. This was time consuming. Electric Key Transmitters were introduced by Major Sir Heppers in 1904 to expedite this process. To further expedite operations, the points at each end of the station were grouped and operated from a lever frame by steel rods supported on rollers at regular intervals. These lever frames were located close to the points in view of the limited range of the rod operation. To permit higher speed over points these were provided with plunger type locking devices, operated from the lever frames also by steel rods. In addition, the detectors in the wire transmission of the Home signals checked not only correct setting of the point but also the locking of point switch by the plunger lock. The control over setting of points was exercised by exchange of keys from the station master transmitted manually or by electric Heppers key transmitter.

13.4.3 To provide for better coordination and faster operation the signals and points at each end of the yard were grouped and operated from a common lever frame. This permitted interlocking between the levers to ensure proper sequence of operation and position of all relevant levers.

13.4.4 The lever frames had two categories depending on the method in which levers were interlocked with each other in a lever frame.

13.4.4.1 Direct Locking type-Lever had direct attachment of the tappets which were interlocked through a system of dogs and bars to ensure sequential operation of the levers as per the signalling system for the station. These were suitable for small lever frames only.

13.4.4.2 Indirect locking type- The levers had catch handles which ensured that the lever could not be moved form its position unless the catch handle was pressed to release the lever from the body of the frame. These were well suited for larger lever frames as they could accommodate more interlocking.

13.4.5 With the use of lever frames for operation of signals and points, interlocking of stations gained pace to permit higher and higher speed of trains passing through the stations. Another signal "Warner" which had a fish tailed arm was used at interlocked stations. This was to be used below a stop signal (Outer) or a fixed Red light to indicate the conditions of running through the station without stopping at the station when it was taken `OFF'.

13.4.6 The single wire Signals required effort for pulling of the wire from the lever frame for lowering the semaphore arm but the return of the arm was ensured by the counter weight of the semaphore arm. This was not efficient in practical conditions. The operation of points by steel rods from a lever frame had a limited range. To operate points over larger distances from the lever frames East Indian Railway introduced Double wire operation of points in 1920. About the same time Mr. Backer of Assam Railway introduced Double Wire Signaling in which operation of signals and points were carried out by double wire from one lever frame. Thus there were two distinct systems in use for operations of signals and points namely Single wire and Double wire.

13.4.7 Stations, where the distances for signal and point operations were much longer or the numbers of lines were too many, more than one cabin with lever frames was provided for operation. These lever frames were inter connected with each other through inter-cabin controls which were initially mechanically operated (single wire or rod). These mechanical controls had to be replaced with electromechanical controls (Reversers or Electric Motors) as the distances and the intensity of operations increased.

13.4.8 In cases where the Signals were operated from lever frames near the points, the Station Master had the control on Home signal either through keys or alternatively a slot on the `Home" signal. The Station Master had a central lever frame from which the appropriate Key was released or the slot operated on the respective Home signal. The cabins at the far end of the yard had to set the points properly and operate the slot before a Home signal could be lowered by a particular cabin. Cooperation of the concerned Cabins and the Station Master was required for lowering a Home signal.

13.4.9 The Block working through the Morse telegraphy was not found satisfactory as the train frequency and speeds increased. Electric Block Instruments were installed at the stations to control the train movements as per requirement of Absolute Block System.

13.4.10 Mr. Neales of GIP Railway introduced the Ball token instrument for single lines. The Station Masters at either end of a Block section could speak to each other on a telephone. These instruments on single lines ensured a tangible authority to proceed. Only one token could be issued at any time from the pair of instruments at the end of a block section so that only one train could move in the Block Section at a time. There were other types of instruments such as Tyres, Theobalds, etc working on similar principle.

13.4.11 On double lines M/s Cargil and Sengupta introduced in 1920 "Carsen type of Lock & Block" instruments. These were connected to the Last Stop signals controlling the entry of trains in the concerned Block section. The electrically connected instruments ensured co-operation of both the station masters. The two instruments were normalized before another train could be allowed to enter the Block section. It ensured that only one train would be in the Block section at any one time. There were other types of similar instruments such as SGE, Sykes which were introduced for the same purpose.

13.4.12 Assam Railways in 1920 introduced along with double wire signaling Multiple Aspect Upper Quadrant (MAUQ) signals on its MG sections. In these systems signals and points were operated by a system of two wires kept under constant tension to impart positive movement to overcome ill effects of contraction and expansion of wire due to temperature and with increased range of operation. The Signals had four aspects namely: Stop (Red), Proceed (Green), Caution (Yellow) and Attention (Double Yellow). Although this type of signaling had better aspects for the driver for controlling their trains, but in actual practice the working of Signals and Points had certain deficiencies.

13.4.13 The year 1928 brought the advent of Colour Light Signalling on the railway in India. On the suburban systems of Central Railway Automatic signaling was introduced in 1928. On South Indian Railway Multiple Aspect Color Light Signalling with Automatic Signalling was provided in 1930 using miniature all-electric lever frames to operate the large yards from one place, over long distances. The signals and points were power operated through multi-core under ground copper cables. The lines were track circuited to detect presence of vehicles. The Automatic Block system was adopted on suburban lines for operating electric trains in quick succession. However some railways, Central and Eastern, continued to work suburban trains on Automatic Signalling with Mechanical lever frames and Two Aspect Semaphore signals for many years.

13.4.14 1925 witnessed introduction of selective ringing systems for voice calls on the Railway Control. Telecommunication systems were updated and Traffic control systems were installed to enable instructions being passed from the Traffic controller to the Station Masters at stations for regulation of train movements to cope with the increased tempo of the rail operations. This was on omnibus type of speech circuits connected to all stations on a section with facilities for selective ringing of stations. The controller plotted a graph of train movements based on the information passed on by the station masters of the section from time to time. This enabled him to plan further movements and give instructions to the stations accordingly.

13.4.15 For administrative control of various out lying Control Offices and Work Centers by the Head Office, Railways started having elementary type of Magneto manual telephone exchanges and administrative trunk lines dedicated for Railway's use. These exchanges connected various important Railway officials and functionaries connected with train operation and maintenance of various assets like track, locomotives and carriages. All these circuits were hired from the Dept. of Post and Telegraph.

13.4.16 In 1945, Railways were permitted by Govt. of India to develop their own wireless services considered necessary for their operational needs. Old war surplus wireless sets were used to build up a railway-wide network of wireless telegraphy for exchange of information and data. In many areas this constituted the main source of communications since the performance of the overhead lines hired from DOT deteriorated day by day.

13.4.17 Standards of Interlocking were adopted much later in 1930 after the Railways had installed various types of the systems. These standards were merely an attempt to regularize the various systems already in use at that time by various Railways. There were three standards of Signaling namely Standard I, II and III. Other stations had Non-interlocked working.

13.4.18 The heterogeneous growth of signaling systems and equipments from different sources brought the need for standardization and coordination amongst various railway systems. Indian Railway Conference Association (IRCA) was set up for this purpose followed by Central Standard Organization (CSO) in 1930 for preparation of designs, standards and specifications to suit local conditions of Indian railway systems. Signaling and Telecommunication were dealt with by Signal and Interlocking Standards Committee (SISC).The minutes of the proceedings of this committee indicate clearly the efforts made not only to evolve common standards but also to develop new designs taking inspiration from some of the imported equipments. The designs and drawings developed also provided the technical know-how to the Indian industries for local manufacture of the equipments. Standardization also helped in providing larger volumes of supply to make the manufacture of these equipments cost effective.

13.4.19 Manufacture of Mechanical Signalling equipments in India were started around 1906 by Westinghouse Saxby Farmer, Henry Williams and Guest Keen Williams. The range of manufacture was increased progressively by Westinghouse Saxby Framer to include double wire signalling, electro-mechanical signalling as well as power signalling.

13.4.20 Railway had started their own workshops to undertake overhaul and repair work of the signalling equipments to overcome the shortage of expertise and capacity in the industry in the country at that time. The main workshops were Trichinapoly, Howarh, Gorakhpur, Ghaziabad, Ajmer and Byculla.

13.5 DEVELOPMENTS IN RAILWAY SIGNALLING & TELE COMMUNICATION AFTER INDEPENDENCE (1947-2000)

13.5.1 The pace of industrial developments in the country got a boost after Independence. This needed much more transport capacity. Railways were the only developed and organized system of transport and were called upon to organize rapid expansion of Railway transport capacity and higher degree of safety in their movements. The capacity for manufacture of Signalling & Telecommunication equipments in the country was extremely limited. There was shortage of foreign exchange for import of new Signalling & Telecommunication Systems. Best efforts were made to develop indigenous systems using the then existing technology and manufacturing capacity. Railway workshops contributed significantly in this activity. In 1952, the growing importance of the Signalling and Telecommunication services was accepted and a separate department was formed to manage these under Member Engineering, Railway Board.

13.5.2 In order to cope with increased distances and have more reliable operation of Signals and Points, double wire lever frames were introduced at some stations. The signal aspects were increased to give the drivers more accurate information of the state of line ahead and to enable them to control their trains better. These had been used earlier on some Railways (Assam Bengal Railway) but had certain deficiencies. These deficiencies were removed before these were used for larger application. Double wire signalling system used lever frames which were different in both shape and principle of operation. The actuation of signals and points was positive for reliable and accurate operation. The Station Master controlled the operation by issue of route and signal keys. There were other safety devices attached to the system like broken wire lock, detector for points etc. These double wire systems were found capable of operating semaphore signals in the upper quadrant and also give more than two aspects. The multiple aspect semaphore signalling found larger acceptance. The double wire operated multiple aspect signalling was found more economical in operation on MG lines as it could operate the signals and points at most stations with a single cabin.

13.5.3 Many BG Railway system preferred to have two cabins at the two ends of the yard to operate the points by rod and signals by single wire. This system had the advantage of being flexible to accommodate the long layout of yards. But the operating cost was higher and operation of signals by single wire was not entirely satisfactory. There was need for inter-cabin controls. Mechanical systems for inter-cabin controls, using single wire, were not satisfactory and gave rise to unsafe practices. Electric controls were added to make the working of such installations satisfactory.

13.5.4 Higher speeds of trains having higher loads required longer braking distances. This required signals to be operated over longer distances which was not feasible with single wire operation. Some Railways adopted double wire operated signals from single wire lever frames. Others adopted electric motor operation of the far off semaphore signals. Still others adopted a hybrid approach.

13.5.5 With double wire operation of signals, Multiple Aspect Signalling became feasible with mechanical systems. This suited well for higher speed trains which needed more braking distances and much advance warning on the state of the line ahead. Double wire operation of signals and points was modified due to difficulties in working of mechanical detectors. Electric detectors were provided to improve their working. This required more electrical equipments in the form of lever locks on signal levers for safety reasons.

13.5.6 A switch was made mandatory to electric operated color light multiple aspect signalling when AC electric traction was introduced on Main line to counter the problems of signal visibility and other deficiencies. The availability of power from the Overhead Traction System resolved the requirement of power for such a system.

13.5.7 On single line sections Block instruments provide a tangible authority to make a train movement in a block section. The exchange of this authority to a run through train passing the station at fast speed was a problem. New type of "Token Less" instruments developed by Podanur workshops (SR) in 1960 which permitted the clear aspect of the last Stop signal to be used as authority to proceed in a block section doing away with the tangible authority.

13.5.8 Track circuits were gradually installed at many stations at isolated locations for detecting the occupation of lines. There was acute shortage of wooden sleepers needed for track circuiting. Alternative means of axle counter were tried for vehicle detection purposes. Axle counters were imported and installed on Delhi-Meerut and other sections and were found acceptable. These needed foreign exchange for import which was not so easily available. A project was undertaken to develop an alternative design in consultation with Indian Institute of Technology, Delhi, Railway Workshops, Private firms and RDSO. The designs evolved were tested and approved for large scale use in 1970. These axle counters were later used for providing automatic signalling on some sections of busy lines (Mathura-Palwal) as also for vehicle detection in Block sections along with existing Block Systems. Still later they were also used to prove non occupation of main line between Block Stations on Single/double line.

13.5.9 Operation of points with rod and even with double wire was not feasible over much longer distances. Thus more and more cabins were required for longer yards introducing multiple agencies which delayed the operations apart from introducing unsafe elements in working. The working of points was made power operated. The lever-frames on busy routes were replaced by a Panel and safety relays for interlocking. First of these installations called "Route Relay Interlocking" was introduced in Church gate in 1958 on Western Railway and later on at many major stations of Indian Railways. This system of interlocking was modified and adopted for smaller way side stations as "Panel Interlocking" providing all the flexibility and safety required to operate signals and points over longer distances from one place. The design of such systems was evolved by Indian Engineers with the equipments and technology available in the country.

13.5.10 To provide necessary technical support to Indian industries a new organization called Railway Testing and Research Centre (RTRC) was set up in 1952. This permitted dispensing with the dependence on importation and simultaneously expediting the indigenous production of materials. The two organizations CSO and RTRC were merged in 1957 into Research, Design and Standards Organization (RDSO).

13.5.10.1 While the initial lots of equipments both mechanical and electrical were imported, there arose a need to make these equipments locally not only to conserve foreign exchange but also to develop a new version to suit local operating requirements and climatic conditions as also standardization to enable mass manufacture. This meant redesigning.

13.5.10.2 The designs were made by CSO initially and later on by RDSO These were passed on to the manufacturers for prototypes which were extensively tested in the field before being finalized as standard designs. This expedited the local manufacture of these equipments and gave uniformity all over the Indian Railways thereby simplifying maintenance and procurement practices.

13.5.11 A new type of electric interlocking system was evolved by Indian engineers which suited the local conditions of the environment, man power and operational needs.

These systems were distinctly different from the original parent systems in as much as these incorporated several ideas from different systems as also incorporated locally evolved techniques covering the electrical, mechanical and electronic equipments. The equipments include Axle counters, Safe multiplexers, Block instruments etc.

13.5.12 The first Solid State Interlocking MICROLOK of US & SCO was commissioned at Srirangam station on Southern Railway in 1982. Thereafter several stations on South Central Railways were equipped with these equipments. Indian Railways in association with Indian Institute of Technology, Delhi, Department of Electronics and Indian industry took up the development of Solid State Interlocking system. A prototype was commissioned at Barar Square in Delhi in series with conventional relay interlocking in 1982. After extensive trials, it was approved for independent working. The system was later updated and an improved version was installed at Dushkera station of Central Railway in 1990. Later, one more system has been installed at Bhadli in 1997. Similarly Axle counters were locally developed in association with the Department of Electronics and Indian Institute of Technology. Safe Multiplexers were also developed for use with Block Systems to economize on requirement of line wires.

13.5.13 Railways had their own signal workshops which were started as small units for the maintenance and overhaul of equipments for looking after the day to day maintenance needs, as the indigenous industry did not have the necessary expertise nor was the volume of work attractive for serious business. These units were pressed into service for development of equipment in Railway Workshops based on designs evolved by RDSO. Many varieties of Mechanical Signalling, Electrical Equipment as well as Electronic Equipment were made. Later on this expertise and experience, along with detailed designs was passed on to the industry for bulk production.

13.5.14 The telecommunications also made rapid developments to meet the ever increasing requirements caused by fast development of the traffic. Railway hired more and more lines from Deptt. Of Telecommunication (DOT) to meet these requirements. As the telecommunication system was also getting upgraded with Multi-channel Carrier systems, IR hired carrier channels for their administrative requirement to connect far flung offices and work centers. The Traffic control circuits were added for specific purposes of freight movement and loco and carriage management. Railways also changed their Magneto exchanges with Central battery exchanges and Automatic electro mechanical exchanges. Some teleprinters were selectively deployed to handle the large volume of transportation and administrative traffic, generated by increased movement of rail traffic, All these systems essentially depended on the lines and circuits provided by Dept. of Post and Telegraph.

13.5.15 With the increase in requirement of Railways coupled with sharp increases in the general requirement of public telecommunications the Dept. of Post and Telegraph could not give railway, the priority IR needed. IR decided to have their own dedicated telecommunication circuits. IR made desperate attempts to provide telecommunication facilities by deploying Short wave radio networks constructed out of Shortwave High frequency Radio systems from Military disposals. These were used to provide point to point telephony and telegraphy circuits. On some circuits teleprinters were also tried. Railways started laying their own aerial line wires along the track for their own telecommunication and Block safety circuits. In some cases lines wires of the Deptt. of Post & telegraph were taken over. The maintenance of the Railway owned lines was taken over by Railways themselves to provide desired reliable service. IR provided on some of their line circuits Carrier Systems to extend the circuits to far-off offices and work places. The manual exchanges were upgraded to automatic electro-mechanical and trunk exchanges.

13.5.16 The introduction of 25 KV AC electric traction changed the shape of railway communication drastically as the overhead line wires could not be retained due to electro-magnetic effects of the electric traction. The circuits had to be provided in heavily screened under ground telecommunication copper wire, balanced quadded cables, which also provide for short distance direct physical circuits for Safety Block system. Several equipments had to redesigned and manufactured for working on these cables. This development work was undertaken by Telecom Research Center of the Dept. of Post & Telegraphs and Indian Telephone Industries. New Control office and way side equipments were developed using available electro-mechanical switches in the country. Special train wire and telegraph equipment was also developed for Morse telegraph circuits. Special Voice Frequency Telegraphy Equipment was developed for long distance telegraph and teleprinter circuits. Special filters for safety Block circuits were also developed for different type of Block instruments. The Block circuits were changed to suit the new arrangements. Later these equipments were modernized by evolving solid state control office and way station equipments by Indian firms and RDSO.

13.5.17 Railway Reforms Committee recommended in 1962 that railways should develop their own Telecommunication network. IR installed the Microwave Radio Relay systems for their long distance communication circuits and also a back up the traffic control systems during failure of the overhead lines and cable systems. First system was installed on Southern Railway in 1967 connecting various Divisional centers. This was followed by other Railways. Soon IR had the largest national network of Microwave Radio Relay system. The initial systems used Kystron Tubles for generation of Radio frequencies along with conventional analog multiplexers replaced later by solid state techniques for Radio frequencies. The radio systems as well as multiplexers were in course of time made digital. In 1980s German consultants were appointed by Indian Railways to prepare a blue print for modernisation of telecommunications.

13.5.18 The cable using copper along the track were subjected to wide spread theft making these almost unserviceable and needed frequent repairs. The traction current in the electric traction was increasing steeply due to sharp increase in train movements as also the increasing trailing loads. This demanded redesign of the under ground cable systems to take care of the electro magnetic effects. The use of Thyristor controlled locomotives was likely to cause adverse electro-magnetic effects on telecommunication circuits along the track in the under ground cables. To over come these difficulties IR switched over to Optical Fibre based digital communication systems (OFC) which are unaffected by electro-mengetic disturbances as well as less prone to thefts. First OFC system was laid on Nagpur-Itrasi- Durg section in 1982. This required use of new type control office and way side equipments for traffic control circuits. The Block systems was redesigned using latest solid state multiplexers and safety coding for safety circuits. These multiplexers were initially imported but later these were developed by Indian firms in association with Indian Institutes of Technology. The digital technology in microwave systems and the Optic fibre, makes the composition convenient and highly suitable to modern data transmission.

13.5.19 A big thrust was given for improving safety on Indian Railways in the year 1998 and the Chairman Railway Board introduced route wise priority for completion of safety work. As a result track circuiting of run through lines on all stations with speed over 75 KMPH got completed. To provide 2 km breaking distance to driver, all stations on 'A' route were equipped with Second Distant Signal. Pace of introduction of colour light signalling was speeded up and by the close of 20th Century all stations on 'A' and 'C' routes and over 50% stations on 'B' route had multi aspect colour light signalling. Interlocking of level crossings was expedited. Trials of new devices for train actuated approach warning at level crossing were initiated.

13.5.20 The later part of 20th Century saw the advent of new technologies in Railway Signalling on Indian Railways. Digital axle counter of M/s ALCATEL was put on trial on Maulali-Cherlapally section of South Central Railways and were found successful. These equipments were introduced on Central, South Eastern and Southern Railways. Audio Frequency Trade Circuits of M/s US&S, ADTRANZ, Siemons were extensively provided on Southern, Central and Western Railways. Use of LED signals. Integrated Power Supply using SMPS technology were adopted. Higher performance point machines were other areas, where indigenously developed technology was adopted. Predictive maintenance of Signalling equipment using Data Logger and Networking was introduced bringing a complete change in signalling maintenance philosophy on Indian Railways.

13.6 21ST CENTURY - INDIAN RAILWAY SIGNALLING AND TELECOMMUNICATION

13.6.1 The Successful trials of new S&T technologies on pilot projects undertaken during closing years of last century gave confidence to Indian Railways to plan and adopt these new S&T technologies on a wider spectrum. Railway Board took a policy decision to use Solid State Interlocking on way stations. At this juncture of time replacement of signaling of 1494 stations and rehabilitation of over aged signaling assets at 911 stations were approved under Special Railway Safety Fund (SRSF). Hence bold initiative were taken by Indian Railways to adopt SS9 at way stations. As a result SSI have been commissioned at 45 stations and 254 new stations have been sanctioned for adoption of this new technology.

To ensure safety in block working, use of Axle Counter for automatic check of last vehicle has been provided at 296 block sections. AFTC have been provided at 1763 location for various track circuiting purposes, to improve reliability & eliminate the need for installing & maintaining insulated joints. So far more than 3000 Axle Counters have already been installed for track vacancy detection where insulated sleepers were not available.

Development of ETCS technology by UIC on European Railways in recent years has paved the way for adoption of a Fail – Safe Train Protection & Warning system on Indian Railways. This Euro balise based new technology is presently under installation on Delhi-Agra and Chennai suburban sections. A pilot project of indigenously developed Anti Collision Device (ACD) by Konkan Rail Corporation is under installation on NF Railway. After successful introduction of a train management system in Mumbai suburban section of Western Railway, a major project of Centralized Traffic Control and Mobile Train Radio Communication (GSM-R) is now under installation on Delhi-Kanpur section of Indian Railways.

Introduction of new technologies in Signalling & Telecommunication are playing a vital part in safe and speedier train operation on Indian Railways. With more and more signalling works getting implemented with state of art technologies and new systems under introduction, these are going to provide the most vital solutions for optimum utilization of railway assets besides improving efficiency in train operator with a high level of safety and passenger satisfaction.

The Second half of 20th century saw Indian Railways signalling switching over from Semaphore signals to Colour Light signals. The introduction of new technologies in recent years is paving the way for next switch over of Indian Railways Signalling from Colour Light Signalling to "In-Cab Signalling" in the 21st Century.

13.6.2 A chronological list of Key Events is given in Page C-19.

List of Abbreviations

ABB	:	Asea Brown Boveri
AC	:	Alternating Current / Air Conditioned
ALCO	:	American Locomotive Company.
BB & CIR	:	Bombay Baroda and Central India Railway
B.E.S.A.	:	British Engineering Standards Association
BG/B.G.	:	Broad Gauge
BGML	:	Broad Gauge Main Line Loading Standard
B.H.	:	Bull Headed
BHEL	:	Bharat Heavy Electricals Ltd.
BNR	:	Bengal Nagpur Railway
CAD	:	Computer Aided Design
C.E.	:	Chief Engineer
CI/C.I.	:	Cast Iron
CKD	:	Completely Knocked Down
CLW	:	Chittaranjan Locomotive Works
COFMOW	:	Central Organisation for Modernisation of Workshops
CR	:	Central Railway
CSO/C.S.O.	:	Central Standards Office
CST	:	Central Standards Trial series
C.V.O.	:	Companion of Victorian Order
DC/D.C.	:	Direct Current
DCW	:	Diesel Component Works
DH/D.H.	:	Double Headed
DHR	:	Darjeeling Himalayan Railway
DHRE	:	Darjeeling-Himalayan Railway Extensions – Name of a company
DLW	:	Diesel Locomotive Works
DOT	:	Department of Telecommunications
EBR	:	Eastern Bengal Railway
EIR/E.I.R.	:	East India Rail
ER/E.R.	:	Eastern Railway
FBBS	:	Flat Bottom British Standard
F.F.	:	Flat Footed
FPS	:	Foot Pound System

Ft.	:	Feet
GBSR	:	Gaekward Baroda State Railway
GIP/G.I.P.	:	Great Indian Peninsular Railway
HFL	:	Highest Flood Level
R & D	:	Research & Development
ICF	:	Integral Coach Factory
IDA	:	International Development Agency
INAE	:	Indian National Academy of Engineering
IR/I.R.	:	Indian Railways
IRCA	:	Indian Railway Conference Association
IRICEN	:	Indian Railway Institute for Civil Engineering
IRIEEN	:	Indian Railway Institute for Electrical Engineering
IRIMEE	:	Indian Railway Institute for Mechanical and Electrical Engineering
IRISET	:	Indian Railway Institute for Signal and Telecommunication Engineering
IRS/I.R.S.	:	Indian Railway Specifications
ISO	:	International Standards Organisation
KM	:	Kilometre
KMPH	:	Kilometres per hour
LWR	:	Long Welded Rail
L.S.C.	:	Loco Standards Committee
M	:	Metre
MAUQ	:	Multiple Aspect Upper Quadrant
MG/M.G.	:	Metre Gauge
MGML	:	Metre Gauge Main Line Loading Standard
MSL	:	Mean Sea Level
MSP	:	Measured Showel Packing
MSR	:	Madras State Railway
NBR	:	North Bengal Railway
NE/N.E.	:	North Eastern
NF/N.F.	:	North Frontier
NR/N.R.	:	Northern Railway
NW/N.W.R.	:	North Western Railway

O & R R	:	Oudh & Rohilkhand Railway
OFC	:	Optical Fibre Cable
OHE	:	Over Head Equipment
POH/P.O.H.	:	Periodical Overhaul
P.R.C.	:	Pre-stressed Reinforced Concrete
PSC	:	Prestressed Concrete
P. Way	:	Permanent Way
PWD/P.W.D.	:	Public Works Department
R.C.C.	:	Reinforced Cement Concrete
RCF	:	Rail Coach Factory
R.E./RE	:	Rail Electrification
RDSO	:	Research, Designs and Standards Organisation
RSC	:	Railway Staff College
RTRC	:	Railway Testing and Research Centre
SC/S.C.	:	South Central
SE/S.E.	:	South Eastern
SIDA	:	Swedish International Development Cooperation Agency
SIRO	:	Scientific and Industrial Research Organisation
SISC	:	Signal & Interlocking Standards Committee.
SLM	:	Swiss Locomotive Manufacturers
SKD	:	Semi Knocked Down
SNCF	:	French National Railway/Societie Nationale Chemin de Fer
SR	:	Southern Railway
TOT	:	Transfer of Technology
TQM	:	Total Quality Management
TSC	:	Track Standards Committee
U.K.	:	United Kingdom
U.S.A.	:	United States of America
USD	:	United States Dollar
VDC	:	Volts Direct Current
V.T.	:	Victoria Terminus
WAP	:	Wheel and Axle Plant
WDS	:	Type of Diesel BG Locos for shunting duties on IR

WR/W.R.	:	Western Railway
YDM	:	Type of MG Diesel Loco for mixed (passenger & freight) duties on IR
ZDM	:	Type of Narrow Gauge Diesel Loco for mixed use for passenger and freight services on IR

BIBLIOGRAPHY

The List is arranged in five sections, General, Civil, Mechanical, Electrical and Signalling. It is arranged author wise alphabetically and under a sub head `Report and Documents' where no author is indicated in the publication.

GENERAL

Acworth, W.M.	Railways of England	1889
Addi Robert Bawn	Darjeeling and its mountain railway, A guide and sovenoir, Darjeeling Himalayan Railway Co. Ltd.	1921
Ahrons, E.L.	Steam Locomotive	1922
Andrews, C.B.	The Railway Age	1937
Antia, F.P.	Indian Transport Costs	1932
Bell, Horace	Railway Policy in India	1894
Bhandari, R.R.	Rail Transport Museum	1980
Bhandari, R.R.	Locomotive in Steam	1981
Bhandari, R.R.	Jodhpur Railway	1982
Bhandari, R.R.	Kalka Simla and Kangsa Valley Railways	1983
Bhandari, R.R.	Exotic Indian Mountain Railways	1984
Bhandari, R.R.	Western Railway Metre Gauge System	1986
Bhandari, R.R.	The Blue Chip Railway	1987
Bhandari, R.R.	Western Railway Narrow Gauge System	1998
Bonhem, J.	Oudh in 1857	1928
Brown, Ashley	Future of the Railways	1929
Buck, Edward J.	Simla-Past and Present	1925
Case, R.C.	Essay on Coal	1927
Champion, F.W. and Nicolls	With Camera in Tigerland	1927
Choksey, R.D.	Economic History of Bombay, Deccan And Karnatak	1945
Clark, J. Frank	The Great Indian Peninsula Railway	1900
Davidson, E.	Railways of India	1868
Dutt, Romesh Chunder	The Economic History of India in the Victorian Age	1903
Edwardes, S.M.	The Gazetteer of Bombay City and Island	
Gadgil, D.R.	Industrial Evolution of India	1948
Ghosh, S.C.	Organisation of Railways	1927
Haldane, J.W.C.	Railway Engineering	1897

Huddleston, G.	History of the East Indian Railway Vol-I, & Vol-II	1906, 1939
Hughes, Hugh & Jux	Steam Locomotive in India, Part-I Narrow Gauge; The continental Railway Circle, Middlesex, U.K.	1969
Hughes Hugh	Middle East Railways	1981
Iyer, K.V.	Indian Railway	1924
Jain, Raj Kumar	Men May come and men may go	1993
Johnson, E.R. and T.W.V. Metre	Principal of Railroad Transportation	1924
Kennedy, J.P.	B.B. & C.I. Railway-Report on Line	1954
Khosla G.S.	A History of Indian Railways	1988
Khosla G.S.	Railway Management in India,Thacker & Co.	1972
Kirby, Withington Darling and Kilgour	Engineering in History	1956
Kitchlew, R.N.	Gauge Policy of IR, Kitchlew, R.N.	1933
Lee, Charles E.	Evolution of Railways	1943
Laut Agnes C.	Romance of the Rails	1936
Macleod and Kumar	Technology and the Raj (1700-1947)	1995
Mitchell John W	The Wheels of Ind	1934
Natesan, L.A.	State Management and Control of Railways in India	1946
Neele, G.P.	Railway Reminiscences	1904
Newell (Lt.-Col.) H.A.	Bombay (The Gateway of India)	
Noble, C.B.	Father and Son	1938
Raymond, W.G.	Elements of Railroad Engineering	1937
Ralph (Sir L. Wedgood and J.E. Wheeler	International Rail Transport	
Ramanujam, T.V.	The Functions of State Railways in Indian National Economy	1945
Ransome-Wallis, P.	Railways at Home and Abroad	1951
Rao M.A.	Indian Railways, National Book Trust	1974
Rao Y. S.	The Railway Board,S. Chand	1978

Russel, W.H.	My Diary in India	1858-59
Sahni, J.N.	Railways One Hundred Years, Min. of Rly.	1953
Sanyal, N.	Development of Indian Railways	1930
Saxena, R.N.	Four Decades of Indian Railway, Academic Foundation	1991
Sharpe, E.R.S.	Bombay, The Gateway of India	1930
Sulivan, R.J.F.	One Hundred Years pf Bombay	1937
Shepherd, S.J.	Bombay	1932
Shardhit, C.Marr.	Bombay "Today and Tomorrow"	
Sharma, S.N.	History of GIP Railway Vol.-I	1990
Singh, Dr. Vijay Kumar	Railway Freight Rates in India	1983
Thorner, Daniel	Investment in Empire	1950
Thornton, William T.	Indian Public Works and Cognate Indian Topics	1875
Texeria, A.M.	The Origin of the Name of Madras	1930
Trevithick, Richard	The Engineer and the Man	1934
Theroux Paul and Mccurry Steve	The Imperial Way	1985
Tiwari,C.P.	Indian Railways	1921
Valentia, G.V.	Voyages and Travel in India Ceylon, Etc.	1809
Wiener, L.	Articulated Locomotives	1930
Wilson, H. Raynar	Railway Signalling	1922
Wood (Sir), W.V. and J. Stamp	Railways	1928

REPORTS & DOCUMENTS - GENERAL

A complete story of the Asam Rail Link Project	1951
A project is established	1950
A Monograph on Indian Railways Goods Rating Structure	
Administrative Report of Indian Railways	1951
Assam Rail Link Project	1950
Full Steam Ahead (Railway Board)	
Government of India Act	1919
Government of India Act	1935
Great Western Railway-Special Centenary Number	1935
History of Indian Railways	1961
History of Defunct Railways	1964
History of Railways, Quinquennial	1928, 1933, 1938, 1947
Indian Railways	1950-51
Indian Railways (Various issues)	
India Old and New (G.I.P. Railway)	
Indian State Railway Magazine (Various issues)	
Journal of Institute of Locomotive Engineers (No.135 &141)	
Journal of Railway Staff College (Various issues)	
Memorandum on the Formation of the Southern Zone	1950
Memorandum on the Formation of the Western Zone	1951
Memorandum on the Formation of the Central Zone	1951
Memorandum on the Formation of Northern, North Eastern And Eastern Zones	1951
Menezes Committee Report-Planning Commission	1987
Mukerian Pathankot Section Link	
Orissa Review	1949
Picturesque India	
Professional Papers on Indian Engineering	1863 to 1885
Railway Workers in India (Ministry of Railways-Railway Board)	
Railway at work	1947
Railway Gazette	17.09.1923

	05.01.1940
Railway Reforms Committee Report	1984
Report of the Indian Industries Commission	1916
Reports and Minutes of Evidence of the East Indian Railway Committee	1920-21
Report of the State Railway Workshops Committee	1926
Report of the Royal Commission on Labour in India, Vol.VIII,Pt.1	1930
Report of the Railway Board on Indian Railways	
Report of the Railway Convention Committee	1949
Report of the Indian Railway Enquiry Committee	1937
Report of the Railway Rates Advisory Committee	
Select Committee Report	1884
Towards Better Conditions of Travel	1952
The Railway Gazette,	1950
Treaties, Engagements and Sanads	1932

Agarwal, M.M.: "Indian Railway Track", -Prabha & Co., New Delhi (2005)

Agarwal M.M.: "Railway Works Engineering"-Prabha & Co., New Delhi (2004)

Agarwal M.M. & Arya Bhushan: "Indian Railway Safety-Ultimate goal to prevent accidents"-Prabha & co., New Delhi (2005)

Agarwal G.S.: "Ultrasonic Flaw detection of thermit welded joints"- Indian Railway Technical bulletin published by RDSO, Lucknow (1976 & 1977)

Agarwal V.K.: "Railway Track Formations"- Technical Monograph No. 42- Published by R.D.S.O. Lucknow (1978)

Agarwal V.K.: "Managing Indian Railway-the future ahead"-Manas Publication, New Delhi (2004)

Agor, R.: "Railway Track Engineering"-Khanna Publishers, Delhi (1996)

Anand, Y.P.: "Deputation Report Regarding Track Maintenance of Chinese Railways" (1986)

Antia, K.F.: "Railway Track"-The New Book Company Pvt. Ltd., Bombay (1960)

Armstrong H. John.: "The Railroad-What it is & What it does, Marc Green"- Summons Boardman Publishing Corporation, Omana, N.E.(1977)

Bhandari, R.R.: "Kalka Simla and Kangsa Valley Railways" – Govt. of India, Ministry of Railways, Railway Board- (1983)

Bhandari, R.R.: "Exotic Indian Mountain Railways" Govt. of India, Ministry of Railways, Railway Board – (1984)

Bhandari, R.R.: "Western Railway Metre Gauge System" Govt. of India, Ministry of Railway, Railway Board – (1998)

"Bridge river Brahmputra-past, present & future"-Construction organization of North East Frontier Railway-(1988)

Coombs, D.H.: "British Railway Track"-The Permanent Way Institution Nottingtam, U.K. (1971)

Courpalais, N.H.: "Railway Points and crossings" (1935)

Chandola S.P. & Vazirani V.N.: "Railway Bridges & Tunnels"- Khanna Publishers, Delhi (1997)

"Continuous Welded Rails"- Govt. of India, Ministry of Railways, RDSO (May 1977)

Dabke V.H.& Parikh J.M.: "Notes on Ganga Bridges project at Mokameh Ghat"-Private Circulation (1965)

Gupta B.L.: "Road, Railway, Bridge & Tunnel Engineering"-Standard Publishers Distributors, Delhi (1978)

"Increase of speed on Delhi-Howrah route Feasibility study"- Govt. of India, Ministry of Railways, RDSO Report No. C & M (May 1969)

"Increase of speed on Delhi-Howrah route Feasibility study"- Govt. of India, Ministry of Railways, RDSO Interim Report No. Vol-I (1968)

"Increase of speed on Delhi-Howrah route study of formation Phase-III'- Govt. of India, Ministry of Railways, RDSO Civil Engineering Report No. C-87 (October 1970)

"Increase of speed on Delhi-Howrah route"-Govt. of India, Ministry of Railways, RDSO Report No. C & M-(May 1977)

"Indian Railways-Year Book"-Published by Railway Board – (2004)

"Indian Railway Track Machine Manual"-Government of India-Ministry of Railways, (Railway Board)-(Mach, 2000)

"Indian Railways Bridge Manual"-Government of India, Ministry of Railways, Railway Board-(1998)

"Indian Railway Permanent Way Manual"-Government of India, Ministry of Railways, Railway Board-(2004)

"Indian Railways Track Manual"-Government of India, Ministry of Railways, Railway Board-(1965)

"Investigations for the development of Elastic fastenings" – Government of India, Ministory of Railways, RDSO-C.E.-Report No. C-65 (February-1969)

Jain, R.K.: "Railway bridge across sone, Technical monogram no.27"-RDSO Publication

Jane's World Railways-Forty-third edition (2001-2002)

Kerr.Jan J.: "Building the Railways of the raj."-(1850-1900)-(1995)

Khosla G.S.: "Railway Management in India"-Thacker & Co. Ltd., (1972)

Khanna P.N.: "Civil Engineer Hand Book"-Engineers Publishers (1997)

"Konkan Railway"- Konkan Railway Corporation (1998)

Mundrey J.S.: "Railway Track Engineering" – Tata Mcgraw Hill Publishing Co. Ltd., New Delhi (2000)

"Manual for Flash Butt Welding of Rails"-Govt. of India, Ministry of Railways, RDSO(1996)

"Manual for Fusion Welding of Rails by Alumino-Thermic Process"-Govt. of India, Ministry of Railways, RDSO (1995)

"Manual for Instruction for laying and maintenance of short welded rails" – Govt. of India, Ministry of Railways, RDSO (1990)

Mac George, G.W.: "Ways and Works in India"-(1894)

"North East Frontier Railway-History of Railway bridges"-North East Frontier Railway

"Permanent Way Technique and Permanent Way Economy by Gerhard Schram"- Otto Elsner Verlags Gellschaft Darmstadt.-(1961)

Rangwala S.C. & Rangwala P.S.: "Principles of Railways Engineering"-Charotar Publishering House, anand-(1991)

Rao Krishna S.H.R.: "Technical Monograph No. 35"-RDSO-(1970)

Report RBF-16 for flood estimation-RDSO

RDSO – Bridge Sub-structure and Foundation Code-1985

Shahney G.P.: "Construction of 14x150 Ft. BGML bridge and its training works across the Beas at Mirthal on New Kukerian-Pathankot line"

Shivdasani and Kane: "Konkon Railway" – (1998)

Salkade: "Points & Crossing" – Popular Book Deport, Bombay – (1937)

Sethi, H.K.L.: "River Training and control for bridges"

Singh Inder: "Points & Crossing" – Verman & Co., Saharanpur, U.P. (1974)

Singh Harjit: "Railway Steel Bridges" – Karuna Prakashan, New Delhi (1992)

Singh K.P." "High Speed Trains Around the World: Prospects for India"-RITES Journal (April, 2000)

Sreedharan E. "Restoration of Pamban Bridge"

Stauffer, D.M. : "Modern Tunnel Practice"-(1928)

Technical Monograph No.50 – Govt. of India, RDSO

"Track Maintenance on high speed routes"-Govt. of India, Ministry of Railways, RDSO (1971)

Vaswani Dr.N.K.: "Railway Engineering"-Roorkee Publishing House, Roorkee (1965)

REPORTS & DOCUMENTS –CIVIL ENGINEERING

Bridge river Brahmputra-past, present & Future	Construction organisation of North East Frontier Railway	1988
Continuous Weld Rails,	RDSO	May 1977
Down Memory Lane-N.R. Loco Workshop, Charbagh		June 2004
Increase of speed on Delhi-Howrah route Feasibility study	RDSO (Report No.C&M)	May 1969
Increase of speed on Delhi-Howrah route Feasibility study	RDSO (Report No.C&M)	May 1959
Increase of speed on Delhi-Howrah route Feasibility study	RDSO (Interim Report No.Vol-I)	1968
Increase of speed on New Delhi-Howrah Route-study of formation phase-II	RDSO Civil Engineering Report No. C-87)	October 1970
Indian Railway Track Machine Manual	Railway Board	2000
Indian Railways Bridge Manual	Railway Board	1998
Indian Railway Permanent Way Manual	Railway Board	1998
Indian Railways Track Manual	Railway Board	1965
Investigations for the development of Elastic fastenings	RDSO-C.E. Report No.C-65	February 1969
Konkan Railway	Konkan Railway Corporation	1998
Manual for Flash Butt Welding of Rails	RDSO	1996
Manual for Fusion Welding of Rails by Alumino-Thermic Process	RDSO	1996
Manual for Gas Pressure Welding of Rails	RDSO	1995
Manual for Ultrasonic Flaw Detection of Rails and Railwelds	RDSO	1995
Manual of instructions for laying and maintenance of short welded rails	RDSO	1990
North East Frontier Railway-History of Railway bridges	North East Frontier Railway	
Permanent Way Technique and permanent Way economy by Gerhard Schram	Otto Elsner Verlags Gellschaft Darmstadt.	1961
RDSO report-History of evolution of various design of B6 wagons		Mach 2004
Souvier-Century Celeberations-Liluah Workshop		Mach 2001
Track maintenance on high speed routes	RDSO	1971

MECHANICAL ENGINEERING

Atkins Bill	Exploring Indian Railways, Delhi Oxford University Press	1994
Cornwel, E.L.	History of Railways-Ed., Himiyn Publishing Group Ltd. (London)	
Diwakar, R.R.	Bihar through the ages, Govt. of Bihar	1950
Harrison, M.A.	Indian Locomotives	1972
Hughes Hugh	Indian locomotive part1-Broad gauge	1851-1940
Hughes Hugh	Indian locomotive part2-Metre gauge	1872-1940
Hughes Hugh	Indian locomotive part3-Narrow gauge	1863-1940
Hughes Hugh	Indian locomotive part4-Narrow gauge	1941onward
Kendrith, S.T.	Progressive Building of Railway Carriages	1926
Kipling Rudard	From Sea to Sea-Vol.II	1889
Marshal M.P. &	The Time Table of Technology, Netherland Field White	
Orton, A.	The Diesel Engine	1938
Sinha, Dr. P.P.	Munger through the ages, Dr. Jai Prakash Narayan IRS College, Jamalpur.	

REPORTS & DOCUMENTS-MECHANICAL ENGINEERING

Administrative Reports on the railways in India, Public Works Department, (Railways)	1885-86 to 1903
Annual reports, Research Designs and Standards Organisation Director, General RDSO, Ministry of Railways, Lucknow	1998-99
Brochure "Loco Workshop Parel, Bombay, Central Railway" on World Bank team visit	
Down Memory Lane – N.R. Loco Workshop, Charbagh	June 2004
Pamphet"Dahod workshop-History & Achievements"	01.12 1999
& Chief workshop Engineer, Report No.M/324/W/4.2.11/PP	30.11.1999
RDSO report – History of evolution of various design of BG wagons	March 2004
RDSO's Report No.MP-PRO (Revision OO)	December, 1998
Development of DMU & Rail Bus.	
Times of India, New Delhi	14.08.1999
Design of High speed Coaches by EDS/Carriage/RDSO	
Souvinier-Century Celeberations-Liluah Workshop	March 2001

ELECTRICAL ENGINEERING

Arora, Dr.A.K.	History of Bombay Suburban Railway	1853-1985
Awasty, H.D. (G.M. & C.E., Rly. Electrification)	Railway electrification in India	Oct.–Nov.1964
Bhandari, R.R.	Six Articles in "Electric traction in India 1925-1950", Published in SLS Journal (Vol.59 Nos. 689-694)- Electrification on Indian Railway.	1983
Burtt Phillip	Railway Electrification and Traffic Problems	1929
Cook & Gipson	Report on the proposed extension for the mainline	12.05.1934
Danuser, Reto (Swiss electrical engineer)	My recollections of the very beginning of 25kv, 50 cycles ac traction in India, Rail Transport Journal Vol. III, No.2	April-June 1994
Dover, A.T.	Electric Traction	1928
Hinde, W.	Electric and Diesel-Electric Locomotives	1948
Loosli, H.	Railway electrification in Switzerland, Institute of Locomotive Engineers Journal No.228	22.05.1952
Lydall, F.	The electrification of the Suburban and the main line sections of the Great Indian Peninsula Railway	April,1932
Mukerjee, M.N. (Dy.CEE/RE Calcutta	Railway electrification on the Eastern Railway. Paper presented on the occasion of Golden Jublee of Electric Traction in India.	1975
Mukerjee, M.N. & Sankarnarayanan C.A.	Aliminium-alloy conductor for ac traction overhead equipment- Proceedings of the Institution of Electrical Engineers (UK) Vol.126 No.7	July,1979
Nandkeolyar, A. Dy.CEE/RE	Conversion for 3000 Volt dc to 25 kv ac traction RE Journal, Vol.5-No.3	Aug.-Sep.1964
Narayan, S.S. Distt. EE/S. Rly.	Conversion of Madras-Beach-Tambram sector from 1500 Volt dc to 25 kv ac, RE Journal, Vol.8-No.6	Feb.-Mar.1968
Parmanand	Scheme for ac/dc working at Igatpuri RE Journal, Vol.5, No.3	Aug.-Sep. 1964
Shastri, D.V.K. CEE/S/Rly	Ac Traction comes to S.Rly.,R.E. Journal Vol.8-No.6,	Feb.-Mar. 1968
Shastri, D.V.K. CEE/S/Rly.	Over night conversion from dc to ac on the Suburban lines, RE Journal, Vol.8, No.6	Feb.-Mar. 1968
Twinberrow, T.D.	The mechanism of Electrical Locomotives	1932

REPORTS & DOCUMENTS – ELECTRICAL ENGINEERING

AC Traction comes to S.Rly. by D.V.K. Shastri CEE/S/Rly.-RE Journal Vol.8-No.6 February-March 1968.

Aluminium-alloy conductor for ac traction overhead equipment by M.N. Mukerjee and CA Sankarnarayanan-Proceedings of the Institution of Electrical Engineers (UK) Vol 126 No.7 July, 1979.

Annual Reports of South Indian Railways (Trichy) Section-I from the years 1930-31 to 1940-41.

Article entitled "Power required for Electrically Lighting Railway Carraiges with Stone's System" from the July 1904 issue of "Railway Engineer".

Article on Stone's System published in "Transport" dated 28th October 1898 Reports of South Indian, Jodhpur-Bikaner, Bengal Nagpur, Malwa-Rajputana, North Western and Bengal North Western Railways about status of Train Lighting.

Booklet on 'RAILWAY ELECTRIFICATION' published by Central Organisation for Railway Electrification, Allahabad, in Dec. 2004.

Conversion for 3000 volt dc to 25 kv ac traction by A. Nandkeolyar, Dy.CEE/RE, RE Journal, Vol.5-No.3, August-September 1964.

Conversion of Madras-Beach-Tambram sector from 1500 Volt dc to 25 kv ac by S.S. Narayan, Distt. EE/S. Rly., RE Journal, Vol.8-No.6, February-March 1968.

Electrification of Indian Railways-Report of Nouvion Mission (SNCF) June-Sept., 1956.

Kalyan Power House, 1947 Extensions, Central Railway – brochure issued at the inaugural function on 9th Dec. 1952.

LCWS Committee reports of meeting held in 1889, 1892, 1893, 1894, 1905 and 1907.

My recollections of the very beginning of 25 kv,50 cycles ac traction in India by Reto Danuser (Swiss electrical engineer), Rail Transport Journal, Vol III-No 2, April-June 1994

Over night conversion from dc to ac on the Suburban lines. By D.V.K. Shastri CEE/S/Rly.-RE Journal, Vol.8 No.6, February-March, 1968.

Proceedings of Electrical Standards Committees Meetings.

Proceedings of the Institution of Mechanical Engineers. Vol-123

Project Report for conversion of Madras beach-Tambaram section from 1500 V dc to 25 kv ac and electrification of Tambaram-Villupuram section-S.Rly. Nov.-1960.

Railway Board letter No.72/RE/141/1 dated 21st July-1992

Railway electrification in India by H.D. Awasty, General Manager & Chief Engineer Railway electrification-RE Journal, October, November 1964.

Railway Electrification in Switzerland Institute of Locomotive Engineers Journal No.228. (paper presented by H. Loosli-22nd May 1952.

Railway Electrification in Switzerland-Publication of Swiss Federal Railways. (Approx.1955)

Railway electrification on the Eastern Railway by M.N. Mukerjee, Dy. CEE/RE, Calcutta. Paper presented on the occasion of Golden Jubilee of Electric Traction in India, 1975.

Record notes of the A C Review Committee meetings.

Records notes of discussions of the 14th Meeting of Electrical Section of IRCA.

Record notes of Maintenance Study Group Train Lighting and Air-conditioning.

Report on the Application of Electric Traction for the Bombay Suburban Railway-Merz and Mclellan-London-October 1913.

Reports of 1st, 2nd, 3rd, 4th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 14th, 15th, 16th, 17th, 18th, 21st, 22nd, 23rd and 24th meetings of Electrical Standards Committees and various sub-committees formed by them

Reports of the 4th, 5th, 6th, 7th, 9th, 10th and 14th meetings of Carriage and Wagon Standards Committee

Reports of the 1st to 3rd MSG (TL & AC) Meetings

Reports of 8th, 9th, 10th and 11th AC Review meetings

Reports dated 11th Nov. 1929, 25th Jan. 1930 and 15th Nov. 1933 of the Electrical Members of CWSC

Reports of RDSO

(a) "Evaluation of the performance of Double Battery Parallel Block 24-vdc Train Lighting System", issued in 1967

(b) "Fires of Electrical origin in All Metal Coaches", issued in 1968

Report on the electrification of lines in the neighborhood of Calcutta (East Indian Railway and Eastern Bengal Railway) by M/s Merz and Mclellan, London (August 1924).

Report on the electrification of part of GIP Railway main line-Merz and Mclellan-London-July 1919.

Report of the Sub-Committee of CEE's formed by the 10th ESC Meeting to review the performance of wooden body air-conditioned coaches.

Report on the proposed extension for the mainline by Cook & Gipson-12th May 1934.

Scheme for ac/dc working at Igatpuri by Parmanand-RE Journal, Vo.5 No.3-August-September 1964.

Six Articles by R.R. Bhandari (Electric traction in India 1925-50) published in SLS Journal (Feb.1983 to July 1983-Vol.59 Nos. 689-694)-Electrification on Indian Railway.

Story of Chittranjan Locomotive Works by R.K.Vir.

Techno-economic evaluation of 2x25 kv ac system on Indian Railways-RDSO Report No.TI/Report/PSI/00047

The Electrification of the Suburban and the main line section of the Great Indian Peninsula Railway-April 1932 (Vol.7) By Shri F. Lydall-Journal of the Institution of Electrical Engineers.

The mechanism of Electrical Locomotives by T.D. Twinberrow-Proceedings of the Institution of Mechanical Engineers-1932 Vol-123.

The Swiss Federal Railway-Electrification completed. Published by the Swiss Federal Railways (Approx. 1960).

UIC Seminar at Johannesburg, 2000. Paper on 'Traction Power Systems-CONVERSION-DC to AC' by A.K.Jain.

SIGNALLING & TELECOMMUNICATION

Agarwal S.K.	Development of signalling and Road ahead
Chandrika P.	"Indian Railways Signalling-Today and Tomorrow" -talk delivered in UIC's User Producer Interaction Programme at Tokyo (1998) and published in Rail International (1198)
Dutton S.J.	Railway Signalling (1928)
Fraser H.J.	Lewis's Railway Signal Engineering (1932)
G.G. Biswas & Sanjay Dungrakoti	An overview of Electronic Interlocking and its adaptation on Indian Railway – IRSTE Journal 2005
Kaul M.K.	50 years of Telecommunication of Indian Railways
Kaul M.K.	Modern Railway Signalling (1983)
Mishra A.K.	Dawn of Revolution in Railway Telecommunication System
Prasad Chandrika	"End of the search for a suitable Automatic Warning System for Indian Railways"-published in Indian Railways (Sept.1999)
Prasad Chandrika	"Indian Railways Vision 2025-Signalling "talk delivered at Railway Staff College Vadodara in the Seminar on Indian Railways Vision 2025 in June 2002
Raghwan K.S.	Southern Railway marches ahead-Modernisation of Signalling and Telecommunication in Post Independent era
Ramaswamy V.	Growth of Signalling on IR-post Independent 50years
Sethi S.P.	Modern Railways Transportation
	Vol I Operational Problems
	Vol II Safety rules & Regulations
Sanjay Dungrakoti	IRSTE Journal 2005
Thiruvengadam P.T.	Development in Railway Signalling (1971)
Tattersall A.E.	Modern Development in Railway Signalling
Westwood J.N.	Railways of India (1974)

REPORTS & DOCUMENTS – SIGNAL & TELECOMMUNICATION

Development in Railway Signalling by P T Thiruvengadam
Eight Signal Maintenance Study Group Reports 1996-2005
Indian Railways Signal Engineering Manual Part I 1988
Indian Railways Signal Engineering Manual Part II 2001
Indian Railway Vision 2025 Seminar – Railway Staff College Vadodara
Journal of Institution of Railway Signal & Telecom Engineers 1996-2005
Modern Signalling (Principles & Practices) by M K Kaul
Railway Signalling Installation & Management –An Indian Perspective by S M Sikdar
RDSO's Signal Standard Committee Reports 1996-2005
RDSO's Telecom Standard Committee Report 1996-2005

Chronological List of Key Events

Indian Engineering Heritage (Railway)

- General
- Civil
- Mechanical
- Electrical
- Signal & Telecom

March, 2007

Chronological List of Key Events in Railways (General)

1813	First step for ending East India Company's monopoly taken
1820s	Effort by steamship lines in India with Government support was made in 1820s and 1830s
1820s	Efforts to develop railway system all over world
1825	First railway line from Stockton to Darlington opened to traffic on 27th September
1825	Railways started in England on 27th September
1829	Development of Railways in France started
1830	15 miles long Baltimore-Ohio line in USA opened in May
1830s	Extensive growth of railways took place in Europe.
1831	First idea of railways in India conceived in the Presidency of Madras which proved unsuccessful
1835	Development of Railways in Germany started
1837	Development of Railways in Russia started
1839	Development of Railways in Holland & Italy started
1842	Queen Victoria advised not to travel by railways
1844	Meeting of prominent citizens held on 13^{th} July to consider desirability of railway line between, Bombay, Thane, Kalyan and Bhoreghat.
1847	Prospal between Bombay and Kalyan (70 miles) cleared in September.
1848	Louis Phillip of France forbidden to travel by railways for fear of life
1850	Railway line was considered "hazardous and dangerous venture" in India
1853	Formal inauguration of the First Railway line in India from Bori Bunder (Bombay) to Thana done on 16th April; The train having 14 railway carriages and 400 guestes left Bori Bunder with 21 gun salute on 16th April.
1853	In India, Railways developed both as private and state enterprise between 1853 & 1951.
1853	Lord Dalhousie in his minutes in April laid stress on importance of speedy and wide introduction of Railways lines in India
1858	A private company (Eastern Bengal Railway) got concessions for construction and management of railway lines commencing from the left bank of Hooghly towards Eastern & Northern part of Bengal including a line to Darjelling.
1862	Calcutta to Ranaghat (45 miles) opened to traffic in September
1862	In December Indian Branch Company proposed to construct light railways.
1862	Lord Elgin laid a policy for constructing narrower gauges
1863	Governor General Lord Elgin while opening the Koilwar bridge in February, over sone river declared it the magnificent bridge in the world.
1868	After surrendering by loss making "Calcutta and South Eastern Railway" State started owning railways from first April.
1869	Direct construction and ownership scheme adopted by Government of India

1869	Railway enterprise in India was at low ebb
1869	Schemes of railway extension to Punjab and Rajputana finalized
1877	State Railway Directorate transferred from single Director to three territorial directors and one Director of stores.
1880	Post of Director General in lieu of three territoral directors created
1882	About 10 more narrow gauge lines introduced during the period 1882-1907
1894	Nilgiri Railway company went into liquidation in April.
1896	A new company with the same title formed for construction of Nilgiri Railway in February
1896	New company formed to construct the proposed extension from Mettu Palayam to Ootacumund.
1897	Post of Director General Abolished
1901	Post of consulting Engineer for State Railways abolished in October
1903	Government purchased the Nilgiri line from the new company on Ist january
1903	Indian Railways Conference Association setup
1903	Kalka Shimla line (59.44 miles) opened to traffic on 9th November.
1903	Satpura line of 2'-6" gauge opened.
1905	On recommendation of Sir Thimson Reberton, CVO Railway Branch of Public Works Department of the Government of India abolished and Railway Board consisting of a Chairman and 2 members under the Department of commerce and industry created.
1907	Matheran light railway of 2' - 0" gauge opened.
1908	On recommendations of Railway Finance Committee Railway Board was reconstituted in October, with Chairman re-designated as to President with direct access to Viceroy and Railway Board becoming Railway Department under the charge of Member commerce and industry as Railway Member.
1908	Pathankot Nagrota section opened to traffic on Ist December
1920	Due to great slump between 1920 & 1940 Railway development slackened.
1924	Legislative Assembly agreed to separate railway finances from General fiinancesin September.
1924	Railway Board again reconstituted with Chief Commissioner as President and an ex-officio Secretary to Government of India and two members.
1926	Governor of Punjab performed the opening ceremony for construction of 100 mile long, 2'-6" gauge line from Pathankot to Shanan on 2nd May.
1936	Air Conditioning introduced in passenger coaches.
1947	Immediately after Independence, Railway Board consisted of five members including Chief Commissioner, Financial Commissioner and three members.
1948	There were 42 independent railway systems in India with largest Pvt. Railways being (Nizam State Railway) with 2247 route kms.
1951	Central Railway and Wesern Railway established on 5th November

1951	Southern Railway established on 14th April
1951	South Indian Railway & Nilgiri Railway made a part of Southern Railway on 14th April.
1952	Northern Railway and North Eastern Railway established on 14th April.
1952	Railway staff college, Vadodara setup
1952	Railway Testing and Research centre setup (RTRC)
1954	The position of Chief Commissioner for Railways renamed as Chairman Railway Board
1955	Indian Railway Institute for Civil Engineering, Pune Setup
1955	Integral Coach Factory, Perambur established.
1955	South Eastern Railway established on Ist August
1957	Indian Railway Institute for Signal and Telecommunication, Secunderabad setup.
1957	Research design and Standard Organisation-Lucknow setup after merger of various standards committees and RTRC
1958	North East Frontier Railway established on 15th January.
1959	New post of Member Mechanical created in Railway Board.
1966	South Central Railway established out of Central Railway and Southern Railway on 2nd October.
1969	All systems brought to Divisional System of Indian Railways
1969	First Rajdhani train at 120 kmph introduced in November 1969
1969	New Delhi-Howrah Rajdhani Express introduced at 120 kmph speed.
1970	Administrative Reform Commission report suggested Railway Board should not exceed 6 members and a chairman.
1971	Railway minister announced to end economic drag due to multiple gauges.
1974	Rail India technical & economic services (RITES) formed
1976	Indian Railway Construction Corporation (IRCON) formed
1977	National Rail Museum for preservation and promotion of heritage, tourism, education and entertainment opened to public.
1980	The first Double Decker train 'Vrindavan Express' ran between Madras & Bangalore
1982	Konkon Railway corporation for constructing and operating for 10 years incorporated on 19th July.
1982	Railway Reforms Committee recommended 4 additional zones after studying. Efficiency Bureau Reports of 1954,1961,1965 to the nine existing zones.
1984	Introduction of first Metro Rail in Kolkata
1985	Computerised Passenger Reservation System introduced
1985	Chairman Railway Board held positon of member also.
1985	Duality of Chairman Railwwy Board abandoned on Ist July.
1986	Indian Railway Institute for Electrical Engineering, Nasik setup
1987	A new Member Electrical created after change of Mechanical member was split

1987	Diesel Component Works, Patiala setup
1996	Inauguration of East Coast Railway-Bhubneshwar took place on 8th August
1996	Inauguration of East Coast Railway-Allahabad took place on 20th August
1996	Inauguration of East Coast Central Railway-Hajipur took place on 8th September.
1996	Inauguration of North Western Railway-Jaipur took place on 17th October.
1996	Inauguration of South Western Railway-Bangalore took place on Ist November
1996	Inauguration of West Central Railway-Jabalpur took place on 8th December
1997	Addition of 8031 Km lines at an average rate of 161 kms per year took place after independence upto 1997
1998	Inauguration of Bilaspur Zone-Bilaspur took place on 20th September
1998	Guinness Certificate for 'Fairy Queen'-the oldest working steam Locomotive in the world
1999	Darjeeling Himalayan Railway declared 'World Heritage Site' by UNESCO.
1999	Centenary Celebrations of the Nilgiri Mountain Railway
1999	Guinness Certificate for Delhi Main Station equipped with the World's largest Route Relay Interlocking System.
2000	Railway Board consists of 7members including Chairman from 2000 onwards.
2002	Introductin of Jan Shatabdi Trains
2002	East Central Railway (HQ-Hazipur) and North Western Railway (HQ-Jaipur) become operational w.e.f. Ist October.
2002	150 th year of Indian Railways starts w.e.f. 16th April 2002.
2003	Indian Railways have 16 (earlier 9) Zones and 67 (Earlier 59) Divisions with effect from 1st April 2003
2003	Indian Railways complete 150 years of existence on 16th April 2003
2002-07	The Tenth plan of Indian Railways envisages an outlay of Rs. 60,600 crore, which is 4% of Total outlay for the Plan.
2005	Indian Railways have total akilometerage of 63,465 on 31.03.2005 consisting of 47,749 kms of BG 12662 kms of MG & 3054 Kms of NG.
2006	Garib-Rath AC trains introduced on I.R.

Chronological List of Key Events in Railways (Civil)

1789	Edge Rails introduced by Jessop for ancient cart ways
1789	Iron plates replaced with cast iron beams for Tramways in U.K.
1804	Discovery of Trevithick regarding easy movement by adhesion of a smooth wheel to a smooth rail
1814	George Stephenson invented steam locomotive for traction
1821	Construction of Ist railway line from Stockton to Darlington started by George Stephenson
1825	First railway line from Stockton to Darlington opened to traffic on 27th September
1829	"Rocket" Locomotives used for freight and passenger traffic proved successful
1830	Construction of railway line between Liverpool and Manchester in U.K. completed
1830	Rail-road era began with completion of Liverpool-Manchester on 15th September
1831	First idea of railways in India conceived in the Presidency of Madras which proved unsuccessful
1836	Captain A.O. Cotton a Civil Engineer of Madras advocated desirability of Rail road in India
1837	Construction of railway line from St.Petersburg to suburbs of Pavlovask in Russia completed by a Pvt. Co.
1842	Hurricane was one of the reasons for adopting 5'-6' track gauge from safety consideration
1843	Idea occurred to Mr. Geogre Clark, CE of Bombay Government to connecting Bombay with Thana, Kalyan, and Bhore Ghat Incline.
1845	Trial survey to link Calcutta with Delhi conducted
1847	Prospal between Bombay and Kalyan (70 miles) cleared in September.
1847	Request for despatch of men and materials by sea to Board of Directors for laying railway line was made May/June
1849	First agreement with East Indian Railway (EIR) & Great Indian Peninsula Railway (GIP) stipulated a gauge of 4'-8 1/2" for India
1850	First tender for constructing railway line between Howrah and Pandooah (38 miles) sanctioned by Governor General of India on 6th September.
1850	Lord Dalhousie wrote in his minutes in July that object of constructing an experimental line from Calcutta to Rajmahal was to prove that it is practicable to construct railways in India with a fair remunerative return.
1850	Work for railway line between Bombay and Kalyan started on 31st October.
1850s	Work on First railway line in South india between Veyasarpady and Walajah Road (63 miles) started
1852	First locomotive witnessed shunting up near Byculla in Bombay on 18th February
1852	Reasons recorded by Mr. W. Simms consulting Engineer to Government of India for preferring 5'-6" over 4'-8 1/2 " Gauge for Indian Railway System.
1853	Formal inauguration of the First Railway line in India from Bori Bunder (Bombay) to Thana done on 16th April; The train having 14 railway carriages and 400 guestes left Bori Bunder with 21 gun salute on 16th April.

1853	Rails continued to be imported from England and European countries till manufacture of rails started in India by M/s TISCO & IISCO in 1940s
1854	Line commissioned for 24 miles between Howrah and Hooghly on 15th August
1854	Locomotive taken on a trial trip from Howrah to Pundooah on 18th June.
1854	Railway line opened upto Hooghly (24 miles) on 15th August
1855	Railway line-opened upto Raniganj on 3rd February.
1855	First railway line in South India between Veyasarpady and Walajak Road opened to traffic on Ist July.
1856	Work commenced for Koilwar bridge across Sone river
1857	Revolt by Raja Kanwar Singh on 25th July halted the work of Koilwar bridge over Sone river
1861	Public Works Department recommended in a note for adopting narrower Gange in India
1862	Calcutta to Ranaghat (45 miles) opened to traffic in September
1862	Construction of 2'-6" gauge Gaikwad Baroda State Railway (GBSR) line from Dabhoi to Miyagram line due to economic reason.
1862	In December Indian Branch Company proposed to construct light railways.
1862	Lord Elgin laid a policy for constructing narrower gauges
1863	Governor General Lord Elgin while opening the Koilwar bridge in February, over Sone river declared it the magnificent bridge in the world.
1864	Sir John Lawrence during his period from 1864 to 1869 followed Lord Elgin's policy of constructing narrow gauges.
1865	First train ran over Yamuna bridge at Allahabad on 15th July
1866	The work of bridge over Yamuna bridge at Delhi completed.
1867	Mhowke-Mullee viaduct collapsed on 19th July Subsequently viaduct filled up to become a continuous embankment.
1870	Committee setup to decide gauge to be adopted in India
1870	Lord Mayo's expressed his views on 17th May, in favour of narrow gauge in India.
1870	Lord Mayo recorded his reasons on 30th December for not agreeing to 5'-6" gauge and his preference for adopting 3'-3" gauge.
1871	Further extension from Jagati to Goalunda (45 miles) opened in January.
1871	Introduction of Metre gauge in India on account of its being cheap and economic railway.
1873	Due to failure of rains and prospects of scarcity in Bengal East Bengal Railway (EBR) pushed forward for a railway line from Ganges to Jalpaiguri in January.
1877	Governor of Madras Presidency got estimate prepared for an alternate proposal for Nilgiri line viz. a railway line from Mettupalayami to a point 2 miles north of Kallar and an inclined ropeway from there to lady Canning's seat and another rail line from the head of ropeway to Coonoor, The proposal dropped being hazardous.
1877	For Mountain Railway for Nilgiri Hill's, a detailed analysis prepared by Capt. J.I.I. Morant, District Engineer for the Nilgiri Distt.

1877	Mr. Monnier, a French inventor, designed a reinforced concrete sleeper. He suggested use of cement concrete sleepers for Railway Tracks.
1878	A scheme for 2'-0" wide gauge line submiitted by Franklin Prestage for Darjelling Railway line sanctioned by Lieutenant Governor.
1880	Franklin Prestage took the lead for constructing Darjelling Himalayan Railway
1881	Construction of 2'-0" gauge Darjelling Himalyan Railway line completed.
1882	About 10 more narrow gauge lines introduced during the period 1882-1907
1882	M. Riggenback, started preparing detailed estimate of rack railway.
1884	First survey for Kalka Shimla line was made
1885	Nilgiri Railway company' formed and got registered on 30th September.
1886	Contract for construction of Nilgiri railway executed between secretary of State and Nilgiri Railway Company on 26th February.
1887	Yamuna bridge at Delhi Commissioned for Rail Traffic.
1888	Bridge over river Ganga at Varanasi constructed between 1888 & 1894
1894	Proposal for railway line in the Konkan by Southern Maratha Maharastra Railway company.
1896	New company formed to construct the proposed extension from Mettu Palayam to Ootacumund.
1897	Barsi Light Railway of 2'-6" gauge opened.
1897	Nilgiri line opened between Meetu palayam to Connoor on 15th June.
1897	Work of construction for Ist bridge over Godavari started on 11th November.
1897	Work on longest bridge in India Bridge No. 531 started at Dehri-on-Sone
1898	A contract between secretary of State and the Delhi-Ambala-Kalka company for 2'-0" gauge Kalka-Simla line signed on 29th June.
1900	Shortly after start of construction of Kalka Shimla, a scheme to link Shimla with Dalhousie via, Kalka worked out.
1900	Welding process of Rails developed.
1901	Due to military requirements a portion of line built to 2'-0" gauge changed to 2'-6" gauge after Government of India's approval
1903	Kalka Shimla line (59.44 miles) opened to traffic on 9th November.
1905	19 km long, 2'-0" gauge Neral-Mathern railway built by Sir Adamjee Peerhoy 20th Cent. Shortage of wooden sleeeper led to development of metal sleepers.
1907	Matheran light railway of 2' - 0" gauge opened.
1908	Pathankot Nagrota section opened to traffic on Ist December
1908	The Nilgiri line extended from Coonoor to Ootacamund on 15th October.
1911	Pamban viaduct constructed between 1911 & 1913
1914	A formal contract between DHRE and secretary of State for construction of Kishanganj branch and Teesta Valley branch signed on 25th April.
1914	Pamban viaduct commissioned in February.
1915	Both Kishanganj and Teesta valley branch lines opened to traffic.
1918	M/s Tata sons wrote to Railway Board about desirability of a Railway Line between Bombay Harbour and Chiplan.

1919	Survey for a M.G. line between Karad to Ulva via. Chiplon carried out during 1919-1921 which proved to be expensive and un-remunerative.
1925	The proposal to link Shimla with Dalhousie revived.
1926	Survey for B.G. line from thana or Mumbai Mahad carried. Take off point of Diva found most suitable.
1926	Track Standard Committee (TSC) deliberated on improving and standardising Cast Iron (C.I.) Sleepers in its meeting held between February-May.
1929	Nagrota-Joginder Nagar section opened to traffic on Ist April.
1946	Survey for Diva-Dasgaon Railway project sanctioned.
1947	Decision for connecting of broken links of same gauge taken.
1947	Dismantling of unimportant lines between 1940-1947 reduced the route kms by 850 kms.
1947	Malviya bridge re-opened for single line traffic in september.
1948	Government of India (GOI) gave green signal for 'Assam Rail Line Project' on 27th January.
1948	Indian Government takes over the working of Darjeeling line from Darjeeling Himalayan Co. on 20th October.
1950	Central Board of transport did not apaprove Diva-Dasgaon railway project
1951	Large sections of 2'-0" gauge Sivok-Kalimpong branch washed away and line abandoned.
1953	Bridge construction near Mokameh sanctioned to facilitate traffic to Assam
1953	Railway Board ordered a preliminary survey of Diva-Dasgaon project both for BG and MG
1954	After restoration, section re-opened to traffic on 15th April.
1955	Indian Railway Institute for Civil Engineering, Pune Setup
1959	Manufacture of 52 kg rails started in Bhillai plant established with Russian help after independence.
1959	Railway Board decided to include Diva-Uran via Panvel a new BG line in March.
1964	Cylone washed away, 124 spans of Pambon viaduct on 22nd/23rd December.
1965	Second bridge over river Krishna river, 45 m down stream of Ist bridge constructed.
1965	Traffic restored ater regirdeing of spans of Polmbon viaduct, hit by cyclone on Ist March
1966	Railway line from Panvel to Apta opened for traffic on 31st January.
1969	New Delhi-Howrah Rajdhani Express introduced at 120 kmph speed.
1970	The design of CST-11sleepers discussed in 46th Track Standard Committee (TSC) in May 1970
1970	Ultra sonic rail testing started on IR
1971	Gauge conversion policy emerged to have a uniform gauge on I.R.
1971	Portable rail testers imported from German, assembled in India
1972	Bridge over Mahanadi between KatniSirgrauli constructed.
1973	The line beyond jawanwala Shahar closed to traffic on 11th April and track between Jawanwala Shahar and Guler dismantled thereafter to make way for pong dam.

1974	Indigenous production of portable rail testers started in India
1974	Rail India technical & Economic Services (RITES) formed.
1976	Indian Railwaya Construction Corporation (IRCON) formed.
1983	Policy of uni-gauge reviewed and decision for up-gradation of existing MG track taken due to financial limitations between 1983-1986.
1984	Introduction of first Metro Rail in Kolkata
1987	As per report in Railway Gazette of January 1987, 70000 kms of track was under construction in various countries despite economic recession of 80s which hit Railway Industry.
1987	Jubilee bridge over River Hooghly opened in February
1989	Railway Board approved construction of 69 km long Mangalore Udupi line as a first phase of Konkan Railway
1990	Construction work started by Konkan railway corporation.
1992	1,000 kms of MG and NG route kms identified for conversion to BG between 1992 to 2000
1997	Addition of 8031 Km lines at an average rate of 161 kms per year took place after independence upto 1997
1997	Karlis Goppers in his Swedish International Development Co-operation-Agency report in July pointed out that Konkan Railway project is the biggest and perhaps most difficult railway project undertaken in the century at least in this part of world.
1998	Entire Konkan Railway system come in to operaton on 26th January.
2002	150th year of Indian Railways starts w.e.f. 16th April 2002.
2003	Indian Railways complete 150 years of existence on 15th April 2003.
2004-05	Indian Railways have a route km of 63,465 with Broad Gauge on 47749 kms, Metre Gauge 12662 kms, Narrow Gauge as 3054 kms.

Chronological List of Key Events In Railway [Mechanical]

1813	George Stephsenson (1781) had become an engineer of repute.
1814	George Stephenson, built 1st locomotive named 'Blucher' which was in service upto 1826.
1821	George Stephenson appointed as an Engineer in Stockton & Darlington Railway
1825	1st public passenger train hauled by locomotive 'Locomotion' ran on 27th September
1826	Railway between Liverpool & Manchester started.
1827	Liverpool and Manchester Railway Company advertised for competition for building a locomotive to their stiff specifications. Competition was won by father and son team of Stephensons.
1827	Railway claimed 30% saving in haulage cost per ton-mile with locomotives in comparison to that of horses.
1851	First steam locomotive called 'Thomason' which arrived in India, started the operation of earth work for Ganga canal near Roorkee on 22nd December.
1853	1st train started running between Bombay and Thane by Great Indian Peninsular Railway Company.
1853	About 40 companies were engaged in building railway lines in India from 1853
1853	Almost all important equipment e.g. rails, locomotives rolling stock, workshop machinery were imported from England in CKD or later in SKD condition upto 1947
1853	G.I.P. company ran first passenger train in India and Asia from Bori Bandar on 16th April.
1854	Railway line from Howrah to Hooghly opened to passenger traffic on 15th August
1854	Howrah-Hooghly line extended to Pandooah on 1st September
1855	Locomotives – 'Fairy Queen' and 'Express' built
1862	Move to shift locomotive portion of workshop from HWH to Jamalpur initiated.
1862	Pandooah to Jamalpur section opened to traffic on 8th February
1867	Lucknow came on the rail map on 23rd April 1867 under the banner of Indian Branch Railway Company as part of Oudh and Rohil Khand Railway
1870	A rolling mill was set up in Jamalpur workshop to turn out standard flats, rounds, hexagonal, angles, channel and fish plates for rails.
1870	Charbagh, Lucknow workshop employed a good number of native labour mostly Bihari.
1870	India's first railway employees' Union formed by Anglo Indian workers
1879	Parel loco workshop set up at a distance of 8 kms from Bombay V.T.
1888	For imparting practical training to staff of Jamalpur workshop, evening classes started.
1893	An iron foundry set up in Jamalpur workshop
1896	First major expansion and remodeling of Jamalpur workshop took place for manufacture of new locomotives from workshop made components and boilers

1896	Workmen's trains started from three directions to bring workmen to Jamalpur workshop
1898	A steel foundry along with a new iron foundry set up for making the Jamalpur workshop self sufficient for all iron steel castings.
1901	A steam power house based on coal burning stationary boilers, set up in Jamalpur workshop
1901	Policy of standardization of locomotives in India started
1902	First time in India, manufacture of 30 ton weigh bridges started in Jamalpur workshop.
1903	Mr. Bremerton, Secretary to GOI, PWD (Railways) on 23rd May, 1903 observed in his administrative report for the year 1902, that Mr. CW Hodson, Director of Railway construction was deputed while in England to consult English authorities regarding relaxation in existing standard for fixed and moving dimension for Indian Railways and strength of bridges, axle loads and weight of rolling stock and placing advance orders for rolling stock.
1903	Secretary of state approached British Standards Association and a committee was setup for standardisation.
1905	Technical school to impart academic training to higher category of staff started at Jamalpur
1910	Orders for 840 BG and 470 MG standard BESA engines placed.
1912	Steam pumps installed in two boats in river Ganga, near Munger for supply of water to Jamalpur workshop & town ship developed near city
1914	Due to Great war, further development in Railways almost stopped between 1914-1919
1919	B.B.C.I. initiated certain experiments on MG engines.
1922	Increase in fuel bill added further fillip to standardisation process between 1922-1923
1922	Success of experiments promoted similar arrangement of extra wide fire boxes for BG and agents reported no objection to running of these engines.
1923	Railway Board in consultation with the Agents, decided to set up 'Loco Standards' Committee in October for progressive standardisation as a continuous process. It worked till 1930.
1925	A principal pointed for upgraded Jamalpur school
1925	Charbagh, Lucknow workshop was taken over by EIR firm Oudh and Rohil Khand Railway
1926	The foundation of Dahod workshop laid by Sir Clement Hindley, Chief Commissioner for Railways on 14th January
1927	Scheme for training of future class I Mechanical and Electrical Engineering officers, selected by Federal Public Service Commission, was started in Jamalpur school.
1928	Modified IRS designed locos started arriving
1930	Central standards office (CSO) under Chief Controller of standardisation set up to standardize all equipments commonly in use in Railways.

1931	Dahod workshop started functioning
1936	CSO on Mechanical side confined its attention solely to standardize rolling stock.
1937	Decision was taken that part drawing system be extended to all standard type of locomotives.
1937	One XB locomotive derailed in mid section near BIHTA railway station in Bihar in the month of July. The enquiry on the causes of this derailment influenced future designs.
1939	During war, due to despatch of rolling stock to war zones and intensive utilisation in India the Railway assets were run down between 1939-1944.
1940	New 'W' series locomotives were last to be manufactured in India and served well during the period 1940-1955
1947	Workers from Punjab workshop of Mughalpura and Sukkur workshop filled up place left by migrating Muslim workers.
1950	Import of locomotives from Britain come to an end.
1950	Production of steam locomotives started in Chittaranjan locomotive workshop
1952	After regrouping Charbagh, Lucknow workshop became a part of N.R.
1952	Existing 37 railways rationalised to become part of six zonal railways
1952	Full fledged Member Mechanical, Railway Board took charge of Mechanical and Electrical departments.
1952	Great Indian Peninsular Railway company renamed as Central Railway
1952	Integral coach factory, Madras set up as a production unit for all welded steel, light weight integral coaches
1955	Production of coaches commences from ICF
1956	Jamalpur foundary shop manufactures 60 ton Anvil Block for Chittaranjan Locomotive workshops.
1957	The CSO became a part of RDSO
1960	POH in Charbagh, Lucknow workshop reached its peak
1961	CLW commenced production of Electric locomotives
1961	Diesel locomotive workshop at Varanasi set up
1962	Separate furnishing unit set up in ICF commences production
1965	Repair of Arms of Railway Protection Force department started after 1965 war in Dahod workshop
1967	CLW started production of diesel locomotives
1967	Jamalpur Technical school upgraded and renamed Indian Railway Institute of Mechanical and Electrical Engineering
1970's	Activities in POH workshop Lucknow became subdude due to replacement of steam by diesel locomotives on Indian Railways
1972	2444 steam locomotives produced in CLW from 1950-72
1974	With tapering of steam traction POH of WDM2 loco's started in Parel workshop
1975	POH of diesel electric locomotives started in Charbagh, Lucknow workshop
1979	A central organisation for Modernisation of workshops (COFMOW) established.
1979	Installed capacity in ICF increased from 350 to 750 coach shell per annum

1984	Wheel and Axle plant, Yelahanka, Bangalore (WAP) commissioned on 15th September
1986	By 1986 Charbagh, Lucknow workshop POHed 1000 diesel locomotive, when POH of electric locomotives also started.
1987	Diesel loco POH capacity enhanced to 9 locos per month from June 1987in Parel workshop
1987	Installed capacity in ICF further increased to 850 coach shells per annum
1987	Member Electrical took independent charge of Electrical Department.
1988	Production in Rail coach factory at Kapurthala commences from March
1988	Steam loco activity completely wound up in Parel workshop
1991	Full capacity of 1000 coaches per year achieved by RCF, Kapurthala
1991	Installed capacity further increased to 1000 coach shells in ICF
1992	From June onwards, all activities of steam loco repairs were closed in Dahod workshop
1992	Rehabilitation of Cat 'C' unloadable Box wagon in Dahod workshop started in June
1993	Production of diesel locomotives stopped in CLW
1994	WAP achieved ISO 9002 in November, 1994
1995	From January 95, unloadable Box C wagons were converted to container in Dahod workshop which continued up March 97.
1995	In November, 1995 WAP Bangalore certified as a manufacturer of wheels and axles for supply by Associates of American Rail roads
1996	A new agreement with General Motors (USA) for transfer of Technology in Diesel locomotive field for a period of 10 years signed
1996	CLW achieved ISO 9001 in July 1996
1996	CLW's steel foundry achieved ISO-9002 in October, 1996
1996	Electric loco's POH started in Dahod workshop from 1st September, 1996, which was completed in January 1997
1996	ISO-9001 achieved by ICF in December, 1996
1997	CLW equaled/exceeded the production target in each year during 1997-2001
1997	From January 1997 onward POH of MEMU coaches started in Dahod workshop
1997	Furnishing unit of RCF, Kapurthala achieved ISO 14001
1997	ICF equaled or achieved more than the target in each financial year from 1997 to 2001
1997	In January, 1997 RCF Kapurthala achieved ISO 9001
1997	RCF Kapurthala achieved/exceeded the target of production in each year from 1997 to 2001
1998	Electronic lab established in WAP, Bangalore.
1998	Recertification of WAP, Bangalore by M/s BVQI in February, 1998
1998	Till November, 1998, CLW has manufactured 6000 HP freight ABB Electric locomotives.
1999	'Ashok Samrat' first fully Indian made crane turned out by Jamalpur workshop on 14th February

1999	1st diesel locomotive of WDG4 category assembled and tested on 14th August in DLW
1999	Accreditation of ISO 14001 in June 1999 by WAP, Bangalore
1999	Till September, 1999 DLW produced 4072 diesel locomotives out of which 49 were exported
1999	Till September, 1999, 29467 coaches assembled in ICF out which 425 were exported
2000	By 2000, six new designs of Diesel locomotives developed by RDSO and DLW
2001	Locomotive Fairy Queen manufactured in 1855 still in working condition and hauling tourist trains
2001	Till December, 2001, RCF, Kapurthala has manufactured 11714 coaches
2002	Till May 2002, CLW has manufactured 3014 Electric locomotives
2002	Upto March 2002, CLW has manufactured 638, 5000 HP WAG Electric locomotives with a potential speed of 80 KMPH

Chronological List of Key Events [Electrical]

(a) ELECTRIC TRACTION

1853	Inauguration of Railway Network in India on 16th April, 1853
1890	Encouraging results obtained from electrification of Tramways and first mountain railway and research undertaken by E. Huber-Stocker showed technical feasibility for introduction of electrification on standard gauge
1890	Introduction of Electric Traction in London on 'Southern Railway Suburbs' and main line upto Brighton.
1901	Electric traction proposed due to heavy suburban traffic in Bombay
1904	The proposal to introduce Electric Traction for suburban Traffic in Bombay accepted in principal
1905	Trials for electrification commenced between Seebach and Affoltern on 16th January, 1905 for the first single phase series motor
1910	Population of Bombay city reached a million mark
1912	Mr. C.H. Merz, designer of London U.G. electric Railway appointed to report on railway electrification in India, who prepared a report on this the same year.
1912	Prussia, adopted 15 KV 16 2/3 cycles single phase for electrification of its state Railways
1913	First detailed report submitted by Mr. C.H. Merz for electrification on suburban service of GIP/BB & CI port lines and main line services on GIPR in October 1913
1914	2nd detailed report was submitted by Mr. C.H. Merz on electrification in January 1914
1914	Work War I erupted
1914	World War I impeded the progress of railway electrification
1919	GIPR accepted original 1914 report to choose 1500 V overhead system operation on heavily graded section
1919	Merz & Mclellan submitted the revised detailed report on electrification in July, 1919
1919	The recommendations reviewed after World War I
1920	Mountain section of the St. Gothard line on Swiss railways opened to electric traction in stages
1922	Preliminary work for electrification, started on Harbour branch and Victoria Terminus local lines
1924	Electrification of Harbour branch between Mumbai VT and Kurla completed in December, 1924
1924	Report submitted by M/s Merz and Mclellon on possibilities of electrification of certain lines in neighbourhood of Calcutta did not justify the prospects financially.
1925	on Mumbai Kurla, electrified track with 12' wide stock started on 3rd February
1926	First electric locomotive of type IC-CI (Be 6/8) introduced in regular service for haulage of freight trains on Gothard line
1929	Electrification of entire section from Mumbai VT to Pune completed on 5th November, 1929

1929	M/s Merz and Mclellan's second report on electrification of GIPR main line accepted and a thermal plant commissioned
1929	Whole line between Erstfeld to Bellinzona on Swiss railways electrified on 29th May.
1930	Electrification of Mumbai to Igatpur completed in December 1930
1931	Electrification of double track from Madras Beach to Tambaram and siding at Madras Beach, Madras Egmore Tambaram stations completed on 2nd April and first electric train started running on 11th May
1931	Suburban services between Madras Beach and Tambaran converted to all electric on 1st August
1932	2610 HP, EF/1 locomotive was the most powerful locomotive to run on IR during 1932
1934	Madras Beach sidings electrified by November
1947	South Indian Railway drew up a scheme for the electrification of main line from Madras Egmore to Villupuram and branch line from Chingleput to Arkonam
1949	Revised report prepared by S.I. Railway to further electrify track beyond Villupuram up to Tiruchchrappalli, via. main and chord lines
1950	All infringements for running of 12' wide stock removed and service on electrified route could run up to Thana on quadruple track
1950	IC-CI locos upgraded to run at 75 KMPH after its mid life overhaul
1953	IR again considered electrifications of Calcutta lines
1954	Madras Egmore to Tambaram electrification sanctioned in April
1955	On Southern Railway Mainline electrification up to Villupuram approved in March
1956	Madras Egmore-Tambaram electrification scheme re-investigated at the end of year for adopting 25KV AC system
1956	SNCF team led by Mr. F.F. Nauvion visited India from June to September to study IR plans and recommended 25 KV industrial frequency system for electrification
1957	Experimental pre-stressed concrete masts between Shoeraphali and Tarakeshwar on Eastern Railway erected
1957	IR decides to adopt 25 KV, 50 cycles, single phase, AC system for electrification
1957	Howrah-Sheoraphdibaudel section of E.Rly. electrified on 3000 V DC and inaugurated by Jawahar Lal Nehru on December 1957
1958	An attempt to steal OHE mast wire between Haripal and Nalikul resulted in collapse of RCC masts due to shock load, which sealed the fate of such masts
1958	Electrification of Bandel-Burdwan section inaugurated by Dr. B.C. Roy on 31.08.58
1959	Inauguration ceremony held on 15th December for 25 KVA electrification
1959	Power was switched on 12th December for electrification of 1st phase of 25 KVA electrification near Kendpesi
1959	The first WAM – I locomotive arrived at Calcutta harbour on 30th November
1960	Asansol electric loco shed started functioning

1960	Asansol-Dhanbad and Pradhan Khunta – Pathardih lines electrification inaugurated by Railway Minister on 22nd December
1960	Decision to adopt 25 KV AC system on Madras Egmore – Tambaram electrification taken in November
1960	Electric traction between Rajkharsawan and Dangoaposi inaugurated on 11th August
1960	Kumardubi feeding post energized on 10th August
1960	Sitarampur-Asansol electrification inaugurated on 29th August
1960	Special train for the congress of Economic Commission for Asia and Far East hauled by electric loco from Asansol (vis Pradhan Khunta) to Pathardih ran on 25th November
1961	Asansol to Waria near Durgapur, section electrified on 31st March
1961	Asansol/Kalipahari-Damodar-Chakardharpur section electrified on 8th June
1961	Electrification extended to Gomoh from Dhanbad on 1st February
1961	Gomoh-Koderma section energized on 21st August
1961	Gujhandi-Gaya section energized on 13th November
1961	Kandra-Tata Nagar-Sinni section electrified on 1st July
1961	Koderma-Gujhandi section energized on 31st August
1962	Chandauli Majhwar-Mughalsarai section energized on 25th July
1962	Dhanbad-Kusunda-Tetulmari branch line energized on 10th January
1962	Gaya-Sone Nagar section electrification inaugurated on 30th June
1962	Sone Nagar-Chandauli Majhwar section energized on 7th July
1963	Electric traction on Tata Nagar-Khargpur section started on 4th January
1963	Some branch lines around Adra and Burnpur energized in June
1965	1st goods train hauled by electric engine on Madras Egmore – Tambaram section ran on 26th March
1965	1st express train on electric traction run on Madras Egmore – Tambaram section on 14th August
1965	Electrification of Howrah-Burdwan line with 25 KV, 50 cycles, single phase, AC system completed in early 1965
1967	Madras Beach – Tambaram section converted from DC to AC traction on 14th/15th January
1971	Trial of first Aluminium overhead equipment carried out at Bamrauli station of NR but abandoned due to short life span of Aluminium
1983	Central Organisation for Railway Electrification (CORE) took up the use of spun PSC masts designed by RDSO mainly due to corrosion of steel problem in coastal areas in November
1993	2 X 25 KV auto transformer feeding system of power supply introduced on Bina-Katni, Bishanpur/Chirimiri coal route of Central & South Eastern Railway

(b) TRAIN LIGHLING AND AIR CONDITIONING

1844	'Cheap Trains Act' Passed by British Parliament, providing for lighting in carriages, giving a statutory beginning to the important amenity of 'Lighting' in trains. This act also became applicable to India when the Railways started in 1853.
1890-1899	East Indian Railways installed gas lighting in 400 carraiges.
1897	Manager of Jodhpur-Bikaner State Railway installs Sone's axle driven Dynamo system in his carriage-for the first time in India.
1897	South Indian Railways install Stone's Electric Lighting plant in one carriage.
1901	Rajputana-Malwa railway Company provides one rake with 'Battery Only' system of lighting, in May 1901.
1903	'South ndian Railway carries out first large scale service trials of Stone's system of Electric Train Lighting.
1905	Bengal-Nagpur Railway, for the first time, provides electric fan in a 1st –cum-2nd class composite carriages.
1907	The Committee of Locomotives, Carriages and Wagons Superintendents, in its 9th meeting, decide to adopt Stone's Electric Train Lighting System and gave clear signal to Railway Companies to go ahead with this system.
1929	The Committee of Carriages and Wagons Superintendents, in its meeting in June 1929, recommended adoption of 'Parallel Block Rake Double Battery' system of train lighting as standard for B.G. and M.G. coaches. It also recommended to Railway Board to include Electrical Engineers as members of the Committee.
1934	The first IRS specifications relating to train lighting dynamo were published as Specification E-1/34.
1935	Electric Standards Committee set up and first meeting held in Simle from 23rd September to 27th September.
1936	First step to provide some cooling facility by placing Ice Blocks in metal trays in upper class coaches.
1949	Electrical Standards Committee recommends adoption of either Ice-Activated or Electro-Mechanical system of air conditioning in trains.
1950	Fans provided in 3rd class coaches.
1950	110 V dynamo used for the first time, in AC coaches.
1950	Railway Board decides to build 14 self generating Air-Conditioned coaches with plant imported from J.Stone of UK.
1953	110 Volts DC standardized for all BG AC coaches
1957	First fully air conditioned train (Deluxe) introduced, with 400 volts power supplied from Diesel Generating sets installed in two power cars.
1990	First specification of Roof Mounted Package Units (RMPUs) for Air Conditioning Plant in trains, issued by RDSO.
2004	Indian Railways switch over to environment friendly gas (R-134) for AC Coaches.

Chronological List of Key Events [Signal & Telecom]

1853	Flag and Light.
1862	Disc signals and Light-No interlocking.
1870	Semaphore signals-Main & Outer signals-No interlocking.
1871	Counter balanced Semaphore signals with separate light.
1892	Semaphore signals combined with spectacle.
1892	Key interlocking introduced with keys transmitted by hand.
1893	Saxby Farmer installed some interlocking gadgets.
1894	G.H. List detector locking apparatus.
1898	List and Morse key interlocking system.
1904	Heppers Electric Key Transmitter-Major Sir Hepper lever frames.
1920	East Indian Railway introduced double wire operated points.
1920	Mr. Baker introduced double wire signaling on Assam Railway. Bracket signals for diverging lines on single wire.
1920	Mr. Neale of Great Indian Peninsula Railway invented Ball Token Instrument.
1920	M/s Cargil and Sengupta introduced Carsen instrument for block working Northern Railway.
1958	First Route relay interlocking at Church Gate, Western Railway.
1959	Route Relay interlocking at Kurla, Central Railway.
1959	First Panel Interlocking by southern Railway at Madras Fort.
1960	Push button type toekenless instruments-Podanur workshops(SR).
1966	CTC on North Eastern Railway.
1968	CTC on Northeast Frontier Railway.
1970	Axle counters made by S & T Workshops at Podanur and Byculla.
1970	Indigenous CTC on Southern Railway.
1980	Use of Digital Microwave for Block Signalling.
1982	First SSI installation by US & SCO at Srirangam on Southern Railway.
1982	Use of fiber optic communication for Block Signalling.
1982	Auxiliary Warning System introduced by Siemens India on Western Railway.
1984	Auxiliary Waning System introduced by Siemens India on Central Railway.
1998	First Digital Axle Counter on Maulali – Cherlapally section on South Central Railways.
1998	Track circuiting of run through lines in all station with speed over 75 KMPH was completed.
1999	Predictive Maintenance of signalling system using data logger and networking introduced on Kota division of Western Railway.
2000	Route relay interlocking at Delhi Main with 1122 routes becomes the biggest RRI installation in World Railways and enters Gunnies Book of World Record.

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