RS/IEH(R)/1/04

INDIAN ENGINEERING HERITAGE
RAILWAYS

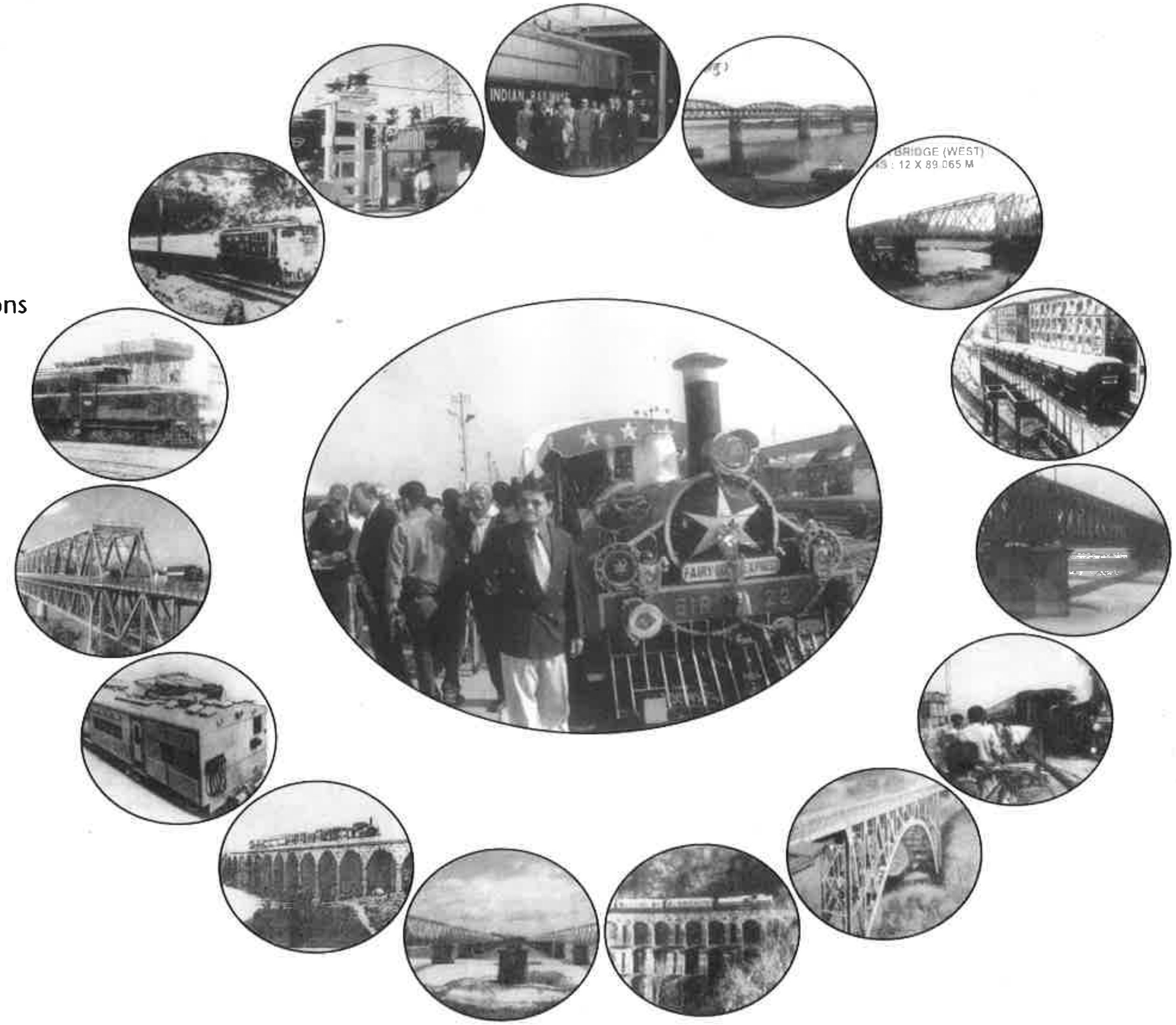
INDIAN ENGINEERING HERITAGE
RAILWAYS

Concept and design by:
Dr. DUS Valluri, Hyderabad

Published by:
The Indian National Academy of Engineering
6th Floor, Vishwakarma Building,
Shaheed Jeet Singh Marg,
New Delhi - 110 016.

Graphics by:
SREE DIGITAL ARTS, Hyderabad

Printed by:
Tirumala Tirupati Publications,
Hyderabad - 4.



CONTENTS

(Appendices are given at the end of each chapter with reference to the paragraph to which they relate)

PREFACE

The Indian National Academy of Engineering (INAE) is a peer body of around four hundred and fifty 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 through the 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. R.N. Iyengar
Railways	-	Shri R.K. Jain

After accepting the assignment, the Chairman, Railway Board, 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 IR is a comparatively a fairly recent Railway (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 according to engineering disciplines, viz. 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 where sufficient contributions are made for IR. A Table of Contents and a List of Abbreviations have been given in the beginning and a Bibliography at the end for a study in depth.

The Group acknowledges the assistance provided by the National Academy of Engineering; 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 Mr. 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.

December 12, 2000 (Raj Kumar Jain)

Chairman, Study Group

ADDITIONS BY NEW GROUP

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.

September 30th, 2002 (V.K. Agarwal)

Chairman Study Group

FOREWARD

India has a long history and tradition of engineering as can be discerned from our scriptures, ancient, medieval and relatively more recent structures. The Vedas mentions canal irrigation, the Ramayana a pontoon type bridge, the Harappan Civilization – well laid-out towns and underground drainage network, the rust-proof Iron Pillar of Delhi, the Earth dams of Chola period, the temples of Pallavas, the forts like Kalinjar, Palaces, etc. Unfortunately, very few historical records exist now of these wonderful structures. One is therefore left wondering about the ingenuity of our forefathers.

The Indian National Academy of Engineering, the peer body consisting of eminent engineers of the country has taken this task of documenting some of the engineering accomplishments of yester-years. One of them is the introduction and extension of railways all over the country. It is said that after the Central Government and the Defense Forces, it is the Railway Network which binds this country. It is also no exaggeration to state that railways were to a large extent responsible for the rapid development of areas covered by the network.

The engineers of the nineteenth and the early twentieth centuries had to tackle enormous challenges to accomplish what we take for granted as a Railway Network. The present volume on Indian railways documents the accomplishments as culled from the archives. It has been a gigantic task well carried out by the Engineers from the Railways.

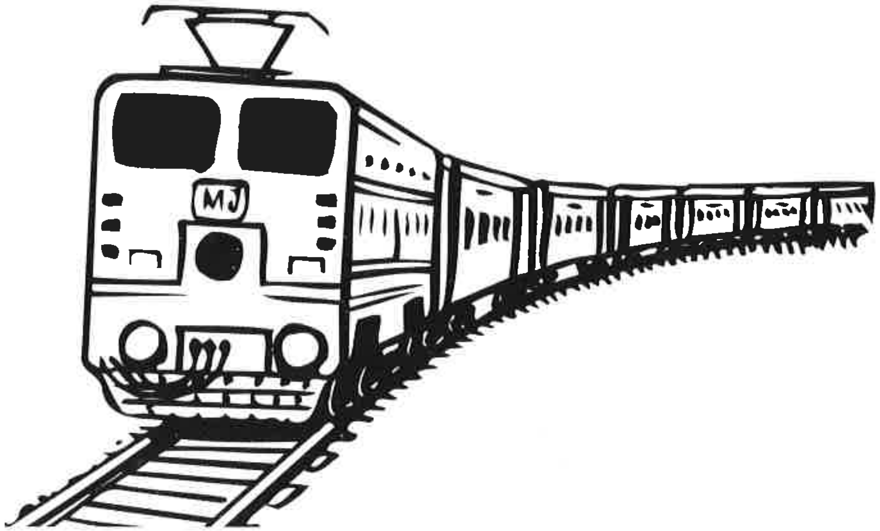
A. Ramakrishna
President

List of Abbreviations

ABB	:	Asea Brown Boveri
AC	:	Alternating Current
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 Modernization 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
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 Railway
NF/N.F.	:	North Frontier Railway
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 Electrification
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 Railway
SE/S.E.	:	South Eastern Railway
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 on 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
ZDM	:	Type of Narrow Gauge Diesel Loco for mixed use for passenger and freight services on IR

Chronological History



CHRONOLOGICAL LIST OF KEY EVENTS - 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
1813	First step for ending East India Company's monopoly taken
1814	George Stephenson invented steam locomotive for traction
1820's	Effort by steamship lines in India with Government support - 1820's and 1830's.
1820's	Efforts to develop railway system all over world.
1821	Construction of 1st railway line from Stockton to Darlington started by George Stephenson
1825	Daniel Thornero's book Investment in Empire and British Railways and steam shipping Enterprise in India covered the period 1825-1849
1825	First railway line from Stockton to Darlington opened to traffic on 27th September
1825	Railways started in England on 27th September
1829	"Rocket" Locomotive used for freight and passenger traffic proved successful
1829	Development of Railways in France started
1829	Railways started in France
1830	15 miles long Baltimore-Ohio line in USA opened in May
1830	Construction of railway line between Liverpool and Manchester in U.K. completed.
1830	Development of Railways in USA started
1830's	Extensive growth of railways took place in Europe
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.
1835	Development of Railways in Germany started
1836	Captain A.P. Cotton a Civil Engineer of Madras advocated desirability of Rail-road in India
1837	Development of Railways in Russia started
1837	Construction of railway line from St. Petersburg to suburbs of Pavlovask in Russia completed by a Private Company
1839	Development of Railways in Holland & Italy started
1839	Railways started in Holland and Italy
1840	Effort by steamship lines reached to its fulfillment
1842	Hurricane was one of the reasons for adopting 5'-6" from safety consideration
1842	Queen Victoria advised not to travel by railways
1843	Idea occurred to Mr. George Clark, CE of Bombay Government to connect Bombay with Thana, Kalyan and with Thane and Bhore Ghat Incline.
1844	Meeting of prominent citizens held on 13th July to consider diviability of railway line between Bombay, Thana, Kalyan and Bhoreghat.
1844	Mr. Rowland Macdonald Stephenson became the first agent of East Indian Railway Co.
19th century	Rails designed as Double Headed (D.H.) used
1845	Trial survey to link Calcutta with Delhi conducted
1847	Cold working season for const. of Railway line considered good
1847	Proposal 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 in May/June
1848	Louis Phillip of France forbidden to travel by railways for fear of life.
1849	First agreement with EIR & GIP stipulated a gauge of 4'-8 ½" 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	Prior to introduction of railways it was considered "hazardous and dangerous venture" in India
1850	Work for railway line between Bombay and Kalyan started on 31st October
1850's	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 " aguge for Indian Railway system
1853	First railway line in India from Bombay to Thana inaugurated on 16th April
1853	By effort of Macdonald Stephension the line was ready upto Pundooah by middle of year.
1853	Formal inauguration with 14 railway carriages and 400 guests 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 Railway lines in India
1853	Rails continued to be imported from England and European countries till manufacture of rails started in India by M/s TISCO & IISCO in 1940's
19th century	C.I. sleepers on IR being used from the beginning of the century
1853 1879 1880 1900 1914 1920	Route Kms in India - 32 Route Kms in India - 13362 (9832 km laid by Pvt. Companies + 3500 km laid by State) Route Kms in India - 14745 Route Kms in India - 39834 Route Kms in India - 55773 Route Kms in India - 66067

1940 1997 2001	Route Kms in India - 54694 (After partition of India) Route Kms in India - 62725 Route Kms in India - 63028
1854	First locomotive reached Calcutta via Australia by HMS Dakegree
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 – extended upto Pundooah on 1st September
1854	Railway line opened upto Hooghly (24 miles) on 15th August
1855	Location of bridge over Yamuna river at Allahabad decided.
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 1st July
1856	Lord Dalhousie left India
1856	Work commenced for Koilwar bridge across Sone river.
1857	Contract for construction of railway line between Bombay and Thana awarded to M/s Faviell and Fowler
1857	Revolt by Raja Kanwar Singh on 25th July halted the work of Koilwar bridge over Sone river
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 and Northern part of Bengal including a line to Darjeeling
1858	Construction work restarted from November for Koilwar bridge over Sone river
1858	Mhowke-Mulle viaduct on Pune-Kalyan section completed
1859	Actual construction of Yamuna bridge, Allahabad started
1859	Construction of EBR lines commenced in April
1859	Site for bridge over Yamuna at Delhi decided.
1860	Western abutment over Yamuna river at Delhi built in December

1861	Ehegaon viaduct on Kalyan – Igatpuri section opened on 1st January
1861	Masonry arch bridge No. 13 between Chaleshar and Yamuna bridge railway station completed
1861	Public Works Department recommended in a note for adopting narrower Gange in India
1862	All the wells except for Pier No. 13 of Yamuna river bridges, Allahabad completed by August
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	Extension to Jagati (62 miles) opened to traffic in November
1862	In December Indian Branch Company proposed to construct light railways
1862	Lord Elgin laid a policy for constructing narrower gauges
1862	Work completed for Koilwar bridge over Sone river completed on 22nd December
1863	Governor General Lord Elgin while opening the Koilwar bridge in February, over Sone river declared it "the magnificent bridge in the World
1864	B.No. 73 & 75 on Western Railway opened near Mumbai
1864	Sir John Lawrence during his period from 1864 to 1869 followed Lord Elgin's policy of constructing narrow gauges
1864	Yamuna bridge at Allahabad Commissioned for Rail traffic.
1865	Allahabad Bridge over Yamuna river opened to public in August
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
1868	After surrendering by loss making "Calcutta and South Eastern Railway" State started owning railways from 1st April
1869	Direct construction and ownership scheme adopted by Government of India
1869	Railway enterprise in India was at lewebb
1869	Schemes of railway extension to Punjab and Rajputana finalised
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
1870	Second bridge on same substructure of Koilwar bridge over Sone river commissioned
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 Railways.
1872	Construction of bridge at Rajghat, Narora started
1873	Due to failure of rains and prospects of scarcity in Bengal EBR pushed forward for a railway line from Ganges to Jalpaiguri in January
1874	Rajghat bridge Narora completed on 5th June
1876	B.No. 211 over river Palar on Chennai-Egmore-Villupuram section constructed.
1877	Governor of Madras Presidency got estimate prepared for an alternate proposal for Nilgiri line viz. 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. The proposal dropped being hazardous

1877	Mountain Railway for Nilgiri Hill's - a detailed analysis prepared by Capt. J.L.L. Morant, District Engineer for the Nilgiri Distt.
1877	Mr. Monnier, a French inventor, designed a reinforced concrete sleeper
1877	Mr. Monnier, a French inverter suggested use of cement concrete sleepers for Railway Tracks
1877	State Railway Directorate transferred from single Director to three territorial directors and one Director of Stores
1878	A scheme for 2'-0" wide gauge line submitted by Franklin Prestage for Darjeeling Railway line sanctioned by Lieutenant Governor. Darjeeling Steam Tramway Co-. formed
1878	Complete MG section from Sara at the left bank of Ganges to Siliguri (197 miles) opened to traffic in June
1879	B.No. 687 over river Coleroon on Villupuram-Tiruchirapalli section of Southern Railway constructed.
1880	Franklin Prestage took the lead for constructing Darjeeling Himalayan Railway
1880	Post of Director General in lieu of three territorial directors created
1881	Construction of 2'-0" gauge Darjeeling Himalayan Railway Line
1881	Title of Darjeeling Steam Tramway Co. changed to Darjeeling Himalayan Co. on 15th September
1882	About 10 more narrow gauge lines introduced during the period 1882-1907
1882	M. Riggenback, started preparing detailed estimate of rack railway
1884	1st survey for Kalka Shimla line was made
1884	Cassion No. 1 of Jubilee bridge met with a serious accident on 26th April
1884	Mr. Monnier obtained a patent for RCC sleeper, which however did not work well.
1884	Work on Jubilee bridge over Hooghly river started
1885	"The Nilgiri Railway Company" formed

1885	Second survey for Kalka Shimla line done
1885	Cassion No. 2 of Jubilee bridge reached full depth and Hooghly abutment founded on 17th January
1885	Naihati abutment of Jubilee bridge grounded at 60-69 ft. on 4th April
1885	Nilgiri Railway company registered on 30th September
1886	Contract for construction of Nilgiri railway executed between Secretary of State and Nilgiri Railway Company on 26th February
1887	Balawali bridge over Ganga commissioned
1887	Yamuna bridge at Delhi Commissioned for Rail traffic.
1888	Bridge over river Ganga at Varanasi constructed between 1888 & 1894
1889	Sinking of cassion No. 1 of Jubilee bridge completed on 30th December
1892	Track width of Great Western Railway of England altered to 4'-8 ½ "
1893	1st B.G. bridge over Krishna river (B.No. 3) constructed.
1894	Nilgiri Railway company went into liquidation in April
1894	Proposal for railway line in the Konkan by Southern Maratha Maharastra Railway company.
1895	Construction of Elgin bridge across Ghagra started
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
1896	Warren type Girder's of B.No. 73 & 75 replaced
1897	Barsi Light Railway of 2'-6" gauge opened
1897	Nilgiri line opened between Meetu palayam to Connoor on 15th June
1897	Post of Director General abolished
1897	Work of construction for 1st 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
1898	Construction of metre gauge Elgin bridge across Ghagra completed.
1899	8 pin truss girders of Ehegaon viaduct replaced
1899	Line to Coonoor was opened to traffic by new company on 15th June
1899	To strengthen Rajghat bridge, Narora Left Guide bund constructed
1900	1st bridge constructed between Rajahmundri and Kavvur over river Godavri
1900	1st bridge over river Roopnarain commissioned in April
1900	1st train passed over the Godavari bridge on 6th October
1900	Construction work of Dehri-on-Sone bridge completed on 22nd February
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
1901	Post of consulting Engineer for State Railways abolished in October
1903	Government purchased the Nilgiri line from the new company on 1st January
1903	Indian Railway Conference Association setup
1903	Kalka-Shimla line (59.44 miles) opened to traffic on 9th November
1903	Satpura line of 2'-6" gauge opened
1904	It was decided to change the site of Ootacamund station from Charing Cross to St. Mary's Hill where it now exists.
1905	19 km long, 2'-0" gauge Neral-Mathern railway built by Sir Adamjee Peerbhoy
1905	Bridge No. 448 over river Aie constructed

20th century	Shortage of wooden sleeper led to development of metal sleepers.
1905	Jamalpur Technical School upgraded to Indian Railway Institute for Mechanical and Electrical Engineering.
1905	On recommendation of Sir Thomson 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.
1906	Secretary of State decided to purchase Kalka-Shimla line on 1st January
1907	Matheran light railway of 2'-0" gauge opened
1907	Necessity of a bridge over Ganga near Patna felt
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 1st December
1908	The Nilgiri line extended from Coonoor to Ootacamund on 15th October
1909	Railway line from Shimla station extended by1/2 mile upto old bullock cart office for purpose of providing loading point for goods traffic
1911	Pamban viaduct constructed between 1911 & 1913
1913	Darjeeling Himalayan railway Extension Company registered on 25th January
1913	Left Guide Bund of Rajghat bridge - Narora extended in length
1913	A second bridge was placed over the same substructure of Yamuna bridge at Delhi
1914	A formal contract between DHRE and Secretary of State for construction of Kishanganj branch and Teesta valley branch signed on 25th April
1914	Balawali bridge strengthened in 1914
1914	Off break of World War 1

1914	Pamban viaduct commissioned in February
1915	Both Kishanganj and Teesta Valley branch lines opened to traffic
1915	Main current swung to right bank of Rajghat bridge after flood
1915	The spur moved towards the bed of the stream during monsoon diagonal to the alignment of bridge over river Dhanuk
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
20th century	Central standard office took the development of a standard C.I. sleeper in the 3rd decade of century
1920	Due to Great slump between 1920 & 1940 Railway development slackened
1920	Policy decision taken for progressive standardization
1922	Regirdering to new spans of B.No. 211 over river Palar
1923	Superstructure for 2nd bridge at Dehri-on-Sonestarted.
1924	Legislative Assembly agreed to separate railway finances from General finances in September
1924	Railway Board again reconstituted with Chief Commissioner as President and an ex-officio Secretary to Government of India and two members
1925	2nd bridge at Dehri-on-sone completed over Sone river on 6th March
1925	Construction of bridge over Godavari on Kazipet Belharshah (K.B.) section started
1925	Need for regirdering of Malviga bridge over Ganga felt
1925	The proposal to link Shimla with Dalhousie revived.
1926	Governor of Punjab performed the opening cermoney for construction of 100 mile long, 2'-6" gauge line from Pathankot to Shanan on 2nd May
1926	Old early steel type bridge No. 531 on Dhanbad Mughalsarai section strengthened
1926	Survey for B.G. line from Thana or Mumbai Mahad carried. Take off point of Diva found most suitable

1926	TSC deliberated on improving and standardising C.I. sleepers in its meeting held between February-May
1927	Bride No. 459 over Reyond Khud on Pathankot-Joginder Nagar Section constructed
1927	Construction of bridge over Godavari on Kazipet Belharshah (K.B.) section completed
1927	Gaj Bridge on Phathankot-Joginder Nagar Section constructed.
1927	Willingdon bridge on CCR section of Eastern Railway completed during 1927-1929
1929	Nagrota – Joginder Nagar section opened to traffic on 1st April
1930	Re-numbering of tunnels of Kalka-Shimla line done remained unchanged till now with tunnel no. 46 not existing
1930	Various standards committees setup
1933	2nd bridge over river Roopnarain completed on 23rd March
1933	Girders of first bridge over Yamuna river at Delhi replaced being of early steel category
1934	Balawali bridge re-strengthened
1934	TSC discussed E.I.R. type C.I. plate sleepers already in use and accepted the design and cleared for Trials during its meeting from 20th to 30th March
1938	1 X 100 ft. girder span provided instead 1 x 40 ft. span on Western approach of Br. No. 448 over river AIE due to floods
1942	Section closed and track materials sent to aid British war effort in April
1945	Regirdering of Malviya restarted after its temporary suspension due to 2nd World War from May 1945
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	Due to formation of East Pakistan (Bangladesh) traffic to Assam was disrupted

1947	Due to partition of India on August 15th, 11000 kms of route km lines transferred to Pakistan
1947	Due to sever flood, pier No. 1 of Gaj Bridge washed away which was subsequently replaced with a new pier at a new site and spans were increased
1947	Immediately after Independence, Railway Board consisted of five members including Chief Commissioner, Financial Commissioner and three members
1947	Malviya bridge re-opened for single line traffic in September
1947	Malviya bridge re-opened for double line traffic in December
1947	Various Railways worked washed on Regional, Divisional or Dist. Systems
1948	B.No. 227 over river Torsa constructed
1948	Development of Railways in Spain started
1948	G.O.I. 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
1948	There were 42 independent railway systems in India with largest Pvt. Railways being (Nizam State Railway) with 2247 route kms
1949	Ehegaon viaduct converted from double to single line to pass wider rolling stock.
1949	Main flow again turned to left bank of Rajghat bridge, Narora
1949	Original bridge (B.No. 521) constructed over river Tista
1950	Central Board of transport did not approve Diva-Dasgaon railway project
1950	Chittaranjan Locomotive Workshop setup
1950	Construction of 1st bridge over Brahamputra at Saraighat started
1951	Central Railway and Western Railway established on 5th November

1951	Eastern approach of B.No. 521 washed away due to floods and bridge extended by 3 additional spans of 150′ each
1951	Large sections of 2′-0" gauge Sivok-Kalimpong branch washed away and line abandoned
1951	Southern Railway established on 14th April
1951	South Indian Railway & Nilgiri Railway made a part of Southern Railway on 14th April
1951	Traffic on 2nd line transferred to separate diversion
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)
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
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 1st August
1957	Indian Railway Institute for Signal and Telecommunication, Secunderabad setup
1957	Research Design and Standards Organisation – Lucknow setup after merger of various standards committees and RTRC
1958	Aie Bridge further extended by 2 spans of 100 ft. each
1958	North East Frontier Railway established on 15th January
1959	Manufacture of 52 kg rails started in Bhillai plant established with Russian help after Independence
1959	New member Mechanical created in Railway Board
1959	Railway Board decided to include Diva-Uran via Panvel a news BG line in March

1959	Regirdering Malviga bridge sanctioned
1959	Work started on Br. No. 399 at confluence of rivers Rihand and Sone in December
1960	Indus water treaty with Pakistan signed
1960	National Highway No. 17 between Goa-Konkan came in to being between 1950-1960
1961	Board sanctioned Diva-Panvel-Uran line in May
1961	Erection of Girder of Saraighat bridge started in January
1962	Sub structure of bridge No. 399 completed in May
1962	Work completed on 1st bridge over Brahmputra river in October
1963	2nd Godavari bridge constructed
1963	B.No.76, 25 x 30.48 m on Jharsuguda (Balungir) section constructed
1963	Construction of 3rd bridge over river Roopnarain started in October
1963	Construction of 3rd bridge over river Roopnarain completed in December
1964	Cyclone washed away, 124 spans of Pambon viaduct on 22nd / 23rd December
1964	Diesel Locomotive Workshop, Varanasi setup
1965	2nd bridge over river Krishna river, 45 m down stream of 1st bridge constructed
1965	Traffic restored after regirdeing of spans of Polmbon viaduct, hit by cyclone on 1st March.
1966	Railway line from Panvel to Apta opened for traffic on 31st January
1966	Railway Minister announced setting up of six additional zones and seventh was added later on
1966	South Central Railway established out of Central Railway and Southern Railway on 2nd October
1967	Start of use of C.C. sleepers on IR
1969	All systems brought to Divil. System of Indian Railways
1970	Administrative Reform Commission report suggested Railway Board should not exceed 6 members and a Chairman
1970	The design of CST-11 sleepers discussed in 46th TSC in May 1970
1970	Ultra sonic rail testing started on IR
1971	Embayment started forming to left guide bund of Rajghat bridge, Narora
1971	Gangue conversion policy emerged
1971	Portable rail testers imported from German, assembled in India
1971	Railway minister announced to end economic drag due to multiple gauges.
1972	After necessary work done before monsoon, Rajghat bridge started behaving properly.
1972	Bridge over Mahanadi between Katni-Sirgrauli 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	2nd bridge over Godavari commissioned
1974	Indigenous production of portable rail testers started in India
1974	State Railway Directorate established
1976	Traffic on realigned section between Jawanwala Shahar and Guler opened to traffic
1977	Regirdering for Elgin bridge for B.G. done
1978	Spans 1, 2 & 3 of 3rd bridge over Krishna river in replacement of 1st bridge launched
1979	Spans 4 to 9 of 3rd bridge over Krishna river launched
1980	Balance west of 3rd bridge over Krishna river completed
1980	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
1983	Marginal bund on left bank of Aie river breached.
1983	Policy of uni-gauge reviewed and decision for up-gradation of existing MG Track taken due to financial limitations between 1983-1986.
1983	Right guide bund over Aie river washed away
1984	Wheel and Ale Plant, Bangalore setup
1985	CRB held position of member also.

1985	Duality of Chairman Railway Board abandoned on 1st July.
1985	Marginal bund of Bridge No. 440 over Aie river rebuilt.
1986	Indian Railway Institute for Electrical Engineering, Nasik setup
1987	A new member Electrical created after change of Mechanical member was split
1987	As per report in Railway Gazette of January 1987, 70,000 kms of track was under construction in various countries despite economic recession of 80's which hit Railway Industry
1987	Diesel Component Works, Patiala setup
1987	Jubilee bridge over River Hooghly opened in February
1988	Rail Coach Factory, Kapurthala setup.
1989	Railway Board approved construction of 69 km long Manglore udupi line as a first phase of Konkan Railway
1990	Construction work started by Konkn railway corporation
1991	Cross girders and stringers of B.No. 211 over river Palar changed.
1992	10,000 kms of MG and NG route kms identified for conversion to BG between 1992 to 2000
1992	CRB again took responsibility of a member as a measure of economy from 1st April, 92 to 1st January 97.
1992	IR decided to reduce multi gauge system quickly to boost economy
1996	Inauguration of East coast Railway – Bhubaneshwar took place on 8th August
1996	Inauguration of East coast Railway – Allahabad took place on 20th August
1996	Inauguration of East 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 1st November
1996	Inauguration of West Central Railway – Jabalpur took place on 8th December
1997	First bridge abandoned due to construction of 3rd bridge over Godavari.
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 comes in to operation on 26th January
1998	Inauguration of Bilaspur zone – Bilaspur took place on 20th September
1999	Third bridge over Brahamputra at Jogighopa completed
2000	Gauge wise percentage of route kilometerage, freight and passenger output BG 71%, 98.9% and 91.8%MG 23.8%, 1.15% and 7.8% respectively
2000	New bridge in replacement of old Balawali bridge commissioned in March
2000	Railway Board consists of 7 members including Chairman from 2000 onwards
2000	There were 59 functional divisions on Indian Railway
2000	Total kilometerage of railway line in India increase to 63028 km
2001	Kilometerage of different gauges in India as on 31st MarchBG 44776 KMMG 14987 KMNG 3265 KM

CHRONOLOGICAL LIST OF KEY EVENTS - MECHANICAL

1813	George Stephsenson (1781) had became 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 1937	CSO on Mechanical side confined its attention solely to standardize rolling stock. 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 1965	Separate furnishing unit set up in ICF commences production 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 1992	Installed capacity further increased to 1000 coach shells in ICF 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

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 1913
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 on Harbour branch and Victoria Terminus local lines for DC electrification, started
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 electric track 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 upto Tiruchchrappalli, via. main and chord lines
1950	All infringements for running of 12' wide stock removed and service on electrified route could run upto 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	Mainline electrification upto 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
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

CHAPTER-I
RAILWAYS IN INDIA
(INDIAN RAILWAYS)

1. THE BEGINNING:

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

1.2 The first attempt though unsuccessful for preparing a railway project 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.

1.3 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 manufactured products 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.

1.4 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 for the construction of the Railway line by sea 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 38 miles between Howrah and Pandooah was sanctioned by the Governor General of India. The letter was signed by Mr. F.J. Holliday on 6th September,1,850. Due to certain unfortunate events in supply of equipment, the line could only be commissioned on 15th August,1,854 for a length of 24 miles.

1.5 Simultaneously 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 Peninsular 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 individually and jointly lobbied for Govt. support for Railways in India & U.K.

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 16th April, 1853 forming part of the originally cleared proposal of a 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.

2 EXPANSION PHASE:

2.1 By 1879 (in about 25 years) 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.

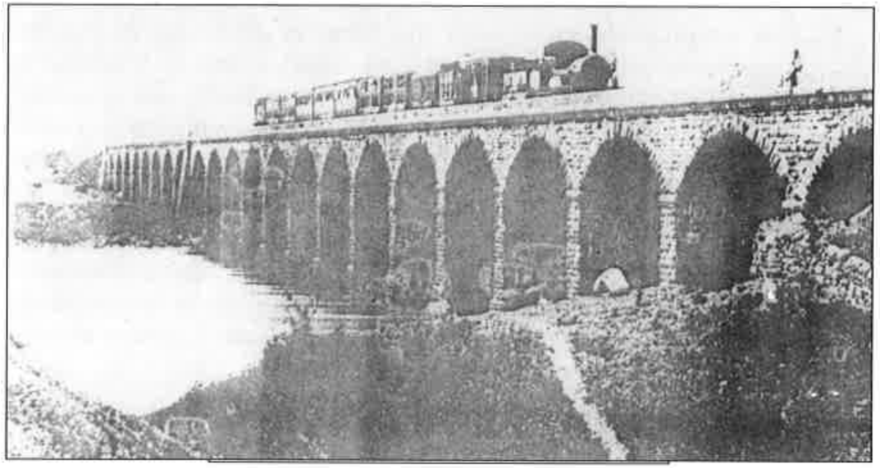
TABLE -I

Year 1	Route Kilometers in the year in column (1) 2.	Route Kilometers added per annum during the period 3.
1853	32	—
1879	13,362	534
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

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 dispatch 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 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 Quetta in 1930s also took their toll.

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 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 leaving 54,694 km for the Indian State.

2.4 Immediately after Independence, the policy changed towards using more efficiently and productively the existing Railway network and to expand it only for generally new areas of growth or strategy. By 1997 the addition has been 8031 km only on an average of 161 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 90 years, the target of Mackey committee given in 1908 for the expansion of system to 100,000 Route miles has not been achieved even half way. 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.



CHAPTER-II
HISTORY OF RAILWAY ORGANISATION

1. ORGANISATION OF RAILWAY BOARD:

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.

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 of 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.

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.

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.

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 Honourable Member, Commerce and Industry Department, as the Railway Member;

(3) The President of the Board was given direct access to the Viceroy as if he were a Secretary to the Government of India.

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.

1.6 Immediately after Independence in 1947, there were five members of the Board including the Chief Commissioner, Financial Commissioner and three Members for Engineering, Staff and

Transportation matters. In 1954, the position of Chief Commissioner for Railways was renamed as Chairman, Railway Board with altered delegation of authority. A new position of Member of Mechanical (including Electrical & Stores matters) was brought in 1959 which was further split with a new position of Member (Electrical) in 1987. Till 1985, Chairman, Railway Board also held the position of Member in addition to the Chairman's responsibility. On 1.7.1985 he was relieved of this duality by having one more Member in the Board. Again for a short period between 1.4.1992 to 1.1.1997 Chairman once more took the responsibility of a Member as a measure of economy. As of 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. CONSOLIDATION & RESTRUCTURING (1947-2000):

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 defense strategy and bringing unity in national fabric. Most of the system was regrouped in six railway zones; viz., Southern Railway (SR) (14.04.1951); Central Railway (CR) & Western Railway (WR) (5.11.1951); Eastern Railway (ER), Northern Railway (NR) & North Eastern (NE) Railway (14.04.1952), leaving a few private Railways to run till their existing lease contracts expired. Other than IR there is hardly any private railway now except for Port Railways, etc.

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 1.8.1955 due to heavy workload and North East Frontier (NF) Railway out of erstwhile NE Railway due to unwieldy size on 15.01.1958. 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 2nd October, 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.

2.2.1 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. As in 2000, there are 59 functional divisions on I.R. (ranging from 4 to 8 divisions on each of 9 zonal Railways).

2.3 In 1982 Railway Reforms Committee while examining the work load on existing 9 zones had recommended carving out of 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 bringing the total to 16. These are gradually being set up 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.

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 up only in 1920 with various Standards Committees being set up, e.g. Track, Bridges, Loco, Signalling etc. Central Standards Office (C.S.O.) was set up in 1930 for standard designs & specifications and later a Railway Testing and Research Centre (RTRC) was set up separately in 1952. The two were merged to constitute Research, Design and Standards Organisation (RDSO) at Lucknow in 1957. RDSO has played an important role in developing indigenous technical 'know how' to the extent that IR is now largely independent 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.

2.5 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.

ii) Integral Coach Factory at Perambur (ICF) in 1955.

iii) Diesel Locomotive Works at Varanasi (DLW) in 1964.

iv) Wheel and Axle Plant at Bangalore (WAP) in 1984.

v) Diesel Component Works at Patiala (DCW) in 1987.

vi) Rail Coach Factory at Kapurthala (RCF) in 1988.

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.

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. Indian Railway Institute for Mechanical & Electrical engineering (IRIMEE) by upgrading the existing Jamalpur Technical School established around 1905.
2. Railway Staff College (RSC) at Vadodra in 1952
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.

2.7 These organisational changes have been a continuous process. Periodic reviews have been made as new situations have arisen and have helped IR to generally be a profitable concern despite various political, economic and social factors affecting adversely their operational efficiency. It seems to be becoming more and more critical for IR to retain this unique position and more innovative changes would be necessary to meet the challenges of changed environment of modern times.

CHAPTER-III

RAILWAY GAUGE

1.0 Gauge is the minimum distance between running faces of the two rails. 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.

2.0 THE STANDARD (4' 8-1/2") 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 edge 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' 8-1/2" (an odd figure) is in existence today. It is a 5' 00" gauge reduced by width of two of Jessop's 1-3/4" 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 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.

3.0 GAUGES IN INDIA:

Recognizing 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 rail 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 1/2",

" The wider gauge of 5 feet 6 inches, which I would recommend for adoption, will give 9 1/2" 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 norwester, 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.

3.1 Metre Gauge (MG):

Some historical developments in this regard are given below:

(i) 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.

(ii) Early in 1869, railway enterprise in India was at low ebb: the lines built had cost exorbitant sums: their working expenses were high, their profits were meager 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.

(iii) 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 would 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".

(iv) 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 to 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.

(v) 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 were 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.

(vi) 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, with the adoption of 3 feet 3 inch gauge, 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 foot 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.

(vii) 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".

(viii) 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.

3.2 Narrow Gauge:

The first narrow gauge line of 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)

4.0 DIFFERENT GAUGES ON INDIAN RAILWAYS:

In spite of initial thinking of a uniform gauge on Indian Railways due to economical and historical considerations, 3 different gauges, viz. Broad, Metre and Narrow Gauges have finally been adopted on IR. The width and kilometerage of these 3 different gauges as on 31.03.2001 on I.R. are given below:

Std. of Gauge	Gauge width in FPS System	Gauge width in Metric System	Route km as on 31.03.2001
(i) Broad Gauge	5'-6"	1676 mm	44776 km
(ii) Metre Gauge	3'-3 3/8"	1000 mm	14987 km
(iii) Narrow Gauge	2'-6"	762 mm	
	2'-o"	610 mm	3265 km
(iv) Total of all Gauges			63028 km

A map of Indian Railway is attached at the end of this Chapter.

4.1 Problems of Change of Gauge:

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

1. Inconvenience to passengers.
2. Difficulty in transshipment of goods.
3. Inefficient use of rolling stock.
4. Hindrance 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.

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

5.0 UNI-GAUGE POLICY OF INDIAN RAILWAYS:

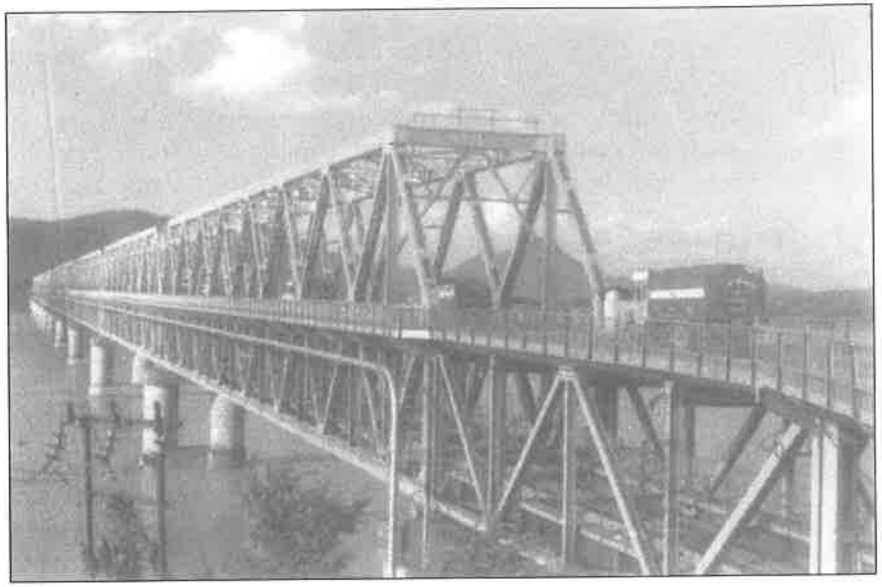
In the post Independence period, the policy of multiple gauges came up for reconsideration again & again. Firstly it was decided after partition in 1947 that broken links should be connected by the same gauge and similarly missing links in MG system be constructed to do away with some of problems associated with break of gauge to have a whole system of each 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, subject to availability of financial resources. The policy resulted in a gradual neglect of maintenance of MG track and rolling stock.

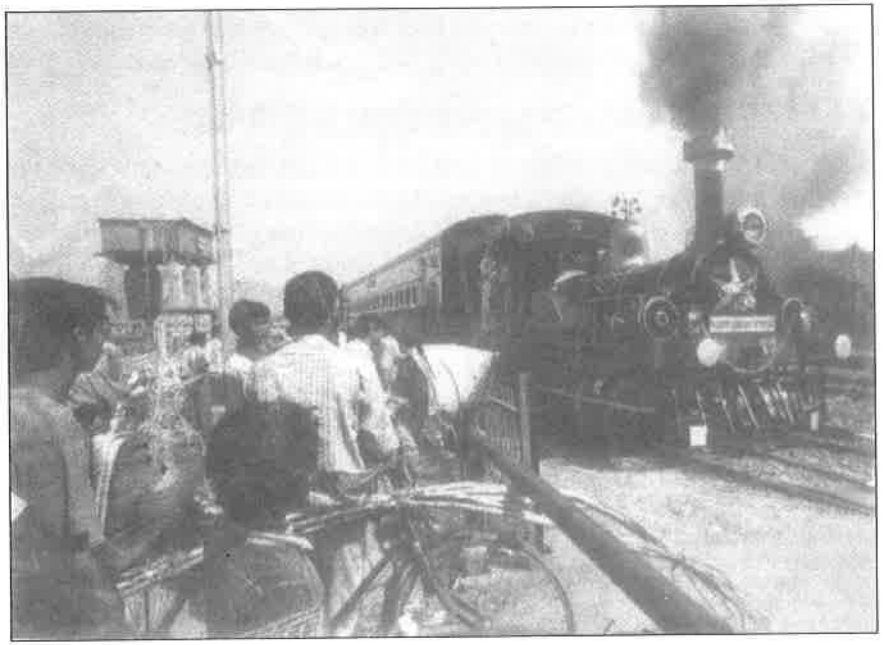
5.1 Recognizing the financial limitations and also the maintenance neglect that was affecting the safety of MG system, the policy got reviewed during 1983 to 1986 to improve capability of the MG system by upgradation. It was experimented and found practical to increase the speed of MG passenger trains to 120 kmph and 75 kmph for freight trains on IR. World experience supported the view that 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.

5.2 IR decided 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. Ten thousand route km of MG and NG lines were identified for conversion irrespective of traffic or economic needs and completed during 1992-2000. The position of MG system on IR from 1947 is indicated in the following table :

Table : Metre gauge Route Kms

1947-48	24133
1950-51	25237
1960-61	25168
1970-71	25847
1980-81	25424
1990-91	23599
1997-98	17044
1999-2000	15072
2000-01	14987





CHAPTER-IV
PERMANENT WAY

1.0 INTRODUCTION:

The history of railways is closely linked with the growth of civilization 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 the 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 the 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 the 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 Thane in about 1 hr 15 min time. IR system has grown up in 2000-2001 into a network consisting of 63,028 route km Crisscrossing the country from Himalayan foot hills in the north to Cape Comorin (Kanyakumari) in the south and Dibrugarh in the east to Dwaraka in the west, it is the 2nd largest state owned railway system in the world under unitary management.

1.1 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.

2.0 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 fish plates 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. (Fig. 4.1)

2.1 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 vehicles. 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 for pulling a number of coaches or wagons.

(v) In middle of 19th 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 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 to conserve forests for better ecology, the use of wooden sleepers has been restricted in spite 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 20th century. These metal sleepers had longer life, required less maintenance and provided better lateral stability. The different types of metal sleepers mostly used were steel trough sleepers and cast iron sleepers like CST-9 on IR.

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 the 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 2nd 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 the 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 & used from 1967 onwards on IR. Starting from that beginning, IR today manufactures & uses about 5.0 million 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 the next 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. IRs today carry out welding of rails by flash butt, alumino-thermic and by gas pressure welding technologies.

(viii) Rails are joined by fish plates to hold the rails together both in the horizontal and vertical planes. The fish plate 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 20th century have been progressively replaced by elastic fastenings like elastic rail clips, rubber pads, etc. to give resilience to track for better riding quality.

3.0 Following aspects of Permanent Way are dealt 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.

3.1 Rails:

Rails are of various shapes (sections), like double headed, bull headed and flat footed. 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 kg per metre.

3.1.1 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.

3.1.1.1 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 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. (Fig. 4.3)

3.1.1.2 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 B.H., rails 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. (Fig. 4.3)

3.1.1.3 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 were used on IR. (Fig. 4.3): 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.

3.1.1.4 British Standard Specification (BSS):

Further modifications 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

3.1.1.5 Indian Railways Standards (IRS):

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.

3.1.1.6 Development in rail shapes in chronological order is shown in figure 4.4.

3.1.2 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.

3.1.3.1 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 for different type of loading permissibly

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

On IR 72 UTS rails are normally used. 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.

3.1.3.2 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.

3.1.4 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 Bhilai. 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.

3.1.5 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.

3.1.5.1 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.

3.2 Sleepers:

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

3.2.1 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 in 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. With the reducing availability of wood due to depleting forests in India, the use of wood for railways sleepers is being minimised. For ordinary track sleepers it is abandoned. The requirement of timbers (also called wooden specials) is being met partially by import from neighbouring countries.

3.2.2 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

3.2.2.1 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 & 4 Key type), GKN type, Henry William (Forced up Lugs, Reinforced, Forced up Lugs).

3.2.2.2 Clip and Bolt Type Steel Sleepers:

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

3.2.2.3 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.

3.2.2.4 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.

3.2.3 Cast Iron Sleeper:

Cast Iron Sleepers have been extensively used on IR from the beginning of 19th 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" was 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 20th 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. (Fig. 4.5)

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 (20th to 30th March, 1934) discussed East Indian Railway type cast iron plate sleepers already laid in track, and finally accepted. Cost of complete sleepers 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) The 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 adapted to suit Pandrol T-401 clips with rubber pads. It was not found successful. There were further development as CST-12 and CST-13 for special fittings and to suit welded tracks with elastic fittings, but these were not found suitable.

(ii) 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.

3.2.4 Concrete Sleepers:

The evolution of concrete sleepers has been due to economic reasons, higher speeds, modern track structure and depleting forests all over. In 1877, Mr. Monnier, a French gardener and inventor of reinforced concrete, designed a concrete sleeper and obtained a patent for it in 1884 but this did not work successfully. The design was further developed. Railways of Austria and Italy produced first concrete sleepers with promising design around the turn of the last century. This was closely followed by other European Railways where large scale trials were made mostly due to economic considerations. Much progress, however, could not be achieved till the Second World War when the wooden sleepers practically disappeared from the European market. Almost at the same time modern track was born as a result of extensive research carried out by French Railways and other European Railways. Heavier rails sections and long welded rails came into existence. These conditions gave a spurt to development of concrete sleepers and the countries like France, Germany and Britain went in a big way for development of concrete sleepers to perfection.

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.

3.2.4.1 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. (Fig. 4.6)

(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.

3.2.4.2 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.

Factories were set up for the 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 in 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.

3.2.4.3 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.

CHAPTER-V
Railway bridges

1.0 Introduction:

1.01 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 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. Railway engineers took this hurdle as a challenge and started planning for the construction of the bridges so that all weather through communication could be achieved avoiding transshipment.

1.1 PROBLEMS ASSOCIATED WITH BRIDGE CONSTRUCTION:

For establishing a railway network, India was a difficult country. India was not a flat country like Russia where Czar Nicholas could sit down with a foot rule and a map of the country, draw two straight lines between Moscow and St. Petersberg and declare: 'this is a route which the railway line should take'. India was also not a small country like most of the European countries. Natural difficulties were in the form of mountains, rivers of mighty extent, challenging ghat sections, marshy land, regions experiencing heavy rainfall, dreaded areas infected by malarial mosquitoes and wild animals, vast deserts, undulating grounds, etc. In India mighty rivers like Ganga, Yamuna, Brahmaputra, Hoogli, Narmada, Mahanadi, Godavari, Ghaghra, Gandak, Kosi, etc. have to be crossed. In the monsoon season the rivers carry voluminous flow, causing many a time, breaches in banks. Some rivers are notorious for changing their course and outflanking the bridge making it redundant. River Kosi of north Bihar has shifted over 122 kms. from east to west over a period of 200 years. In coastal areas, creeks and straits posed difficult problems in bridge construction. Atmosphere is very corrosive in coastal area.

In such situations survey is difficult and time consuming. Credit goes to those engineers, who did excellent survey facing all sorts of hurdles with limited equipment and came up with accurate results.

1.2 MATERIALS OF CONSTRUCTION:

1.2.1 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 layer of lime mixed with surkhi was used.

1.2.2 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 to work like pile foundation.

1.2.3 Stone was used as stone top bridges. In such cases an adequate thickness of stone sills was put over the two supports to work as a beam / slab, particularly for smaller bridges.

1.2.4 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. India is having a large number of rivers, and steel bridges are comparatively larger in number over IR.

1.2.5 Reinforced cement concrete (R.C.C.) became popular in twentieth century. By the end of nineteenth century, about 60% of present network of IR was already built. Hence R.C.C. bridges are comparatively less in number. First pre-stressed concrete bridge in India was built as a railway bridge. Tamil Nadu PWD built second pre-stressed concrete bridge. Now a days, most of the railway bridges are constructed either as R.C.C. or pre-stressed concrete (P.R.C) bridges.

1.3 TYPE OF BRIDGE STRUCTURES:

1.3.1 Most of the bridges constructed in the past are arch bridges. A large number of such bridges are still existing and performing well.

1.3.2 For smaller openings stone top slab and timber structures have been adopted. Life and performance of such bridges are not very satisfactory. These are continuing in areas where traffic is lighter.

1.3.3 Steel was the most favoured material used in bridges, particularly in super structure. For spans varying from 30 feet to 100 feet (9 to 30 m), plate girder bridge were adopted. For 100 feet 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. Rail cluster bridge is a cluster of rails put together to add strength so that the same may be used as a bridge. Steel trough is fabricated from steel plates, molded in a specific fashion, to form a trough type of structure.

1.3.4 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.

1.3.5 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. Timber pile bridges are still used in temporary work like diversions.

1.4. METHODS OF CONSTRUCTION:

1.4.1 Most of the important bridges on IR in olden days were constructed having well foundations for sub-structure and steel open web triangulated girders as super-structure. Examples of such important bridges are the Yamuna bridge at Allahabad commissioned for rail traffic in 1864 and the Yamuna bridge at Delhi commissioned in 1887. Similarly the railway bridge at Varanasi over mighty river Ganga was constructed between 1888 to 1894 with well foundations and triangulated girders.

1.4.2 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. This ensures cutting of soil and facilitates 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.

1.4.3 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.

1.4.4 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 750 ft. and a height of 182 feet. 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 with lime mortar were built. Girders were fabricated, assembled at the bottom and lifted step by step with the help of jacks upto the whole 182 feet height.

(b) Bridging of the deep gorges on the Kalka – Shimla section was done by arch bridges in multiple tiers. Upto a suitable height, first tier of arch bridges was built. 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.

1.4.5 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 WR.

1.4.6 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. As an economy measure causeway was provided with some sort of pucca masonry structure in the dip so that it may not get damaged during floods. When the causeway is flooded and the velocity and depth of water is low, the train could be allowed to pass under special instructions.

1.5 SOME SPECIFIC RAILWAY BRIDGES:

1.5.1. General:

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,

1.5.2 Bridges in the Plain Region of the Northern India:

The 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:

1.5.2.1 Bridges over River Ganga:

(a) Malaviya Bridge:

The Malaviya Bridge, originally known as Dufferin Bridge, numbered No.11 on the Moghal Sarai-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 important bridge has 7 main spans of 350 feet each and 9 other spans of 110 feet each. The bridge is having well foundations in brick masonry, ranging from a depth of 70 to 160 feet for the main spans and from 60 to 110 feet 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 lakhs. Design work was assigned to M/s Rendell, Palmer and Tritton. Fabrication work was assigned to M/s Braith Waite, Burn and Jessop Construction Company. 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 Malaviya Bridge. No protection work either on the upstream side or on the down stream side has been provided. The bridge is performing well.

(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 11x250 ft. spans of through open web girders on deep well foundations.

This is an early steel single line girder bridge commissioned in 1887 at the cost of Rs.27.94 lacks. The bridge was strengthened in 1914 and again in 1934. Its replacement with a new bridge became necessary which was commissioned in March 2000. Brief details of the new bridge are as under:

ITEM	DETAILS
Design discharge	16,200 cumecs with flood frequency of 1 in 100 years.
Span	22x36.035 m spans with clear water way of 830.17 m.
Type of super structure	BG double line with PSC box girder.
Type of well foundation	Circular wells of 9.0 m dia. having steining thickness of 2.00 m and depth of 27.0 m.
Piers	Twin circular piers of 2.5 m dia having height of 7.81 m.
No. of wells	21 for piers and 2 for abutments

The released rail bridge is being considered for use as Road Bridge, after necessary modifications.

(c) 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 lakhs.

The bridge is having 33 spans of 80 feet each. Sub-structure of the bridge is on well foundations in brick masonry with lime mortar. Super-structure consists of 80 feet span plate girders.

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 720 feet long left guide bund was constructed for protection. Subsequently, during 1913, the same was extended to 1830 feet. 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 800 feet. To control the course of the river, a 500 feet long repelling spur at 80 feet up stream of the river was constructed. Left guide bund was also strengthened.

(iii) The protection work behaved well during the rising flood of 1951, but a chance of outflanking was there. Further extension of left guide bund including some other strengthening works was done.

(iv) During 1971 again embayment started forming to left guide bund for which necessary work was done before monsoon of 1972. Now the bridge is behaving properly.

(d) Rajendra Pul at Mokameh:

Between Malaviya 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 that the bridge construction near Mokameh was sanctioned in 1953.

The bridge caters for a catchment area of 293,000 square miles and a discharge of 2518,000 cusecs. The bridge has 14 spans of 397 feet and 4 spans of 104 ft 9 inches, two on either side. On north side a guide bund of 5000 ft on upstream side and 1000 ft. on down stream side is constructed. Bridge consists of double-D well foundations of 53 feet 6 inches x 32 feet and average foundation pressure of 13.6 tons per square foot.

Super-structure is for a single BG line at lower level and two lanes for road traffic on the upper portion with a total width of 24 feet. 5 feet of footpath is provided on either side. Girders are double decked Warren type with a girder depth of 60 ft.

Girders were designed by Freeman Fox and Partners of London. Design was checked by Central Standards Organisation (CSO), New Delhi. Fabrication work was assigned to M/s BBJ of Calcutta. Total steel work was 13,287 tons out of which 6,819 tons was HT steel and balance mild steel.

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 Bihar in particular.

1.5.2.2 <u>Bridges over River Yamuna</u>:

(a) Bridge No. 30 at Allahabad:

This bridge is located on Mughal Sarai- Allahabad section of the NR. 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. The bridge was opened to public in August, 1865 after special test trials.

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 decked triangulated girders for rail cum road traffic, with track on the upper portion. Discharge at the bridge site is estimated at 15 lakhs cusecs with maximum velocity of 12 feet per second. Sub structure is on well foundations in brick masonry with lime mortar having depth varying from 42 to 22.5 feet. 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 9 feet 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, 52 feet in diameter, over which the pier was built. About 2.5 million cubic feet of masonry and brickwork was used on this bridge.

(b) Yamuna Bridge at Delhi:

Site for bridge at Delhi was finalised in 1859. By December, 1860, western abutment was built. After a depth of hardly 3 to 7 feet, the foundation met with rock. Next foundation was laid over rock underlying at about 14 feet depth. Flood of 1861 badly dislocated the well. On examination, it was found that foundation of dislocated well was resting on sloping rock. Some smaller dia wells were constructed and connected by steel to give support. Similar types of problems e.g. availability of rock at very shallow depth was encountered in all the foundation work except pier Nos. 6 & 7, which were laid in alluvial soil. The work was finally 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 for single line only was provided. At the bridge site, river course was stable and hence no protection works are provided. Super structure of the bridge is double decked, 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 first bridge constructed in 1866 was of early steel category 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. At that time, foundations are not having adequate grip length and the bridge is closed for traffic. The work of a new bridge has been recently sanctioned at the cost of 72 crores to replace the old one.

Yamuna Bridge at Naini near Allahabad is identical to this bridge, as far as the super- structure is concerned.

1.5.2.3 <u>Bridges over River Sone</u>:

(a) Koilwar Bridge :

The first bridge over river Sone was constructed at Koilwar numbered as bridge No.200 and located on the Patna - Mughal Sarai 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. This was coming costly. A decision was finally taken to construct a bridge over river Sone with a sub structure of well foundations in brick masonry and super structure of wrought iron lattice. Work commenced in 1856. Work was going on well, when Independence struggle broke out, Danapur and surrounding areas revolted on 25th July, 1857 under Raja Kunwar Singh. Work again started in Nov. 1858 and the design of the piers was modified.

The bridge has 28 spans of 47.854 m (150feet) + 2 spans of 14.173m. It is a double decked under slung bridge where rail traffic is passing on the top and vehicular traffic on the bottom. 20 feet diameter wells were sunk built on strong iron curb shoes having vertical rods attached to them and connected with horizontal rings of iron in the brick work up to the top of the wells. These wells were sunk through the sand into the clay to an average depth of 31.1 feet below the bed level. The super structures are under slung triangulated girders having depth of 14 feet 6 ½ inches. Work was completed on 22.12.1862 at a cost of Rs. 43 lakhs. The sub-structure was for double line. The second bridge was constructed on the same sub-structure and commissioned in 1870.

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:

This bridge, the longest Railway Bridge in India and perhaps the fourth longest in the world, is located on Dhanbad - Mughal Sarai section of Eastern Railway. It is having 93 spans of 100 feet. 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 the same was completed on 22.2.1900 at a cost of Rs. 32.32 lakhs. The old early steel type bridge was strengthened during 1926. 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. The Sub-structure of the bridge can accommodate double line. 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 are under slung triangulated girders of early steel type.

Super-structure work for the second bridge started in 1923 and completed on 6.3.1925. Currently, in connection with multi gauging of the tracks on this section, a new bridge has been sanctioned and construction is being taken up.

(c) Bridge No.399:

The bridge is located on Chunar-Chopan section of the Northern Railway having 14 spans of 250 feet (76.2m)+2 spans of 100 feet (30.48m), totalling 3881.2 feet (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. At 1.5m below, silt factor is coming to 3. As per Lacey's formula, waterway required was 3360 feet. Waterway available at the proposed site is around 3500 feet with stable banks and straight alignment. A configuration of 14 spans of 250 feet + 2 spans of 100 feet, one on either end of the bridge has been adopted. Sub-structure for the abutments consists of double-D type of wells, 24 feet x 40 feet (7.315m x 12.19m). Pier wells are double-D 28 feet x48 feet (8.534 mx14.63m.).

M/s Hindustan Construction Company, the contractors, started work in December, 1959 and completed the sub-structure in May, 1962. Well curbs are lined with ½ inch thick steel plate to absorb the shock of explosion while blasting through rocky strata. Care was taken while sinking the wells to avoid tilt and shift. Worst shift took place to pier No.5 having a tilt of 162 mm and shift of 219 mm.

In many places it was noticed that the bottom of foundation are not likely to rest on an even surface. Bottom plugging was done in 1:2:4 grade concrete and dredge holes, 2 to 4 feet deep, are provided in rocky strata for keying effect. In sandy strata dredge hole size was increased to 6 to 8 feet. M/s BBJ were contractor for fabrication and erection of girders work.

1.5.2.4 <u>Bridges over River Ghaghra</u>:

(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 61 m triangulated through girders. Sub-structure consists of well foundations in brick masonry having a depth of 90 feet. On both sides left and right guide bunds are constructed. Catchment area of the river at the bridge site is 33,633 square miles with a maximum discharge of 8.5 lakh cusecs.

Elgin 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.

1.5.3 <u>Bridges in North-Eastern Region of the Country</u>:

This is the region where river Brahmaputra along with its tributaries is 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:

1.5.3.1 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 Brahmputra varies between 5 to 15 kms. In some places it spreads upto 23 kms. After the rainy season, river meanders in the khadar width. As far as carriage of sediments is concerned it is the second in the world, after Yellow river of China. At Dibrugarh during 1950-61, the 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. Waterway available at the gorge was 892m. Down stream of the gorge site, river widens but was having well-defined banks. Bridge was located where waterway available was equivalent to Lacey's waterway i.e. about 1200m. Brahmputra is used as navigational channel also, for which a clearance of 12m was required.

Keeping in view high seismicity and doubtful behaviour of cantilevering the spans, simply supported spans were accepted. Bridge is designed for 2 lines of MG track convertible to a single line of BG with BGML loading. 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	10x403 feet 4½ inches + 2x108 feet 11 inches
	(10x122.95 m + 2x33.2 m)
Total weight of girders	11,115 tonnes
Foundation	a. Main wells Double-D type 16.31 m x 9.75 m with steining thickness of 2.75 m.
	b. Shore wells Twin circular of 6.1 m dia well with steining thickness of 1.52 m.

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:

For the third bridge Jogighopa site was selected. The bridge has been completed recently in 1999. Salient Features are:

Length of the main bridge:	2.284 kms
Length of road viaduct:	1.082 kms
Span	1x32.6 m + 14x125 m +
	1x94.6 m + 3x125 m + 1x32.6 m
Guide bunds	(i). North Bank-850 m
	(ii).South Bank-478 m
Maximum design discharge	90,400 cumecs
Maximum Velocity	5 m per sec.
Navigational clearance	12.5 m above HFL
Foundation	Double – D, 11m x17m.

At the bridge site available waterway is 3100m. Appropriate span arrangements are provided. Rocky strata is available at one pier at a depth where very little grip would be available if the foundations rested there. Location of the pier was shifted towards north by 30.4m reducing the span length to eliminate its resting on rock. 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 was 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 dia piles in hard rock were involved in the work.

1.5.3.2 Some 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 of the world. 5000 mm of annual rainfall is common. Rainfall intensities of up to 900 mm in 24 hrs. occur 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 Brahamputra 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 100 feet. Sub-structure consists of well foundations of 20 to 22 feet diameter with depth varying from 55 to 66 feet. Super- structure is steel girders. Two spans of 100 feet are through triangulated girders. Next five spans are semi through triangulated girders. The last span of 100 feet is semi through plate girder. Bridge is having roller and rocker bearings. Bridge was originally constructed in the year 1905 as 2x40 feet + 5x100 feet. In place of 1x40 feet span on the western approach, 1x 100 feet girder was provided due to floods in 1938. This was further extended by 2x100 feet spans in 1958 with additional protection works. 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 250 feet + 7 spans of 150 feet. Sub-structures consist of well foundations in cement concrete. Wells are 22 feet dia having a depth of 48.67 feet. Super-structure consists of through type triangulated girders to MGML standard. Roller and rocker bearings are provided. Originally the bridge was constructed as 4x150 feet + 1x250 feet spans with through type girders in 1949 in connection with 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 150 feet. 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 150 feet each. The bridge was constructed in 1948 in connection with 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. Three rows of cement concrete blocks with boulders in crates have been placed on the right guide bund. 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. Sub-structure of the bridge consists of well foundations in cement concrete with 22 feet dia wells having depth of 65 feet. Warren type triangulated steel girders are provided in the super-structure to MGML standard with roller and rocker bearings.

(d) Bridge No.415 over River Dhanuk:

The bridge is located on Lumding-Badarpur section of the NF Railway. It has 1 span of 20 feet + 1 span of 40 feet + 1 span of 350 feet. Originally the bridge was having 2 spans of 40 feet + 1 span of 100 feet + 5 spans of 40 feet on 10 degree curve. The piers that carried 5x40 feet spans and the Northern end of 100 feet 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 6 feet and were leaning heavily to one side when the movement ceased. A 350 feet span girder has been provided due to uncertainty of obtaining stable foundations for shorter spans. A bowstring girder with the road carried at half the depth of girder on 12-degree curve is provided. The design and working drawings of the girder were provided by consulting Engineers M/s Randel, Palmer and Tritton of England. Erection of the 350 feet girder was completed during the year 1920-21.

1.5.4 BRIDGES IN THE SOUTHERN REGION OF INDIA:

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

1.5.4.1 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. Watson recorded three reasons for selection of the bridge site, viz., (i) narrower channel width compared to its neighbouring area,(ii) availability of permanent banks on both ends, and (iii) non-availability of rock within the sinking zone. The hydraulic parameters are a discharge of 15 lacks cusecs and maximum velocity of 5 m. per second.

Bridge has 56 spans of 150 feet and one span of 40 feet (on Kovvur end) with an overall length of 9096 feet. Keeping in view that there were no adverse effects to the down stream anicut due to this larger waterway available, the waterway has not been restricted.

In foundation work cement mortar in the ratio of 1:4 was used below low water level while lime mortar was used in other parts. 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. For pier nos.1 to 6, spare caissons of Indus Bridge were used. Some wells are double - D of 34 x20 feet, some are circular ones with external dia. of 24 feet 10 inches. In pier Nos.37, 38 and 39, double hexagonal well curb of Krishna Bridge was used. All wells were sunk by dredging and sinking except pier well nos.1 and 2, which were sunk by pneumatic method.

Super-structure consists of deck under slung open web triangulated girders 14 feet and 3inches deep. All girders were fabricated in England and then transported to site. While erecting, two methods were adopted, viz. (a) by block and tackle suspended from the gantries placed at pier top and (b) by hydraulic jack method.

Height of the pier from the LWL is about 43 feet. Weight of the single girder is 46 tons and that of one complete span is 142 tons. Work started on 11th Nov.1897 and the first train passed on 6.10.1900. Counting working days only, average progress of the bridge work was 12 feet of linear waterway per day. Work was completed at a cost of Rs.46.9 lacks. After commissioning of the third Godavari Bridge in 1997, this bridge is not in use. Bridge is still standing as a heritage.

(b) Second Godavari Bridge:

In 1963, the second Godavari Bridge was constructed 1050m down stream of the first bridge. 27 spans of 91.44m and 7 spans of 45.72m are adopted. 91.44m span was chosen since the old bridge was having its half span i.e. 45.72m. It is a rail cum road bridge, having 2-lane road bridge with one footpath on either side. For main foundations, double D-wells of 12.4 m x 7 m size are adopted. Abutments and smaller spans are on circular wells of 9.6 m dia. Piers are of 2 circular sections of 4.27 m 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. K-type truss spaced at 7m. is adopted for bridge superstructure. The bridge was commissioned in 1974.

(c) Third Godavari Bridge:

It became necessary to construct a bridge in lieu of first Godavari 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 Godavari Bridge is 28 spans of 94.0 m on double-D well foundation. The existing longest PSC box girder railway bridges were 45 m span over Vasai creek and 53 m span over Thane creek.

Cantilever method was used for construction. Each girder is supported on pot bearings of 1050 tons capacity. Initial three sets of bearings were imported from Switzerland. The remaining bearings were manufactured by BBR (India) Ltd. of Bangalore. It is a fusion of Indian feat and Swiss perfection.

(d) Bridge on Kazipet-Balharshah (K.B.) Section:

This bridge having 44 spans of 80 feet plate 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 3800 feet with catchment area of 39,600 sq. miles. The bridge is constructed for the full width. 80 feet span was found to be overall economical. Deep wells are having 15 feet outer dia. with 3 feet 9 inches steining. Each pier is supported over twin wells placed 21 feet center to center. Shallow wells have 15 feet outer dia. with steining 2 feet 6 inches thick. Later on when problems occurred while sinking these wells the steining thickness was increased to 3 feet 9 inches.

All the plate girders weighing 45.5 tons for 80 feet 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.

1.5.4.2 Bridges over River Krishna:

(a) Bridge No.3 is located on Vijaywada-Gudur 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 x 8m with steining thickness of 2m. Super-structure 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, spans No.s 4 to 9 were completed while during 1980-81 balance work was completed.

1.5.4.3 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 100 ft. each. The substructure of the bridge is on well foundations in stone masonry with lime mortar. Super structure is under slung triangulated girders. Early steel girders were replaced by specially designed under slung plate girders. These were 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	16x30.48 m	Through triangulated girders over well foundations in stone masonry with lime mortar.
Katjuri	553	411/3 to 412/1	18x45.72 m	—do—
Keoki	557	414/2 to 415/3	20x45.7 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, a dredge hole upto 30 ft. depth was made and only then the well started moving down. 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 30 ft. 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 46.72 m + 3 spans of 31.48 m + 1 span of 121.785 m. 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 30.48 m 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.

1.5.5 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:

1.5.5.1 Reyond Khud Bridge No.459 :

Reyond Khud Bridge is unique, being the only steel arch bridge on IR. It was constructed in 1927 on narrow gauge Pathankot - Joginder Nagar section of NR. Just beyond Kangra station, the railway line crosses the Reyond Khud having a depth of more than 200 feet. 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 180 feet of three-pinned steel arch, while the end spans are plate girders of 40feet spans. Braith-Waite 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 tons. The erection was completed in six weeks time.

1.5.5.2 Gaj Bridge:

The bridge is located on NG Pathankot-Joginder Nagar section (NR). Bridge was originally constructed in 1927-28 as 8 spans of 100 feet on shallow foundations of depth varying from 14 to 26 feet. 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 150 feet and another span of 60 feet. The present bridge is having 7 spans of 100 feet and one span of 150 feet + one span of 60 feet, and is designed for a discharge of 1,91,000 cusecs.

1.5.5.3 Arch Gallery Type of Bridges of Kalka-Shimla Section:

Kalka-Shimla section is one of the most difficult sections 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:

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	Kandaghat-Kanow	54.8m	-do-

1.5.6 VIADUCTS OF THE GHAT SECTIONS

1.5.6.1 Ehegaon Viaduct:

Ehegaon viaduct on Kalyan-Igatpuri section (Central Railway) was opened on 1.1.1861. Viaduct consists of three spans of 42.76 m each totalling 130m. Viaduct 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 course of time these girders became weak. 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 diversion completed in 1951.

1.5.6.2 Mhowke-Mullee Viaduct:

The viaduct on Kalyan-Pune section.(CR) consisting of 8 spans of 50 feet (15.24m) arches with rail level 135 feet (41.15m) above ground level was completed in 1856. Soon after construction, rumours 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 whole place has been filled up and there is now a continuous embankment.

1.5.7 BRIDGES IN THE COASTAL REGIONS OF INDIA

1.5.7.1 Pamban Viaduct:

Pamban Viaduct bridges 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. There is one lift span known as Scherzer span with two leaves of total 65.27m length. Of other spans, 143 are of 12.2m and two of 12.1m. The first 19 spans from Mandapam end are pre-stressed concrete girders and the rest are steel girders. The viaduct is in the coastal area and needs frequent maintenance since coastal atmosphere is corrosive. 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.

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 pre-stressed concrete girder spans on the Madapam end and Scherzer left only. Restoration work started immediately. It was possible to complete the regirdering work and restore the traffic on the viaduct in a short period of two and a quarter months on 1.3.1965.

1.5.7.2 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 2 feet 6 inches dia. 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 48.5 m and one span of 20.6 m of PSC box girders and bridge No.75 with 11 spans of 48.5 m.

1.5.8 SOME OTHER BRIDGES OF INTEREST

1.5.8.1 Bridges over River Hooghly:

Two prestigious railway bridges over river Hooghly are described below:

(a) Jubilee Bridge:

Jubilee bridge, bearing No.8 is located on Bandel-Naihati section of the Eastern Railway having two end spans of 164.592m each + one central span of 36.728m. On either end of the main bridge, there are viaducts of lengths 999.13m and 134.42m respectively. Viaducts are masonry arch bridges having a total of 141 spans varying from 10 to 48 feet. The site, about 28 mile upstream of Calcutta where river Hooghly is having main waterway of 1200 feet (the narrowest), was selected. River Hooghly is an inland waterway for navigational purposes and clearance is required to pass 500 to 600 tons of vessels. These factors determined the span configuration and the position of the piers.

The work started in 1884. Size of the caissons used was 66 feet x 25 feet. A serious accident took place on 26th April, 1884 to Caisson No.1. At that time the new moon with the strong southerly breeze blowing caused flood tide of extra-ordinary force. The Caisson, 66 ft. x 25 ft, was moored ready for sinking, built up to a height of 44 feet weighing over 700 tons and floating with an immersion of 32 feet. 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 tons 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.

Sinking of caisson No.1 commenced in 30 feet deep water and was completed on 30th Dec. 1884 after sinking upto a depth of 100.28 feet below mean sea level. Caisson No.2 reached a full depth of 100.39 feet on 17th January, 1885. The Hooghly abutment was founded at a depth of only 29.18 feet by 17th Jan, 1885. Here stiff clay afforded a firm base. The Naihati abutment had to go much deeper and was finally grounded at 60.69 feet below MSL on 4th April, 1885.

The total length of cantilevering span including mid supported portion is 120 feet (cantilever) + 120 feet 6 inches (middle supported portion) + 120 feet (cantilever) is 360 feet 6 inches. The central 120 feet 6 inches 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. The 420 feet spans weighing 1010 tons spans were assembled on the approach viaducts. The pontoons used were 225 feet long, 26 feet 6 inches wide and 9 feet deep giving a total displacement of water of 300 tons per foot of immersion. As the tide rose, the stream end of the span was lifted, leaving the span free to run out on the trollies at the land ward extremity. The bridge was constructed for double line. Clearance available on the bridge and heavier train loads are not permitting provision of double line movement for the new wider rolling stock. The bridge was opened in Feb.1887at a cost of Rs.39 lakhs.

(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 29 at a cost of the Rs. 1,14,67,000/-. Waterway available at this site is 2525 feet. The viaduct at Bally end consists of 22 spans of 30 feet girders on masonry piers on RCC piles 40 to 50 feet long. The 8 main piers are founded over well foundations, which are octagonal steel caissons, 70 x 37 feet. A unique feature of the bridge was that a caisson (70 feet by 37 feet) had been sunk in a tidal river in 4 feet of water with a current velocity of six miles an hour.

1.5.8.2 Bridges over River Roopnarain:

The first bridge over river Roopnarain bearing No.57 was commissioned in April, 1900, having 7 spans of 91.44m plus 4 spans of 30.48m. 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 bridge was completed with the same span arrangement and super-structure on 23.3.1933.

A third line from Howrah to Panchkura was constructed. The third bridge is constructed 650 feet down stream of the existing bridge. For launching of the caissons, mid period between full and new moon was chosen as the water rise is comparatively low at that time. 53 feet 6 inches by 32 feet double-D wells with dredge holes of 14 x 14 feet and steining thickness of 9 feet are provided for new Roopnarain Bridge. For shore piers, two wells 20 feet external diameter at 28 feet 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.

1.5.8.3 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 lacks cusecs. Bridge consists of 14 spans of 45.72m, originally constructed in 1879 as 14x46.94m. 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.

1.5.8.4 Palar Bridge:

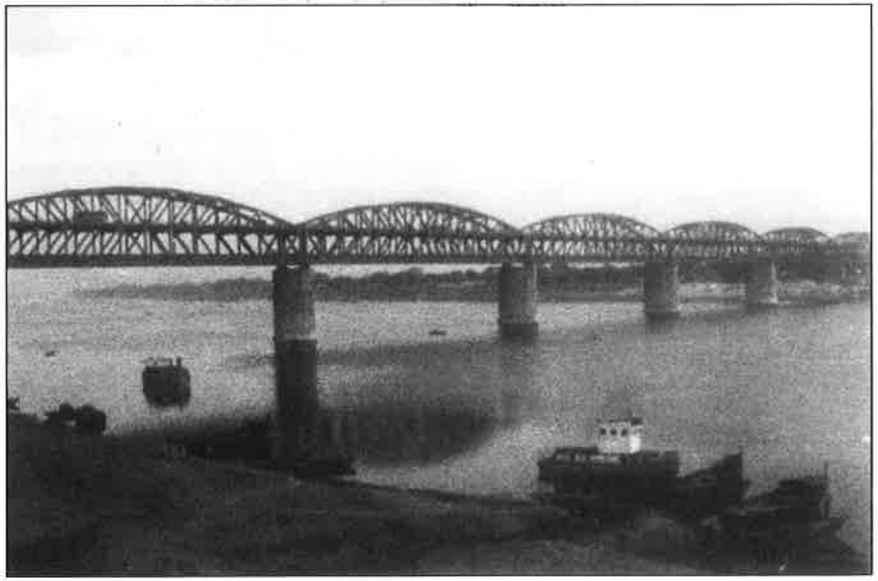
Bridge No.211 over river Palar is located on Chennai-Egmore-Villupuram section of the Southern Railway and consists of 18 spans of 36.6m each, originally constructed in 1876. Sub-structure of the bridge consists of double-D well foundations in brick masonry with lime mortar mainly resting on sandy soil mixed with clay, kankar and mooram. Super-structure consists of open web triangulated girders having a clear span of 36.6m. No weep holes had been provided on the abutments. Yet no problem has been encountered so far. During 1991, cross girders and stringers were changed. Stringers are directly resting on the bed blocks and end cross girders are not provided. On the down stream side, one parallel bridge is under construction for BG having 36 spans of 17.5m each with PSC girders.

1.5.8.5 Masonry Arch Bridges :

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

Bridge No.	Section	Span	Remarks
278	Kanpur-Tundla	1x21.34	Brick masonry with lime mortar
86	Kanpur-Tundla	1x24.4	Brick masonry with lime mortar
13	Tundla-Agra	1x27.43	Brick masonry with lime mortar

Arch Bridge No.13 on Tundla-Agra section having a span of 27.43 m located between Chaleshar and Yamuna bridge railway station was commissioned in 1861. It is constructed in brick masonry with lime mortar and is still serving. It is a good example of engineering skill.



Malaviya Bridge over Ganga, Varanasi

CHAPTER-VI7RAILWAY CONSTRUCTION PROJECTS

1.0 Civil engineering structures like buildings, houses and shelters, etc. are possibly the oldest structures existing on the earth. From time immemorial man has been continuously working hard for constructing buildings and shelters for his comfort and safety to avoid the vagaries of nature and to protect himself from wild animals. From older times, the engineering professionals have been constantly striving for making the living conditions better by constructing buildings, houses, shelters and such other structures.

Transport is another 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 and have made significant contribution in national development. The Indian Railways have been the principal mode of transport in the country and has played a key role in social and economic development of our country; IR has kept pace with advancements in technology and has successfully adopted appropriate technology for moving large volumes of passenger and freight traffic.

2.0 CONSTRUCTION OF FIRST RAIL-ROADS IN THE WORLD:

Efforts were made in 1820s all over the world to develop railway system after George Stephenson in 1814 invented steam locomotive for traction on railway tracks. Following are the land marks:-

(i) 1821-1825 Construction of first railway line in the world from Stockton to Darlington in UK was started in 1821 by George Stephenson, one of the great "Rail road and locomotive builder" and took about 4 years to complete the work. The first public Railway in the world was opened to traffic on 27th September 1825; On this day a train consisting of several carriages and carrying passengers and goods and hauled by steam locomotive "Locomotion" designed by George Stepehenson made its maiden journey from STOCKTON to DARLINGTON.

(ii) 1825-1840 (i) The construction of Railway line between Liverpool and Manchester in U.K. was completed in 1830. The Rail-road era really began with the opening on September 15, 1830, of the Liverpool and Manchester Railway. In this railway, all the features of the modern public transport system were used. It was public carrier of both passenger and freight traffic and the traction used for all traffic was "mechanical". Liverpool & Manchester Railway, with the success of "Rocket" Locomotive in 1829, became the ideal Railway in that area.

(ii) 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.

(iii) The success of Stockton and Darlington Railway and Liverpool and Manchester Railway generated ideas to develop Railway system in India.

3.0 THE FIRST RAILWAY CONSTRUCTIONS IN INDIA:

(i) 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 rail-roads 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. Subsequently, the work was started in 1850s and the first railway line in South India could be opened only on 1st July1856 between Veyasarpady and Walajah Road, a distance of 63 miles under the banner of Madras Railway Company.

(ii) 1841-1853 (a) 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 (38 miles).

Two serious mishaps prevented the commissioning of the first train by one more year. 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 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.

(b) 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 a 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 for construction work.

On 18th February 1852, the first locomotive was witnessed shunting near Byculla in Bombay. The formal inauguration ceremony of the first train in India was, however, performed on 16th April, 1853, when 14 Railway carriages carrying about 400 guests left Bori Bunder amid loud applause of a vast multitude and to the salute of 21 guns. The party reached Thana in about 1¼hours traversing a distance of about 21 miles. The train was hauled by three locomotives named SULTAN, SINDH AND SAHIB.

3. 1 <u>Prejudice & opposition</u>:

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:

(i) 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."

(ii) 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."

(iii) In India in 1850s, when the Railways were about to be introduced in this 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."

(iv) 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.

4. 0 <u>GROWTH OF INDIAN RAILWAYS:</u>

Starting from a humble beginning of running first train on Indian soil in 1853 for a distance of 21 miles, the Indian Railways has slowly and progressively grown up into a giant network having over 62000 route kms at the end of twentieth century criss-crossing this great country from north to south, east to west and in all other possible directions.

The details as to how the Indian Railways system has grown up progressively is given chronologically in the following.

4.1 <u>A Chronology of Development of Railway System in India</u>:

<u>1831-33</u> The first idea of constructing a railway line was conceived in the year 1831 to construct a railway line from Madras to Bangalore to improve the transport system of Southern India.

<u>1844</u> Mr. R.M. Stephenson formed East Indian Railway Company for construction of railway lines and submitted his first proposal for construction of rail lines in India.

<u>1845-46</u> Trial survey of new railway line was done in the year 1845 to construct a railway line from Calcutta to Delhi.

<u>1850</u> Construction of new railway line was started from Bombay to Thana by Great Indian Peninsula Railway Company.

<u>1853</u> First railway line from Bombay to Thana was opened for passenger traffic for a distance of 21 miles.

<u>1854</u> Railway line between Howrah and Pundooah (24 miles) was constructed and opened for passenger traffic.

<u>1856</u> Railway line between Veyasarpady and Walajah Road (63 miles) was constructed and opened for traffic under the banner of Madras Railway Company. This was the first proposal initiated in 1831 but could be implemented only in 1856.

1850-68 First stage of development of Railways in India is classified as 'guarantee system'. The Government guaranteed a minimum percentage of return to the share holders in order to attract the private enterprise to construct Railways, but retained right to purchase these Railways at the end of 25 years or 50 years. A number of Railway companies were formed for construction of Railway viz., East India Railway (EIR), Great Indian Peninsula Railway (GIP), Bombay Baroda and Central India Railway (BB & CIR) and Madras State Railway (MSR) etc.

1862 The first narrow gauge line on Indian soil having 2 ft.6 inch gauge opened near Baroda by Gaekwad's Baroda State Railway.

1866 Railway line from Calcutta to Delhi completed after opening Yamuna Bridge at Allahabad and Delhi.

1869-80 In 1869, it was decided by British Government, that future Railway projects should be either under a new 'guarantee system' or as State owned Railways. A few states started construction of Railway lines separately. The Government, however, exercised considerable measure of control to bring them as 'well managed Railways' under the new 'guarantee system' as well as 'State managed Railways'. After 1870 the development was very fast and by 1879, railway mileage had increased to 6128 miles.

1870 Lord Mayo, the then Governor General of India recommended Metre Gauge on Indian Railway in addition to existing BG

1873 The first MG railway line on Delhi-Rewari section was constructed and opened for traffic on 14th February 1879.

1880-1919 The railway network added every year was about 1000 to 1500 kms.

1903 Kalka-Simla line was opened for traffic.

1930 Route kms of IR became 66300. There was general economic depression in the country and subsequent growth of the railway was somewhat hampered.

1939-42 During 2nd World War, IR were called upon to release track materials, locomotives and wagons for construction of lines in middle east. This resulted into closing of 26 branch lines. Railway Workshops were used for manufacture of defense materials. At the end of war, there were heavy arrears of renewals and replacement of various assets.

1947 Due to partition of the country, there was division of railway lines and assets between India and Pakistan. The revised route kilometre in India after partition was 54,694.

1947-51 After Independence, there were 42 railway systems consisting of 13 class I railways, 10 class II Railways and 19 class III Railways. These included 32 lines owned by ex-Indian states. Government of India decided to rationalise these railways and put them in workable groups, which could be viable and work efficiently.

Re-grouping of railways was completed and 6 zones were formed namely Central Railway, Northern Railway, North-Eastern Railway, Southern Railway and Western Railway.

1951-99 The main objective of planning of Indian Railways in post independence era has been to develop rail transport to provide appropriate support for the planned growth of national income as a whole. While doing so, the emphasis has been suitably re-adjusted during each 5 year period to take note of certain special features. During the period there were 9 five year plans having appropriate allocation for railways for construction of new lines, rehabilitation of worn out assets and other such developmental schemes with in the financial resources of the Government.

2001-2002 Total route kilometre on 31st March 2001 is about 63028.

5.0 TYPE OF CONSTRUCTION PROJECTS ON RAILWAYS:

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

(a) **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.

(b) **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..

(c) **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 Bombay VT, Howrah station, Delhi Main Station, Madras station, etc.

(d) **Important Civil engineering structures**: This includes important Civil Engineering structures like railway office complex, railway workshops and such allied structures. Some of these structures are innovative and unique in concept, design or in construction and details of these are given separately.

6.0 NEW RAILWAY LINE PROJECTS:

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

6.10 Konkan Railway :

Konkan is a thin strip of land, about 50 kilometres at its widest between the Arabian Sea and the Western Ghats or the Sahyadri mountain ranges. Mythology says Lord Parshuram, the sixth incarnation of Lord Vishnu, created the region. After cleansing the world of evil forces several times, he is said to have come to this region and rested, blessing the area with his presence. Little surprise that the only temple in the country in his memory is found in the Konkan, near Chiplon in Maharashtra.

6.11 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. Both these factors led to, people from the region, migrating to Mumbai or to the Gulf. For years, the west coast, south of Mumbai upto Mangalore, remained under developed. The terrain had proved too daunting for construction of a railway line. On eastern side, the high Sahyadri ranges with its ridges protruding to the sea made access to the Deccan plateau tortuous. There were several rivers, flowing from east to west, from the high mountains to the sea. These had distinct tidal basins in the lower reaches. The only railway in Konkan Region, apart from rail links to Mumbai and Managalore, was a Metre Gauge line to Marmagoa Harbour.

Although the first railway line was laid from Bombay to Thana in 1853, the area just south of Bombay along the coast remained without a line for over a century and a half. 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 would be 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 Thana 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.

It was in the later part of 1950s and early 60s that National Highway No.17, the Konkan- Goa road came into being. But with a turning and twisting geometry of this road, the journey from Konkan to Bombay remained a difficult one. Diva-Dasgaon railway project came up for consideration during the post-war construction programme and was sanctioned for survey in 1946. This was not approved by Central Board of Transport in 1950.

In 1953, the Railway Board ordered a preliminary survey of Diva-Dasgaon project both for Broad and Metre Gauge line with steam and diesel traction. In March 1959 Railway Board decided to include Diva-Uran (via Panvel) BG line as a new line. After final location survey, the financial prospects for the line indicated 1.48% loss at the end of the sixth year after inauguration. Board sanctioned the projet (Diva-Panvel-Uran line) in May 1961. Subsequently, the line from Panvel to Apta was extended and opened for traffic on 31.01.1966.

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 crores. An innovative approach for financing this project was evolved in which a corporation was to be set up to construct the line and operate it for ten years. The equity capital of the company was to be contributed by Central Govt. and the beneficiary states, and the balance was to be raised by 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.

6.12 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 mountainous terrain containing many rivers undertaken, 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.

The salient features of the project are given in appendex 6.12

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 from 26th, January 1998.

6.13 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 have been planned.

6.20 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/or 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.

6.21 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 Calcutta to Ranaghat (45 miles) was opened in September, 1862 and extension to Jagati (62 miles) was opened in November, 1862. The line was further extended to Goalundo (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.

Prospects 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 NBR 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 197 mile from Sara at the left bank of Ganges, to Siliguri on metre gauge alignment was opened for traffic by June, 1878.

6.21.1 Franklin Prestage, the Agent of the guaranteed Eastern Bengal Railway, was fascinated by the ethereal views of Kanchenjungha Mountain 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 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 were stationed at Kurseong, while the mechanical superintendent was at Tindharia.

6.21.2 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.

6.21.3 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. 67 miles long Kishanganj Branch was longer than the main line of DHR whereas the Teesta Valley Branch was only 26 miles in contrast to 50 miles of the main line.

By 1915, both lines were completed and opened for traffic. The capital outlay was Rs.51.1 lakhs, the gross earnings Rs.3.3 lakhs and net earnings Rs.1.6 lakhs 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.

6.21.4 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.

6.21.5 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.

6.21.6 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 made 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 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.

6.21.7 On January 27, 1948, Government of India gave the green signal for the 'Assam Rail Link Project' and assigned it the highest priority. An idea at the beginning of 1948, became a reality before the end of 1949. On December 9, 1949, the all India railway link to Assam was opened for goods traffic.

6.22 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 Govt. 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 2ft. 0 in. gauge line from Kalka to Simla (now Shimla) . The Govt. of India later yielded to the military requirements of 2'-6" gauge. This meant change of gauge for a portion of line built in the year 1901.

6.22.1 The line measuring 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.

6.22.2 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, 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 4900 feet and 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 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.

6.22.3 Throughout its length of 60 miles the line runs in a continuous succession of reverse curves upto 120 feet radius along the valleys and spurs, flanking mountains, and finally rising to 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 works 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.

6.22.4 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 aqueducts being the most common means of carrying the line over the ravines between the hill spurs. There is only one 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.

6.23 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 s corruption 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.

6.23.1 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'.

6.23.2 **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 dropped.

Incidentally the first rack railway in India was a short section of broad gauge Upper Bolan line on the North West Frontier

6.23.3 **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 a 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 runs 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 11-3/4 miles at a cost of Rs.244 lakh. The terminal station is Udagamandalam.

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

6.23.4 **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 17.5 degrees. There are about 208 curves on the section, out of which 180 curves are 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.

6.23.5 **Rolling Stock:** The train normally consists of a first class coach at the front, followed by a first/third composite, three thirds 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 who cannot see the actual signal because of the sharp curvatures of the line.

6.23.5.1 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. When the train is entering the tunnels, the guard of the train switches on the lights.

6.23.5.2 **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 tourist 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.

6.24 NERAL MATHERAN RAILWAY:

This is a 19 km long narrow gauge (2' gauge) section taking off from Neral on Bombay-Pune mainline and terminating at the hill station of Matheron. Matheron hill is about 800 metres high 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 keep pollution from motorists the people have ensured that the pucca road access to Matheron is kept about two kilometres away from the tourist town. The narrow gauge railways itself is of tourist interest with very sharp curves and grades. The section operates in day time only.

6.25 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 Uhlhydro-electric scheme. The Railway Board, found it desirable to construct a 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.

6.25.1 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 and was opened for traffic in less than 3 years time. Pathankot to Nagrota section (109.5 kms) 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 was 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.

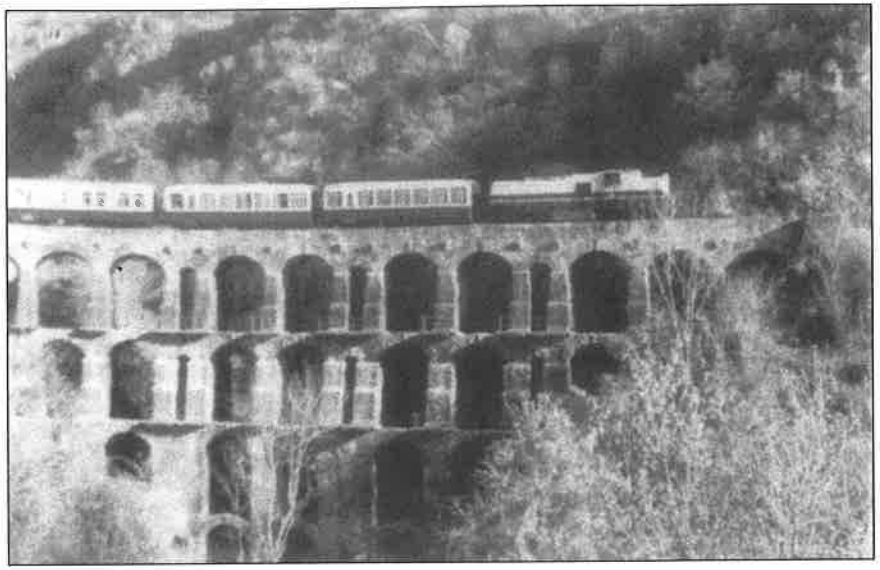
6.25.2 As a result of the Indus water treaty between India and Pakistan in 1960, the construction of a multipurpose dam across the river Beas near Talwara was taken in hand. Due to ponding of water in the reservoir of Pong Dam and threatened submergence of the existing track, the line beyond Jawanwala 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.

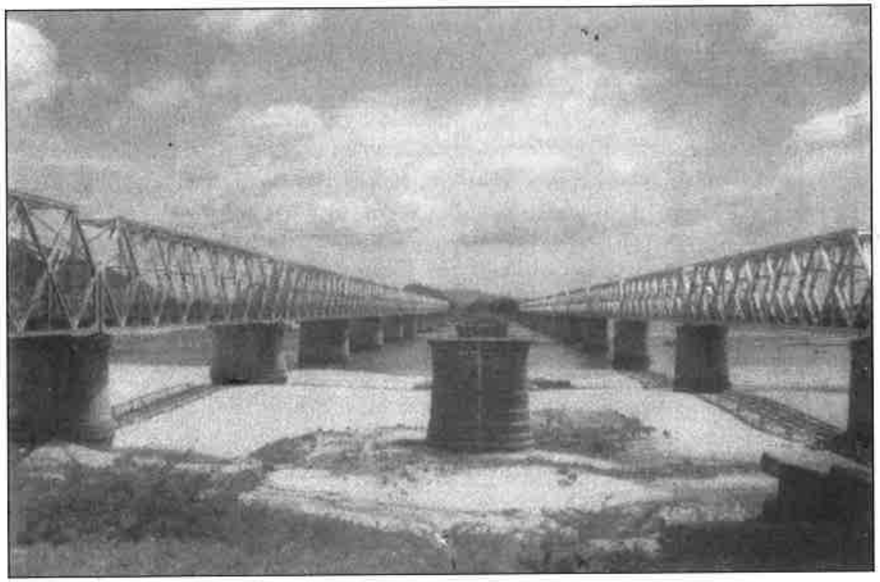
6.25.3 On Kangra Vally the curves are comparatively easy. There are only two tunnels. The steepest gradient is 1 in 19 for a length of 700 feet. This is the steepest gradient for any adhesion line on Indian Railways. There are 20 crossing stations. Due to steep gradients 11 slip sidings are provided on 10 stations. There are in all 971 bridges.

APPENDIX-6.12

SALIENT FEATURES OF KONKAN RAILWAY

Gauge	:	B.G.
Route Kilometrage	:	760 km.
Ruling Gradient	:	1 in 150 (compensated)
Bridges	:	1998 No.
Longest Bridge	:	2.0658 km.
Length of bridged track	:	27.23 km.
Tallest viaduct	:	64 m. high on Panval Nadi.
Tunnels	:	92 No.
Longest tunnel	:	6.506 km.
Length of tunnel track	:	84.8 km.
Ballastless track	:	22.642 km. (in 6 tunnels)
Curves	:	342 No.
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 No.s
Track	:	52 kg, welded rails on PRC sleeper
Speed potential	:	160 kmph.





CHAPTER VII
THE RAILWAY LOCOMOTIVES AND OTHER ROLLING STOCK

1.0 HISTORY:

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.

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.

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.

1.4 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 (Bombay).

1.5 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 (2001 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.

2.0 MECHANICAL DEPARTMENT ON IR:

2.1 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.

2.2 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, and 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.

2.3 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 originally 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.

3.0 STANDARDISATION:

3.1 The first problem the Indian Railway 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".

3.2 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 interchangeability 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.

3.3 The First World 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.

3.4 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.

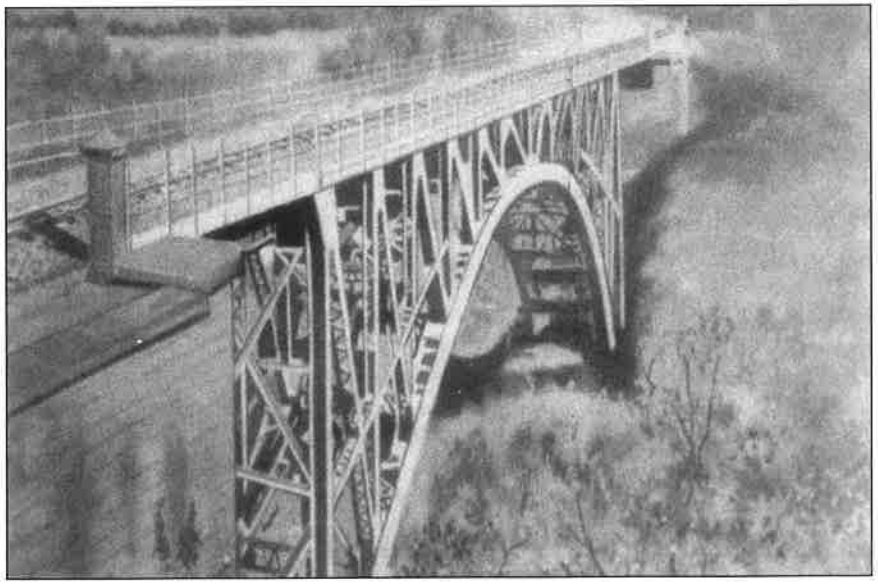
3.5 The success of the trials, with extra wide fireboxes, encouraged the adoption of a similar arrangement for BG. Although BBCI administration requested for sanction of 20 locomotives, the Railway Board agreed to two engines of each type (MG & BG) to be tried thoroughly in running, at least for one 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.

3.6 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 continuous 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 fulfillment 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.

4.0 DIESEL LOCOMOTIVES

5.0 COACHING STOCK

6.0 WAGON STOCK



CHAPTER-VIII
MECHANICAL WORKSHOPS

1.0 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.

1.1 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.

2.0 <u>JAMALPUR WORKSHOPS (EIR)</u>:

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.

2.1 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.

2.2 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 under took 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.

2.3 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.

2.4 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.

2.5 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.

3.0 <u>LOCOMOTIVE WORKSHOP, PAREL, BOMBAY (GIP):</u>

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 outturn of POH repairs of 32 steam locos per month.

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 with effect from 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 m^2, track (Permanent Way) length inside shops of 11 km, roads and pathways 14 km, 1186 machinery and plants, with a wage bill of about Rs.11 million per month and 650 thousand units of energy consumption

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 out-turn 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.

4.0 KHARAGPUR LOCOMOTIVE WORKSHOP (BENGALNAGPUR RAILWAY)

5.0 PERAMBUR WORKSHOPS (MSM)

6.0 GOLDEN ROCK WORKSHOPS (SIR)

7.0 TRICHANAPALLY WORKSHOP (SOUTH INDIAN RAILWAY)

8.0 DAHOD WORKSHOPS (BB & CI):

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.

8.1 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 14^{th} 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.

8.2 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' unloadable 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 unloadable 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 1^{st} 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.

8.3 The shop made valuable contribution in maintenance of rolling stock for BB &CI and later WR in critical periods.

9.0 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.

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).

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.

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."

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.

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.

9.6 Charbagh shops became a part of N. Rly. in 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.

CHAPTER-IX
PRODUCTION UNITS

1.0 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.

2.0 CHITTARANJAN LOCOMOTIVE WORKS, CHITTARANJAN:

The unit was initially set up for production of Steam Locomotives and started production in 1950. CLW have produced a total of 2444 steam locomotives. Production of steam locomotives was stopped in 1972.

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 May 2002 a total of 3014 Electric Locomotives have been manufactured by CLW.

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 versus actual production of CLW in the last four years is indicated below:

YEAR	TARGET	ACTUAL
1997-98	160	165
1998-99	155	165
1999-00	108	120
2000-01	120	120

3.0 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 intensities and loads. 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.

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.

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 in-house, to meet IR's varied requirements. The latest design is WDP2-3100 HP high speed passenger locomotive.

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.

3.4 The target versuss actual production of DLW in the last four years is indicated below:-

YEAR	TARGET	ACTUAL
1997-98	161	164
1998-99	161	161
1999-00	138	137
2000-01	103	103

4.0 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.

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 .

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 versus actual production of ICF in the last four years is indicated below:-

YEAR	TARGET	ACTUAL
1997-98	1010	1010
1998-99	1050	1057
1999-00	1004	1006
2000-01	1000	1000

5.0 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.

5.1 RCF developed and manufactured 3 tier AC coaches in 1993-94 which have been popular with the travelling 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 have so far been manufactured by RCF which are successfully running on Shatabdi 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 is also recommended for ISO-14001 certification on environment.

The target Vs. actual production of RCF in the last four years is indicated below:

YEAR	TARGET	ACTUAL
1997-98	1020	1031
1998-99	1075	1087
1999-00	1181	1182
2000-01	1090	1090

6.0 WHEEL & AXLE PLANT, YELAHANKA, BANGALORE (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.

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 m width & span of 15 m), 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.

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.

6.3 In its 15 year life till 1999, the W&AP 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.)

W&AP has implemented TQM including the essential aspects like energy conservation, environmental friendliness, welfare of the employees, vendor development etc.

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

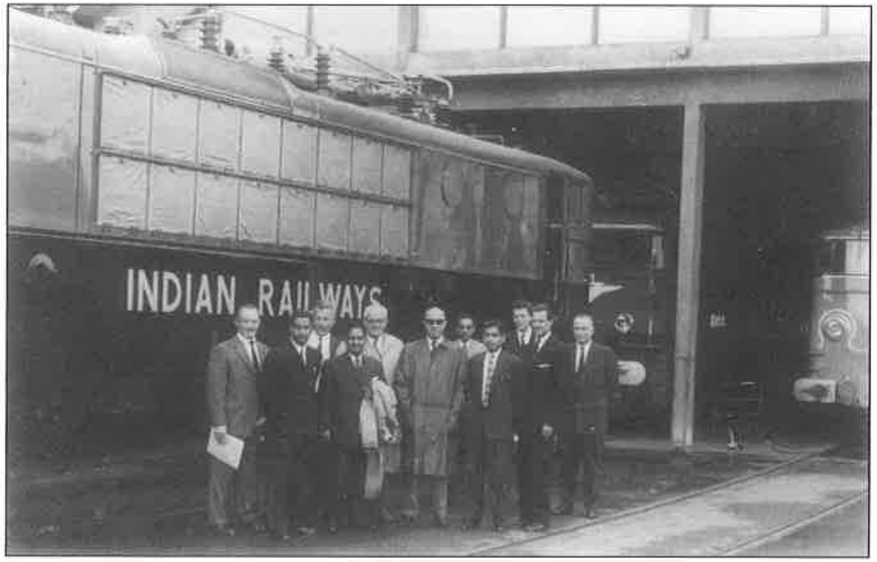
6.5 Technical Innovations:

(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) WAP has developed a second stage slag making without increasing the cycle time saving about 20-25 minutes time.

(iii) WAP has designed and developed suitable roller bearings for conveyor assembly using indigenous resources. These are giving reliable service and overcome the need to import.

7.0 DIESEL COMPONENT WORKS, PATIALA:



APPENDIX 9.6.4

TECHNICAL DEVELOPMENT IN WHEEL & AXLE PLANT:, 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 cylinder, 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) Dispatch of wheel-sets 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 to 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.

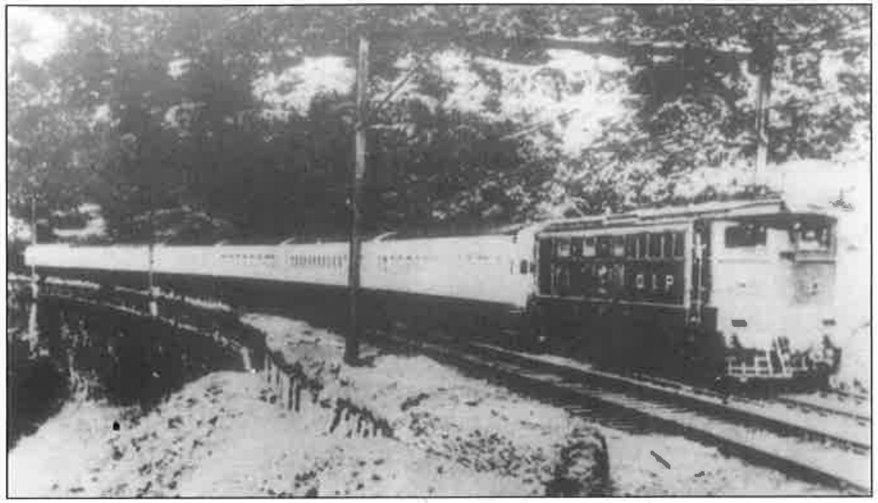
(xii) Console & tracer of Joint lathes replaced with in-house developed units.

(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-assemblies.



CHAPTER-X
D .C. ELECTRIFICATION

1.0 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 the 16th,1853. With this development India was 24th country in the world, 3rd in Asia and first 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.

1.1 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.

1.1.1 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.

1.1.2 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.

1.1.3 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-1.1.3 (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-1.1.3 (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

1.1.4. 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.

1.1.5 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 convertor 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.

1.1.6 The preliminary works on dc electrification started around 1922 both on Harbour Branch and Victoria Terminus 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 micro-ohms. 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.

1.1.7 By 5th Nov.29, 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 Dec.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.

1.1.8 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.

1.2 Rolling Stock - EMUs:

1.2.1 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 quardruple main lines at V.T. This became a bench mark section for testing all new generation of EMU stock for Bombay area.

1.2.2 The electrification of HB, an 18 km section between Bombay VT and Kurla, was completed in December, 1924. The service was started on 3rd Feb.1925 with 12' wide stock. 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. All infringements to running of 12' wide stock were removed from entire Bombay Division (GIPR) by this time. All postwar stock imported or built in India were of 12 feet width only.

1.2.3 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. 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
	BogiesPart	- M/s Cammel Laird
	BogiesPart	- M/s Societe Franco Belge de Materiel Du Chemin de Fer.

(b) Technical particulars:

	- 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) Sitting 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

1.2.4 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.

1.3 Rolling Stock - Locomotives:

1.3.1 Merz & Mclellan 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 1in 37 gradient ghat (hilly) sections {even 1 in34 at some places}, they looked to the Swiss experience of St. Gothard line having similar grades. Swiss had developed heavy freight locomotive in the initial stages, with designs influenced by the steam loco technology. The traction motors were rigidly mounted on the frame and the torque transmitted by a wheel reduction gear and rod drive transmission. All the main driving wheels were coupled by means of connecting rods. This concept was restricted to freight locomotives on GIP railway. Although in Switzerland there were two types of passenger locomotives based on similar arrangement, one for St. Gothard line (max. speed 75 kmph) type Be 4/6 and one for flat country line (maxm speed 100 kmph) type Ae 3/6 II, the vibrations caused by unbalanced mass of the rod drive made this system unsuitable for the fast locomotives for high speed operation.

1.3.2 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 tonnes, which was operating at a maximum speed of 65 kmph, also operated satisfactorily at slow 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 adopted 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 "Crocodiles" by railway men. The EF/1 locomotive bogie carried 2 traction motors which worked the two herring bone gears fitted to the driving axle through 2 jack 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.

1.3.3 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.

1.3.4 For Passenger locomotives, 3 different design prototypes were field tested. EA/1 type wi th 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, it forced IR engineers to use indigenous means to keep them going.

1.3.5 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.

1.3.5 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

1.4 Future:

After almost exponential increase in suburban and mainline traffic during past seven decades, the 1500V DC system is proving to be inadequate and IR has recently 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".

APPENDIX-X-1.1.3 (I)

EXTRACTS FROM M/S MERZ & MCLELLAN REPORT GENERAL FEATURES OF ELEC TRICAL 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".

8. "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 unit working, we recommend its adoption."

APPENDIX-X-1.1.3 (II)

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 metre 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.

BIBLIOGRAPHY:

(i) Report upon the Application of Electric Traction for the Bombay Suburban Railway-Merz and Mclellan-London-October 1913.

(ii) Report on the electrification of part of GIP Railway main line-Merz and Mclellan-London-July 1919.

(iii) Report on the proposed extension for the mainline by Cook & Gipson-12th May 1934.

(iv) History of Bombay Suburban Railways (1853-1985) by Dr. A.K. Arora.

(v) The Swiss Federal Railway-Electrification completed. Published by the Swiss Federal Railways (Approx.1960).

(vi) Railway Electrification in Switzerland Institute of Locomotive Engineers Journal No.228. (paper presented by H. Loosli-22nd May 1952.

(vii) Railway Electrification in Switzerland-Publication of Swiss Federal Railways. (Approx.1955)

(viii) 6 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.

(ix) 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.

(x) The mechanism of Electrical Locomotives by T.D. Twinberrow-Proceedings of the Institution of Mechanical Engineers-1932 Vol-123.

(xi) Kalyan Power House , 1947 Extensions, Central Railway – brochure issued ar the inaugural function on 9th Dec. 1952.

CHAPTER-XI

A.C. RAILWAY ELECTRIFICATION

1. ELECTRIFICATION OF LINES IN AND AROUND CALCUTTA:

1.1 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 neighbourhood 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 the access from the city have been carried out by the extension of the suburban lines into and through the center of the city, there could be a large increase in the suburban traffic. Then electrification only would solve the problems of dealing with the increased traffic, which would also be financially justified.

After independence (in1947), IR again considered electrification of railway lines in 1953. Based on a world study tour of a group of railway officers, 3000 v dc system was chosen in preference to the 1500 v dc system, then in operation in the Bombay and Madras areas. Howrah-Sheoraphali-Bandel, including Sheoraphali-Tarakeshwar branch line, electrification work was completed in Dec.1957 at 3000 v dc 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.

1.2 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. 56 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 25kv 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 country to have opted for 50 cycles ac electrification but it was at 20 kv as against 25kv 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.

1.3 CONVERSION OF 3000 V DC SYSTEM ON HOWRAW-BURDWAN SECTION TO 25 KV AC:

1.3.1 Strategy for Conversion:

As mentioned earlier the Howrah-Burdwan main line and part of Howrah Yard were electrified at 3 kv dc in 1957/58. 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 energised 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 remodelling and modernisation of signalling 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 :

(i) Augmentation of insulation

(ii) Increase of clearances

(2) Provision of booster transformers and return conductors.

(3) Modifications to the power supply system and sectionalising 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 signalling, telecommunication and remote control equipment),and low tension general electrical services.

(5) Modifications to electric rolling stock.

1.3.2 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 work 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 energised on 25 kv ac on 23rd May 1965 and then Memari to Bandel on 27th June 1965. 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 energisation 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-electric 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.

1.3.3 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. Recommendation 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 for which RDSO prepared key designs and 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.

2. <u>ELECTRIFICATION IN THE INDUSTRIAL BELT:</u>

2.1 <u>FIRST PHASE OF 25 KV AC ELECTRIFICATION:</u>

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 Japenese group were ordered. The first WAM1 locomotive then designated as BBM I 20250 (first to be manufactured), arrived at Calcutta harbor on 30th 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). The electrification work was considerably behind schedule on the fixed installation side. However IR had committed itself to inaugurate ac traction on 15th December, 1959. IR got on loan a complete sub-station with high voltage transformer and circuit breakers from SNCF. This was installed in December within ten days at a site near Kendposi (SE Railway) where an existing 66 kv power transmission line crossed the "iron ore railway line" Dangoaposi-Rajkharsawan (See Photograph). 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 steps 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 Kendposi, 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 energised 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 energised 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.

Of the 100 locos, 69 WAM1 locomotives (for SE Rly.) were 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 Rly. The other 31 WAM1 locomotives (for E Rly.) 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.

2.2 PROGRESS OF ENERGISATION:

In 1961, the 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 energised 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 energised 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 energised. 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,energising Chakradharpur-Rourkela section (102 kms) on 12th February completed the electrification of the industrial belt.

By this time the next electrification project for the suburban lines east of Calcutta radiating from Sealdah station had been finalised. Asansol loco shed contributed to the preparation work by equipping and testing a prototype push pull rake. On 4th of January, 1963 the electric operation on Tatanagar-Kharagpur section (128 kms) started and can be considered as the onset to the future main line electrification. In June 1963 electrification on South Eastern Railway of some branch lines around Adra and Burnpur, totalling 26 kms, completed the system in this industrial belt and the first phase of ac electrification on IR as well as the commissioning of the WAM1 locomotives. Gradually the ac electrification spread to Northern, Western, Southern, South Central and Central Railways. Progress of electrification on IR since its inception in 1925 till 31.3.2000 is given in Appendix-XI- 2.2

2.3 TECHNOLOGY ADOPTION AND DEVELOPEMENT:

2.3.1 Having decided to adopt 25kv 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 even today serves as a master reference book on all matters pertaining to AC Electrification on Indian Railways.

2.3.2 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 favourably 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.

2.3.3 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 programme a success. To mention a few:

BICC of U.K., SAE of Italy and NICHIMEN of Japan, followed by initial Indian contractors, namely KAMANIS, ECEC and BEST & CROMPTON.

3. ELECTRIC TRACTION IN SOUTH INDIA:

3.1 ELECTRIFICATION ON SOUTH INDIAN RAILWAY (1500 v. dc):

The electrification of 29.1 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 Kms of single track had been completed and inaugurated by His Exccellency the Governor of Madras on 2nd April 1931. The first electric train for public was started on 11th of May, 1931. Gradually, the suburban services between Madras Beach and Tambaram were all electric from 1st August, 1931.

The initial rolling stock consisted of 17 EMUs of three coaches each 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. The electric stock had articulated bogies. 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 Minambakkam and at Egmore Sub-stations were carried out by the Power and Traffic Controller from Egmore by remote control.

Electrical energy 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 were duplicate, both for power supply and automatic electric signalling circuits. Madras Suburban electrification accelerated real estate development adjacent to the Railway and value appreciated considerably of the property between Madras and Tambaram and even further.

3.2 SOUTHERN RAILWAY ADOPTS 25 kv ac:

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 upto 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 after detailed investigations a 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) The first section where indigenous (BHEL built) 110 kv transformers were utilised for the substation was on this section.

3.3 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 staff and officers 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.

4 IR ADOPTS SINGLE SYSTEM FOR ELECTRIFICATION:

4.1 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 future foreseeable increase in traffic 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.

4.2 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.

4.3 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 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 realised 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. Development of GTOs in the mean time enabled development of efficient dual voltage system by having an efficient and cost-effective dual voltage rolling stock. 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.

4.4 It is planned that both Central and Western Railways will gradually convert to 25 kv ac. In addition changing the insulation levels, special features for the conversion are:

(i) Retention of existing catenary and contact wires i.e. 242 sq. mm and 193 sq. mm.

(ii) No neutral section is proposed in Thane-MBCST and Borivili-Churchgate-areas, by feeding the entire section from same phases.

(iii) Circuit Breakers are proposed in SPS (Sectioning Posts) and SSPS (Sub Sectioning Posts)

(iv) Gas insulated switch gear proposed in substations with space constraints.

4.5 STRATEGY FOR CONVERSION:

While taking up the conversion of 1500 V dc traction system to 25 kv ac traction system, following phasing has been planned:

(a) **Central Railway**

Section	Target date
Vasai Road-Diva-Panvel	
Jassai	Dec.2001
Tilak Nagar-Panvel	Mar.2003
Thane-Turbe	Mar.2003
Igatpuri-Titwala	Mar.2003
Pune-Vangani	Mar.2004
Karjat-Khopoli	Mar.2004
Titwala-Thane	Mar.2006
Vangani-Kalyan	Mar.2006
Thane-Mumbai CST(Main)	Mar.2008
Mumbai-Tilaknagar (Harbour)	Mar.2008
Mahim-Wadala	Mar.2008
Kurla-Trombay	Mar.2008

(b) **Western Railway**

Virar-Borivili	Dec.2001
Borivili-Andheri	Dec.2004
Andheri-Churchgate	Dec.2006

5 SPECIAL-FEATURES OF ELECTRIFICATION ON IR:

5.1 Following innovations were adopted for the first time on IR

(a) 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.

(b) Electrification of Waltair section (isolated from the electrified network):

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.

(c) 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 Aluminum Overhead Equipment, comprising of 19/2.79 mm Aluminum Alloy catenary with two standard 107 sq. mm grooved aluminum contact wires and Aluminum 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

(d) 2 x 25 kv system on IR:

IR have introduced 2x25 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 2x25 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 trains seem to have been abandoned and not a single such train has been run. The system has not been extended to any other section.

(e) Use of Prestressed Concrete Masts 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, structure 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, 7.9m long and 250-270mm 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 N., W., S. and SC Railways. However following problems are still experienced.

(i) Difficulty in transportation, handling and erection due to heavy weight.

(ii) Different type of fittings and separate earthing arrangements are needed.

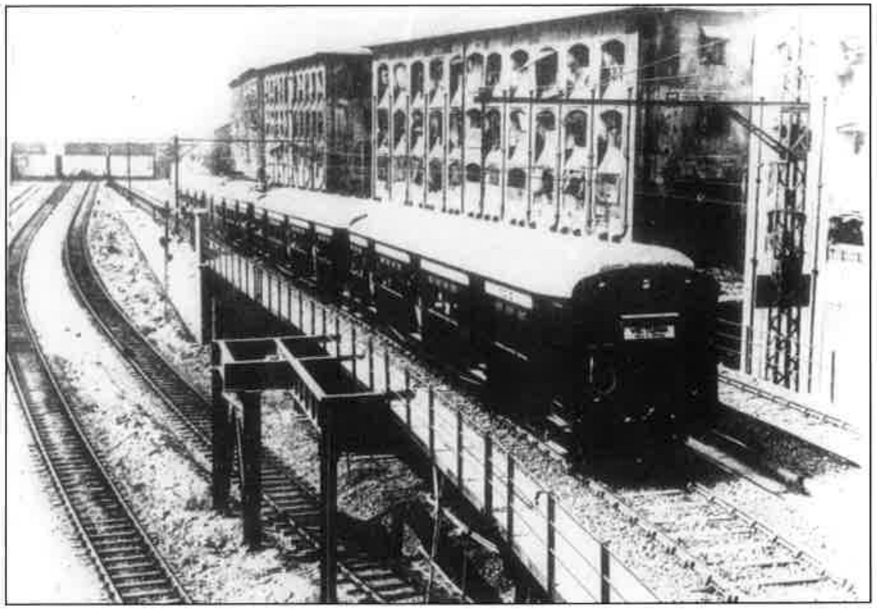
(iii) Spun PSC masts usually get totally damaged and need replacement in case of accidents.

(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.

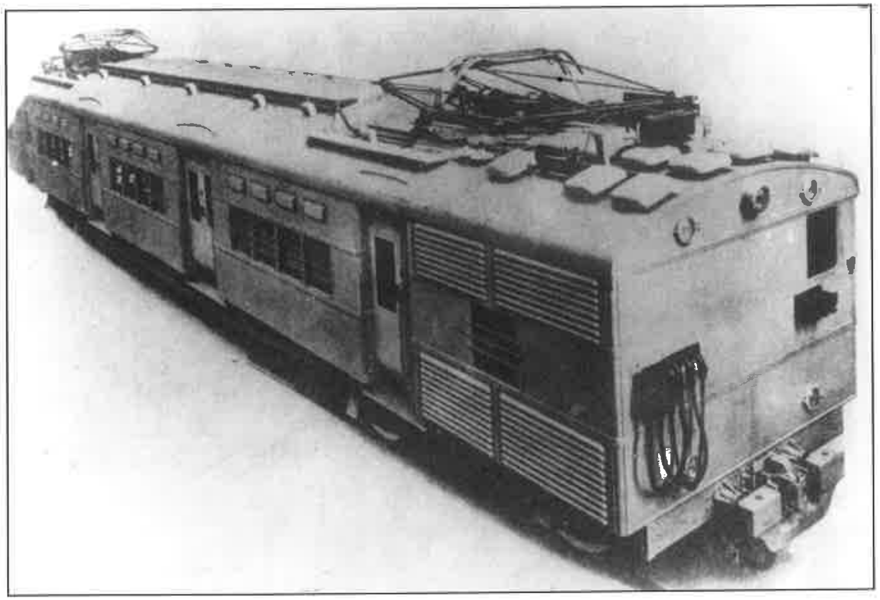
In view of these difficulties, the use of spun PSC masts has been limited.



APPENDIX-XI-2.2

PROGRESSIVE YEAR WISE EXTENSION OF ELECTRIFICATION ON INDIAN RAILWAYS

YEAR	RKM ELECTRIFIED	PROGRESSIVE TOTAL
1925-56	529	529
1956-61	216	745
1961-66	1678	2423
1966-71	1383	3706
1971-76	956	4662
1976-81	696	5358
1981-86	1543	6901
1986-91	3182	10083
1991-96	3434	13517
1996-2000	1467	14984
2000-2001	414	15398



BIBLIOGRAPHY :

(i) Report on the electrification of lines in the neighbourhood of Calcutta (East Indian Railway and Eastern Bengal Railway) by M/s Merz and Mclellan, London (August 1924).

(ii) 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.

(iii) 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.

(iv) Electrification of Indian Railways-Report of Nouvion Mission (SNCF) June-Sept. 1956.

(v) Railway electrification in India by H.D. Awasty, General Manager & Chief Engineer Railway electrification-RE Journal, October, November1964.

(vi) 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.

(vii) Scheme for ac/dc working at Igatpuri by Parmanand-RE Journal, Vo.5 No.3-August-September 1964.

(viii) Aluminum-alloy conductor for ac traction overhead equipment by M.N. Mukherjee and C.A. Sankarnarayanan, Proceedings of the Institution of Electrical Engineers (UK) Vol. 126 No.7 July,1979.

(ix) Railway Board letter No.72/RE/141/1 dated 21st July-1992

(x) Techno-economic evaluation of 2x25 kv ac system on Indian Railways-RDSO Report No.TI/Report/PSI/00047

(xi) Annual Reports of South Indian Railways (Trichy) Section-I from the years 1930-31 to 1940-41.

(xii) 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.

(xiii) AC Traction comes to S.Rly. by D.V.K. Shastri CEE/S/Rly.-RE Journal Vol.8, No.6, February-March 1968.

(xiv) 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.

(xv) Conversion of Madras-Beach-Tambaram 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.

CHAPTER-XII
SIGNALING & TELECOMMUNICATION

1. THE BEGINNING:

1.1 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 arm of the traffic policemen took the form of signals ushering the era of semaphore signalling in railways.

2. GROWTH OF RAILWAY SIGNALING:

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.

2.2 Construction of new lines picked up with formation of State Railway Directorate in 1974. 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 signaling in the initial stages had the least of the equipment. Hence, the lines were opened based on practices followed at "Home".

2.2 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 superceded 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 superceded 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.

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 railways specified the minimum complement of Signals for various classes of stations were laid down.

3 INITIAL SIGNALING & TELECOMMUNICATION SYSTEMS ON THE RAILWAYS -(1853-1900):

3.1 While railways were initiated in Indian 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 signaling systems in the Country.

3.2 These signaling 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 signaling 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 signaling 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.

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" 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.

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.

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.

3.6 This situation continued for many years. The systems were gradually improved as the traffic grew on the lines and need for faster operations at stations became an inescapable necessity.

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.

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 by mistake be lowered before proper setting of the points or the signals may not go back to `ON' position due to contraction of the wire or by outside interference.

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 engaged with extension rods attached to the point switches.

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.

3.6.5 Various methods and designs of key locks were adopted by different railways for Key Interlocking namely:

3.6.5.1 Standard-Key-Locking (1892)

3.6.5.2 List and Morse Key Locking (1894)

3.6.5.2 Saxby Farmer Key-Interlocking

3.6.5.3 Four line Signaling Key Interlocking

3.6.5.3 Three Line Signaling Key Interlocking

These were arrangements for locking points and releasing the signals to achieve the desired sequence of operation.

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.

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.

4. DEVELOPMENTS IN RAILWAY SIGNALING AND TELECOMMUNICATION DURING 1900-1947:

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 increase 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.

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.

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.

4.4 The lever frames had two categories depending on the method in which levers were interlocked with each other in a lever frame.

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 signaling system for the station. These were suitable for small lever frames only.

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.

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'.

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 effective 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 for operation of signals and points 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.

4.7 Stations, where the distances for signal and point operations were much longer or the number of lines were too many, more than one cabin with lever frames was provided for operation. These lever frames was inter connected with each other through inter-cabin controls which were initially mechanically operated (single wire or rod). These single mechanical controls had to be replaced with electromechanical controls (Reversers or Electric Motors) as the distances and the intensity of operations increased.

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.

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.

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 to ensure 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.

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.

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 increase 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.

4.13 On the suburban systems of Central Railway Automatic signaling was introduced in 1928. On South Indian Railway Multiple Aspect

Color Light signaling with Automatic signaling 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. Some railways, Central and Eastern, continued to work suburban trains on Automatic signaling with Mechanical lever frames and Two Aspect Semaphore signals for many years.

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.

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.

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.

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.

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 helped in providing larger volumes for supply to make the manufacture cost effective.

4.19 Manufacture of Mechanical Signaling equipment in India was 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 signaling, electro-mechanical signaling as well as power signaling.

4.20 Railway had started their own workshops to undertake overhaul and repair work of the signaling 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 Bycalla.

5 <u>DEVELOPMENTS IN RAILWAY SIGNALING & TELE COMMUNICAT- ION AFTER INDEPENDENCE (1947-2000)</u>:

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 development of Railway transport capacity and higher degree of safety in their movements. The capacity for manufacture of Signaling & Telecommunication equipment in the country was extremely limited. There was shortage of foreign exchange for importation of new Signaling & 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 Signaling and Telecommunication services was accepted and a separate department was formed to manage these under Member Engineering, Railway Board.

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 driver more accurate information of the state of line ahead to enable 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 signaling 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 to give more than two aspects. The multiple aspect semaphore signaling found larger acceptance. The double wire operated multiple aspect signaling was found more economical in operation on MG lines as it could operate the signals and points at most stations with a single cabin.

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.

5.4 Higher speeds of trains having higher loads required longer braking distances. This required signals to be operated over longer distances 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.

5.5 With double wire operation of signals Multiple Aspect Signaling became feasible with mechanical systems. This suited well for higher speed trains which needed more braking distances and much advance warning on the state on 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.

5.6 A switch was made mandatory to electric operated color light multiple aspect signaling when ac electric traction was introduced on Main line to counter 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.

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 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.

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 signaling 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.

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.

5.10 To provide necessary technical support to Indian industries a new organization Railway Testing and Research Centre was set up in 1952. This permitted dispensing with the dependence on foreign consultants and simaltenourly raising the indigenous production of materials. The two organization CSO and RTRC were merged in 1957 into Research, Design and Standards Organization (RDSO).

5.10.1 While the initial lot 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.

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 design. This expedited the local manufacture of these equipments and gave uniformity all over the Indian Railways simplifying maintenance and procurement practices.

5.11 The systems were imported from a number of sources. A new breed 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.

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 in Barar Square in Delhi in series with conventional relay interlocking in 1982 After extensive trials, it was commissioned for independent working. The system was later updated and an improved version is installed at Dushkera station of Central Railway in 1990. Later one more system has been installed at Bhadli in 1997. Installation at 3 more stations is in progress. 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.

5.13 Railways had their own signal workshops started as small units for the maintenance and overhaul of units 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 Signaling, 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.

5.14 The telecommunications also made rapid developments to meet the ever increasing requirements caused by rapid development of the traffic. Railway hired more and more lines from Dept. 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.

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 needs 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 Dept. 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.

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.

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 Tubes 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.

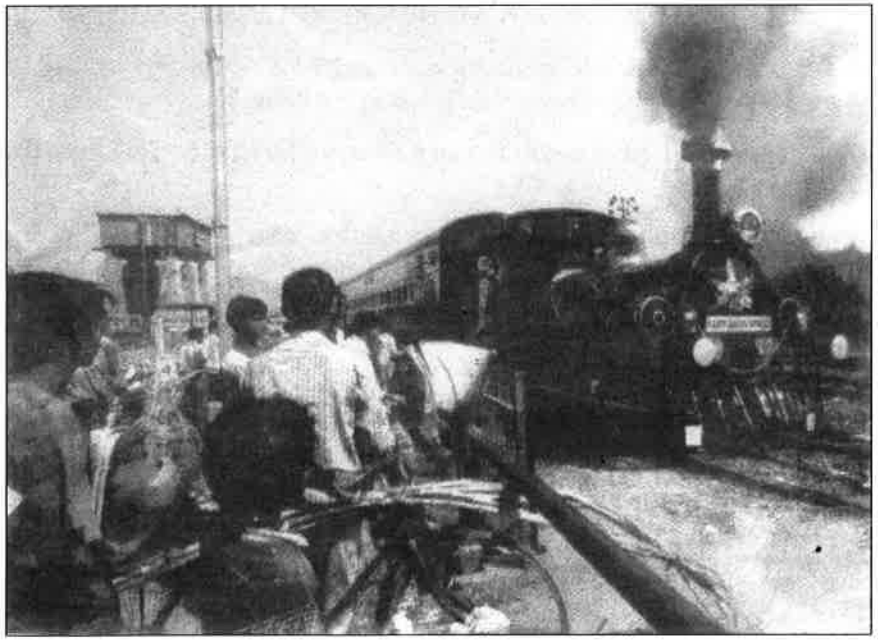
5.18 The cable using copper along the track were subjected to wide spread theft making these almost unserviceable and needing frequent repairs. The traction current in the electric traction was increasing steeply due to sharp increase in train movements as also the increasing trailing loads. This demanded 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 overcome 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 wire 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.

5.19 A big trust was given for improving safety on Indian Railways. Mr. V.K. Agarwal Chairman Railway Board introduced route wise priority for completion of safety work. As a result track circuiting of run through lines on all station 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 20^{th}

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 speeded up. Trials of new devices for train actuated approach warning at level crossing were initiated.

5.20 The later part of 20th Century saw the advent of new technologies in Railway Signalling in 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 & SCO, ADTRANZ, Siemons were extensively provided on Southern, Central and Western Railways. Use of LED signals. Integrated Power Supply using SMPS technology were adopted. Higher performace 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.

5.21 A chronological List of Key Events is given in Appendex 5.21



APPENDIX-5.21

CHRONOLOGICAL LIST OF KEY EVENTS IN SIGNALING

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 Warning System introduced by Siemens India on Central Railway.

1998 First Digital Axle Counter on Maulali – Cherlapally section on South Central Railways.

1998 Track circuting of run through lines in all stations 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 Gunies Book of

World Record.

Documents consulted (Signalling & Telecommunication)

(i) Report on the electrification of lines in the neighbourhood of Calcutta (East Indian Railway and Eastern Bengal Railway) by M/s Merz and Mclellan, London (August 1924).

(ii) Railway electrification on the Eastern Railway by M.N. Mukerjee, Dy. CEE/RE, Calcutta. Paper presented on the occasion of Golden Jublee of Electric Traction in India,1975.

(iii) 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.

(iv) Electrification of Indian Railways-Report of Nouvion Mission (SNCF) June-Sept.,1956.

(v) 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.

(vi) Scheme for ac/dc working at Igatpuri by Parmanand-RE Journal, Vo.5 No.3-August-September 1964.

(vii) Aliminium-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.

(viii) Techno-economic evaluation of 2x25 kv ac system on Indian Railways-RDSO Report No.TI/Report/PSI/00047

(ix) Annual Report of South Indian Railways (Trichy) Section-I from the years 1930-31 to 1940-41.

(x) 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.

(xi) AC Traction comes to S.Rly. by D.V.K. Shastri CEE/S/Rly.-RE Journal Vol.8-No.6 February-March 1968.

(xii) 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.

(xiii) 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.

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	
Ramanujam, T.V.	Rail TransportThe 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 Tommorrow"	
	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

A complete story of the Assam 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 Enginers (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

CIVIL ENGINEERING

Agarwal, M.M.	Indian Railway Track, Prabha & Co.	2000
Agarwal M.M.	Track Maintenance on German Railway	July 1972
	Agarwal G.S. Ultrasonic Flaw detection of thermit welded joints RDSO in Indian Railway Technical bulletin of Feb-1976 & 1977	
Agor, R.	Railway Track Engineering, Khanna Publishers	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 Kangra Valley Railway, A Northern Railway Publication	1983
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.	Concise hand book of Civil Engineering, S. Chand & Co.	1990
Chandola S.P. & Vazirani V.N.	Railway Bridges & Tunnels, Khanna Publishers,	1997
Dabke V.H. & Parikh J.M.	Notes on Ganga Bridge project at Mokameh Ghat	
Gupta B.L.	Road, Railway, Bridge & Tunnel Engineering, Standard Publishers Distributors	August 1978
Ghosh, B.N.	Analysis of data of 20 bridges on various Railways	
Gregory	Godavari Bridge, Kazipet-Belharshah Railway	
Jain, R.K.	Railway bridge across Son, Technical monogram no.27 RDSO publication	
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
Kundrey S.J.	Railway Track Engineering, Tata Mcgraw Hill Publishing Co. Ltd., New Delhi	2000
MacGeorge, G.W.	Ways and Works in India	1894
Rangwala S.C. & Rangwala P.S.	Principles of Railway Engineering, Charotar Publishing House, Anand	1991
Rao Krishna S.H.R	Technical Monograph No.35, RDSO	1970

Shahney G.P.	Construction of 14x150 Ft. BGML bridge and its training works across the Beas at Mirthal on New Mukerian-Pathankot line	
Shivdasani and Kane	Konkan Railway	1998
Salkade	Points & Crossing, Popular Book Depot, 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 Bridge, Karuna Prakashan, New Delhi	1992
Sreedharan E.	Restoration of Pamban Bridge	
Stauffer, D.M.	Modern Tunnel Practice	1928
Vaswani Dr. N.K.	Railway Engineering, Roorkee Publishing House, Roorkee	1965

REPORTS & DOCUMENTS

Bridge river Brahmaputra-past, present & Future	Construction organisation of North East Frontier Railway	1988
Continuous Weld Rails,	RDSO	May 1977
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)	Oct.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	Feb.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
Track maintenance on high speed routes	RDSO	1971

MECHANICAL ENGINEERING

Atkins Bill	Exploring Indian Railways, Delhi Oxford Univ. 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	1941 onward
Kendrith, S.T.	Progressive Building of Railway Carriages	1926
Kipling Rudard	From Sea to Sea-Vol.II	1889
Marshal M.P. & Field White	The Time Table of Technology, Netherlands	
Orton, A.	The Diesel Engine	1938
Sinha, Dr. P.P.	Munger through the ages, Dr. Jai Prakash Narayan IRS College, Jamalpur.	

REPORTS & DOCUMENTS

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	
Desmond Pamphet "Dahod workshop-History & Achievements"	01.12 1999
& Chief workshop Engineer, Report No.M/324/W/4.2.11/PP	30.11.1999
RDSO's Report No.MP-PRO (Revision OO)	December, 1998
Development of DMU & Rail Bus. Times of India, New Delhi	14.08.1999

ELECTRICAL

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-June1994
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 Jubilee of Electric Traction in India.	1975
Mukerjee, M.N.& Sankarnarayanan	Aluminum-alloy conductor for ac traction overhead C.A. 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.	Conversion of Madras-Beach-	

Distt. EE/S. Rly. — 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 Proceedings of the Institution of Mechanical Engineers. Vol-123 — 1932

REPORTS & DOCUMENTS

Report on the electrification of lines in the neighbourhood of Calcutta (East Indian Railway and Eastern Bengal Railway by M/s Merz and Mclellan — August, 1924

Report of Nouvion Mission (SNCF), Electrification of Indian Railways — June-Sep 1956

Railway Board letter No.72/RE/141/1 dated 21st July-1992

Report No.TI/Report/PSI/00047, Techno-economic evaluation of 2x25 Kv ac system on Indian Railways

Reports Annual of South Indian Railways (Trichy), Section-I, — 1930-31 To 1940-41

Report on Project 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

Report on the Application of Electric Traction for the Bombay Suburban Railway-Merzand Mclellan-London — Oct, 1913

Report on the electrification of part of GIP Railway main line-Merz and Mclellan-London — July, 1919

Report on the Swiss Federal Railway-Electrification completed, Published by the Swiss Federal Railways — Approx.1960

Report on Railway Electrification in Switzerland-Publication of Swiss Federal Railways — Approx.1955

SIGNALLING & TELECOMMUNICATION

Agarwal, S.K. — Development of Signalling and road ahead

Dutton, S.T. — Railway Signalling — 1928

Fraser, H.J. — Lewis's Railway Signal Engineering — 1932

Kaul, M.K. — Modern Railway Signalling

Kaul, M.K. — 50 years of Telecommunication of Indian Railway

Mishra A.K. — Dawn of revolution in Railway Telecommunication System

Raghavan K.S. — Southern Railway marches ahead-Modernisation of Signalling and Telecommunication in Post-independence era,

Ramasamy V. — Growth of Signalling on IR-Post ubdeoebdebce 50 years.

Sethi S.P. — Modern Railway Transportation Vol-I Operational Problems Vol-II Safety Rules and Regulations.

Tattersall, A.E. — Modern Development in Railway Signalling — 1936

REPORTS & DOCUMENTS

R.D.S.O.'s Annual Reports

Signal Interlocking and Standards Committee's reports — 1903