



# **MUMBAI METROPOLITAN REGION DEVELOPMENT AUTHORITY**

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**MASS RAPID TRANSIT SYSTEM  
FOR  
VERSOVA-ANDHERI-GHATKOPAR CORRIDOR IN MUMBAI**

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**VOLUME III A of IV**

**Performance Requirements  
Performance Specifications and Technical Proposal of Preferred  
Bidder**

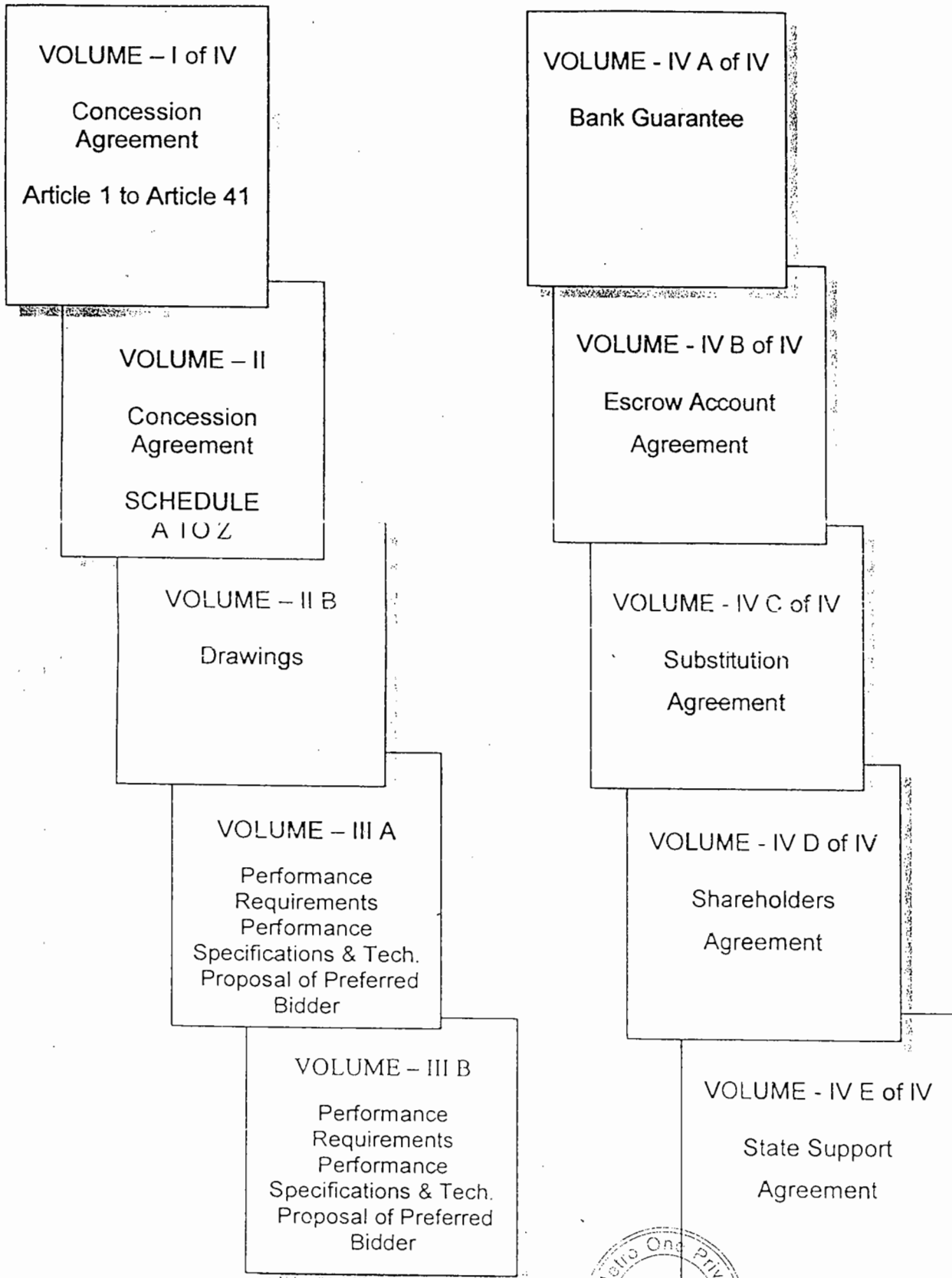
**RELIANCE Energy**  
Anil Dhirubhai Ambani Group

 **VEOLIA**  
TRANSPORT



VERSOVA-ANDHERI-GHATKOPAR CORRIDOR  
CONCESSION AGREEMENT

DOCUMENT TREE




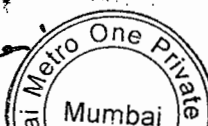


# Technical Proposal

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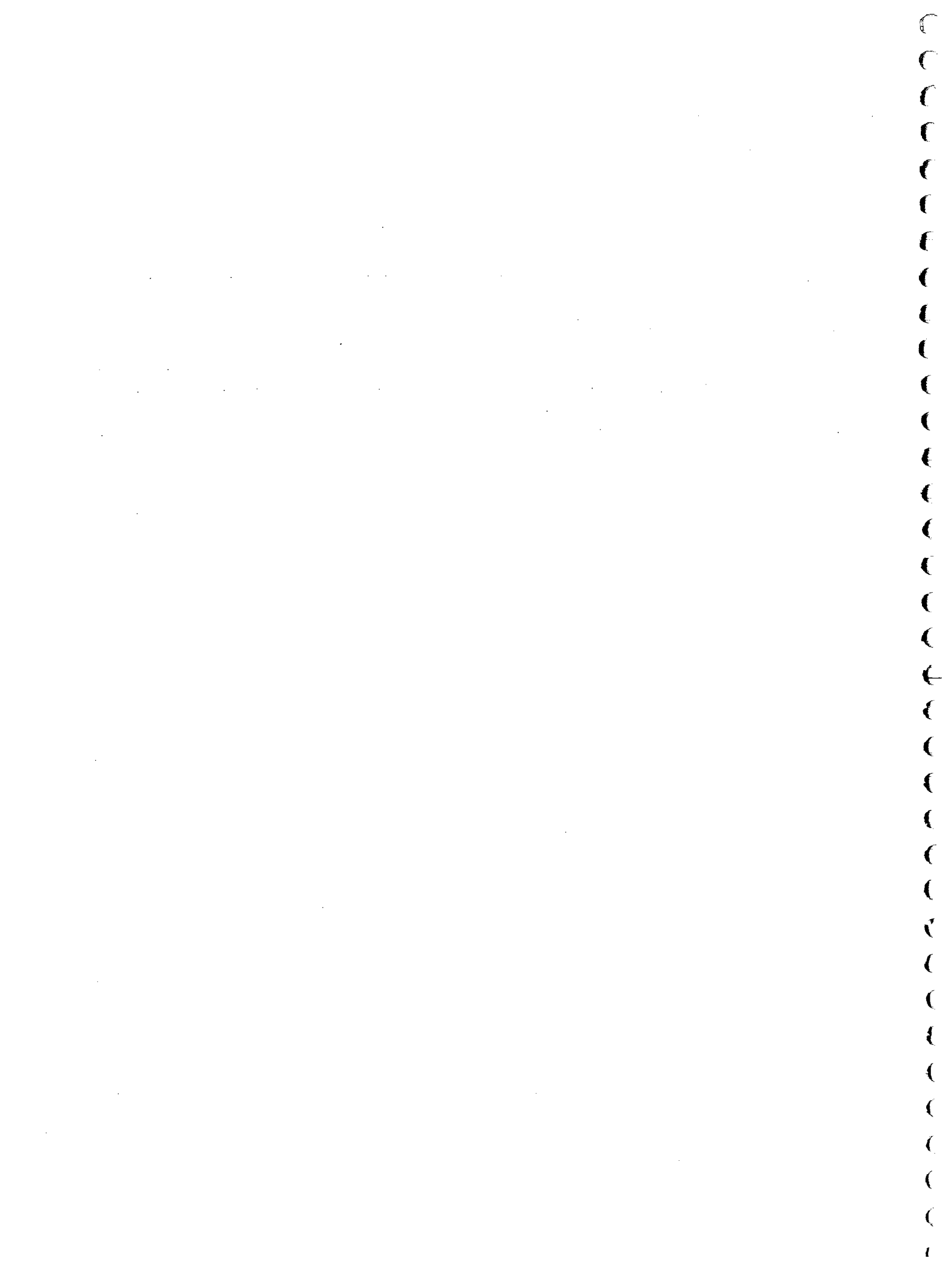





**PART A**

**TECHNICAL PROPOSAL OF PREFERRED BIDDER**









## 1.0 EXECUTIVE SUMMARY

### 1.1 Appreciation of the Project

#### 1.1.1 Prologue

Mumbai, the most vibrant city in the country, has historically been the commercial and financial capital of the country, with all its attendant dynamism. Most leading industrial houses are headquartered at Mumbai or have a major presence here. Mumbai (which connotes a wide spread area comprising "Brihan" or Greater Mumbai) is also a great industrial center; it is home to media, advertising and the fashion industry; it is home to the world's biggest movie and entertainment industry. Mumbai boasts of the nation's biggest airport and seaports, along with rail and road gateways to the hinterland, and leads the country in the share of international trade. Mumbai also supports a myriad other trades in a significant manner.

Mumbai's celebrated cosmopolitan culture really sets it apart from, and ahead of, the pack of other metros in the country. It is truly among the "world cities" dotting the global map. Mumbai challenges and stretches ideological boundaries, and therefore remains at the forefront of unleashing individual and collective potential. Consequently, Mumbai remains, and has always been, a strong magnet to people from all walks of life to settle, thrive and excel.

The enormous growth that the metropolis has experienced presents its own challenges for urban management and puts tremendous stress on the civic amenities. The situation is further accentuated due to peculiar geographic features of the city : Mumbai is essentially an island city (made up of seven islands), which has been sewn up and integrated with the main land. The growth has been along two principal corridors as characterized by the suburban Central and Western railway services running in the south-north direction. Each of these rail routes are flanked by the main road arteries viz. the Western express highway and the Eastern express (Sion -Panvel) highway.



### 1.1.2 The connectivity conundrum

While numerous options are available for north-south connectivity, few, if any, exist for the east-west connectivity, especially for the suburbs located north of central Mumbai. The connectivity between the two rail routes is available at Dadar/Wadala, while the road connectivity is available adjacent to Sion station, all located in the central part of the city.

The northern suburbs have become densely populated in the past couple of decades, leading to a spurt in residential, commercial and social (educational, healthcare etc.) development. In recognition of this phenomenon, even mainstream businesses have either completely or substantially moved their base northwards, with the Andheri-Kurla Road and the SEEPZ area being among the most prominent destinations for such re-location.

This has resulted in a ***northward shift in the center of gravity of the city's population.*** More commuters availing of the public transport now originate in the northern suburbs than ever before. The sheer lack of east-west connectivity results in severe hardships for commuters requiring to make these crossovers, especially on a daily basis.

In the current scenario, traversing between two far-flung northern suburbs, each located along the two principal flanks, is akin to negotiating the entire length of a *hairpin configuration*, in order to traverse between two points located at or near the *hairpin tips*! Consequently, locations which may be only 6km to 10 km apart require a one-way commute of anywhere between 20km to 40 km!

### 1.1.3 The Versova-Andheri-Ghatkopar Elevated Mass Rapid Transit Rail System (V-A-G MRTS) : A Solution Long Overdue!

In appreciation of the accelerated east-west mass transportation needs of the commuters, the Mumbai Metropolitan Regional Development Authority ["MMRDA"] has judiciously taken up the development of the V-A-G MRTS on priority. The severe space constraints, as well as the already severe traffic congestion along this identified corridor, has virtually dictated the need to develop the MRTS above grade i.e. elevated.

Once successfully commissioned, the V-A-G MRTS would serve three important purposes:

- [I] Provide the much needed east-west connectivity, at the mid-points of the *hairpin* configuration
- [II] Provide an alternate and more attractive mode of transport to the commuters on this stretch
- [III] Provide substantial flexibility to the urban planners, by augmenting capacity and de-congesting the traffic along the corridor

Given the situation, the need to expedite the development of the V-A-G MRTS cannot be emphasized enough!

## 1.2 The Bid

### 1.2.1 Global Bids

MMRDA have invited global bids for the development as well as operation and maintenance of the proposed Mass Rapid Transit System for the Versova-Andheri-Ghatkopar corridor on a Build-Own-Operate and Transfer (BOOT) basis for a concession period of 35 years, inclusive of a 5-year construction period. . The total route length, including a spur to Sahar International Airport, is approximately 13 km of a Standard Gauge (1435 mm) track. MMRDA has invited bids in two stages – an initial detailed Technical Bid, followed by the technically qualified bidders required to submit their Financial bids.

### 1.2.2 Bidder

Reliance Energy Limited, the largest integrated power utility in the private sector in India, has partnered with CONNEX of France, Europe's leading operator of Rapid Transit Systems, to form a highly credible, capable and competent Consortium for submitting the bid for the commercial development, operation and maintenance of the proposed V-A-G MRTS. The Consortium proposes to design, develop and operate the V-A-G MRTS as a **commuter-centric transportation utility**.

### 1.2.3 The Consortium

Reliance Energy Limited ["REL"] is a part of the Reliance Group, which has unmatched credentials in operating utilities on a commercial basis. The Reliance Group's portfolio includes India's leading utilities in the petroleum, telecom and power sectors, the latter being directly operated by REL. Besides the experience in operating utilities, the Reliance Group has proven credentials in successfully developing, commissioning and managing global-scale projects in diverse sectors.

**The RELIANCE Group, founded by Dhirubhai H. Ambani (1932-2002), is India's largest business house in the Private Sector, with Total Revenues of over Rs 99,000 crore (US\$ 22.6 billion), Cash profit of Rs 12,500 crore (US\$ 2.8 billion), Net profit of Rs 6,200 crore (US\$ 1.4 billion) and Exports of Rs 15,900 crore (US\$ 3.6 billion).**

**The RELIANCE Group's activities span exploration and production (E&P) of oil and gas, refining and marketing, petrochemicals (polyester, polymers, and intermediates), textiles, financial services and insurance, power, telecom and infocom initiatives. The Group exports its products to more than 100 countries the world over.**

**RELIANCE is the largest Indian private company on several financial parameters, and is ranked among the largest 150 companies globally by net profits and among the largest 400 companies by sales. RELIANCE Group revenue is equivalent to about 3.5% of India's GDP. The Group contributes nearly 10% of the country's indirect tax revenues and over 6% of India's exports.**

**RELIANCE ENERGY LIMITED (REL) is a 75-year old company. REL, a Reliance Group company, is the LARGEST Integrated Power Utility company in India in the private sector with its own Generation, Transmission, Distribution and Power Trading operations and supplying RELIABLE and QUALITY power to more than 25 million Industrial, Commercial and Domestic consumers in several parts of India. REL and its affiliates distribute over 5,000 MW of power, the largest by a private sector Utility in India.**



REL and its affiliates Own and Operate several Power Plants with total installed capacity of 940 MW Utility Power at five locations. Other Reliance group companies own and operate 1095 MW Captive Power Plants at seven locations.

REL is in the process of setting up a 3740 MW Gas based project near Delhi, at Dadri. The power project, to be developed in phases, will also be the world's largest gas based power generating plant at a single location.

CONNEX SA is a subsidiary of the French group VEOLIA -Group, the world leader in Transportation and Environmental Services (turnover 2003: € 28.6 billion)

In 2004, Connex employed 61,000 persons, carried 1,5 billion passengers for a turnover of €3,6 billion with a solid presence on four continents. Connex operates all modes of transport with 23,500 road vehicles (buses and coaches), 3,500 rail transit vehicles (trains, underground trains and light trains) and 49 ferries.

Connex, the No.1 private operator of public transport in Europe, with a presence in 23 countries and working relationships with 5,000 local authorities, has consciously positioned itself as a proactive supplier, able not only to meet various needs but to anticipate them as well.

Connex is the leading provider of contract passenger rail services in the world today.

Additional information on the consortium partners has been presented in the subsequent chapters.

#### 1.2.4 The Associates

While the Consortium is firmly placed to undertake the project, it intends to associate with MTR Corporation, Hongkong, the operator of the renowned Hongkong MRTS, to provide it with crucial technical support for project management and system integration services. Extensive support has already been extended by MTR Corporation for the preparation of this Technical Proposal.

The present MTR network consists of 50 stations on 87.7 route-kilometers, serving over 2.3 million passengers daily by operating over 1000 train cars. The MTR system is ranked amongst the

world's safest and most reliable system, with service delivery as high as 99.9% and punctuality attained at 99.3%.

#### **1.2.5 The best blend**

Taken together, the Consortium brings to the table unparalleled strengths in project development, commercial operations of utilities and operations of Rapid Transit Systems.

It is pertinent to highlight here that the Consortium Partners, along with their Associates, would bring to the table a propitious blend of local, European and Far East Asian best practices and sensibilities.

### 1.3 The Proposal

The Consortium partners, along with their associates, have deliberated at length on the appreciation of the project and the Bid Documents, in order to understand MMRDA's requirements as well as to bring out all the facets of the development in great detail. The Bidders have crystallized the result of this elaborate brainstorming exercise into **Vision and Mission Statements** for this development. The Vision and Mission Statements have served as the **guiding posts** for the entire Technical Bid preparation.

#### VISION

**To create and operate a landmark rapid transit system providing strategic transportation connectivity and delivering a comfortable and pleasant commuting experience.**

#### MISSION

- To provide a fast and safe mode of transport
- To provide a punctual and reliable service
- To ensure comfort and convenience of the users, both on board and on the premises of the MRTS
- To provide user-friendly facilities and passenger services for the convenience of new and unfamiliar commuters
- To ensure quick and easy access to the MRTS, and provide for convenient and direct connections to other transportation services, wherever possible
- To provide special amenities and services for the old, infirm and physically challenged commuters
- To be a SMART utility service provider by employing leading edge technologies and designing innovative services and solutions
- To provide a variety of user amenities on the MRTS premises in a clean and pleasing ambience

## 1.4 The Technical Bid

### The Methodology

The bidder has studied in detail the provisions of Vol-I, Vol-II & Vol-III of the Bid Document and was actively involved in obtaining clarifications from time to time personally as well as through email, and has understood the requirements and stipulations of the Bid Document along with later modifications issued through addendums.

The bidder has studied the project plans prepared by MMRDA and has inspected the site to appreciate the various factors determining the technical feasibility, as well as to appreciate the site related risks involved in the execution of the project.

### The Scope of the Project

The scope of the project as stipulated in the bid documents covers the construction of a double line elevated standard gauge (1435mm) rail corridor along Versova – Andheri – Ghatkopar involving 13 stations including a spur to International Airport at Sahar. The total length of this corridor including the spur is 12.853 Kms.

The project also involves the construction of an elevated depot at D.N. Nagar for stabling and maintenance of coaches, and the construction of a single line entry to the depot. The length of this single line entry to depot is 450 m with additional 5 km of track within the Depot. The track at D.N.Nagar depot will be Ballast less.

An alternative site for the depot has also been identified by MMRDA at Ghatkopar end with an elevated entry beyond Asalpha station. This involves an elevated tract of 1.74 km after crossing the central railway tracks at elevated level and then with a downward ramp in 1 in 40 grade for provision of a depot at ground level. The 5 km of track at Ghatkopar depot shall be with ballast etc.



### Mandatory Requirements

It is appreciated that corridor alignment, location of stations, system gauge, quality of service, car shed location, accessibility to physically challenged people, coach air-conditioning and electric traction, 25kV AC OHE are the mandatory requirements stipulated by the bid documents and the system proposed by us fully conforms to these requirements. We have however, identified certain key areas where some changes to the system are desirable. These have been presented as suggestions as appropriate place in our offer.

#### **1.5 The Proposed Mass Rapid Transit System [MRTS]**

The proposed MRTS has been designed to provide for the following service requirements and levels, which is in compliance with the stipulations in the bid documents.

##### **1.5.1 The Service**

The train service will operate from Versova to Ghatkopar. The service will call at Versova and continue to DN Nagar, Azad Nagar, Andheri, Western Express Highway (WEH), Chakala, Airport Road, Marol Naka, Sakinaka, Subhash Nagar, Asalpha Road and terminate at Ghatkopar. The Airport train service will be diverted from the Airport Road Station and terminate at Sahar Airport.

The total journey time between Versova and Ghatkopar would be within a target duration of 21 minutes, which includes the halt/dwell time.

The passenger service shall be provided from 05:30 in the morning until 24:00 of the day, operating for a period of 19.5 hours each day. The peak hours are expected to be from 08:00 to 13:00 and from 17:00 to 22:00 Hrs.

The Initial Service Level in 2011 shall be based on a train service headway from Versova of 4 minutes during peak hours and 8 minutes during non-peak hours as required in the Technical and Performance Specifications. The headway shall be reduced to 3 minutes during peak hours and 6 minutes during non-peak hours at the Ultimate Service Level in 2041.

The train service to Sahar Airport station shall be provided by diverting every second to sixth train, such that the waiting time at Sahar Airport Station does not exceed a maximum of 20 minutes.

**Capacity expansion in step with increasing demand**

The Bidder has provided for phase wise expansion of service capacity by adopting optimum combinations of the two possible means viz. [i] reducing the headway and [ii] increasing the number of cars per rake.

The summary of the Service Level Forecast and Fleet Expansion is provided below:

Year	Passengers per hour per direction	Headway in Peak Hour (minutes)	Total No. of Rakes (including spare trains)	Cars per Rake
2011	18600	4.0	13	4 – Cars
2021	23600	3.25	16	4 – Cars
2031	30500	3.5	14	6 – Cars
2041	39500	3.0	17	6 – Cars

**Safety**

The design of MRTS will employ the best design practices to minimize the likeliness for accidents to passengers on stations and in trains. The stations will be designed to minimize the risk of fire in accordance with applicable codes and local fire safety guidelines / regulations. The layout of the station will be devised so that the passengers can be evacuated quickly and safely by an immediately obvious route including through Automatic Fare Collection (AFC) gates. For emergency evacuation of a train, provision will be made to clear the platform in 4 min.

In the event of a power outage, all train and station systems and services which are vital to safety will be provided with a back-up power supply, so that, if necessary, the passengers may be evacuated without harm to their health or well-being.



A set of safety and emergency procedures will be formulated to deal with different routine and emergency situations. These will be included in Safety and Disaster Management Manuals.

**Service Reliability and Availability**

The equipment for the MRTS will be of a robust design. Every effort will be made to improve reliability of equipment in a cost effective manner. The target is that the overall availability of services will not be less than 97% during 1<sup>st</sup> year of operation. During 2<sup>nd</sup> and subsequent years, target service availability will be at least 99%. The maximum kilometerage between failures (MKBF) will not be less than 100,000km.

**1.5.2 Rolling Stock**

The Bidder offers to deploy an advance and modern Rolling Stock (Electrical Multiple Unit Stock), along with numerous state-of-the-art features on the prestigious V-A-G Mass Rapid Transit System.

The proposed design of the EMU stock will fully meet the required parameters of the MMRDA as contained in the Bid document.

The train formation has been determined keeping in mind the severe service conditions (Steep Grade and Sharp Curves) as well as the stringent operating parameters (High Acceleration, Heavier Load, Optimum Running Time and Higher Deceleration) under which the train sets are required to operate.

The proposed train formation is : DT-M1-M2-M2-M1-DT

DT – Driving Trailer

M1 – Motor Coach

M2 – Motor Coach with emergency cab and Hostler Controls



During the initial stages of MRTS operation period when the traffic demand does not warrant 6 car Train sets, the system may be operated with 4 Car Train Set consisting of 2 motor coaches and two driving Trailer coaches as a measure of economy.

The Rolling Stock shall be aerodynamically efficient and aesthetically attractive.

The coaches would be of lightweight design with 4 doorways along each side and roof mounted air-conditioning system. Each Coach will be fitted with 7 to 8 longitudinal benches made out of Stainless Steel / Glass Reinforced Plastic (GRP) which can accommodate 42 to 48 seated passengers. Standing room in coach will be ample with a normal crush load of 300 passengers (6 persons per sq. meter) and a maximum of 375 persons at dense crush load ( 8 persons per sq. meter). The coaches shall have vestibules for passenger distribution and emergency evacuation.

The coaches shall be designed and constructed to be energy efficient. Air-conditioning would be provided maintain a passenger area temperature of 25 deg-C and humidity of 60% for passenger comfort. The coaches would be equipped with public address (PA) systems and emergency communication system with the train crew. Internal panels for advertisements and information shall be provided in the coaches.

The Cab design shall be ergonomic with frontal emergency exit provided to the drivers. Appropriate communication systems shall be provided to ensure crew to crew, crew to control center /stations, and crew to passenger contact.

In general, all equipment and systems provided will be electromagnetically compatible with each other and with all existing external systems.

### **1.5.3 Track**

Track for the entire alignment including Car Depot at D.N. Nagar and Airport line will be elevated and be of Standard Gauge. It is, therefore, proposed to provide non-ballast track for the entire elevated portion including at the D.N. Nagar Car Depot. [At the alternative depot site at Ghatkopar, the track will be at ground level and will be a ballasted track]



Pre-cast RCC Blocks will be provided as per the design standards, and the track fittings will include Rubber pad on Steel shims, Pre-cast track bolts, CI bearings, Pandrol clips/ Vossloh fittings & Grooved Rubber Pads.

The total track length shall be 31.446 km, of which the rail section for 26.076 km shall be of 60 kg and for the 5.370 km at the 52 Turnouts shall be 49 kg.

The rail expansion joints for continuous welded track will be designed to suit the rail temperature ranging from 10 deg to 60 deg C.

Buffer stops will be provided to standard designs at Ghatkopar and Versova and Sahar Airport Station and in yards. The numbers of Buffer Stops are 26.

The track shall be designed to ensure riding comfort for the passengers, and to ensure cleanliness as well as minimal and fast maintenance for the operator.

#### **1.5.4 Signaling**

Track alignment for the corridor is on elevated structures from Versova to Ghatkopar including the spur line from Airport Road to Airport station. For this dedicated track for Mass Transit of commuters, train control and signaling system has been designed to meet a design headway of 120 seconds. It shall comprise modern Automatic Train Protection (ATP) system with CAB signaling.

Line side signals will also be provided at all stations with points and crossing, which shall be used for the purpose of back up signaling. The system shall be based on fixed block principle.

All the stations with points and crossings shall be provided with one set of Computer Based Interlocking (CBI) with facility to operate these points and crossings locally as well as being centrally controlled from Operation Control center (OCC).

The CAB-borne and wayside signaling equipment has been designed with sufficient redundancy so as to meet the desired reliability and availability requirements. The proposed system will have self-diagnostic & predictive on-line maintenance feature to minimize the





failure & recovery time. The mimic panel for this corridor shall be housed in the OCC at DN Nagar. The depot shall be provided with an independent Computer Based Interlocking.

### 1.5.5 Stations

The stations would be designed so as to reflect the singular character of the MRTS as distinct from other modes of transport. Each station would be uniquely designed to reflect either a bold and modern society, or to reflect a blend of modern and traditional Indian architecture. The choice would be made so that the every individual station favorably accentuates and yet does not distract from the surrounding milieu.

The design and construction of the elevated station buildings within severe space confines poses special challenges. In order to ensure smooth passenger services as well as orderly operations despite the constraints, it is proposed to plan the passenger flow at three levels viz. Road level, Concourse level and Platform level. User-friendly graphics and signage would be carefully designed and strategically located to aid the passengers to navigate quickly and smoothly in the premises. The entire station design shall also ensure ease and comfort to the old and physically challenged commuters. The construction and choice of materials shall ensure that the structure is both elegant and safe.

The Road level flow would ensure easy access to the station in general, and to the concourse level in particular. Access shall be provided by appropriately locating covered staircases as well as escalators to cater to peak load conditions. Special provision of lifts for the old and physically challenged passenger shall be made.

The Concourse level would comprise the main entrance lobby and would be the non-paid area. Commuters would be required to purchase tickets here to proceed to the paid area. The Concourse level would provide public amenities such as food and other stalls, vending machines, information kiosk etc.

The Platform level would be accessible only to ticket holding passengers. Platforms, 135 m in length, and having widths sufficient to accommodate peak rush volumes at the particular station, shall be provided on both sides.



The proposed automatic fare collection (AFC) system for MRTS will be a closed system which has controlled entry and controlled exit to and from paid areas using AFC gates. Innovative fare collection systems such as payment by smart cards, mobile phones etc. are envisaged to be deployed to enhance the user-friendliness of the system.

#### 1.5.6 Car Depot

The car depot for the Versova – Andheri – Ghatkopar corridor will be located at DN Nagar (or alternatively at Ghatkopar). Due to space constraints the car depot will be at the elevated floor at the level of the main line track. The proposed car depot is going to deal with the running maintenance activities and the Depot activities of the Rolling Stock.

The Car Depot is intended to be a multipurpose area. It will not only serve the maintenance and repair functions of the MRTS Trains, but also will include cleaning facilities, stabling sidings, administration buildings, training facilities, stores, test track, emergency vehicles and control centre.

The following facilities would be located in the Car Depot:

- a) Depot & Workshop for Rolling Stock
- b) Depot for Fixed installations
- c) Depot for General services
- d) Administration and Training facilities
- e) Operational control centre
- f) Remote control center

#### 1.5.7 Operations Control Center [OCC]

The OCC is the “nerve center” of the entire MRTS. The OCC would be designed as a modern, hi-tech enclave to house the Operations Control staff.

The OCC would be designed to provide control over two critical functions viz. the Engineering Control (SCADA/COM) and Traffic Control (SIGNALING/COM), both housed under the same roof for better co-ordination.

## **1.6 Design, Engineering, Construction and Commissioning**

### **1.6.1 Project Planning & Execution**

#### **Critical Locations**

There are some locations along the alignment, which are considered as critical & involve dependency on external organizations. The alignment has primarily been planned with column locations along the central verge of the road alignment with deviations at curves and transitions. These locations will involve widening of the road and relocating the central verge for construction of column foundations for the elevated corridor. The spans of the elevated corridor have been selected to vary between 20 to 31 meters except at certain locations of road crossings and railway & expresses way crossings where longer spans of 60 M and 40 M have been adopted. At station locations shorter spans of less than 20M have been adopted. At certain locations where road diversions cannot be done portal frames have been proposed to accommodate the alignment of the rail corridor.

#### **Diversion of Existing Underground Services**

Diversion of utilities such as water supply pipelines, sewage pipelines, gas pipelines, power and communication cables etc. is likely to be a major constraint in execution if not planned in advance. It is seen that a 200mm diameter water supply pipe line is located underground along the central verge and is likely to come in the way of pile foundations all along and will have to be diverted on priority. Other similar services such as Power & Telecommunication Cables, Gas Pipe Lines needing diversion will have to be coordinated with the concerned utilities. The details of these have been presented in a separate chapter in the technical documentation furnished along with this bid.

#### **Road Widening**

There are many locations where widening of the road is necessary. Advance action for removal of encumbrances within ROW is requested in order to avoid hassles during construction stage. At station locations, acquisition of additional area outside the ROW by MMRDA in advance is desirable so that clear site is handed over to avoid delay in station buildings construction. All these locations along with sketches have been indicated in the technical documentation.



A large number of Electrical Light Posts are running along the central verge of the road will have to be diverted on the side of the Footpaths on priority to enable construction of the wayside works.

#### Coordination with Railways and Other Government Departments

Other critical locations affecting the progress of work would be the construction of 60M spans across the railway tracks. The design of the way structure crossing over the tracks would need approval of the Railways. The construction of these structures would also need permission and special supervision by the Railways. Similarly, considerable interaction with BMC and other local government authorities in relation to the project will be required. The bidder would be appoint appropriate liaison personnel to coordinate these activities. MMRDA assistance and associations at higher level may also be necessary to mitigate risks involved on this account.

#### Traffic Control

The construction of the elevated corridor will need barricading the road for a width of 8m all along and controlling traffic to avoid accidents & delay. A special departmental force will be engaged to assist the police department for coordinating traffic during construction.

The alignment near Asalpa and between Asalpa to Ghatkopar passes through a congested area with steep approach gradients, will need special attention in planning, execution & safety during construction.

Special attention will have to be paid for timely construction of the elevated depot structure involving a large number of columns and foundations, as this will control the erection of Girders and linking of track along the corridor.

### **1.6.2 Design Philosophy**

It is proposed to carry out the structural engineering design of Girders, Piles, etc. either through the in house capability of MTR Corporation or through a specialist structural design consultant. As it is proposed to adopt two agencies for simultaneous construction of the corridor an independent design agency is preferred to ensure common design philosophy and construction profiles. Broad details of construction methodology proposed to be adopted have been given in detail in the technical documentation. Though the methodology indicated therein provides for pre-stressed



concrete Girders it may also be required to provide composite construction for longer spans of 40 & 60 M. This will be decided during project implementation. Technical documentation gives details of design philosophy, design profiles, planning, construction methodology, quality control measures, equipments and manpower etc. Details of the organization charts for construction, operation maintenance as well as for the bid preparation have been enclosed as specified in the bid document.

### 1.6.3 Market Study & Optimizing Operation

During the operation and management period a constant review of the market commuter demand during the different periods of the day will be carried out as a regular feature so as to control the size of rake (4 coach or 6 coach train) the frequency necessary during peak and non peak period and management of commuters at stations entering and detraining during various periods would be analyzed for providing all facilities & comforts to the passengers. These would optimized electrical consumption and ensure economic operation.

### 1.6.4 Company / Consortium Management & Training

REL & Connex of France have proposed to join hands and formed a joint venture for submission of this Bid and would be the major equity holders for the project. REL has got proven expertise in the areas of HR Management, Financial Management and Project Management. Connex have got international experience in operation and maintenance of mass transit and other railway systems. The technical, managerial and financial capabilities have been further strengthened by association of MTR / HK as the system integrator for the project.

Experts in respective areas would interact with the Consortium member and impart training on a regular basis. Training will involve construction, operation and maintenance of Standard gauge track structure and other allied services involved in advance technical operations; Signaling & Telecommunications Operations, Radio Communication, Centralized Operation Control, 2/3 min frequency operations including Training in Inspection, Quality Control, Punctuality, Safety, Environmental aspects and Disaster Management.



## **2.0 RELIANCE ENERGY LIMITED – COMPANY PROFILE**

### **2.1 Reliance Energy at a Glance**

Reliance Energy Ltd (REL), established in 1929, is India's leading integrated power Utility company in the private sector. Along with its affiliates, it has a significant presence in power generation, transmission and distribution of power in the States of Maharashtra, Delhi, Orissa, Goa, Andhra Pradesh and Kerala in India.

Reliance Energy Limited (REL) is a Reliance Group company, the latter is the largest Private Sector conglomerate in India with Sales Turnover exceeding Rs. 800 billion (US \$ 17 billion), in diverse infrastructure fields, viz. Power, Oil and Gas Exploration and Production, Refineries, Petrochemicals, Telecom, Infocomm, etc. It ranked 306th on revenue, net income, & assets.

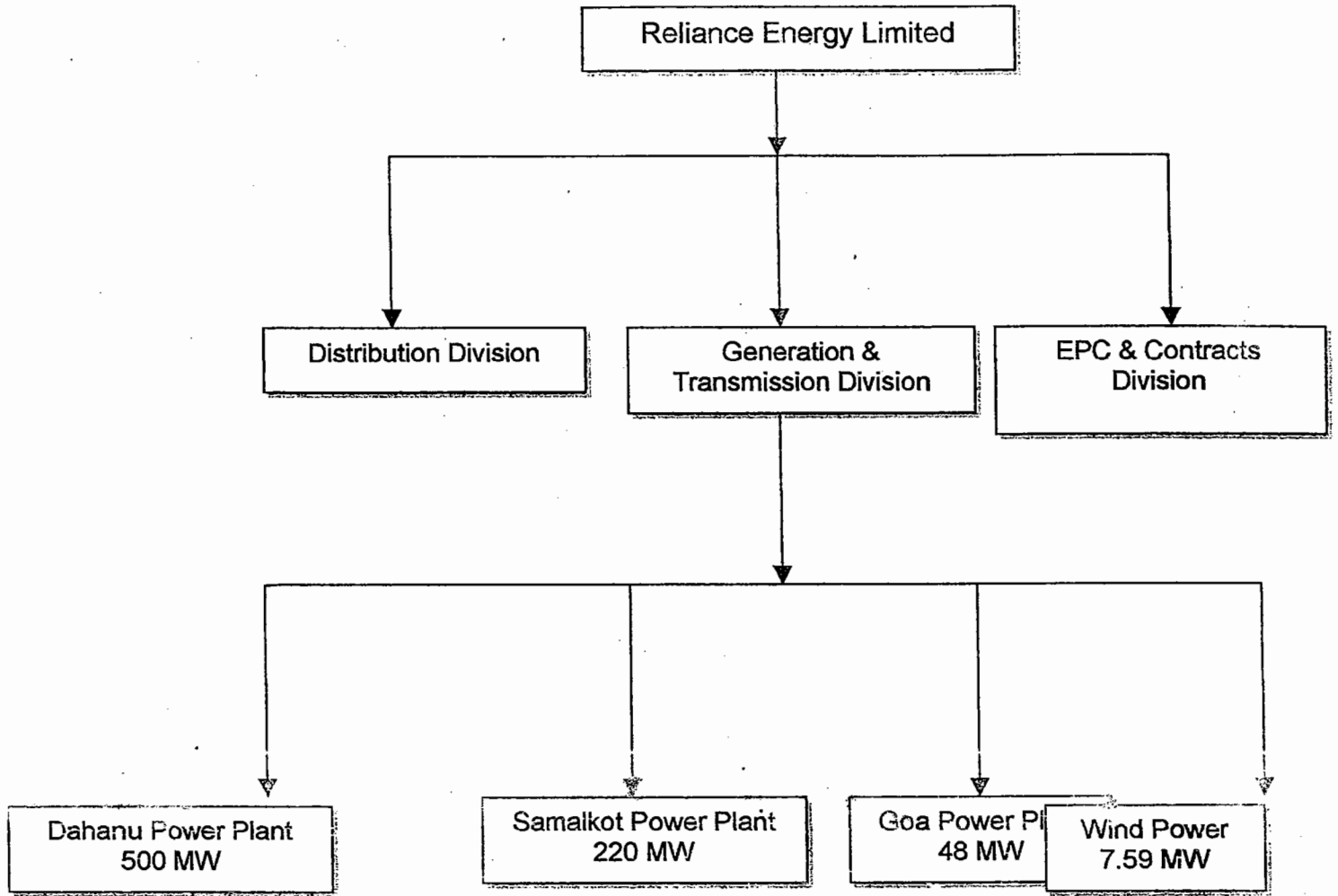
Reliance Energy, its affiliates and sister companies in the Reliance group own and operate over **2000 MW** of power generation capacity. These comprise conventional thermal plants, gas turbine based combined cycle power plants, cogeneration plants and wind electric generators.

**Reliance Energy Limited and its affiliates distribute over 5,000 MW of power - the largest by a private sector Utility in India.** Reliance Energy serves a customer base of about five million in Mumbai, Delhi and Orissa.

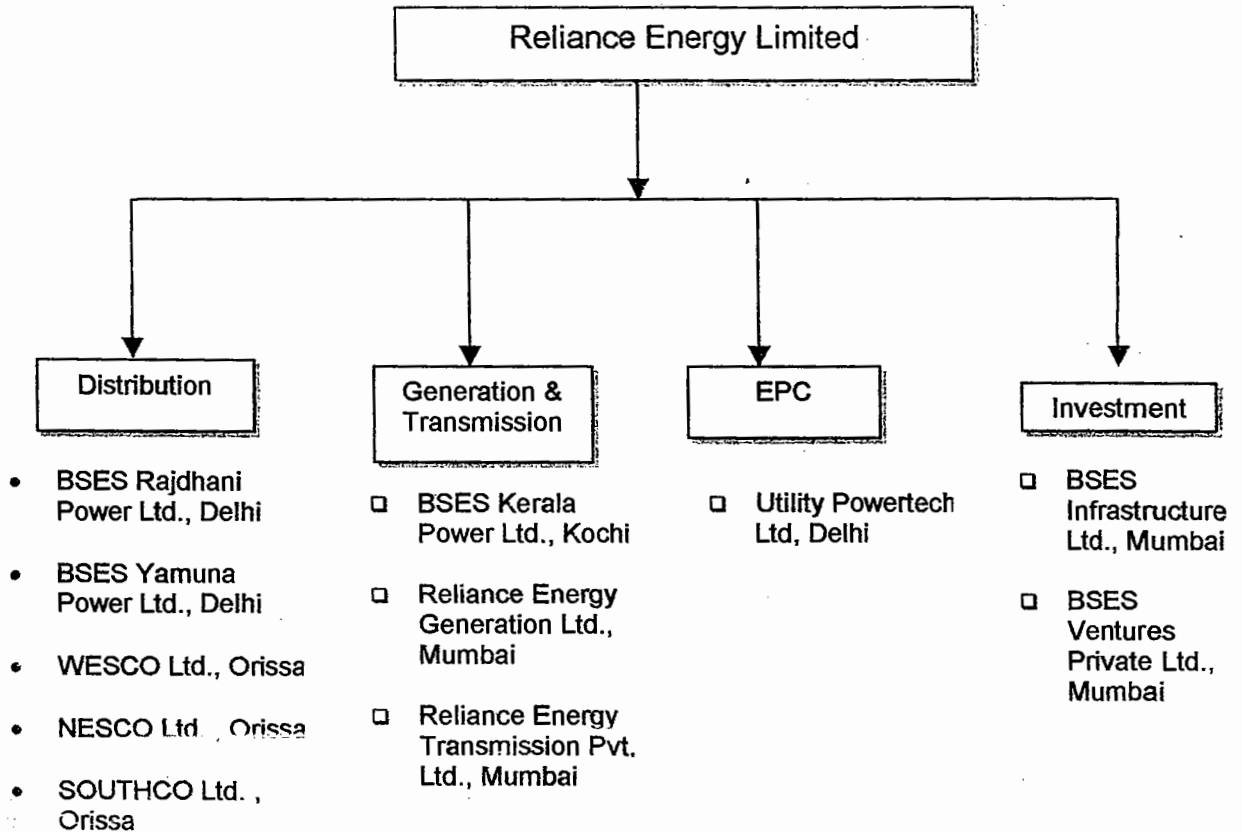
**REL with its affiliate power companies rank among the top 25 listed private sector companies in India on major financial parameters.**

#### **Business Operations**

The following chart outlines, in schematic form, the business divisions of Reliance Energy Ltd.



The following chart outlines, in schematic form, the group companies of Reliance Energy Limited



**2.1 Generation & Transmission**

The Generation & transmission division has proven expertise in designing, engineering, erection, installation, commissioning, operations and maintenance of power generation and transmission projects. The division implements in-house power projects and supports ventures undertaken by other affiliate companies.

The division is fully integrated and has in-house capabilities to address every aspect of power projects including:

- Mechanical
- Electrical



- Instrumentation
- Civil
- Environmental, etc.

The division also provides engineering consultancy to external agencies and projects.

The details of power generating units owned and operated by Reliance Group as a whole is given below.

Owned By	Plant Name	Capacity (Mw)	Fuel	Technology
Reliance Energy	Dahanu TPS	500	Coal	Conventional TPS
	Goa Power Station	48	Naphtha	Combined Cycle
	Samalkot	220	NG and Naphtha	Combined Cycle
	Wind Farm, Jogimatti, Kamataka	7.59	Renewable	Wind Electric Generators
	<b>Sub Total</b>	<b>775.59 MW</b>		
Reliance Energy Affiliates	BSES Kerala Power	165	Naphtha	Combined Cycle
	<b>Sub Total</b>	<b>165 MW</b>		
Reliance Industries	Patalganga	85	Naphtha	Cogen Plant
	Hazira	290	NG/ Retrol/ C5/ C6-C8, C9	Cogen Plant
	Naroda	40	NG/ LDO	Cogen Plant
	Jamnagar	360	LCO	Cogen Plant
	<b>Sub Total</b>	<b>775 MW</b>		
IPCL	Baroda	81	NG	Cogen Plant
	Nagothane	85	Lean Gas/ HSD/ Cracker Gas	Cogen Plant
	Gandhar	154	Naphtha/ Cracker Gas/ MO	Cogen Plant
	<b>Sub Total</b>	<b>320 MW</b>		
<b>Reliance Group Grand Total : 2035.59 MW</b>				

REL, its affiliates and sister companies in the Reliance group own and operate several Power Plants with installed capacity of over 2000 MW, which include 940 MW Utility Power at five locations and 1095 MW Captive Power Plants at seven locations. The experience ranges from conventional coal fired thermal Power Plant to Gas Turbine based Combined cycle and Cogeneration Plants with fuels ranging from natural gas, naphtha, Retrol, C5, C6-C8, LDO, cracker gas, HSD, etc. The Group has experience with Steam turbines of unit rating up to 250 MW, Siemens design (V 94.2) gas turbine, aero-derivative (LM 6000) and heavy duty industrial type (Fr 5 & 6) GE design Gas Turbines.

## 2.2 Distribution

REL and its affiliates distribute over 5,000 MW of power - the largest by a private power sector Utility in India. Reliance Energy serves a customer base of about five million in Mumbai, Delhi and Orissa.

### 2.2.1 Distribution Business in Mumbai

Reliance Energy Limited's Mumbai Electricity Supply Division is into electricity distribution in the suburbs of Mumbai. It caters to a consumer base of 2.22 million and licensed area of 384 sq km

### 2.2.2 Distribution Business in Delhi

Reliance had acquired an equity stake of 51% in two of the three Distribution Companies of Delhi after unbundling and privatization of the erstwhile Delhi Vidyut Board.

- BSES Rajdhani Power Limited headquartered in New Delhi covers south and west areas and caters to a consumer base of 0.984 million and licensed area of 670 sq km.
- BSES Yamuna Power Limited headquartered in New Delhi covers central and east regions and caters to a consumer base of 0.85 million and licensed area of 210 sq km.

### 2.2.3 Distribution Business in Orissa

The three electricity distribution companies of Orissa viz. Western Electricity Supply Company of Orissa Limited (WESCO), North Eastern Electricity Supply Company of Orissa Limited (NESCO) and Southern Electricity Supply Company of Orissa Limited (SOUTHCO), joint ventures with Grid Corporation of Orissa Limited, a Government of Orissa Undertaking, are engaged in distribution of electricity in the State of Orissa.



- NESCO, headquartered in Balasore caters to a consumer base of 0.22 million and licensed area of 28,000 sq. km.
- SOUTHCO, headquartered in Berhampur caters to a consumer base of 0.31 million and licensed area of 47,000 sq. km.
- WESCO, headquartered in Burla caters to a consumer base of 0.27 million and licensed area of 48,000 sq. km.

### **2.3 Engineering Procurement & Construction (EPC)**

EPC Division was set up in 1966 and was undertaking engineering, procurement and construction contracts on a turnkey basis and other value added services for major public and private sector projects both in India and Abroad. The Division has 10 regional offices in major cities of India and Overseas offices in Dubai, Nepal and Bhutan. The Division has to-date undertaken the total engineering, supply of electrical and mechanical equipment, installation and commissioning services and civil works for the following range of projects:

- Thermal, hydro, Co-generation, and gas based power generating stations;
- 400/132 KV transmission lines and switch yards;
- Overhead and underground electrical networks;
- Industrial electrification works for petrochemicals, fertilizers, steel, cement plants, refineries, ports and hotels;
- Indoor and outdoor illumination works;
- Pre-molded accessories for extra high voltage electrical cables;
- Renovation and Modernization of Delhi distribution network; and
- Other Civil Works

The EPC group has executed several projects in the Middle East. The list of overseas projects completed by the EPC group is given in the following table:





Sr. No.	Name of the Client	Nature of Work / Type of Project	Year of Completion
1	Dubai Electricity & Water Authority, Dubai, U.A.E.	132 KV GIS Substations (2 Nos.), 132 KV Cabling, 132 KV Transmission Line, SCADA Communication at Jebel Ali Ind. & Emirates Substations at Dubai.	2000
2	Electricity Corpn. Riyadh. Wadi-Gizan Electrification Scheme, Gizan, Saudi Arabia.	Supply, Installation and Commissioning of 33 kV and 13.8 kV Transmission Line LT Distribution Line, 33 kV 13.8 kV and LT Cables, Distribution Transformers and Consumer Services at Gizan.	1980
3	Royal Commission for Jubail & Yanbu Director General for Jubail Project, Jubail, Saudi Arabia.	Procurement and Construction of 34.5 kV Distribution System (Phase IV) – Supply and Installation of 34.5 kV Cable in duct banks at Jubail.	1983
4	Electricity Corpn. Riyadh. Wadi-Gizan Electrification Scheme, Gizan, Saudi Arabia.	Design, Installation and Commissioning of 13.8 kV/LT Lines, 13.8 kV Cables, Distribution Transformers and Consumer Services at Gizan.	1983
5	Electricity Corpn. Riyadh. Quaseem Rural Electrification Scheme, Quaseem, Saudi Arabia.	Erection of 33 kV Lines, Distribution Transformers and Consumer Services at Quaseem.	1984
6	Department of Power, Royal Govt. of Bhutan. Tsimalakha, Bhutan.	Design, Supply and Installation of Underground Sub-distribution System and Service Connections to Consumers' Installation including Metering Eqpt., in Thimpu and Paro, Bhutan. Switchyard equipment at Singigaon, Bhutan Supply and Installation of Substation Equipment for SAARC Complex in Bhutan.	1992
7	SCECO (South), Abha. Wadi-Gizan Electrification Scheme, Gizan, Saudi Arabia.	Installation of Transmission and Distribution Lines, Substation and Service Connection in 130 Villages in Sabya-Baish Area, Gizan.	1988



Sr. No.	Name of the Client	Nature of Work / Type of Project	Year of Completion
8	Electricity Corporation, Tabouk Regional Electrification Project, Saudi Arabia.	Stringing of 33 kV Overhead lines at ALBir and Electrification of Shwag area.	1991
9	Saudi Consolidated Electric Co. (SCECO) Southem Region, Abha. Wadi-Gizan Electrification Scheme, Gizan. Saudi Arabia.	Operation and Maintenance of the erected Transmission and Distribution Network at Gizan.	1983
10	SCECO (Central) Ar-Rayn Electrification Project, Saudi Arabia.	Electrification of Ar-Rayan area & Stringing of the Second Circuit of Anan – Ar-Rayn 33 kV Overhead Line and Rein-forcement of Distribution System in Nakhelan area.	1989
11	National Thermal Power Corporation Ltd., New Delhi (for Nepal Electricity Authority, Kathmandu, Nepal).	Installation, Testing and Commissioning of 132 KV, 66 KV and 33 KV Substations for 7th Power Project of Nepal Electricity Authority	1999

## 2.4 Awards and Recognition

### 2.4.1 Corporate governance Awards

Reliance Energy Ltd. has received wide acclaim for the initiatives in corporate governance. These awards and recognitions greatly motivate and encourage the Reliance Energy Ltd. team to set fresh benchmarks in corporate governance, particularly in the Indian Power sector:

- The Golden Peacock Award from the Institute of Directors for excellence in Corporate Governance.
- Rotary Vocational Award for Excellence in Corporate Governance.
- The Rotary International of Gujarat, Madhya Pradesh and Rajasthan conferred the "Excellence in Corporate Governance Award" on Reliance Energy Ltd.



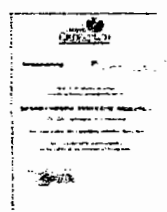
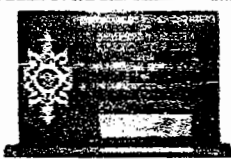

- ICSI Award for pursuit of Good Governance Practices in the year 2001,

**2.4.2 Quality Awards**

- Reliance Energy has become the first electric supply utility in the country to establish an effective and integrated ISO-9001:2000 quality assurance system. Using ISO-9001:2000 as a base, Reliance Energy had developed its own quality system which goes even beyond the requirements of ISO Standard.
- Rajiv Gandhi National Quality Award 2001 (Certificate of Merit) for providing quality and excellence in every aspect of its functioning,
- Qimpro Bench Mark Award - 2003 (Certificate of Merit) for providing quality and excellence in every aspect of its functionality

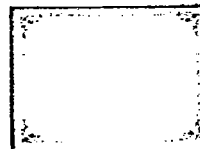
**2.4.3 Environmental Excellence Awards**

Reliance Energy Ltd. contributions have received wide acclaim in the areas of enriching the ecology. Reliance Energy Ltd. in the recent years has received the following Awards:

<p>The Indo-German Annual Environment Excellence Award - 2000 by Greentech Foundation.</p>	
<p>FICCI Award 1999-2000 for outstanding achievement in Environment Conservation and Pollution Control by the Federation of Indian Chambers of Commerce &amp; Industry.</p>	
<p>The first Millennium Business Award instituted by International Chamber of Commerce (ICC) and United Nations Environment Programme (UNEP) for its outstanding contribution to environmental management. Reliance Energy Ltd. is the only company from India and only one out of two power utilities in the world (the other being Tokyo Power Company of Japan) to have been honoured with this Award.</p>	



Best Environmental and Ecological Implementation Gold Award conferred by International Greenland Society.



- Dahanu Power Station was adjudged as the Best Power Station of the country in the 700 MW and below range and was conferred the Environmental Award on the occasion of Thermal Centenary Celebrations 1999.
- The G-51 Millennium Award in the field of Mother Earth Protection conferred by the Indian Institute of Ecology and Environment on the occasion of the World Environmental Congress.
- MCCI – Dr R J Rathi Award 1998 to Reliance Energy Ltd. for pollution control in the category of 'Non-Chemical Industries' by the Mahratta Chamber of Commerce & Industries (MCCI).

**2.5 Organization Structure and Human Resources**

**2.5.1 Introduction**

Our goal is to be a world class power Utility with operations encompassing “well head to the wall socket” offering uninterrupted, affordable, quality, reliable and clean power to millions of customers. Achieving this requires the company to work with a single-minded application, keeping the larger picture in focus. REL believes that this can be made possible in large measure by unleashing the latent capability of people. It is the firm belief of the Company, that quality manpower with adequate and appropriate versatility and capability is the only force that can help us in realizing our vision.

In order to ensure that our philosophy as enlisted above translated into demonstrated action, we have a sound HR strategy backed up by pro-active and progressive HR practices. The Company has in place a robust organization structure and sound manpower plan to support the long term business programmes. We track people with excellent combination of knowledge, experience, skill, attitude best suited to achieve exponential growth plans of the organization.



### 2.5.2 Vast pool of multi-functional human resources

Our employee strength across REL group with broad functional break-up is as provided below

REL Group Employee Strength	Officers	Other staff
Technical	2389	16641
Commercial	248	3088
Support Services	481	2126
<b>Total</b>	<b>3118</b>	<b>21855</b>

Different departments/ divisions have been constituted to get a right mix of experience and educational background. Technical officers would largely be engineering graduates drawn from some of the best universities in the countries and would have significant expertise in electricity generation/ supply business.

Also REL has a significant proportion of employees who are Management graduates, Chartered Accountants and post-graduates in other disciplines handling critical commercial, financial, customer service related aspects of the business.

Further, in order to induct fresh blood, REL carries out campus recruitment every year wherein the best of professional talent is identified early on to undergo tailor made training programme and get groomed as per the organization requirement. In fact almost 25% of our executive strength has been inducted through this methodology. As of date, we can boast of a high caliber, multi functional team of 1150 engineers/ professionals who are best equipped to handle any assignment in the power industry.

As the business environment is becoming more and more dynamic and competitive, the Company recognizes in continuous learning to make a domain enterprise. With the above objective in view, the Company has developed "exclusive Management Institute with world class infrastructure and facilities. The Institute focuses on building self directed leadership and self motivated teams. The Institute not only caters to the In-house developmental needs of the Company, but has over a period of time emerged as a renowned Institute functioning as a training support resource for the entire power sector Utilities.

### 2.6 Our Financials

The performance highlights of the audited financial results of the year ending 31st March 2005 are enclosed along with appropriate bid formats.

Fitch Ratings India Private Limited has assigned a rating of AAA (ind) (Triple A ind) to the Rs. 10 Billion Non Convertible Debenture Programme of Reliance Energy Limited.

## 2.7 Agenda for growth

The enactment of the Electricity Act 2003 has opened up new opportunities in the Indian power sector. REL are undertaking various initiatives as part of the growth plans as discussed below:

### **Transmission**

Reliance Energy Ltd. will develop transmission projects through the recently incorporated Reliance Energy Transmission Company Private Limited. This company will develop transmission lines associated with our generation facilities and mitigate any risk in evacuation of power from our plants. Further, the company will also participate in projects associated with the development of the national grid.

### **Reliance Energy Generation Private Ltd. – world's largest gas based project**

Reliance Energy Ltd. has incorporated Reliance Energy Generation Private Ltd., a Special Purpose Vehicle (SPV) to develop, construct and operate two gas based power projects of approx. 4000 MW capacity each, one near Dadri in the state of Uttar Pradesh and the other at Shahapur in Raigad district of Maharashtra on a Built-Own-Operate basis. With an investment outlay of more than Rs. 200 billion (approximately US \$ 2.2 billion), the power projects, to be developed in phases, will also be the world's largest gas based power generating plant at a single location. Further the proposed projects will be the single largest investment ever across any sector in the state of Uttar Pradesh as also in maharashtra and will act as a catalyst to the overall development and growth of these States.

Land for the projects has been identified and the process of land acquisition has already been initiated. The process of acquiring other requisite statutory clearances required for the project is underway. Further discussions with lenders are at an advanced stage to raise debt for the project.

The first phase of the project is expected to be commissioned in 2006.

### Wind Power

It is expected that the currently evolving regulatory and legal framework for the power sector in India, may stipulate a minimum level of sourcing from non-conventional sources. As a result, in order to develop benign and environment friendly power sources, Reliance Energy is setting up 500 MW of wind based power projects in phases spread across various states in India such as Maharashtra, Gujarat, Rajasthan, Karnataka, Tamil Nadu and Andhra Pradesh.

The total installed capacity of the wind energy in the country today is in the region of 1900 MW. Reliance's proposed capacity would contribute significantly towards Government of India's goal of developing green power capacity.

Reliance Energy Ltd. proposes to invest over Rs. 10000 million (US \$ 228 million) for developing the wind energy farms and will source the power to supply to its own distribution companies and the other distribution Utilities. Tender documents inviting tariff based bids for setting up the wind projects has been already issued.

## 2.8 Reliance Group – An Overview

### Introduction

The Reliance group founded by Dhirubhai H. Ambani (1932-2002) is India's largest business house with total revenues of Rs 800 billion (US\$ 16.8 billion), cash profit of over Rs 98 billion (US\$ 2.1 billion), net profit of over Rs 47 billion (US\$ 990 million) and exports of Rs 119 billion (US\$ 2.5 billion).

The group's activities span exploration and production (E&P) of oil and gas, refining and marketing, petrochemicals (polyester, polymers, and intermediates), textiles, financial services and insurance, power, telecom and infocomm.

Reliance has emerged as India's Most Admired Business House, for the third successive year in a TNS Mode survey for 2003.

The Reliance Group Companies include:

- Reliance Industries Ltd.
- Reliance Energy Ltd.
- Reliance Capital Ltd.
- Reliance Industrial Infrastructure Ltd.

- Reliance Telecom Ltd.
- Reliance Infocomm Ltd.
- Reliance General Insurance Company Ltd.
- Indian Petrochemicals Corporation Ltd.

**Reliance Industries**

Reliance Industries Limited is the largest and one of the fastest growing private sector companies in India, with business activities encompassing all major growth sectors of the Indian economy such as - oil & gas exploration and production, petroleum refining & marketing, petrochemicals including intermediates, and textiles. The company manufactures and markets a wide range of products with market leadership in almost all its businesses.

All its production facilities have a common feature - global scale operations employing state-of-the-art technology in the respective fields. The Reliance Group has also ventured into power, telecom and infocomm areas, thus truly emerging as a well diversified conglomerate with global competence in technology, management and financial capabilities to meet the needs of the rapidly growing Indian market.

With domestic market shares ranging from 40 to 80%, Reliance is also ranked among the top 10 producers globally, for all its major products.

The various businesses of Reliance Industries Ltd. and the respective products and manufacturing plants are provided in the table below:

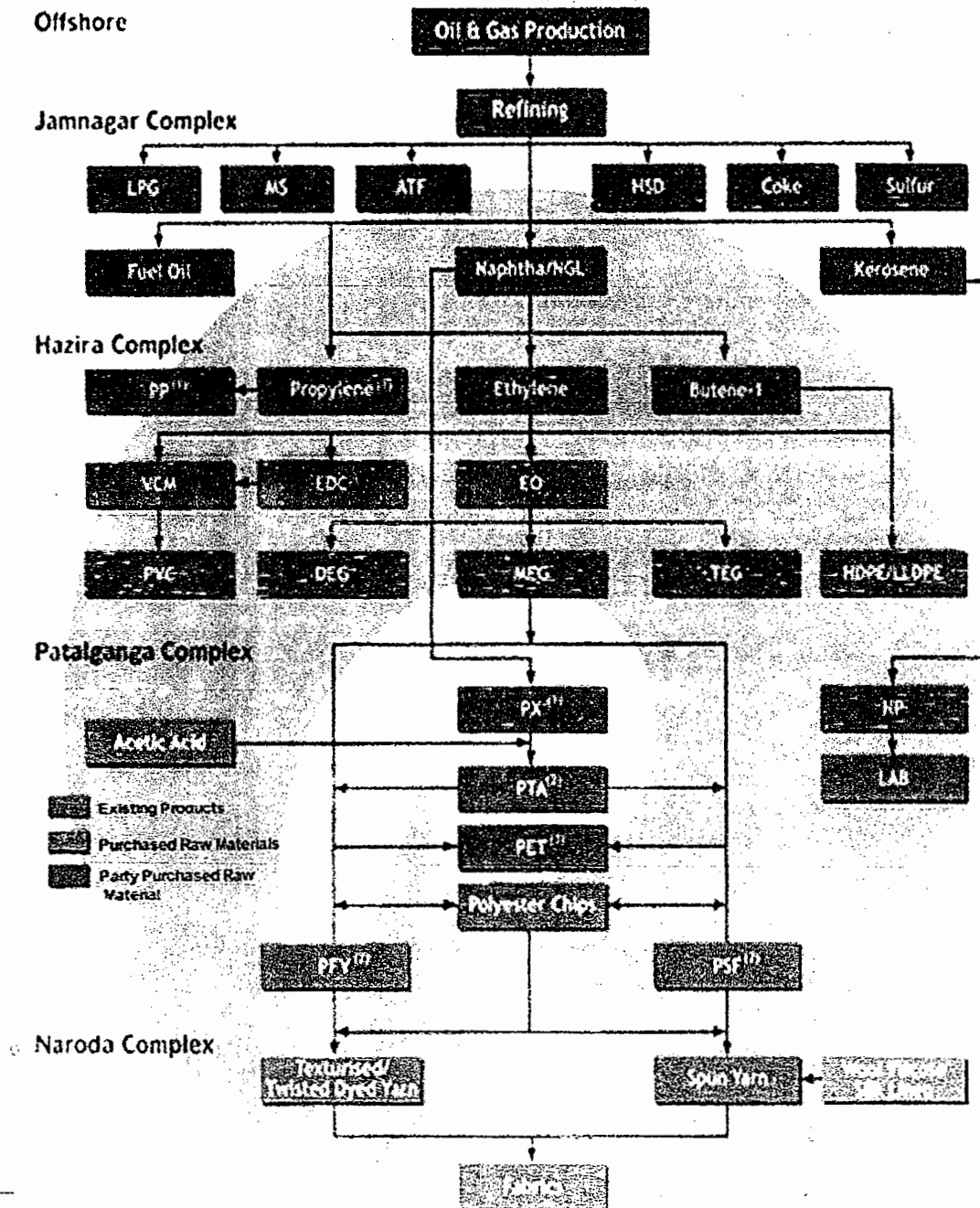
Business Sector	Products	Manufacturing Location	Plant Capacities
Polymers	Polypropylene	Hazira Jamnagar	1050 KT
	Polyethylene	Hazira	435 KT
	Polyvinyl Chloride	Hazira	300 KT
Chemicals			
Aromatics	Benzene	Patalganga Hazira Jamnagar	291 KT
	Orthoxylene	Jamnagar	150 KT
	Toluene	Hazira	197 KT A
	Mix-Xylene	Hazira	165 KTA
	Mix-Xylene(P)	Hazira	-





Business Sector	Products	Manufacturing Location	Plant Capacities
<u>Solvents</u>	Carbon Black Feed Stock	Hazira	-
	Remax I	Patalganga	-
	Remax II	Patalganga	-
	Heavy Alkylate	Patalganga	-
	Heavy Aromatics	Jamnagar	-
	Renine	Patalganga	-
	Washoil	Patalganga	-
<u>Linear Alkyl Benzene</u>	-	Patalganga	115 KT
<u>Cracker Products</u>	-	Hazira	-
<u>Fibre Intermediates</u>	Purified Terephthalic Acid	Hazira Patalganga	1280 KT
	Mono-Ethylene Glycol	Hazira	300 KT
	Ethylene Oxide	Hazira	50 KT
	Di-Ethylene Glycol	Hazira	34 KT
	Tri-Ethylene Glycol	Hazira	11.5 KT
	Paraxylene	Jamnagar Patalganga	1646 KT
	Textile Grade Chips	-	235 KT
<u>Petroleum</u>	Exploration & Production	-	-
	Refining and Marketing	-	-
	CoalBed Methane	-	-
<u>Textiles</u>	-	-	-
<u>Procurement</u>	-	-	-

The product portfolio of Reliance industries is summarised in the block diagram.



Abbreviation	Full Name	Abbreviation	Full Name	Abbreviation	Full Name
ATF	Aviation turbine fuel	LLDPE	Linear low density polyethylene	PP	Polypropylene
DEG	Di-ethylene glycol	MEG	Mono-ethylene glycol	PSF	Polyester staple fibre
EDC	Ethylene di-chloride	MS	Motor spirit	PTA	Purified terephthalic acid
EO	Ethylene oxide	NGL	Natural gas liquid	PVC	Polyvinyl chloride
HDPE	High density polyethylene	NP	Normal paraffin	PX	Paraxylene
HSD	High speed diesel	PET	Polyethylene terephthalate	TEG	Tri-ethylene glycol
LAB	Linear alkyl benzene	PFY	Polyester filament yarn	VCM	Vinyl chloride monomer

### Reliance Infocom

Reliance Infocomm has created an overarching digital infrastructure using state-of-the-art technology on the strength of a 60,000 km terabit capacity optic fibre network linking more than 600 cities and towns in India. The goal of Reliance Infocomm is to progressively expand its optic fiber network and eventually cover 116,000 km, with the ability to seamlessly connect every individual, home, and office in all 640,000 villages and 2,500 towns and cities of India. Reliance Infocomm will offer revolutionary data, video and value-added services in the largest and most complex rollout in the global history of information technology and communication.

### Reliance Telecom Limited

Reliance Telecom Limited (RTL) is promoted by the Reliance Group. The Company has two divisions - Basic and Cellular telephony services. RTL provides cellular services, using GSM standard, in 7 telecom circles encompassing 15 states of India. RTL has met its rollout obligation by covering 50 per cent of District Headquarters in 5 applicable circles. The total subscriber base was over 5, 40, 000 at the end of the year under review, registering a year on year growth of 42 per cent.



### **Indian Petrochemicals Corporation Limited**

Indian Petrochemicals Corporation Limited (IPCL) is the pioneering petrochemical company in India. The company owns and operates three petrochemical complexes, a naphtha based complex at Vadodara and gas based complexes at Nagothane near Mumbai and at Dahej on Narmada estuary in bay of Khambhat. The company also owns a catalyst manufacturing facility at Rabale, Navi Mumbai. The company produces over one million tonnes of merchant products and has turnover close to US \$ two billion.

#### **2.8.1 Financial Strength of the Reliance Group**

**Reliance ranks amongst the world's top 200 Companies in terms of net profits.**

Reliance enjoys a pre-eminent position in India's economy with group revenues of nearly 3.5 per cent of India's GDP. The group's leadership position in India is also reflected in its all round contribution to the national economy.

The group contributes:

- 5 per cent of India's total exports
- 10 per cent of the Government of India's indirect tax revenues

Reliance Industries Limited alone accounts for:

- 30 per cent of the total profits of the private sector in India
- 10 per cent of the profits of the entire corporate sector in India
- 7 per cent of the total market capitalization in India
- Weightage of 15 per cent in the Bombay Stock Exchange (BSE) Sensex
- Weightage of 12 per cent in the Nifty Index
- One out of every four investors in India is a Reliance shareholder.

**Clarifications on Queries by MMRDA**

Sr No	Query by MMRDA	Bidder's Reply
1	<b>Non Conformances</b>	
1.1	<b>Power Supply</b>	
1.1.1	<p>Level of Supply :</p> <p>The proposed power supply system is unacceptable. Three phase power must be supplied to the railway from two separate sources at 33kVA or above.</p>	<p>We confirm that traction power will be supplied to the railway at two separate points at 33kV or above. Please refer to Clauses 12.1.1.3 and 12.1.5.1 in the Technical Proposal. Though the supply will be connected to REL's 3-phase power network, the traction power will be 25kV AC single phase.</p> <p>Station and Depot power supply for general services will be obtained from REL's 3-phase power network. Decision regarding provision of a local 3-phase distribution supply network connecting different stations will be taken during detailed design.</p> <p>There will be no problem in arranging power supply from two separate sources at 33 KV or above. This has already been indicated in the tentative sectioning diagram.</p>
1.2	<b>Rolling Stock :</b>	
1.2.1	<p>Your Proposal mentions a gangway width of 1100 mm. This is non compliant. Please confirm that a minimum width of 1400 mm will be provided as required by the Specification.</p>	<p>It is confirmed that gang ways of minimum 1400 mm clear width will be provided. (Please refer to Clause 10.3.16 in the Technical Proposal.) Gangway width shown as 1100 mm is a typographical error and the same is regretted.</p>



1.2.2	<p>Lighting :</p> <p>The interior lighting as described in Clause 24 of your proposal does not conform to the Specification. Please confirm that lighting as specified will be supplied.</p>	<p>We confirm that lighting as specified will be supplied. (Please refer to Clause 10.1.2 in the Technical Proposal.) As stated in Clause 10.15.1, the <b>Sample Design Specification for Rolling Stock in Appendix B (By Molinari Engineering GmbH)</b> is attached for <b>reference</b> only. The design features shown in Appendix B are indicative and subject to change during detailed design. Any non-conforming features mentioned in Appendix B will not be adopted.</p>
1.2.3	<p>Maximum Wheel Load</p> <p>The maximum wheel load is quoted as 9 tonnes, as the maximum axle load is 18 tonnes this seems unlikely. Please confirm that under worst conditions the wheel load will not exceed the specified 9.35 tonnes.</p>	<p>We confirm compliance on both the maximum axle load of 18 tonnes and maximum wheel load of 9.35 tonnes. We will also aim at limiting the wheel load to 9 tonnes.</p>
1.2.4	<p>Parking Brake</p> <p>Please confirm that the parking brake will be capable of holding a fully loaded train on the steepest gradient with a factor of safety of at least 1.5.</p>	<p>We confirm that the parking brake will be capable of holding a fully loaded train on the section's steepest gradient with a factor of safety of 1.5. However in actual operation, as a measure of abundant safety,</p>

		some of the wheels have to be wedged in case of prolonged stoppage on the steepest gradient. More details of the parking brake will be given during the detailed design stage of the rolling stock.
1.2.5	Provision for Wheelchairs : Please confirm that provision will be made for wheelchairs within the saloon.	We confirm compliance on this requirement.
1.3	<b>Signalling System</b>	
1.3.1	Compatibility with Rolling Stock : Please confirm that the design of the Signalling system is compatible with the Rolling Stock to be supplied and quote examples of where they have been successfully used together	Confirmed. There is no fixed rolling stock proposal at this stage. The Sample Design Specification for Rolling Stock by Molinari Engineering attached in Technical Proposal Chapter 10 Appendix B is for reference only. During the detailed design, the rolling stock to be selected will need to have solid experience in integrating with the proposed signalling system. We agree & confirm that signalling compatibility as an important issue when selecting rolling stock and signalling suppliers during project implementation. There have been a lot of examples where 25kV AC traction system and rolling stock operating satisfactorily with ATP and ATO system, e.g, East Rail, West Rail and Ma On Shan Extension (Hong Kong); Delhi Metro (India); TGV (France)

1.3.2	<p><b>Compatibility with Traction System :</b></p> <p>Please confirm that the proposed Traction System is compatible with the Rolling Stock or the signalling system to be supplied and quote examples of where they have been successfully used together.</p>	<p>We confirm that the proposed signalling system, traction power system will be fully compatible with the rolling stock and the signalling system. Please refer to Clause 14.2.1 in the Technical Proposal. There have been a lot of examples where 25kV AC traction system and rolling stock operating satisfactorily with ATP and ATO system, e.g, East Rail, West Rail and Ma On Shan Extension (Hong Kong); Delhi Metro (India);TGV (France)</p>
1.4	<b>Station Buildings</b>	
1.4.1	<p><b>Roofing :</b></p> <p>The proposed design of the Station Buildings does not meet the requirements for roofing. Please submit a revised design.</p>	<p>The revised drawing as per the requirement of MMRDA is attached separately. This can be further improved at the stage of detailed designing in consultation with MMRDA.</p>
2	<b>Possible Areas Of Improvement</b>	
2.1	<b>Alignment :</b>	
2.1.1	<p><b>Emergency Cross Overs :</b></p> <p>The provision of some emergency cross-overs would greatly improve the possibility of operating a degraded service in the event of an incident affecting one line.</p>	<p>As shown in the proposed track schematic (attachment), a number of cross- overs have been provided along the tracks.</p>



	incident affecting one line.	
2.1.2	<p><b>Turn Round Facilities :</b></p> <p>The submitted design does not allow for the most efficient operations and introduces a number of possible single point failures into the system.</p>	<p>As shown in the proposed track schematic (see attachment), a number of crossovers have been provided along the tracks and one passing loop is provided at the Airport branch. Bi-direction signalling will also be provided for enhancing the train services especially on the incident recovery. The factor of single point failure has also been considered and incorporated in the design. The following show some examples for reference:</p> <ol style="list-style-type: none"> <li>a. Blocking between Versova and Andheri, trains from Ghatkopar can turn-short at Andheri.</li> <li>b. Blocking between Andheri and Airport Road, train services can be divided into two parts:             <ul style="list-style-type: none"> <li>- between Versova and Andheri can be maintained;</li> <li>- between Airport Road and Ghatkopar can be maintained;</li> <li>- Airport services and/or commuter services can be maintained with single line working between Andheri and Airport Road.</li> </ul> </li> <li>c. The point machines are</li> </ol>

		<p>designed as close to the station as possible. It can shorten the recovery time of the point control failed and required to operate by manual locally.</p> <p>d. A passing loop is provided at Airport Branch for parking the defective train in case if it cannot go back to depot during the traffic hours.</p> <p>A comprehensive operation plan will be submitted for approval during the detailed design.</p>
<p><b>2.2</b></p>	<p><b>Building Services</b></p>	
<p>2.2.1</p>	<p><b>Additional Information :</b></p> <p>Please provide a brief outline of the ventilation, air conditioning, fire fighting, fire alarm, electrical, lighting, water, plumbing, drainage and SCADA/BMS for the Stations, Depot, workshops, yard, substations, Administration Building and OCC.</p>	<p>Brief outline of the building services is given as follows:</p> <ul style="list-style-type: none"> <li>■ Air-Conditioning and Ventilation System</li> </ul> <p>The platform and concourse of above-ground stations will rely on natural ventilation. Air-conditioning will be provided for the station control room and certain E&amp;M plant rooms housing signalling equipment and communication equipment. Split type units or fan coil units will be used where air-conditioning is provided.</p> <p>Air-conditioning will be provided for Administration Building and OCC.</p> <p>Mechanical ventilation will be provided for E&amp;M plant rooms. The ventilation</p>



		<p>system will consist of exhaust air fan and/or supply air fan.</p> <p>Ventilation and smoke extraction system will be provided for the enclosed areas of Depot, workshop and yards. Particular attention will be given to cope with the high headroom requirements.</p> <p>■ <b>Electrical Services</b></p> <p>A low voltage distribution system will be provided to distribute power to all building services equipment and system equipment in stations, administration building, OCC, substations, depot, workshops and yard areas.</p> <p>In the event of incoming supply source failure, the essential loads fed by the main LV switchboard will be supplied by the standby generator. The critical system including signaling system, communication system, automatic fare collection system, SCADA system, passenger information system and emergency lighting will be back-up by the UPS system.</p> <p>An earthing and lightning protection system will be provided for stations, depot, administration building, OCC and substations to ensure passenger and operation staff safety.</p>
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		<ul style="list-style-type: none"> <li>■ <b>Lighting</b> <p>Essential lighting will be provided throughout the stations depot, yard, workshops, substations, administration building and OCC to provide the required illumination levels.</p> <p>Emergency lighting backed up by UPS system will be provided to ensure that all escape routes from various areas can be safely and effectively identified in an emergency situation.</p> </li> <li>■ <b>Fire Services System</b> <p>A suitable automatic fire detection and alarm system complying with the requirements of Indian Fire Services Authority will be provided for stations, depot, workshops, administration building, OCC and substations. The fire alarm will be initiated automatically by smoke detector, heat detector, break glass unit etc.</p> <p>A suitable fire suppression system satisfying the requirements of Indian Fire Services Authority will be provided for stations, depot, workshops, administration building, OCC and substations.</p> </li> <li>■ <b>Water, Plumbing and Drainage System</b> <p>The following plumbing and drainage systems will be provided for stations,</p> </li> </ul>
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		<p>administration building, OCC, depot and substations:</p> <ul style="list-style-type: none"> <li>- Fresh Water Supply System</li> <li>- Flush Water System</li> <li>- Wastewater Drainage System</li> <li>- Foul Water System</li> <li>- Storm Water System</li> </ul> <p>■ SCADA/BMS</p> <p>It is not necessary to provide separate BMS systems at the Stations. The SCADA system will provide the monitoring and control of E&amp;M equipment at Stations. Separate BMS systems will be provided for the Administration Building and the Depot. Critical alarms will be interfaced with SCADA for monitoring only.</p>
<p><b>2.3</b></p>	<p><b>Communication</b></p>	
<p>2.3.1</p>	<p><b>CCTV :</b></p> <p>Please reconsider if CCTV is required at the departure end of each platform, given that the maximum train length will be six-cars and the platforms are normally</p>	<p>Based on Hong Kong MTR operating experience, the provision of CCTV monitor at the departure end of each platform can assist the train</p>



	straight.	operator to monitor the platform condition without the need to go outside the driving cab. This can help to reduce the time to perform platform duty and hence reduce the dwell time and improve the overall headway.
2.3.2	<p>Depot P.A. :</p> <p>Please confirm that a PA will also be provided for the Depot.</p>	Confirmed. Depot PA System will be provided at a designated location to be defined during detailed design.
2.3.3	<p>P.A.System :</p> <p>Please confirm that the OCC will have the same flexibility as the Stations control; i.e. the ability to address selected stations, platforms, concourses etc.</p>	Based on Hong Kong MTR operating experience, OCC will only be required to make centralised PA broadcast to the whole station rather than to individual station zone. Therefore, we propose the OCC shall be able to select individual station, multiple stations or all stations for broadcast.
2.3.4	<p>SCADA :</p> <p>Please specify to what extent the communications system will be integrated with the SCADA system for monitoring.</p>	Since it is not required in the specification, we have not proposed any integration with the communications system. However, based on our experience, an integrated MMI for the monitoring and control for the PA, PIDS, CCTV and Radio systems can improve the operational efficiency and will be considered in detailed design.



2.3.5	<p><b>Standards – Radio System :</b></p> <p>Please specify to what extent the trunk radio system proposed is compatible to open, vendor-neutral standards such as e.g. Tetra.</p>	<p>The radio system will conform to ETSI TETRA standard. Please refer to Clause 15.6.2 in the Technical Proposal.</p>
2.3.6	<p><b>Standards – Telephone System :</b></p> <p>Please specify to what extent the telephone and digital transmission system proposed are compatible to open, vendor-neutral standards.</p>	<p>The telephone and digital transmission system will conform to ITU-T standard. Please refer to Clause 15.8.4 in the Technical Proposal.</p>
<b>2.4</b>	<b>Depot Facilities</b>	
2.4.1	<p><b>Emergency Power :</b></p> <p>Please clarify the provision of emergency generators and UPS systems within the Depot.</p>	<p>We confirm that adequate provision shall be made for necessary emergency DG Sets and UPS within the Depot and OCC to support the required essential loads and critical systems in the event of incoming power supply failure.</p>
2.4.2	<p><b>Expansion :</b></p> <p>Your proposal should allow for expansion of some facilities, e.g. the stabling area.</p>	<p>We confirm that the elevated car depot will be suitably designed to allow for expansion of some facilities.. Please refer to Clause 11.1.4 in the Technical Proposal.</p>
2.4.3	<p><b>Hazardous Storage :</b></p> <p>Please confirm the provision of a Hazardous Material Store and Paint Shop.</p>	<p>We confirm the provision of a Hazardous Material Store and Paint shop in the depot premises.</p>

2.4.4	<p><b>Model Room :</b></p> <p>Your Proposal specifies the provision of a "model room" at the Depot. Please provide further information about the intended purpose of this facility.</p>	<p>We intend to provide training facilities for EMU, ATC system, Signalling &amp; Telecommunication equipments, OHE, SCADA system, P way, Operating and other technical staff etc in the model room which is situated in the depot area.</p>
2.4.5	<p><b>Painting of Coaches :</b></p> <p>Your Proposal specifies that the Depot will cater for the "painting of coaches". However, there does not seem to be provision for a painting cabin in the depot layout. Please review and correct this item.</p>	<p>We confirm that the painting shop will be provided in the depot for painting of coaches.</p>
2.4.6	<p><b>Roads &amp; Car Parks :</b></p> <p>Please include roads and car parks in your Proposal.</p>	<p>We confirm that car parking and road will be provided in the depot area connecting to the JP Road. Revised drawing attached.</p>
2.4.7	<p><b>Telecommunication Systems :</b></p> <p>Please clarify the provision of telecommunication systems for buildings and facilities within the Depot.</p>	<p>Depot PA, CCTV, telephone and clock will be provided at designated location to be defined during the design stage.</p>
2.4.8	<p><b>Test Track :</b></p> <p>Please confirm provision of a test track with signalling.</p>	<p>Confirmed. Test track has been planned as part of the depot with signalling system and other protections. Due to space constraint in depot, adequate straight length is not available.</p>



		Hence test track is considered beyond Versova station end by providing additional track with signalling. Provision of test track in the depot premises may be further examined in consultation with MMRDA.
2.4.9	<p><b>Yard Lighting :</b></p> <p>Please submit additional details of the proposed yard lighting, demonstrating that it is sufficient to allow the effective working of the Depot.</p>	High bay lighting will be provided for the car Depot to ensure a lighting level of about 50 – 80 Lux uniformly distributed throughout the yard areas. Please refer to Clauses 13.4.4 and 11.1.5 in the Technical Proposal.
<b>2.5</b>	<b>Electrical Power</b>	
2.5.1	<p><b>Lightening Protection :</b></p> <p>Please confirm that you will provide a lightning protection system for the Overhead Catenary System and Traction Sub Stations.</p>	It is confirmed that lightning protection system will be provided for overhead catenary system and also at traction sub-stations. This has been stated under para 12.1.9 of our technical report.
2.5.2	<p><b>Maintenance :</b></p> <p>Please describe in more detail how system can be maintained considering the possible failure of utility power, transformers, feeders, breakers, etc.</p>	The traction power supply system will be designed and constructed to maximize the maintainability of the system. For example, two feeding tractions substations equipped with two transformers in each substation will be provided to

		<p>supply traction power to the railway. In case one traction substation fails due to the failure of utility power, transformers, feeders and/or breakers, the other traction substation will have adequate capacity to maintain the railway services. In addition, sectioning of the OHL system will be provided to facilitate maintenance and also for diversion of trains from UP line to DN line and vice versa, in case of Emergency Operation.</p> <p>Spare and consumable parts will be provided in order to minimise shut down time due to repairs and maintenance.</p> <p>A maintenance plan will be developed to indicate the planned, preventive and corrective maintenance for all parts of the system. Operation and maintenance manuals for all parts of the system will be provided.</p> <p><u>O.H.E. Failure :</u></p> <p>In case of failure of one feeding post, Power supply will be maintained by extending feed from other F.P. by closing bridging breaker at S.P. The system is being incorporated in SCADA.</p> <p><u>Utility Power Failure</u></p> <p>Providing each station with standby generator and UPS. Considering the importance of</p>
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<p>0</p>		<p>on either side at planned location for use in case of accidental damage.</p> <p>OHE layout plan will be so designed that structures are not located on the platforms.</p> <p>Stations which are at a distance of less than 1.5 Km, and according to the OHE sectioning required, at many places half tension length OHE will be provided to avoid any OHE structure or Anchoring coming close to platform which may endanger passenger safety.</p> <p>Regulating equipment will be auto tensioning of the latest design approved by RDSO and counter weights will be trapezoidal which will not protrude, which will be within setting distance from track centre.</p> <p>OHE base plate is to be designed as analysed along with the way structure taking all the loads coming. Anchor bolts are to be left from the proposed location for OHE and one near by emergency location, and the same is to be fastened with HSFG fasteners. Spare OHE are to be stored at certain location in the way, and the same may be used in case of emergency. OHE mast shall not be mounted on the platform.</p> <p>A detailed OHL layout plan will be developed to show the exact</p>
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		locations of OHL masts, cantilevers, anchor points, terminations and foundations, etc. The loading and design details of the OHL masts and supports will be confirmed in the detailed design and civil provisions for OHL masts and supports at viaduct and station will be designed and constructed accordingly for the installation of OHL system.
2.5.5	<p><b>Overhead Masts :</b></p> <p>Please state what standards will be applied to the design, construction and galvanising of the overhead masts.</p>	The applicable standards for OHL masts have been described in Section 12.2.2.6 of the Technical Proposal under the heading of 'Mast'. Overhead masts will be either BFB, RSJ or fabricated structures fully galvanized accordingly to the loading calculations. During actual designing, portal structures may be required to support OHE. Portal with boom anchoring may also be necessary to avoid side anchoring.
2.5.6	<p><b>Power in Depot :</b></p> <p>Please explain how Rolling Stock is to be moved into workshops that do not have an overhead electric supply.</p>	Movement of Rolling stock in the non OHE portion will be by low horse power battery operated vehicle or by Diesel generator powered van / light locomotive or for small movements through winches.
2.5.7	<p><b>Power Supply for General Services :</b></p>	Power supply to stations, the

	<p>on either side at planned location for use in case of accidental damage.</p> <p>OHE layout plan will be so designed that structures are not located on the platforms.</p> <p>Stations which are at a distance of less than 1.5 Km, and according to the OHE sectioning required, at many places half tension length OHE will be provided to avoid any OHE structure or Anchoring coming close to platform which may endanger passenger safety.</p> <p>Regulating equipment will be auto tensioning of the latest design approved by RDSO and counter weights will be trapezoidal which will not protrude, which will be within setting distance from track centre.</p> <p>OHE base plate is to be designed as analysed along with the way structure taking all the loads coming. Anchor bolts are to be left from the proposed location for OHE and one near by emergency location, and the same is to be fastened with HSFG fasteners. Spare OHE are to be stored at certain location in the way, and the same may be used in case of emergency. OHE mast shall not be mounted on the platform.</p> <p>A detailed OHL layout plan will be developed to show the exact</p>
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		locations of OHL masts, cantilevers, anchor points, terminations and foundations, etc. The loading and design details of the OHL masts and supports will be confirmed in the detailed design and civil provisions for OHL masts and supports at viaduct and station will be designed and constructed accordingly for the installation of OHL system.
2.5.5	<p><b>Overhead Masts :</b></p> <p>Please state what standards will be applied to the design, construction and galvanising of the overhead masts.</p>	The applicable standards for OHL masts have been described in Section 12.2.2.6 of the Technical Proposal under the heading of 'Mast'. Overhead masts will be either BFB, RSJ or fabricated structures fully galvanized accordingly to the loading calculations. During actual designing, portal structures may be required to support OHE. Portal with boom anchoring may also be necessary to avoid side anchoring.
2.5.6	<p><b>Power in Depot :</b></p> <p>Please explain how Rolling Stock is to be moved into workshops that do not have an overhead electric supply.</p>	Movement of Rolling stock in the non OHE portion will be by low horse power battery operated vehicle or by Diesel generator powered van / light locomotive or for small movements through winches.
2.5.7	<p><b>Power Supply for General Services :</b></p>	Power supply to stations, the



		at substation cannot control the switchgear and circuit breakers. Appropriate alarm will be sent to OCC and local control panel stating that the switchgear and circuit breakers itself are set at local equipment mode.
2.5.11	<p><b>Traffic Growth :</b></p> <p>Please clarify the provisions to be made for system capacity for traffic growth up to 2 min headway with 6 cars and for future system expansion.</p>	The traction supply transformer capacity, traction supply switchgear, OHL isolators and OHL wires will be rated to cater for the 2 min headway with 6 car trains operation and allow for future expansion. Power supply requirement, Design of OHE and station building design for entrance and exit of passengers has been considered for traffic growth up to 2 min. headway with 6 cars and future expansion including the cars required for operation.
2.5.12	<p><b>Trip Stations :</b></p> <p>Please confirm the provision of Emergency Trip stations or confirm that these are not required.</p>	As OHL system is provided for the railway and depot, emergency trip stations are not required.
2.5.13	<p><b>Wash Plant :</b></p> <p>Please indicate how trains are powered through the wash plant.</p>	Trains are powered by providing OHE on the washing lines and provision for isolation and earthing for inspection of roof equipment will be provided.
2.6	<b>Rolling Stock</b>	
2.6.1	<p><b>Auxiliary Driving Position</b> Please explain under what circumstances this facility might be</p>	This would be used when the train sets are broken up into

	<p>circumstances this facility might be used.</p>	<p>smaller units in case of failure recovery or maintenance.</p>
2.6.2	<p><b>Blending of Braking Effort :</b></p> <p>Your Proposal specifies that “the electro-dynamic braking force is limited to 70 kN, as the total braking force is distributed among trailing and driving bogies”. Please note that in normal operation only electro-dynamic braking shall initially be used. Friction brakes will be required when the speed has dropped to a level where electro-dynamic braking is no longer effective. Use of the friction brake at higher speeds will cause unacceptable wear of the brake pads. Please review this feature and confirm that acceptable brake blending will be possible.</p>	<p>We confirm that brake blending will be in place so that in normal operation only electro-dynamic braking shall initially be used. Friction brakes will be required when the electro-dynamic braking is no longer effective. Electro-dynamic braking force of 70 kN should be adequate for this purpose. This would be further reviewed during detailed design.</p>
2.6.3	<p><b>Bogies :</b></p> <p>The drawings submitted by you indicate that the wheel sets are guided by rods. With this arrangement the resulting stiffness of the wheel set does not seem adequate for the requirement of operating over a minimum radius of 100m. Please review this point.</p>	<p>This will be further reviewed during detailed design.</p>
2.6.4	<p><b>Brake Resistors :</b></p> <p>Your Proposal indicates provision for brake resistors on the roof of the motor car. Please note that brake resistors are not required by the Specification as regenerated braking energy shall be fed back</p>	<p>This feature is used when overhead line is non-receptive, and electric brake can be maintained by dissipating energy in brake resistor. This feature will reduce the amount</p>



		at substation cannot control the switchgear and circuit breakers. Appropriate alarm will be sent to OCC and local control panel stating that the switchgear and circuit breakers itself are set at local equipment mode.
2.5.11	<p><b>Traffic Growth :</b></p> <p>Please clarify the provisions to be made for system capacity for traffic growth up to 2 min headway with 6 cars and for future system expansion.</p>	The traction supply transformer capacity, traction supply switchgear, OHL isolators and OHL wires will be rated to cater for the 2 min headway with 6 car trains operation and allow for future expansion. Power supply requirement, Design of OHE and station building design for entrance and exit of passengers has been considered for traffic growth up to 2 min. headway with 6 cars and future expansion including the cars required for operation.
2.5.12	<p><b>Trip Stations :</b></p> <p>Please confirm the provision of Emergency Trip stations or confirm that these are not required.</p>	As OHL system is provided for the railway and depot, emergency trip stations are not required.
2.5.13	<p><b>Wash Plant :</b></p> <p>Please indicate how trains are powered through the wash plant.</p>	Trains are powered by providing OHE on the washing lines and provision for isolation and earthing for inspection of roof equipment will be provided.
2.6	<b>Rolling Stock</b>	
2.6.1	<p><b>Auxiliary Driving Position</b> Please explain under what circumstances this facility might be</p>	This would be used when the train sets are broken up into

	circumstances this facility might be used.	smaller units in case of failure recovery or maintenance.
2.6.2	<p><b>Blending of Braking Effort :</b></p> <p>Your Proposal specifies that "the electro-dynamic braking force is limited to 70 kN, as the total braking force is distributed among trailing and driving bogies". Please note that in normal operation only electro-dynamic braking shall initially be used. Friction brakes will be required when the speed has dropped to a level where electro-dynamic braking is no longer effective. Use of the friction brake at higher speeds will cause unacceptable wear of the brake pads. Please review this feature and confirm that acceptable brake blending will be possible.</p>	<p>We confirm that brake blending will be in place so that in normal operation only electro-dynamic braking shall initially be used. Friction brakes will be required when the electro-dynamic braking is no longer effective. Electro-dynamic braking force of 70 kN should be adequate for this purpose. This would be further reviewed during detailed design.</p>
2.6.3	<p><b>Bogies :</b></p> <p>The drawings submitted by you indicate that the wheel sets are guided by rods. With this arrangement the resulting stiffness of the wheel set does not seem adequate for the requirement of operating over a minimum radius of 100m. Please review this point.</p>	<p>This will be further reviewed during detailed design.</p>
2.6.4	<p><b>Brake Resistors :</b></p> <p>Your Proposal indicates provision for brake resistors on the roof of the motor car. Please note that brake resistors are not required by the Specification as regenerated braking energy shall be fed back</p>	<p>This feature is used when overhead line is non-receptive, and electric brake can be maintained by dissipating energy in brake resistor. This feature will reduce the amount</p>

	<p>that the temperature value of 60°C mentioned in the Specification is not the ambient temperature and that there is no snowfall in Mumbai.</p>	<p>for Rolling Stock by Molinari Engineering is attached for <b>reference</b> only. The design features shown therein are indicative only and subject to change during detailed design. Any non-conforming features mentioned will not be adopted. In case of discrepancies, the main text in Chapter 10 will take precedence over these.</p>
<p>2.6.10</p>	<p><b>Passenger Doors :</b></p> <p>Your Proposal includes a "pushback" feature for the door. This is not specified and adds to the overall complexity of the system. Please reconsider the requirement for this device.</p> <p>Your Proposal mentions a "cut out cock for pneumatic isolation" of the door. Please check and provide further information about how the pneumatic door operators that you will supply are compatible with the reliability and availability requirements specified.</p>	<p>Push back feature for the door is an international practice to permit withdrawal of trapped objects and to mitigate hazard of hitting passenger as the door obstruction detection is very complicated to implement in the pneumatic door system. The pushback feature is proven in M-train in Hong Kong MTR and is very much required for Mumbai conditions. We will also consider the use of electric doors during detailed design.</p> <p>The cut out cock is used to isolate the door when there is a single door defect such as avoiding withdrawing the whole train from service. Detailed information regarding reliability and availability for individual component will be provided when the rolling stock supplier is finalised during project implementation.</p>



<p>2.6.11</p>	<p><b>Passenger Doors :</b></p> <p>Section 11 of the technical description by Molinari Engineering GmbH, states that at stations the doors can be opened by passengers using a pushbutton. Please note that this is non conformant as it is not in accordance with the Specification, which specifies central opening and closing of the doors by the driver.</p>	<p>As stated in Clause 10.15.1 in the Technical Proposal, the <b>Sample</b> Design Specification for Rolling Stock (By Molinari Engineering) in Appendix B is attached for <b>reference</b> only. The design features shown there in are indicative only and subject to change during detailed design. Any non-conforming features mentioned in will not be adopted. In case of discrepancies, the main text in Chapter 10 will take precedence over these.</p>
<p>2.6.12</p>	<p><b>Provision for Wheelchairs :</b></p> <p>The drawings in section 3 of the technical description by Molinari Engineering GmbH do not indicate a provision for "safe areas clear of doors and gangways" as required by the Specification. Please re-examine this topic.</p>	<p>The saloon layout will be further reviewed during detailed design to better accommodate wheelchairs within the saloon.</p>
<p>2.6.13</p>	<p><b>Tare Weight :</b></p> <p>The table in section 10.11 specifies a tare weight of 35t for the driving trailer and of 40t for the motor coach. Please provide detailed information on the calculation of this value, considering:</p>	<p>The tare weight indicated as 35 t for trailers and 40 t for motor coach is only approximate, based on the dimensions of the coaches and the assumed weight of the stainless steel design compared to mild steel design of the IR EMUs. The actual weight will be considered after detailed design of Electric, Bogies, and the coach body. The tare weights will be</p>







	<p>Please confirm that the design and provision of the SCADA system will allow for future expansion.</p>	<p>provision of the SCADA system will allow for future expansion.</p>
<p>2.7.3</p>	<p><b>O.C.C. &amp; Station Control Rooms :</b></p> <p>Please briefly describe the OCC and Station control room systems and the software, authority levels and data transmission system proposed.</p>	<p>The SCADA will be an integrated control system for the monitoring and control of all E&amp;M equipment. Operator workstations will be provided at the both OCC and Station Control Room. All equipment will be classified into different equipment classes. The systems will allow user-configurable authority levels to be assigned to individual user. The authority level of each user will determine which type of equipment he would be able to monitor or control.</p> <p>The SCADA will make use of the transmission system provided by the communications for data transmission.</p> <p><u>General Philosophy</u> of SCADA system will be</p> <ul style="list-style-type: none"> <li>A Acquisition of DATA at remote locations</li> <li>B System availability</li> <li>C Open Architecture</li> <li>D System Capability</li> <li>E Communication line subsystem</li> <li>F Human machine interface</li> <li>G Calculation Sub-system</li> <li>E. History and DATA Compilations</li> </ul>

2.7.4	<p><b>OLE Energisation Status :</b></p> <p>Please confirm that SCADA will interface with signalling to provide the overhead line equipment energisation status at the OCC.</p>	<p>We confirm that SCADA will interface with signalling to provide the overhead line equipment energisation status at the OCC.</p> <p><u>System Configuration</u></p> <p>A Conventional SCADA system          B Bay control SCADA system          C Master station configuration          D RTU- Functions and Requirements          E Communication net work          F Optical Network system          G Opto BUS          H Opto NET          I Fibre Optic cable</p>
2.7.5	<p><b>SCADA &amp; BMS Systems:</b></p> <p>Please confirm the provision of building management systems (BMS) at the Stations, the Administration Building and the Depot and that they will be coordinated and interfaced with SCADA.</p>	<p>It is not necessary to provide separate BMS systems at the Stations. The SCADA system will provide the monitoring and control of E&amp;M equipment at Stations. Separate BMS systems will be provided for the Administration Building and the Depot. Critical alarms will be interfaced with SCADA for monitoring only.</p>
2.7.6	<p><b>Traction Power Supply etc. :</b></p> <p>Please confirm that SCADA scope for supervision and control will include traction power supply, auxiliary power supply, fire alarm, fire fighting, ECS, plumbing, drainage, escalators, lifts, UPS,</p>	<p>We confirm that SCADA scope for supervision and control will include traction power supply, auxiliary power supply, fire alarm, fire fighting, ECS, plumbing, drainage, escalators,</p>





	generators, lighting, access security and AFC	lifts, UPS, generators, lighting, access security and AFC.
2.8	Signalling	
2.8.1	ATP : Please consider ATO as part of initial system.	This will affect the financial proposal. Patronage forecast will be carried out. ATO will be provided as part of the initial system if the results indicate a very high patronage figure which requires 2 min headway. However this will be done in consultation with MMRDA.
2.8.2	Introduction of ATO :  Please specify the extent of modifications to the lineside as well as on-board signalling and train protection equipment which will be required for the transition to ATO, should ATO not be provided initially. Especially all modifications which have an impact on availability of the system during normal operating hours should be provided.	It is required to equip some additional hardware and software for both line side and on-board signalling equipment (major in the interface between Signalling and Rolling Stock) when upgrading the ATP system to ATO. It should have no significant change on train protection equipment (both hardware and software). During the modification period, the availability of the system will not be affected significantly. Only minor service delays may occur on some of critical stage work.
2.8.3	Wrong Way Running :  Please confirm if "wrong way" running is possible with the proposed system.	We confirm that bi-directional signalling will be provided. Please refer to Clauses 1.5.4 and 14.1.1 in the Technical proposal.

2.8.4	<p><b>Self Diagnostic Features :</b></p> <p>Please indicate which systems/equipment have self diagnostic features.</p>	<p>We confirm that the following system/equipment will be provided with self-diagnostic features:</p> <ul style="list-style-type: none"> <li>• ATP &amp; ATS (see Clause 14.5.5.3 in Chapter 14);</li> <li>• CBI (see Clause 14.5.7.1 in Chapter 14);</li> <li>• Point Machine (see Clause 14.5.10.2 in Chapter 14).</li> </ul>
2.8.5	<p><b>Shorter Headways :</b></p> <p>Please specify the extent of modifications to the lineside as well as on-board signalling and train protection equipment that will be required for the transition to shorter headways. In particular describe all modifications which will have an impact on the availability of the system during normal operating hours.</p>	<p>Based on the constraints of the alignment (i.e. diamond crossing cannot be used and short overrun at Ghatkopar), the best achievable service headway is 3 minutes. If a shorter service headway is required i.e. (less than 3 minutes), track configuration needs to be enhanced apart from upgrading the ATP system to ATO. Please refer to Clause 14.2.4 in the Technical Proposal.</p>
2.9	<b>Stations</b>	
2.9.1	<p><b>General :</b></p> <p>Your proposal is for stations having only one unpaid area and limited access. Please reconsider your design.</p>	<p>Since the length of the platform is only 135m, the present arrangement is considered as adequate. However additional unpaid area will be provided in consultation with MMRDA at additional cost if necessary.</p>
2.9.2	<b>Ghatkopar Station :</b>	



	<p>Your proposal to move Ghatkopar station is unacceptable as it would increase the distance between the station and an important passenger generator and introduce problems with the vertical alignment.</p>	<p>We confirm that Ghatkopar station will not be shifted from its present location if our justification is unacceptable to MMRDA.</p>
2.9.3	<p><b>MUIP :</b></p> <p>Your proposals does not appear to have taken cognisance of the impact of the MUIIL on the station designs. Please review this.</p>	<p>It is understood that there are lot of changes in the MUIIP proposal. We confirm that necessary cognisance of the impact of MUIIL will be taken into account during detailed engineering.</p>
2.9.4	<p><b>Terminal Stations :</b></p> <p>Please give further attention to the arrangement of terminal stations so as to avoid the use of scissors and ensure that boarding passengers are not confused with regard to which platform they should use.</p>	<p>We still considered that the present arrangement is the most ideally suited at the terminal station. Suitable precautions will be taken to ensure that boarding passengers are not confused by providing suitable signage and PA system etc.</p>
2.9.5	<p><b>Wrong Way Running :</b></p> <p>Please confirm if "wrong way" running is possible with the proposed system.</p>	<p>We confirm that "wrong way" running is possible with the proposed system.</p>
2.10	<b>Ticketing</b>	
2.10.1	<p><b>Spares :</b></p> <p>Please indicate the level of spare machines you would supply.</p>	<p>10% spare or one additional set per cluster/array, whichever is higher.</p>



		higher.
2.10.2	<p><b>Ticket Material :</b></p> <p>It is considered that using magnetic tickets for single journeys will result in additional maintenance requirements. Please consider using tokens.</p>	<p>The comparison between magnetic tickets and tokens for single ride is included in Chapter 16 Appendix A and B in the Technical Proposal. The problem with tokens is that the lost rate is very high in many railway systems worldwide. We will evaluate the latest technology available during detailed design and select the most cost-effective media for single ride.</p>
2.11	<b>Trackwork</b>	
2.11.1	<p><b>General :</b></p> <p>Your proposal contains very few details of the proposed Trackwork. Please supply additional information.</p> <p>This information should include, but not be limited to, details of the fastenings, expansion joints, welding methods and turnouts to be adopted.</p>	<p>Additional information on proposed trackwork is attached.</p>
2.11.2	<p><b>Scissors :</b></p> <p>Scissor crossings are not favoured as they can be a point of single failure. Please consider installing twin cross-overs instead.</p>	<p>As regards the desirability of providing independent cross-over vis -a-vis scissors cross-over, there cannot be two opinions that the former is a better option from the point of view of maintainability. However, this requirement has to be</p>



fastenings (Pandrol and/or Vossloh) shall be procured from vendors of international repute. Pandrol Clip will, generally, be used on the ballasted track. Vossloh-336 fittings may be used on the elevated track, in preference to the Pandrol Clip, since they permit a range of toe loads. This aspect can be decided at the stage of detailed designs.

#### Ballasted Track at alternative Depot at Ghatkopar

Alignment and level pegs will be marked on the finished formation. Ballast will be spread out & compacted by rollers. Sleepers will be laid at the specified spacing and rails linked over them with the specified fastenings, to the specified gauge. At all stages, the rails, fastenings and sleepers will be handled as per the extant procedures to avoid any damage. Thereafter, additional ballast will be spread and the track compacted by On-track tamping machines. The track will be finished to the final longitudinal, lateral and vertical profile, within the specified tolerances.

#### Ballastless Track at D.N. Nagar elevated Depot

The type of ballastless track will be of following types

1. Discretely supported on concrete/ steel/ pedestal line.
2. Embedded rail type inside the rail workshop
3. Plinth type for Washing plant lines.
4. Normal ballastless track for stabling and other running lines.

#### Ballastless Track on mail lines (Viaducts)

##### 1. Concrete Structure:

The laying of ballastless track with RCC derilment gaurds integrated with the plinths is of comparatively recent origin. Advantage will, therefore, be taken of the

latest developments in this field so as to design and construct a structure which will require minimum intervention by way of occupation of track for maintenance, as well as be functional, aesthetic and economical. As a step in this direction, we propose an improvement to our earlier proposal of precast blocks to support the rail over the girders for the elevated track portion. We now propose Plinth Type construction, as being adopted now by Delhi Metro.

In Plinth Type construction, shear reinforcements are left in the top slab of the girder. A rectangular section is erected at this location to support the rails and fastenings and hence the name, "Plinth Type". The rails and fastenings are placed in position before any concreting, with the rails in final alignment of line & level, duly supported by gauge holding frames. Formwork is placed in position and concreting done. A short gap is left after every 4-metre length, which also helps in drainage. A very fine degree of precision is possible with this method of track laying.

#### Welding of Rails.

Though in our offer, we have proposed thermit weiding, as an improvement, we now propose to adopt Flash Butt Welding mostly. Flash Butt Welding is now being used widely on the Indian Railways. We propose to adopt the procedure for such welding as given in the Manual for Flash Butt Welding of Rails, 2004 issued by RDSO. The failure rate of Flash Butt welds is much less coupled with the present day feasibility of using Mobile Flash Butt Welding Plant for welding of the rail ends on the elevated track is a strong factor in favour of this process of welding. Delhi Metro has adopted this type of welding. The daily progress is of the order of 30 joints. Considering the float available, it will be easily possible to complete the track linking work within the time schedule already proposed. At isolated locations, we may have to go in for Alumino-thermic (A.T.) Welding, which is also an internationally accepted process. The procedures followed by

Indian Railways will be suitable for the present project also, especially since provisions, such as (i) three-piece mould which ensures absence of fin in the flange and (ii) short preheating, have been incorporated in the Manual for Fusion Bonding of Rails by Alumino Thermic Process, issued by RDSO. The A.T. Welding is proposed to be limited to unimportant locations, such as yards, for the initial laying. It may, of course, be indispensable to carry out emergency repairs. All welding work will be executed keeping the contents of these two Manuals in view. It will have to be examined in consultation with MMRDA that for such short line both static and a portable flash butt welding plant is justified.

### Rail Expansion Joints

As an improvement to our earlier proposal, efforts will be made to reduce the number of Switch Expansion Joints (SEJs), since each such joint needs to be maintained. This will need detailed designs to incorporate the thermal forces of interaction between the girders and the rail while designing structures. Further LWR can be continued through turnouts. Using these techniques, Delhi Metro have succeeded in reducing the number of SEJs, thus reducing the maintenance inputs. It may thus be possible to provide the specially designed Rail Expansion Joints (as opposed to the standard SEJs on the Indian Railways), simply at the two ends of the entire section of the Main Line. Subject to modifications on this account, the procedure given in the Manual of Instructions on Laying and Maintenance of Long Welded Rails, issued by RDSO, shall be followed for the destressing of the rails.

### Turnouts

The turnouts shall conform to the UIC standards and laid as per the drawing to the tolerances specified with 1 in 20 cant. It is proposed to adopt 1 in 9 type turnout on main line with a lead radius of 300mts and permissible speed of 40Kmph on divergent track. However on depot lines 1 in 7 type turnout with a lead radius of 140mts. and permissible speed of 25 Kmph on divergent track.



The scissors crossovers (1 in 9 type) on main line with 4.5 mts minimum track centre will be provided in consultation with MMRDA.

- 1 The Scissors crossovers on main lines (1 in 9 type) will be with a minimum track centre of 4.5 m.
- 2 The specifications of the turnouts will be as under :
  - i The turnout should have fan-shaped layout throughout the turnout so as to have same sleepers/ base plates and slide chairs for both LH and RH turnouts.
  - ii The switches and crossings should be interchangeable between ballasted and ballastless turnouts.
- 3 The switch rail should be with thick web sections, having forged end near heel of switch for easy connection with lead rails, behind the heel of switch. The switches should have anti creep device at heel of switch for minimizing the additional LWR forces transmitted from tongue rail to stock rail.
- 4 The crossing should be made of cast manganese steel and with welded leg extensions. These crossings should be explosive hardened type for main lines and without surface hardening for depot lines.
- 5 The check rails should be with UIC-33 rail section without being directly connected to the running rails.

#### Buffer Stops

It is proposed to provide friction buffer stops with mechanical impact absorption (non-hydraulic type ) on main and depot lines. The buffer stops will have to be designed for an additional longitudinal force of 85 T, which is likely to be transmitted in case of rolling stock impacting the friction buffer stops on elevated structure.





### 3.0 ABOUT CONNEX SA

Connex is a subsidiary of the French group VEOLIA Environnement, the world leader in Environmental Services (turnover 2003: € 28.6 billion)

In 2004, Connex employed 61,000 persons, carried 1,5 billion passengers for a turnover of €3,6 billion with a solid presence on four continents. Connex operate all modes of transport with 23,500 road vehicles (buses and coaches), 3,500 rail transit vehicles (trains, underground trains and light trains) and 49 ferries.

Connex, the No.1 private operator of public transport in Europe, with a presence in 23 countries and working relationships with 5,000 local authorities, has consciously positioned itself as a proactive supplier, able not only to meet various needs but to anticipate them as well.

Connex is the leading provider of contract passenger rail services in the world today.

#### **Connex philosophy: facilitating mobility**

From Melbourne to Berlin, Bogotá to Jerusalem, Boston to Prague and Paris to Stockholm, the winds of change are sweeping through the public transportation profession. Making it easy for everyone to get from place to place within a city, region or country in the quickest, safest and most comfortable way possible – this is the critical issue in regional development policies. Public transportation firms face the daily challenge of becoming suppliers of mobility.

Freeing up downtown areas, neighbourhood services, rapid connections and users' expectations are factors that vary from one country or region to the next. Transportation systems have to be able to respond within variable contexts to priorities that are always quite specific. Innovation with regard to public transport is as much a matter of meeting new passenger mobility needs as it is of upgrading equipment.





## **Expanding territories**

Connex serves as a long-term partner of local and territorial authorities, and it prides itself on its extensive experience in every area of transportation. The group's growth and presence in a large number of countries is the result of its ability to manage – for both local authorities and territories, and in various regulatory contexts – quality public transportation services.

Connex's originality lies in knowing how to combine network autonomy with a respect for local differences and cultures, plus a pooling of group know-how. Its tailor-made services, ranging from the design of a transportation system to overall responsibility for a public service, always benefit from the latest innovations. In the world of transportation, this decentralized culture allows the group to build up a wealth of experience, which can then be developed and modified from one site to the next in accordance with the particular issues that need to be addressed.

The borders between urban and interurban spaces are becoming blurred: territories are changing, cities are growing and finding new administrative and economic resources, and urban areas are encroaching on inner suburbs, which in turn encroach on the countryside. Connex is able to adapt its networks to these accelerating changes.

## **Managing mobility**

Connex's Passenger Charter states, "Nothing is more valuable than a customer's time." Accordingly, a profound transformation of the public transport market is currently underway. Though transportation offerings are all about management of space and regional development where local authorities are concerned, Connex's central preoccupation is passenger satisfaction in terms of rapidity, ease of use, safety and comfort. The quality of service with regard to managing movements is thus a priority now – the era of mass-produced, standardized transportation systems has ended, though only recently.

Concepts of the "right" to transportation and freedom of movement have been readily embraced by passengers; taking such concepts into consideration is a prerequisite for enticing new public transport users, many of whom think that the car is still the only way they





can exercise this right. Travel times can no longer be just an imposition to be tolerated; for public transportation to win over new users, travel times must become chosen times. Connex

has thus enriched its offering with a number of innovative services that have the potential to become the core of the range, including transportation on demand, real-time information systems, management of exchange hubs, neighbourhood services, and park-and-ride arrangements. Their common aim involves adapting to local contexts, targeting needs on a more individual basis, taking a comprehensive approach to managing regional mobility and, in general, making public transportation more attractive and accessible for all.

These many innovations have been tested on various networks, their impact on clients is systematically evaluated, and they are provided to any Connex site that can make use of them, thanks to the group's knowledge management activities.

#### **Information that circulates in real time**

Information systems are at the heart of the relationship between clients and the transportation services that are available to them. Naturally, this means schedule information for passengers, available at the station, but they should also have access via the Internet and cell phone. This information concerns itineraries and fares, plus the increased number of electronic payment methods. Each request for information must correspond to a transportation solution that allows a client to travel at will and offers the best guarantee of flexibility, speed and reliability. In terms of signage, the information must be clearly and simply displayed. Other messages may concern the entire set of services available through the network and activities offered by the city. In Melbourne, Australia, Connector Plus keeps passengers informed about any system problems via SMS. Internet sites with interactive communication are also available for most Connex networks.

#### **Multi-service exchange hubs**

Connex has capitalized on the idea of developing and expanding exchange hubs by offering various additional services, including ticket windows, newsstands, reservations for performances, bike rentals, cafeterias and more. There is a solid trend toward developing this type of multi-service exchange hub. At Paris La Défense (France), the Eurolum affiliate (Connex's research center) is designing a Service Village for the underground station.



## Safety

When dealing with the problem of safety in public transportation, it is highway safety that immediately comes to mind – how to make school transportation safe, the need to develop stations in such a way that passengers can park and access their vehicles as safely as possible, training for drivers who must transport passenger in conditions of optimal security, fleet maintenance and renewal and much more.

Some of these issues serve as the foundation for various Connex professions and are the subject of constant vigilance, from system design through system use.

In the city, it is more the question of safety within public transportation systems that comes to mind. Lack of security, whether real or perceived, is one of the main reasons given by French people to explain their reluctance to use public transportation. This issue is also of concern to Connex personnel. To combat the lack of safety in public transport, Connex is working on three levels: technical, human and civic. These actions are grouped together under a safety agreement that was initiated by Connex and taken up by the Union for Public Transportation (UTP). Technical initiatives include equipping vehicles with various safety and video surveillance devices, which have a deterrent effect on would-be troublemakers. Human-level interventions include boosting staff presence both in stations and on vehicles and strengthening relationships between Connex personnel and passengers by improving the way in which passengers are welcomed and by providing staff (drivers in particular) with stressing conflict-management training. Finally, on a civic, "educational" level, most urban networks that have to deal with problems are developing – in collaboration with organizing authorities and a number of local players (including schools, police, courts, hospitals, associations and so on) – a number of initiatives, many aimed especially at schoolchildren in order to acquaint them with the world of public transportation as early as possible.

## Transportation for all

Access to transportation should be guaranteed to all, without exception. This implies special actions to translate this right into practice, allowing both the elderly and those with reduced mobility to easily access the various forms of transportation offered by Connex. The elderly, many of whom use public transport, are demanding when it comes to quality of service, level of accessibility, clarity of information and ease of payment. Transportation should also be



comfortable, with staff members that are welcoming and trained to treat passengers with respect. Connex systematically takes these priorities into account for all of its customers, but such issues are of crucial importance in the eyes of older passengers.

### **Innovation and research with quality in mind**

For Connex, research and marketing are the two main pillars of innovation. EuroIum, a research and innovation centre, was created in 1990 to monitor scientific and technical development, support the networks in their requests for information, carry out studies, develop multiple partnerships and take part in various research programs connected with transportation systems. The marketing department, in steady contact with the customer, analyses client behaviour and tracks satisfaction levels through surveys. The centre is constantly developing new services and transportation concepts.

For Connex, innovation involves developing service quality and meeting the new needs of customers, passengers and local authorities. The scope of investigation is very broad, covering regional development, analysis of travel patterns, safety, real-time information systems, intermodal fare ranges, reducing pollution, exchange hubs and identifying future trends.

### **The environment: fighting pollution on all fronts**

With 24,000 road and rail vehicles on routes circling the globe, Connex is aware of its responsibilities in terms of preserving air quality and fighting the greenhouse effect by limiting the gases that cause it. Like Veolia Environnement, which has pledged to reduce its activity-related CO2 emissions by 10% by the year 2006, Connex has made firm commitments and implemented active environmental monitoring. Its four commitments are as follows:

- To reduce (by 2005) CO2 emissions by 20%, unburned hydrocarbon emissions by 16% and particle emissions by 22%.
- To offer environmental training to 90% of its drivers.
- To develop and deploy a system of environmental management for 60% of its global activities by the end of 2008.
- To have 100% of its sites in regulatory compliance by the end of 2008.

A total of 94% of the French think that developing public transportation is essential for fighting pollution. They're right: when you consider that a bus pollutes five to ten times less than an individual car per passenger carried, it's easy to see how Connex, simply by doing its job of

providing 1.5 billion passenger trips per year, has become a major player in the defence of the environment. Over time, the goal is to convince car owners to use other means of transportation – innovative, cleaner methods whose multimodal framework offers them at least as much flexibility, comfort, speed and consistency as a car.

### **Connex trains Connex**

In an industry that is powered by labor, a transportation company's primary resource is its human assets, the people who represent Connex's culture and image to its clients and who keep us informed of our customers' expectations. Their performance makes Connex projects credible and spreads the word regarding the various services we offer. They are the ones who ensure the firm's progress and success on a daily basis.

Connex trains Connex, just as Veolia Environnement trains Veolia Environnement; that is the basic principle. An ambitious training policy for meeting these objectives came with the creation in 1994 of the Urban Environment Institute, the group's skill centre, renamed the Veolia Environnement Campus in 2003. All levels of personnel are involved, from blue-collar staff up to management level. The training programs available – qualifying, accredited and leading to a diploma – are as concerned with initial training as ongoing education.

The group's operational management is very much involved in the structure of training programs: how they are carried out, evaluated and followed-up. The wide range of Connex courses includes all training levels – initial, postsecondary, continuing, accredited and leading to a diploma – available for every category of personnel.

### **Professional training**

Apprenticeship is the cornerstone of a training policy that encourages cooperative preparation for learning a trade. The curriculum runs smoothly: a tutor supervises the apprentice, who alternates one week at the institute with two weeks in the workplace. The training results in a diploma, the CAP (Certificate of Vocational Aptitude), which more than 1.000 young people have earned as a springboard to their professional career as a driver. After the diploma,

graduates are given permanent employment contracts. The initial training is thus a tool that is central to Connex's recruitment policy.



Other training programs offering diplomas include the BEP Certificate in Industrial Vehicle Maintenance, the professional baccalaureate in Maintenance of Automated Mechanical Systems, and a university undergraduate diploma in Urban Services Management (Transportation Option), created in collaboration with the University of Cergy-Pontoise. The latter diploma is also accessible through continuing education via the Job Experience Validation (VAE) system.

There is also a managers' curriculum (created in 2002) designed to prepare group managers to work in a demanding international environment.

### **Prestigious partnerships**

In order to award these diplomas and guarantee high-level training to future personnel, Connex has formed a number of partnerships within the French national education system and with post-secondary educational institutions. In addition to the University of Cergy Pontoise, French partners include Essec Business School and the University of Paris-Dauphine. Elsewhere in the world, partnerships have been developed with universities in Leeds, UK; San Pablo, Spain; and Tsinghua, China, as well as with Morocco's Institute of Business and Management (ISCAE).



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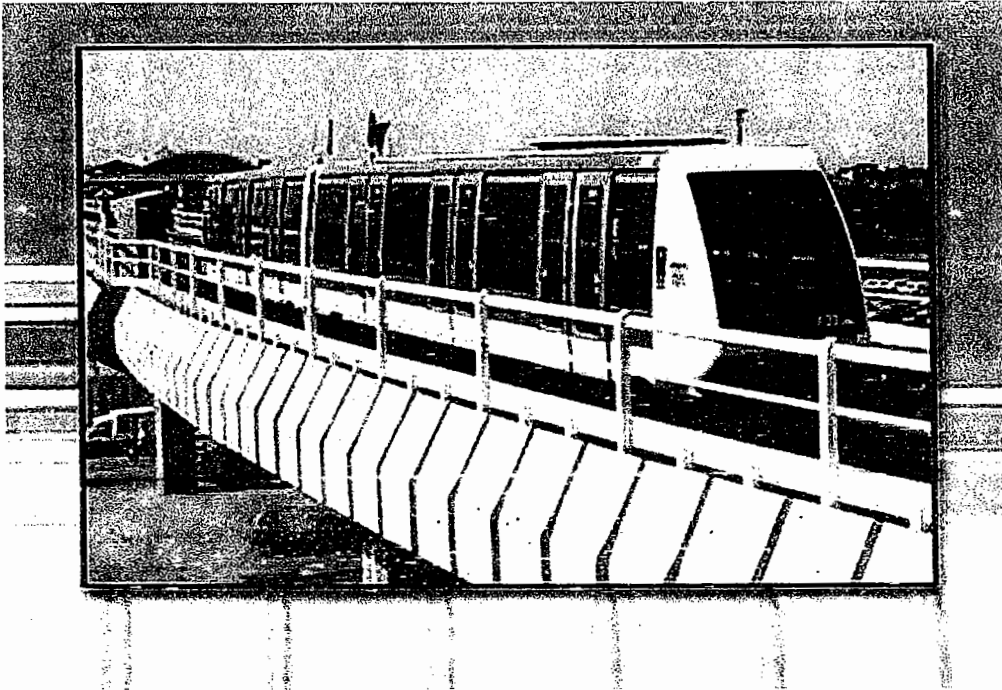
## Connex around the world

### Western Europe - France: Every contract renewed

Turnover 2003: € 1,374 million.

25,273 employees

Fleet: 12,650 vehicles



Fully automatic metro in Toulouse

In 2003, Connex was well-positioned with 153 urban and interurban bus networks, and was able to reinforce its presence in north western France and the Rhône-Alpes region. The contribution of the Vernay transport firm, acquired by Connex in 2002 (3,300 staff members, 2,700 vehicles), was measured in terms of both the integration of the firm and its turnover. In 2003, in the same spirit of consolidating its regional presence and extending its borders, Connex took over the activities of the STAHV in the Vosges, a large (200-vehicle) urban and interurban transport firm that also provides school transportation. The STAHV has a particularly high profile in Epinal, Saint-Dié, Verdun and Remiremont. To Connex's credit, every operating contract that came up for renewal in 2003 – including those in Libourne, Calais and Villefranche sur Saône – was successfully renewed.



Reinforcing its position in the tramway market, Connex started the brand new Bordeaux network in December 2003, bringing to eight the number of tramway networks in France managed by the group — a figure that will grow to 11 in 2004. Since the beginning of 2005, Connex operate the total network of Toulouse including a fully automatic metro.

It was also another successful year for the four tourist train lines (La Rhune in the Basque country, La Mure in the Alps, the Pignes train in Provence and the Trieux steam train in Brittany) that operate under the Connex Tradition name. In 2003, the Mure train, which celebrated its first 100 years of electrification, welcomed a record 95,134 passengers.

In the area of boat transportation, the STAT network in Thonon-les-Bains has been granted a 10-year contract to run a ferry service on Lake Geneva on behalf of the city of Evian. The boat is a 110-passenger catamaran powered by solar energy. Elsewhere on the water, the Connex subsidiary of STN provides the connection between the Channel Islands of Jersey and Guernsey and the département of La Manche.

In New Caledonia, modernization continues on Noumea's suburban transport network, which is operated by Carsud, a partnership between Connex New Caledonia (51%) and the earlier network's drivers (49%), who formerly owned their own vehicles.

In Mayotte, a French territorial entity, the Compagnie Mahoraise de Transports et de Services (CMTS), a Connex subsidiary, organizes and manages transportation for schoolchildren from the island to the lagoon.

**Western Europe - Germany: regionalization efforts are on track**

Turnover 2003: € 292 million

3,260 employees

Fleet: 1,746 vehicles



InterConnex 2

In Germany, where regionalization offers the various länder the chance to entrust their regional network operations to a contractor of their choosing (although infrastructures, stations and traffic remain the responsibility of Die Bahn), railways seem to be a path to success or Connex, which has become Germany's largest private operator of public transportation.

Having won the contract for operating the regional line linking Niebüll, Germany with Tønder, Denmark, the NordOstSeeBahn network (a Connex subsidiary) was entrusted with the operation of the 241 kilometres Marshbahn line running between Hamburg and Westerland on the island of Sylt. The contract will run for 10 years starting in 2005. Connex's offering also includes the creation of an Interconnex line linking Westerland, Berlin and southern Germany. In 2003, NordOstSeeBahn took over the train line between Hamburg and Flensburg, and starting in 2005. Connex will operate the regional Nordharz-Netz trains between Magdeburg and the Harz Mountains in central Germany. In 2003, Connex began the operation of its eight regional rail network, the Ems-SenneWeser lines in Rhineland-Westphalia.



NordWestBahn Regional Train

In addition to its rail activities, the company operates a number of urban and regional transportation services, including the tramway in Görlitz, where Veolia Environnement was awarded the management of all municipal services.

As of January 1, 2004, Connex Germany has changed its organization, and now relies on regional bases to improve the management of the various public transportation systems, coordinate rail and road transport, and bring both means of transportation in closer contact with local authorities and passengers.

## Western Europe - Spain: Barcelona launches its tramway

Turnover 2003: € 29 million

534 employees

Fleet: 315 vehicles



The company's activities on the Iberian Peninsula, where it operates five bus networks, are under the leadership of FCC-Connex. In addition, the CTSA (Spanish Transport Corporation), a bus subsidiary of FCC-Connex, was awarded a contract for the operation of the Vila-Real urban network in northern Portugal. Barcelona's tramway system is nearing completion, and was inaugurated in March 2004. Connex is responsible for the operation and maintenance of the entire system, and has subcontracted the maintenance to the manufacturer of the rolling stock and stationary equipment. In early 2004, in collaboration with the organizing authority, Connex set the standard for staff working conditions, recruitment and training, operations and safety.



**Western Europe - Ireland: a tramway for Dublin**

Starting in July 2004

189 employees

Fleet: 40 vehicles



Dublin inaugurate a new tramway in 2004. Its two lines, totalling 40 kilometres, will be run by Connex Ireland on behalf of the Railway Procurement Agency, the organizing authority. The lines will link Tallaght with Connolly and Sandyford with St. Stephen's Green. Some 21 million passengers are expected to use the system each year.

**Western Europe - Belgium and the Flemish bus network**

Turnover 2003: € 71.5 million

885 employees

Fleet: 600 vehicles

Connex has a presence in the country's Flemish region, where it is a sizeable private operator of buses. It carries out its activities under contract from the publicly held De Lijn company or from the regional government. Connex Belgium recently signed two six-year contracts for the operation of two bus lines, one in Antwerp and the other in Flanders. In addition, Connex provides various services such as transportation for schoolchildren, workers, seasonal employees and tourists plus several on-demand transportation services.







**Western Europe - Denmark: Connex stays on track**

Turnover 2003: € 148 million

2,771 employees

Fleet: 1,002 vehicles

Connex Transport Denmark is now the second-largest bus operator in the country. In 2003, one of the contracts for Copenhagen region – involving the operation of 44 buses – was renewed. Connex currently has a 40% market share in the Danish capital. In addition, Connex operates a rail link between northern Germany and Denmark.

**Western Europe - Sweden: Stockholm leads the way**

Turnover 2003: € 467 million

8,148 employees

Fleet: 2,342 vehicles



The Stockholm subway system today consists of 100 stations, of which about half are situated underground. The tunnel stretches are constructed partly in concrete, partly in rock, and make up 63.3 km of the system's total length of 110 km. This is one of the world's longest systems in terms of route length per inhabitant. The mechanical and technical designs used in Stockholm's subway are copied directly from the New York subway system, including the measurements of the rails themselves and the electrical power distribution system.





Connex has had a solid presence in Sweden since 1998, and since 1999 it has operated the Stockholm metro; in 2003, its contract for the latter was renewed until 2009. Connex also runs three suburban tramlines and one circle line for the capital city.

This contract is a model of how public services can be delegated to a private firm. By means of incentive clauses with bonuses and penalties linked to safety, turnover, timeliness, cleanliness, information, and so on, the contract incorporates various requests for improvement in service for the 250 million passengers who use the system each year.

In the rail transport sector, Connex has operated two major train lines between Stockholm, Sweden and Narvik, Norway and between the latter and Göteborg, Sweden. In the western part of the country, Connex operates the regional train line between Hallsberg and Herrlunga. Connex operates a number of urban and interurban networks, particularly in the city of Eskilstuna starting in 2002 as well as in the Skane region in southern Sweden. In 2003, Connex won the contract for operation of the urban and regional bus lines in Norrköping along with two tramlines, starting in June 2004. In addition, Connex will operate the regional bus lines in Norrbotten, northern Sweden starting in July of 2004.

The contract for Östergötland, which encompasses 200 buses, was renewed. In 2004, Connex will take over the firm of Styröbolaget, which operates 12 ferries in the Göteborg region.

#### **Western Europe - The Netherlands: by car, taxi and ferry**

Turnover 2003: € 196 million

2,814 employees

Fleet: 1,082 vehicles

Through its affiliates BBA (Brabant), SBM (Maastricht) and Limex (Limburg), Connex manages a number of urban and interurban bus lines. BBA also manages four taxi companies (Tiburgse Taxi Centrale [TTC], Continental Breda, Walsmits Goirle and Sieswerda) and the PZN call centre for on-demand transportation in northern Brabant. In southwest Holland, two BBA-operated ferries transport 800,000 passengers per year between Vlissingen and Breskens on the Escaut estuary.





**North America - United States: Boston gives the green light**

Turnover 2003: €187 million

3,767 employees

Fleet: 2,124 vehicles

Connex's US presence began in 2001, when it took over the activities of TCT (Trailways Commuter Transit) and Yellow Transportation (which operates 1,200 vehicles in the Washington-Baltimore region). These firms became the operational subsidiaries of Connex North America in the urban and regional transportation market, including taxi services and on-demand transport for sparsely populated areas and people with reduced mobility. Following this, other contracts were awarded in Fairfax, Virginia and Columbia, South Carolina, as well as one for the operation of the interurban network of Prince George County, Maryland, and one for the operation of 111 buses in Los Angeles.

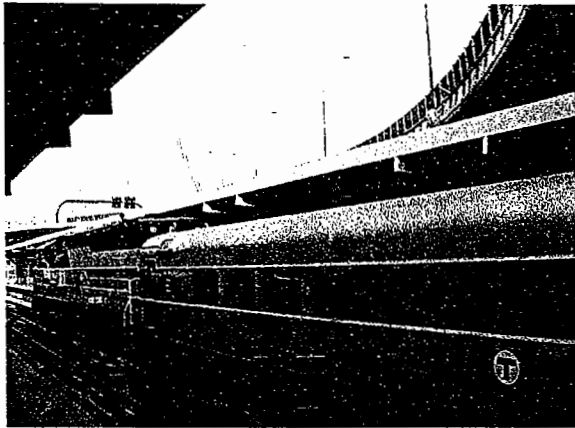
In 2003, the Fairfax County authorities entrusted Yellow Transportation with the operation of the second part of its Fairfax Connector urban network, which links residential zones with several Washington metro stations. At the same time, the organizing authority of the State of Maryland delegated the operation of its interurban network between Columbia and Baltimore to Yellow Transportation.

However, it was in the area of rail transport that Connex was able to reinforce both its position in the North American market and its internal growth strategy overseas in 2003. In Boston, the organizing authority entrusted the operation of its rail network to MBCR (Massachusetts Bay Commuter Railroad Company), a company that is 60% owned by Connex, 20% by Bombardier (a Canadian railway parts manufacturer) and 20% by ACI, a Boston transportation firm. This suburban network, the fifth-largest in America, carries 146,000 passengers per day on 600 kilometers of track, with 13 lines serving 130 stations. It is the first suburban train line in the United States to be run by a private company. Connex's contribution to this network comes in the form of very strict agreements in terms of quality of service, customer service, training for personnel and modernized management methods. Connex win a new contract in Los Angeles starting in July 2005.





**Boston**



**New contract in Los Angeles**



**Pacific – Australia and New Zealand: Melbourne shows its gratitude**

Turnover 2003: € 130 million

1,202 employees

Fleet: 631 vehicles

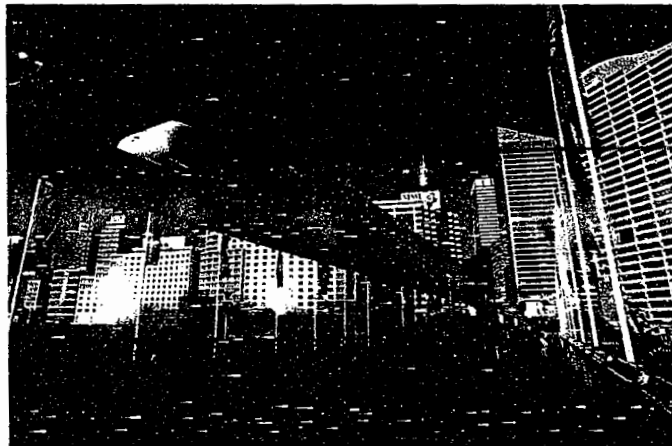


Commuter train in Melbourne





Connex gained a foothold in Australia in 1988 when it took over operation of Sydney's monorail and light-rail systems. The subsequent acquisition of the Southtrans Bus Company in Sydney reinforced the group's presence in New South Wales. In Melbourne in the State of Victoria, Connex was initially awarded the management of the Hillside Trains suburban network, representing half of the overall system. After radical modernization work on the network, station reorganization and renewal of the fleet of vehicles, Connex was awarded (after contract renegotiations) the contract for operating the entire Melbourne suburban network in early 2004, thus tripling the size of its activity in this urban area. This increase is due to Connex's proactive, original commercial dynamic on a continent where its very positive image benefits from an infusion of the group's widely recognized expertise. It also reflects Connex's skill in handling large rail contracts in major urban areas around the world. It should be noted that Connex's Australian teams were also responsible for the group's first foothold in Auckland, New Zealand, where it operates the suburban train network starting in June 2004.



Monorail in Sydney

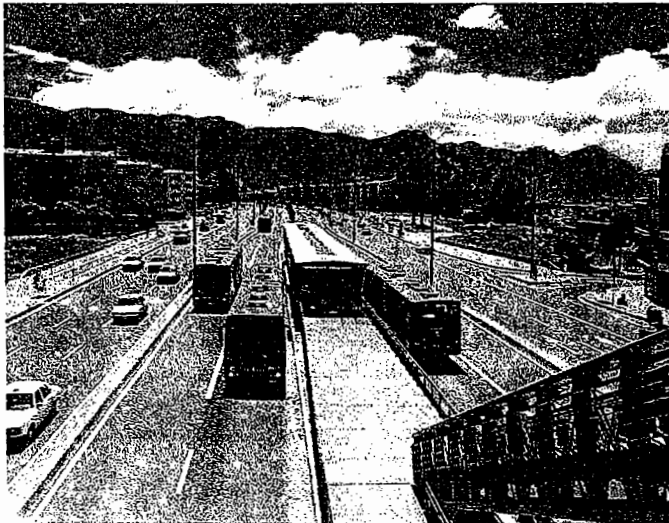


**Latin America - Colombia: a model takes shape**

2003 turnover 2003: € 4 million

355 employees

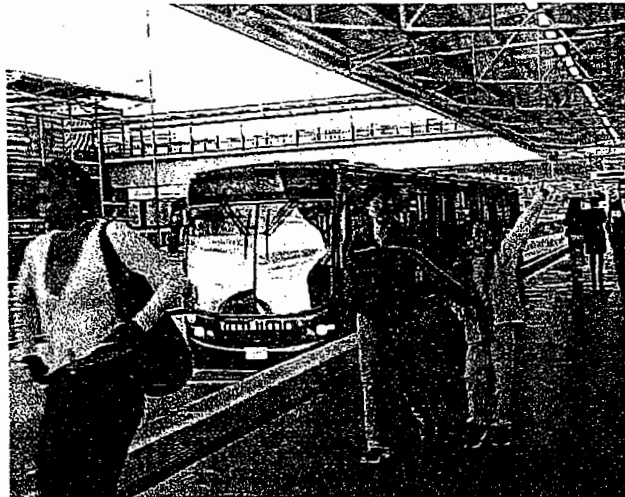
Fleet: 112 articulated buses



In Bogota, a city of seven million inhabitants, the Transmilenio concept combines reduced transport times with a significant decrease in pollution.

The Transmilenio system in Bogota, for which Connex is one of the main operators, has set a global benchmark since its 2001 launch. The city's 40 kilometers of exclusive zones for articulated buses and separate bus lanes allow it to meet massive transportation demands. The system's current capacity, about 850,000 passengers per day, is equivalent to that of a major metro line. This capacity will rise sharply with 2004's launch of Phase II, which will increase the fleet of articulated buses from 500 to more than 800; Connex will double its activity when this happens. On the current Transmilenio network, the average transportation time dropped from 70 to 30 minutes. Pollution will also drop significantly, since 3,000 old vehicles will be retired when Phase II is operational. A number of large cities are currently studying the implementation of systems similar to Transmilenio in order to restructure their urban transport networks while limiting infrastructure costs.





**Middle East - Lebanon: Interurban and tourist activities**

Turnover 2003: € 1 million

54 employees

Fleet: 30 vehicles

Connex has had a presence in Lebanon since 1998, principally in interurban transport activities. In particular, it provides the link between Beirut and Tripoli, a line that carries 60,000 passengers per month. In the center of Tripoli, Connex inaugurated a new bus station in 2002 that offers a range of services, and Connex Lebanon is also involved in a number of tourist activities in partnership with various travel agencies and associations.





**Middle East - Israel: new tramway in sight**

Turnover 2003: € 6 million

141 employees

Fleet: 100 vehicles



**בקרוב: מערך תנועה חדש בירושלים**  
בזאת השנה תהיה להקמת מסלולי תחבורה בינעירוניים (צו לאוטובוס השייך  
לרשות הירוקה) מערך תנועה חדש בירושלים. המערכת תהיה



In Israel, Connex manages two bus networks, contracts it won after the authorities decided to open the transport market to the private sector. The first is an interurban system that links Ashdod with Tel Aviv, and the second is an urban network in Tiberiade that offers a few interurban and school transport services as well.

**Connex is also part of the consortium in charge of the financing, construction, operation and maintenance of Jerusalem's future tramway.**





**FORMAT 31-A  
CHECK LIST FOR USE OF BIDDERS**

**TECHNICAL PROPOSAL**

Before sealing Envelope '1' the Bidder should tick mark in the bracket (✓) the following items and sign the format in token of having ascertained the correctness of the proposal.

SI No	Document	Mark	Page No.	Remarks
1	Is Letter of Transmittal – A (Technical Proposal) given in Format-1 provided	( )		
2	Is Letter of Consent and Authorization given in Format-2 provided?	( )		
3	Is Affidavit given in Format-6 provided?	( )		
4	Is Technical Proposal format given in Format 7 provided?	( )		
5	Is individual Applicant Profile given in Format 8 provided?	( )		
6	Is General Information of Constituent Members to the Joint Venture Agreement given in Format 9 provided?	( )		
7	Is Matrix of Responsibilities in Joint Venture provided in Format 9A provided?	( )		
8	Is Technical Capability given in Format 11, Statement I, IA, II & III provided?	( )		
9	Is Experience of Bidder in Design/Development and Operations of MRTS/RAIL Projects given in Format 12 provided?	( )		
10	Is Method Statement covering General Design Approach and Construction Methodology for Developing the project facilities given in Format 13 provided?	( )		
11	Is proposed organisation given in Format 15 provided?	( )		
12	Is details mentioned as per Format 16 given in Statement I & II provided?	( )		
13	Is Particulars of Major Specialists Major Sub-Contractors/suppliers given as per Format 17 provided?	( )		
14	Is Plant and Equipment proposed to be deployed by the bidder for the work as per details given in Format 18 provided	( )		
15	Is Time Schedule as given in Format 19 provided?	( )		
16	Is Technical Specification as per Format 21 provided?	( )		
17	Is Land Requirements as given in Format 22 provided	( )		
18	Is Additional Information as given in Format 27 provided?	( )		
19	Is Form of Guarantee for Bid Security as given in Format 28 provided?	( )		
20	Is Form of Bank Guarantee for Performance Security as given in Format 30 provided?	( )		
21	Is Check List for use of Bidders as given in Format 31-A (Technical Proposal) provided?	( )		

Bidders are advised to fill in the above details and give page numbers, against each so as to make it easy for the proposal opening authority to accept the proposal on the spot.

Signature:  
Name: J P Chalasani  
Bidder: Mumbai Metro One



FORMAT 32  
BID OPENING CHECKLIST

Bid Reference: \_\_\_\_\_

Bid Opening Date: \_\_\_\_\_ Time: \_\_\_\_\_

Name of Bidder: \_\_\_\_\_

- (a) Is outer envelope of Bid sealed?
- (b) Is Bid - Checklist completed and signed?
- (c) Is documentary Authority for signing enclosed?
- (d) Date of Bid Validity / Bid Security
- (e) Amount of Bid Security \_\_\_\_\_ state Currency
- (f) Describe any "Substitution", "Withdrawal," or "Modification" submitted.
- (g) Name of Bidder representative, if bidder is not present

Signature of responsible official: \_\_\_\_\_ Date: \_\_\_\_\_





Molinari Engineering GmbH  
Achensestrasse 1 - 3  
A-6200 Jenbach  
Austria

Fon +43 5244 600 2911  
Fax +43 5244 600 557

info@molinari-rail.com  
www.molinari-rail.com

# **MRTS Mass Rapid Transit System MUMBAI, INDIA**

## **Technical description 4 Car EMU and 6 Car EMU**

Jenbach, 11. May 2005

Page 1 of 50





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## 1. VERSION

Version 1.4  
11.05.2005

Filename: MRTS\_technical description\_110505\_V1-4.doc

Description: Technical Description of 4-Car and 6-Car-EMU

Number of pages: 50

Written: Christian Hassler  
Checked: Josef Kometer  
Approved: Michele Molinari

Revisions: :

Copyright remark:

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## 2. REFERENCE PROJECT

### The Malaysian EMU

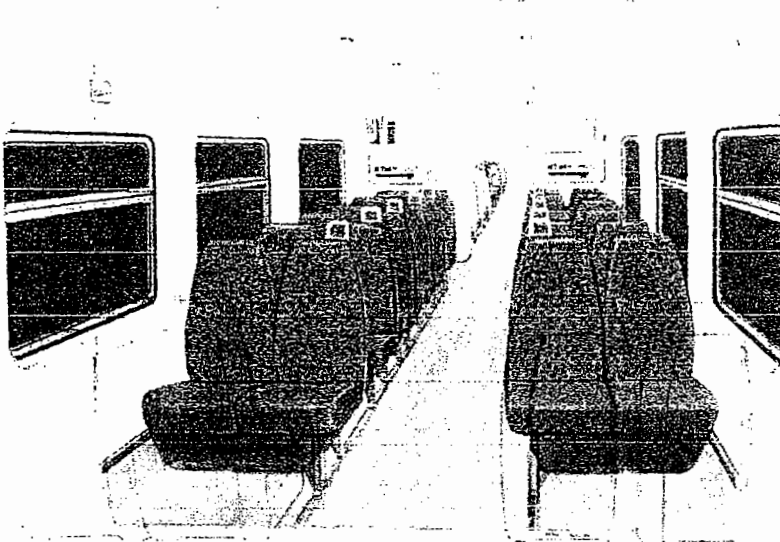


KTMB's Kommuter Service in Kuala Lumpur

In 1994/95 Molinari Engineering's predecessor company Jenbacher Transport supplied 18 advanced electric trains for KTMB in a multi-million dollar contract. Designated Malaysian EMU, the trains featured advanced design stainless steel bodyshells, full air-conditioning and the latest energy saving regenerative three-phase AC traction equipment with numerous safety and comfort features.

Each three-car train had seating capacity for 224 passengers. Other features included power-operated sliding plug doors with pushbutton passenger control, air suspension and a destination indicator.

Jenbacher Transport Malaysian EMUs featured vehicles constructed from welded stainless steel, with 3-phase AC drives and regenerative braking. The interior layout, seating and doors of the unit were specifically arranged to suit a high intensity urban duty with frequent stops.



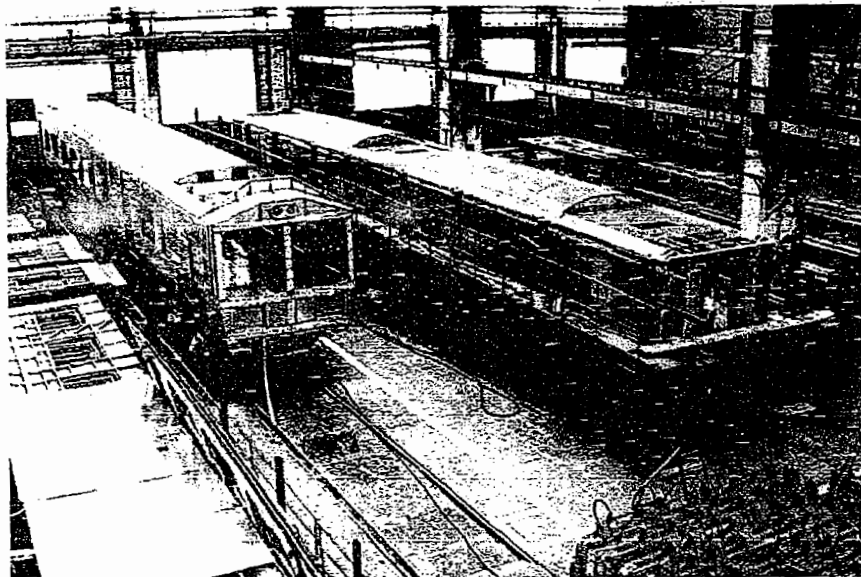
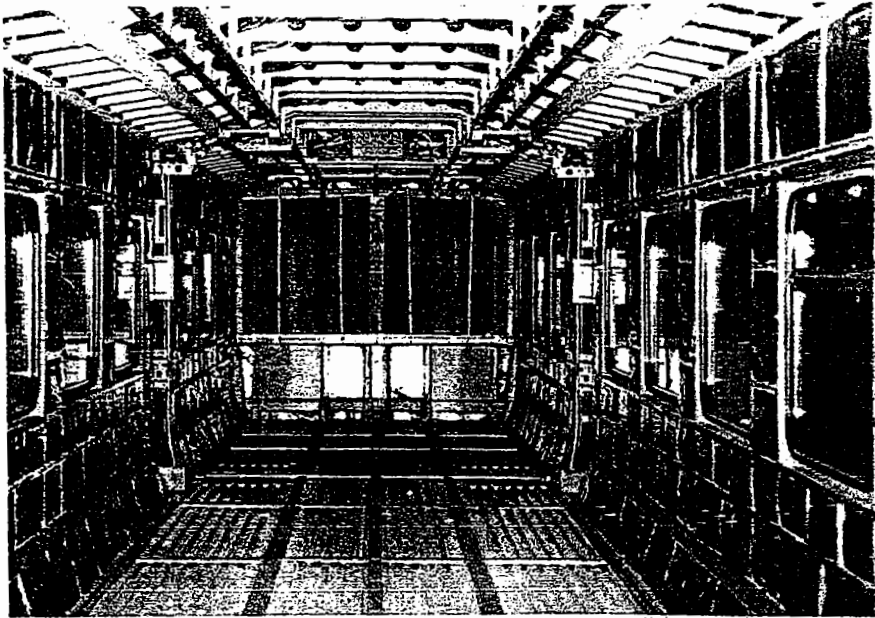
Interior proposal during design engineering

Three-phase power traction equipments were installed in the two end cars in each set, the greater acceleration from station stops, cutting journey times considerably. Three-phase drive also allowed energy saving as well as reduced maintenance costs.

With the improved adhesion benefits of 3-phase AC traction and a greater proportion of the axles in the unit motored, Jenbacher Transport Malaysian vehicle had superior performance. This afforded obvious advantages in being able to meet tighter timetables, thereby permitting more frequent services or running existing timetables with fewer trains.

Superior 3-phase AC traction technology with the ability to regenerate electricity back into the overhead supply when braking, made the Malaysian EMU decidedly much more energy efficient, exceptionally so when taken over the whole life situation.

3-phase AC traction motors have no wearing parts other than bearings, giving inherently higher levels of reliability. Coupled with lower maintenance, this ensures higher levels of availability which are essential to maximising revenue potential. An additional benefit of regenerative electric braking is the significant reduction in friction pad wear and its consequent lower maintenance requirements, with attendant reduced costs and downtime.



Fabrication of stainless steel bodyshells

Conceived and constructed for Malaysia, this three-car electric multiple units were designed for the particular requirements of operators in tropical regions. In order to guarantee corrosion resistance under the extreme environmental operating conditions, the units were constructed from stainless steel. Plug door operation was provided by electric actuators. This system was smoother in operation and provided enhanced reliability and obstruction detection than comparable pneumatic systems.





**Main Technical Data**

Type	Three-car KTMB Class 8 EMU for bi-directional use		
Axle sequence	B' B' +2'2' + B' B'	Track gauge	1,000 mm
Trainset length	68,700 mm	Width of car	2,700 mm
Distance between pivots	15,800 mm	Bogie pitch	2,300 mm
Weight in working order	126 t	Tare weight	121.85 t
Starting accelerations	0.794 m/s <sup>2</sup>	Braking decelerations	0.776 m/s <sup>2</sup>
Riding index	< 2.5	Noise level at saloon compartment 70 + 3 dBA at 90 km/h	
Power supply system	25 kV AC, 50 Hz overhead catenary		
Passenger capacity	224 seats, 90 standees		
Wheel diameter (new)	851 mm		
Maximum speed	120 km/h		
Drive	8 force-ventilated AC induction motors (190 kW each)		
Gear ratio	1:5.47		
Emergency braking	0.79 m/s <sup>2</sup>		
Traction equipment	3-phase AC-propulsion system with 2 independent traction groups, each of 4 motors, a converter and inverter/controlled regenerative equipment		
Auxiliary power supply system	3-phase 415V, 50 Hz converter		
Brake system	Air brake and dynamik brake with automatic parking brake		
Control/emergency power supply	96V battery (charging at 110 DC volts)		
Air conditioning	6 Toshiba roof-mounted, fully hermetic units, each rated cooling capacity 25,000 cal/hr		



Reference Pictures:





### 3. GENERAL DESCRIPTION

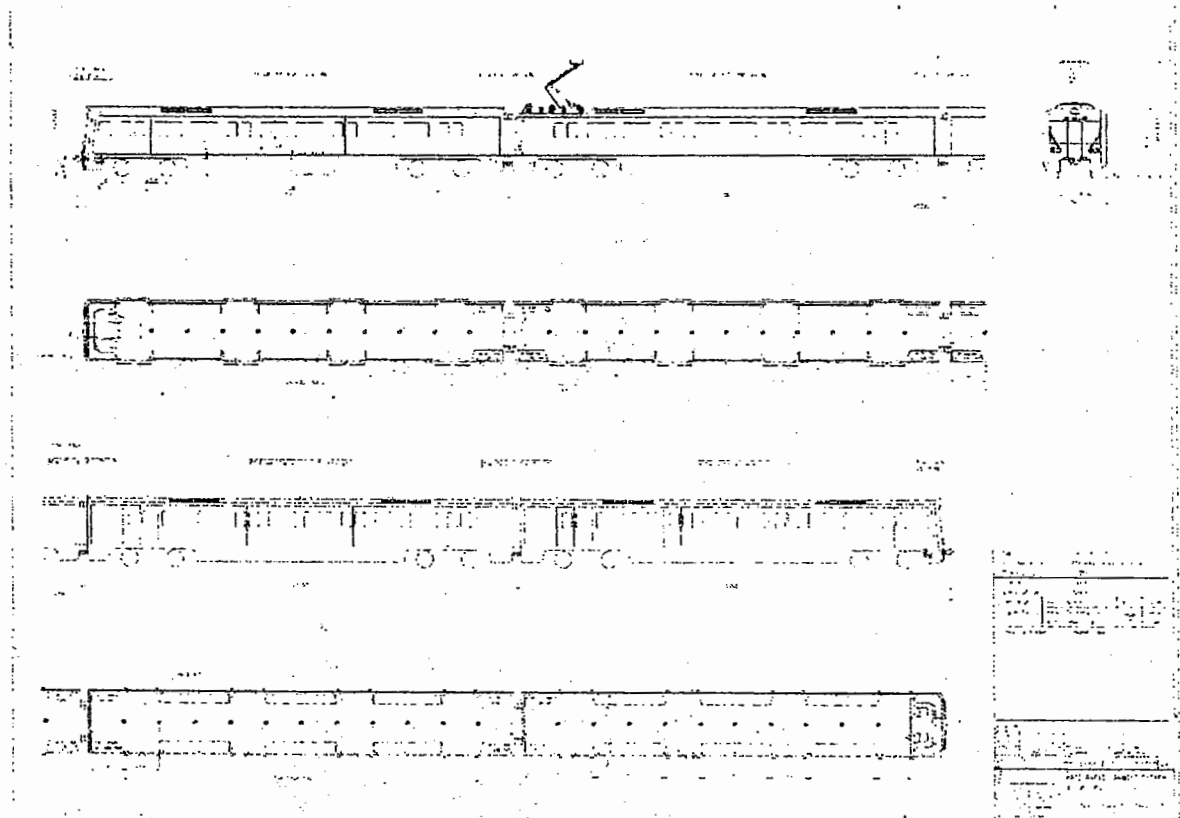
The proposed Electrical Multiple Unit (EMU) for the Mumbai MRTS is a variation of an existing EMU's which is a proven design and which offers high reliability and simple maintenance features.

#### 4 Car EMU

The 4-car EMU consists of two almost equal train parts with driven motor car in the middle (B1 and B2-car) and a in the combination A + B1 + B2 + A.

The axle sequence of the EMU is 2' 2'+ Bo' Bo'+ Bo' Bo'+ 2' 2'.

Each A-car with the drivers cab at the end is equipped with the auxiliary supply. The B-cars contain the equipment for the traction power supply and each is powered by 4 traction motors. B1 contains also the pantograph. B2 has a high Voltage connection to B1 and its own main circuit breaker.





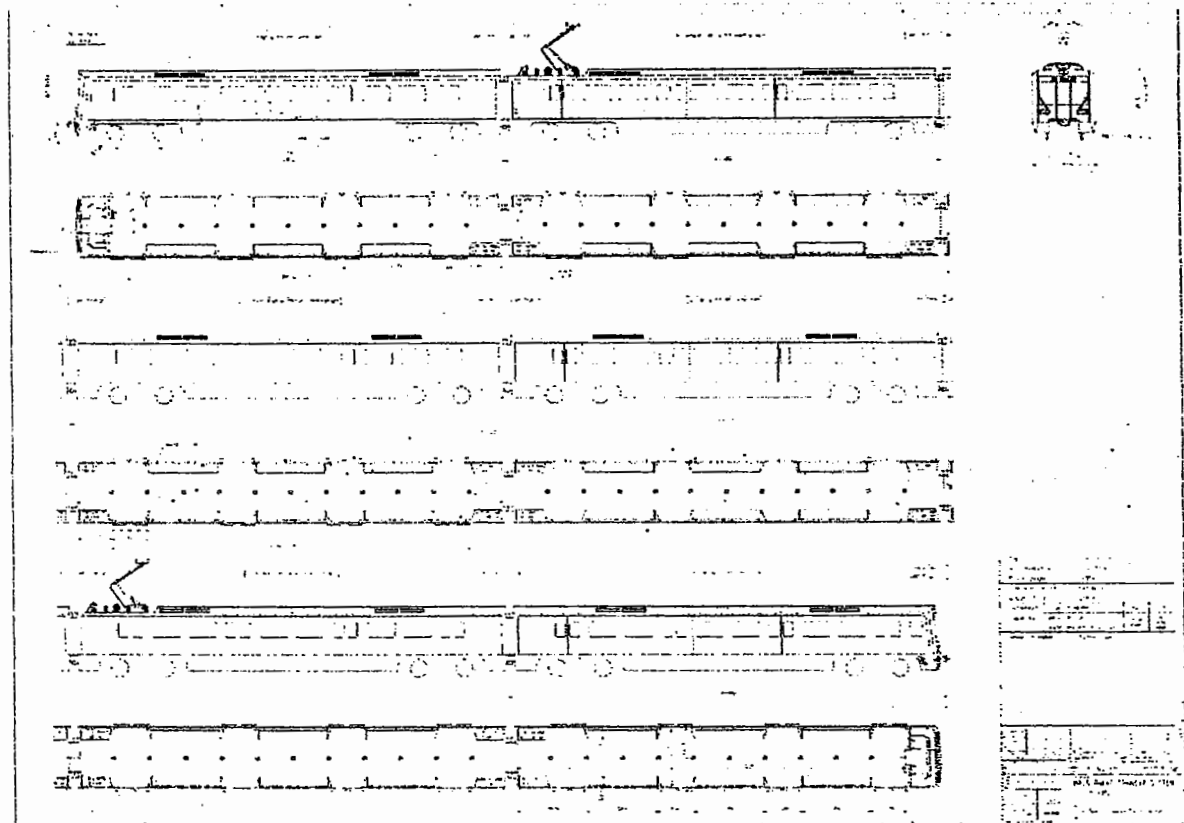
## 6 Car EMU

In case of a 6-Car unit the construction will simply be the same as the 4-Car unit with one additional B1 and C-Car passenger coaches in the train. So the combination is: A+B1+B2+C+B1+A.

The axle sequence of the EMU is 2' 2' + Bo' Bo' + Bo' Bo' + 2' 2' + Bo' Bo' + 2' 2'

Each A-car with the drivers cab at the end is equipped with the auxiliary supply. The B-cars contain the equipment for the traction power supply and each is powered by 4 traction motors. B1 contains also the pantograph. B2 has a high Voltage connection to B1 and its own main-circuit breaker.

The C-Car is only a passenger coach without any traction equipment.



Each car is equipped with 4 large, fast opening entrance doors with a clear width of 1400 mm on each side of the car. The passenger compartment is designed for a maximum passenger capacity with large standing room and a seating bench along the side wall.

The floor height is 1100 mm over top of rail (empty car).

The bogies shall be supplied by known manufacturer and are approved by the Germany Railway Authority EBA.



The design speed for the EMU is 80 km/h.

Up to 2 EMU's can be coupled for emergency evacuation from the track. Coupling is only mechanical without any electrical controlling from the Master unit to the other one.

Regarding the design of the interior of the EMU the following characteristics have to be mentioned:

- A modern and attractive driver's desk, which has been designed according to ergonomic considerations
- Sufficient handrails to allow a safe movement of the passengers through the train

During the development of the EMU the following rules and regulations have been considered, as long they are relevant for the application and there aren't any contradictions between them:

- Indian Railway Standards
- UIC leaflets
- EN/CEN/DIN/ÖV-norms
- BS standards
- EBO (Railway Operation Rules of Germany)
- VDE and VDI-determinations
- Accident prevention regulations
- VDV-scripts
- Fire prevention and protection regulations

For all Indian rules and regulations with regard to this EMU the actual and valid version at the date of submittal are taken into account. If no correspondent standard is published in India the engineering and execution shall be based upon UIC or Germany standards. These can be:

- Static and dynamic calculations
- Strengths calculations
- Welding checks
- Static test on car body
- Dynamic test on bogie frame

All indicated values and figures are indicative. No tolerances will be indicated. All described components and sub-systems as well as the respective supplier are subject to revision.



#### 4. MAIN TECHNICAL DATA FOR 4-CAR EMU

##### Service conditions

Track gauge:	1435 mm
Min. radius of curvature of track:	100 m
Max. gradient of track:	40 ‰
Rail type:	UIC60
Platform height:	1100 mm
Clearance:	UIC 505-1
Rail class:	UIC 700, C2

##### Main technical data

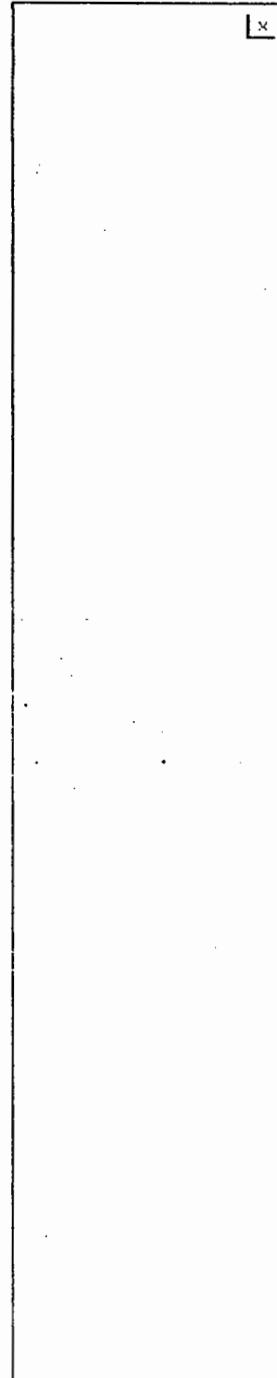
Max. Operating speed:	80 km/h
Max. Certification speed:	88 km/h
Axle arrangement:	2' 2' + Bo' Bo' + Bo' Bo' + 2' 2'
Max. Service power:	2x1200 kW
Max. Starting acceleration:	1.1 m/s <sup>2</sup>
Overall length:	88000 mm
Car body width:	3200 mm
Car body height:	3600 mm
Maximum height:	about 3900 mm
Wagon base:	22000 mm
Coupler Height:	850 mm
Floor height:	1100 mm
Doors at each side:	16 doors
Net width of doors:	1400 mm
Seats about:	168
Standees about: (6 per m <sup>2</sup> )	1032
(8 per m <sup>2</sup> )	1376
Passengers total: (6 per m <sup>2</sup> )	1200
(8 per m <sup>2</sup> )	1544

##### Performance parameters

Tare weight:	about 160 t
Maximum weight under dense crush load:	about 288 t
Max. Axle load:	18 t
Emergency braking deceleration:	1.2 m/s <sup>2</sup>
Designed service life:	30 years
Overhaul period for complete car:	7 years or 2.4 million km
Overhaul period for the main parts:	1.2 million km
Max. Daily running distance:	about 500 km

##### Service conditions

Altitude	0—300 m
Ambient temperature	10 °C — 60 °C





- Cooler
- Break resistant
- High Voltage equipment including pantograph (only B1)

The following main components are mounted on Roof of C-Car (only 6-Car Version)

- Air condition

## 9. CAR BODY DESIGN

A light-weighted construction made out of Stainless Steel is used for the car body.

The strength of the car body meets the requirements of UIC-566 and EN 12663-2000, category P-II. The car body has sufficient strength and rigidity which can meet the demand for lifting in the workshop. The strength of driver's cab meets the requirements of UIC 651.

### Structure type

With a fully-welded thin-wall cylindrical integral bearing structure without mid-beam, the steel structure of the car body of the EMU consists of underframe, side walls, end walls and roof.

### Car body strength

The load bearing structure of the car body can bear the following test load without permanent deformation or exceeding the allowed stress.

### Static compression

- 300 kN compression force is evenly applied on the upper side beams at the ends of the car body.
- 300 kN compression force is evenly applied on the waist at the ends of the car body.
- 400 kN compression force is evenly applied on the location 150 mm above the center line of the underframe at the ends of the car body.
- 1500 kN compression force is applied on the underframe plane and the joint bearing structure.
- 400 kN compression force is applied on the location 150 mm above the underframe plane.
- The evenly distributed 300 kN compression force is applied on the waist of the driver's cab.
- The evenly distributed 300 kN compression force is applied on the upper side beam plane at the end of the driver's cab.

### Static longitudinal pulling force

1000 kN longitudinal pulling force is applied on the end of the coupler connector.

### Vertical static load

The vertical force is evenly distributed. The load is:  $FZ=1.3 \times (M1+M2) \times g$ , M1 is the vehicle mass,  $M2=\text{passenger capacity} \times 80\text{kg} + \text{the area of corridor and vestibule (m}^2) \times 4 \times 75\text{kg}$ ,  $g=9.81/\text{s}^2$ .



Derailment test will according to Clause 4.1.1.5 provisions in the standard of UIC 566. The minimum safety coefficient of the above tests will conform to the provisions in the standard of UIC 566.

The strength of components fixations on the steel structure of the car body can resist the stress caused by acceleration. The stress of the fixation supports does not exceed the yield strength of the material, when the longitudinal acceleration is 3g, the vertical acceleration is  $(1+c)g$  and the lateral acceleration is 1g, where  $c = 2$  at the end of the car and linearly decreasing to 0.5 in the middle of the car.

## 10. EXTERIOR DESIGN

The exterior design of the 4-car and of the 6-car-version will be identical.

### Exterior lining / Front end

The EMU has an aerodynamic and modern design with low aerodynamic resistance. At the front end a faceplate made of GRP will be mounted, which can be removed easily in case of damage.

### Exterior paint

The vehicle will receive a 2K-PUR exterior painting according to UIC 842 consisting of an anticorrosive layer and paint layer. The surface treatment of metal parts and the car body will be carried out according to UIC 842.3. The colour has to be defined by the customer.

### Exterior markings

The exterior markings will be made with adhesive markings according to UIC 580. Name and logo of the operator will be placed according to the customer's requirements.

### Decorative / protection strip

No decorative or protective strips are foreseen.

### Apron, flaps

Out side the body side sole bar aprons and flaps are mounted. Their function is to insulate noise of the Power Unit and protect it from dirt. For noise reduction a special noise insulation and absorption material is mounted on aprons and flaps. Apron and flaps can be flapped up for maintenance purposes.







## 11. DOORS

Four sets of fast opening outside hung doors with exterior door sills are provided on each side of each coaches with when opened will provide 1400mm clear width and 1900mm clear height. The door operating mechanism is housed above the doorway within the coach and can be removed as a unit for ease maintenance

The side door system has the functions of anti-squeeze and automatic locking when the train speed is higher than 5 km/h (5 km/h signal is provided by the car). Each door has an internal emergency unlocking system and a switch isolation system. The internal emergency unlocking system will guarantee that the mechanical unlocking can be performed with a steel wire rope to open the door manually at door system failure.

The doors can be operated centrally by the driver from the driver's cab, or individually by the passengers. The driver can select to open the doors on only one or both sides of the vehicle with the respective switch in the driver's desk.

The passengers can open the doors by pushing the illuminated push-button installed at the interior and the exterior of the vehicle.

The doors close automatically after a default time. Each door has an audio warning horn. The horn is operated by the driver for closing or opening as well when the internal emergency unlocking system is operated. When the door reaches its terminal position the warning horn is shut off.

The doors are locked depending on the speed of the vehicle against opening. In case a door is open the vehicle will be stopped automatically.

An outer operation system will be installed on the doors close to the driver's cab and be operated with a special key when the vehicle is in power-off.

## 12. COUPLER

A proven coupler from Voith Scharfenberg, Germany is installed at each end of the vehicle. The couplers can ensure the mechanical coupling of the vehicles for emergency evacuation.

No electric coupler head is installed.



### 13. GANGWAY

The Gangway is the flexible part of the EMU which takes the relative movements of the cars between each others and allows the passenger to pass from one car into the other in a safe and comfortable way. Gangways of 1100mm clear width and 1900mm clear high are provided at the non cap end of each coach and will allow an optimal passenger flow of up to 2250 passenger per train.

#### **Bellows**

Each gangway is composed of a double-deck twin bellow. It is fixed to the end of the car body to form an eco-friendly sealed structure to provide the passengers with safe and comfortable conditions. The noise level is no higher than 72 dB (A) in the gangway when the speed of the train set is 80 km/h. The fire protection and flame resistance of the gangway are in correspondence with the relevant UIC standard.

### 14. WINDOW SYSTEM

#### **Transparent windows**

The passenger compartments are equipped with tinted insulating double glazing with reduced light transmission in view of Mumbai's sunny tropical climate. The windows are fixed with polyurethane glue from the outside to the car body. With the outside surface of the window glass and the car body skin on the same plane, the car window is designed to be a glass window with a belt cohesion structure.

#### **Movable windows**

In each section of the vehicle skylight windows in the upper part are installed. The opening angle of the skylight window is limited and the window can be locked with a four-square key.

#### **Emergency windows**

In each car are four emergency windows. The passengers can escape from the window by breaking the glass with the special hammer in case of an emergency. The glass meets UIC 564-1 requirements.

#### **Driver's cab windscreen**

The front window will be glued in frameless into the structure and the outside will be even with the structure. The windscreen is of high penetration resistant laminated glass and meets UIC 651 requirements.





## 15. ADDITIONAL EXTERIOR EQUIPMENT

### Windscreen wiping system

The windscreens are equipped with a wiping system, which is electrically driven. The water tank is sufficiently big for daily operations. Per windscreen on one-sector-wiper is installed and part of the system. The wiping system is operated by a switch on the driver's desk.

### Signal horns

Acoustic signals are made by UIC-standard macrophones which are driven by compressed air. These are placed by two in the roof section of the driver's cab. The operation of the macrophones is done by a push-button or a foot-valve under the driver's desk.

### Exterior lighting

The EMU is equipped with the following headlights:

Lower part, outside position: 2 x Red/White combined headlights, diameter 170 mm

Lower part, inside position: 2 x full beam headlights, diameter 135 mm

Upper part, central position: 1 x position lamp, diameter 170 mm

### Exterior handrails

No exterior handrails are installed. When the doors are open the handrails on each side of the doors can be reached easily.

### Insulation

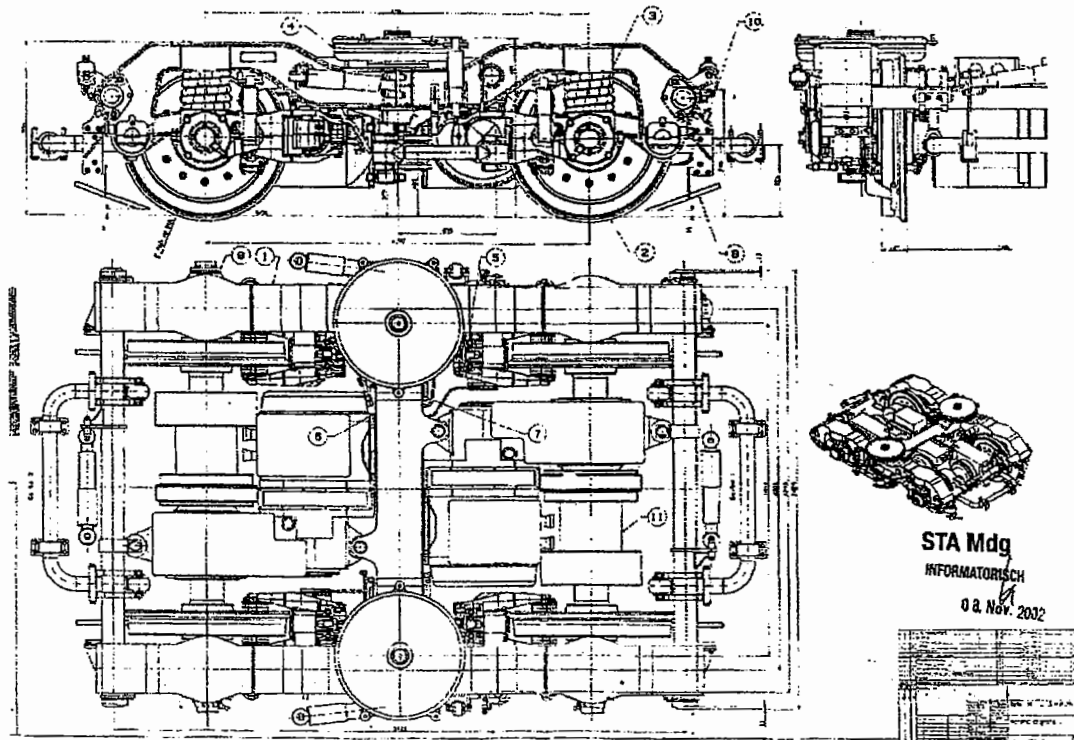
The EMU is provided with insulation (glass wool) in the underframe, in the side walls and in the roof section.

In combination with the foreseen insulation material appropriate k-values will be defined.

The heat insulation is designed to act as a noise absorber at the same time.

## 16. MOTOR BOGIE

### Type Drawing



#### Structure

The motor bogie has a wheel-base of 2,100 mm and is located in the middle below the power pack. It contains two diagonally installed motors with two spur-wheel gears. The bogie frame is designed in a welded-steel construction. All surfaces that accommodate components are processed mechanically. The bogies are designed for a maximum axle load of 20 t.

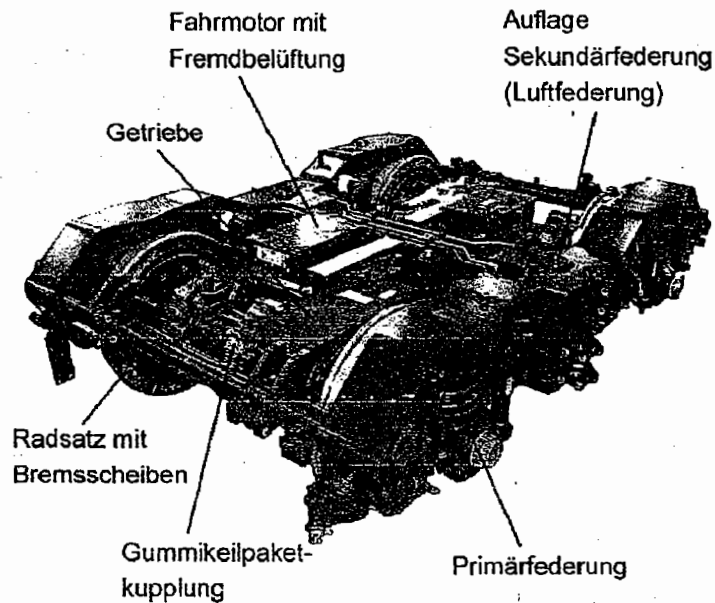
#### Suspension, shock absorption, wheelset mounting

The primary suspension of the motor bogies is implemented with coil springs and vertical absorbers according to the wheelset guide principle.

The wheelsets are equipped with tapered roller bearing units (cartridges). The tapered roller bearings are accommodated in the wheelset guides.

The wheelset guides are located separately on the wheelset bearing and thus allow the wheelsets to be quickly removed and mounted. For acoustic insulation, the primary suspension stage is separated from

the bogie frame by rubber elements. Flat pneumatic springs with an emergency suspension function support the drive module on the welded bogie frame (secondary suspension).



#### Wheelset

The motor wheelsets are designed as monobloc wheelsets. They have two pairs of wheel brake disc's per wheelset. The motor wheel diameter is 860 mm in new condition. The wear limiting dimension is reached at 800 mm. The wheel profile S1002 acc. to EN13715 with reduced thickness is used.

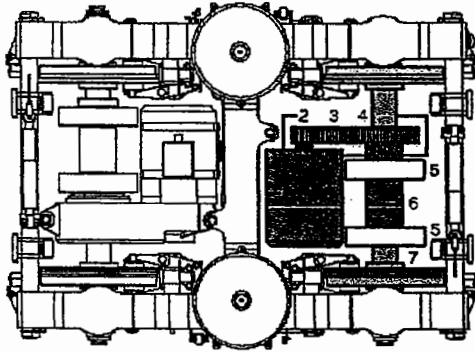
#### Bogie / vehicle body connection

In the case of the motor bogies, the horizontal load transmission takes place via a horizontal pushrod with wear-free metal/rubber elements that is mounted transversely in the bogie. A pendulum support guides the vehicle body. The bogies are connected to the vehicle body via lift-off safety guards.



### Traction motor / drive suspension

The fully suspended drive, consisting of a traction motor and gear, is elastically suspended from the frame of the motor bogie and is not supported on the wheelset shaft. This reduces the dynamic track forces by reducing the unsuspended masses as much as possible.



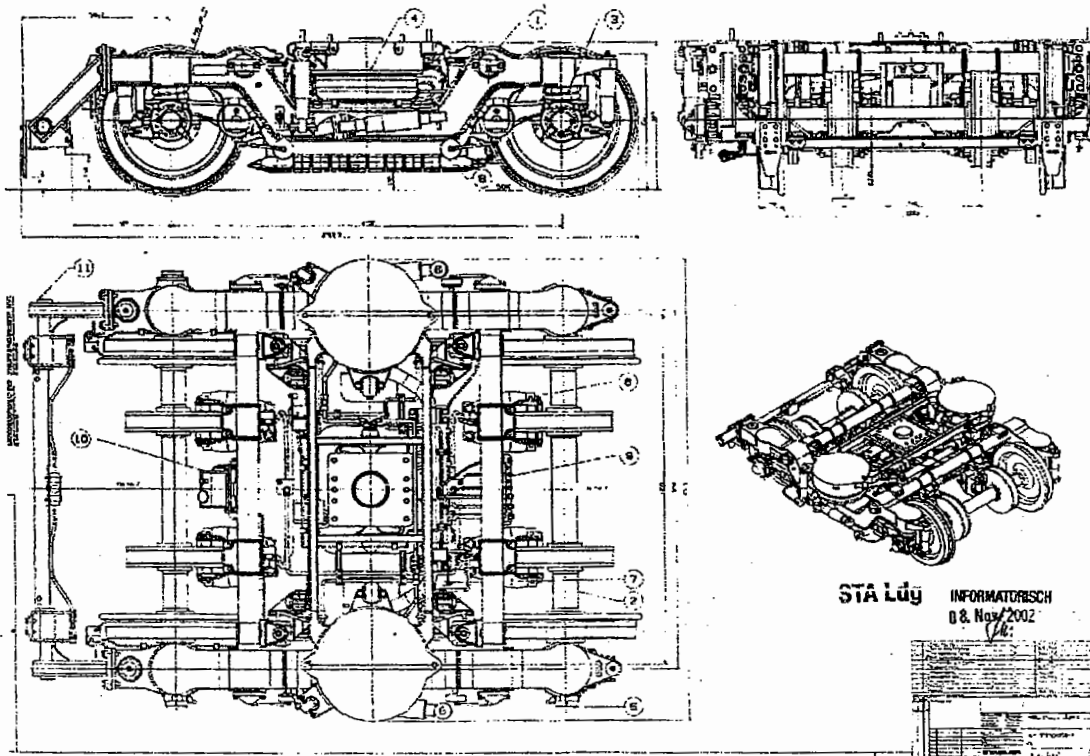
- 1 Motor
- 2 Pinion
- 3 Intermediate gear
- 4 Large gear wheel
- 5 Wedge-type rubber pad coupling
- 6 Quill shaft
- 7 Wheelset

### Further bogie equipment

- Wheel disk brakes
- Sanding system
- Rotational speed sensor
- Earthing contact for protective earthing

## 17. TRAILER BOGIE

### Type Drawing



#### Structure

The trailer bogies consist of a welded steel frame and have a wheel-base of 2,100 mm. All surfaces for accommodating components are processed mechanically. The trailing bogies are designed for a maximum axle load of 20 t.

#### Suspension, shock absorption, wheelset mounting

The primary suspension of the trailing bogies is implemented with coil springs and vertical absorbers according to the axle guide principle.

The wheelsets are equipped with tapered roller bearing units (cartridges). The tapered roller bearings are accommodated in the wheelset guides.

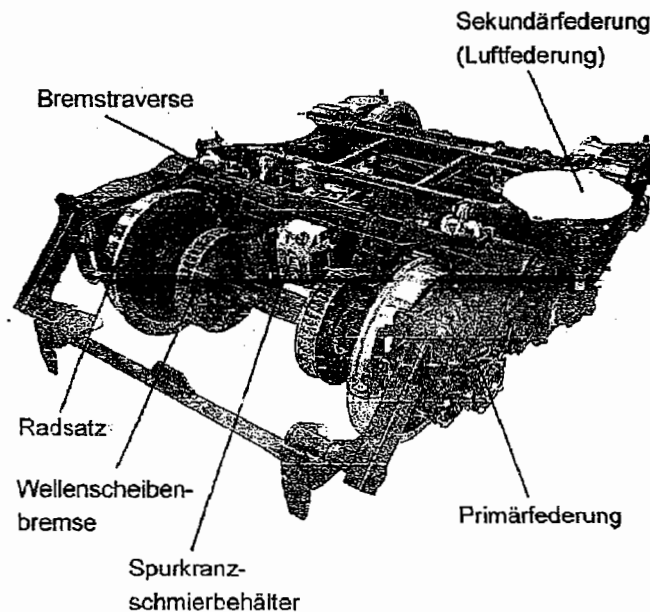
The wheelset guides are linked to the bogie frame via metal/rubber elements. For acoustic insulation, the primary suspension stage is separated from the bogie frame by rubber elements.

The secondary suspension is implemented with pneumatic springs. If a pneumatic spring is faulty, the rubber/metal spring elements in the pneumatic spring bellows will function as an emergency shock absorber.

The level regulation takes place via an overflow valve.

The secondary shock-absorber stage is supplemented by a stabilizer and a vertical absorber. Furthermore, curve-dependent cross stops keep the carbody within the loading gauge. The suspension is designed to maintain high driving comfort while preventing the transmission of structure-borne noise to the greatest possible extent.

One axial box is equipped with an earthing brush for protective earthing. Rotational speed sensors for the non-skid device are installed on two axial boxes.



### Wheelset

The bogie wheelsets are equipped with monobloc wheels. In order to achieve a sufficiently high braking force at maximum speed, all bogie wheelsets are equipped with two axle-mounted brake discs.

The bogie wheel diameter is 750 mm when new. The wear limit is reached at 690 mm. The wheel profile S1002 acc. to EN13715 is used with reduced thickness.





### **Bogie / vehicle body connection**

In the case of trailing bogies, the horizontal load transmission takes place via lemniscate guides and traction rods. A pendulum support guides the vehicle body. The bogies are connected to the vehicle body by lift-off safety guards.

### **Further bogie equipment**

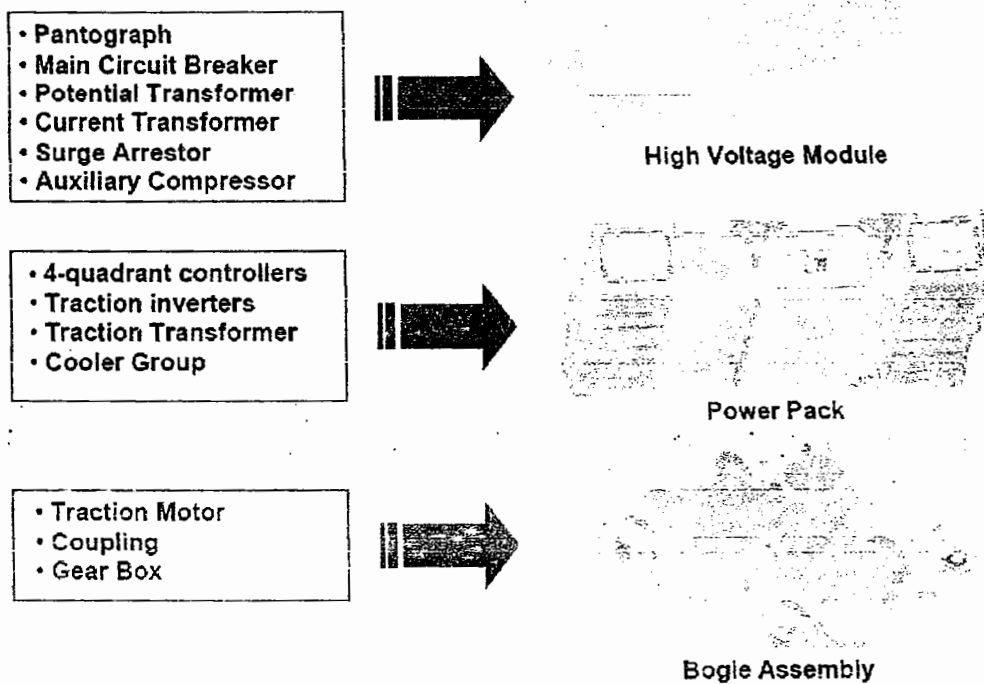
- Axle-mounted disc brakes
- Wheel flange lubrication
- Rotational speed sensor
- Earthing contact for protective earthing
- Track clearer

## 18. TRAIN TRACTION SYSTEM

The proposed traction system is designed to operate in the operating conditions in India between 10° C and +60° C and in severe ambient conditions with rain, snow, and high dust intensity.

The **main units** of the traction system are (all figures and technical parameters preliminary):

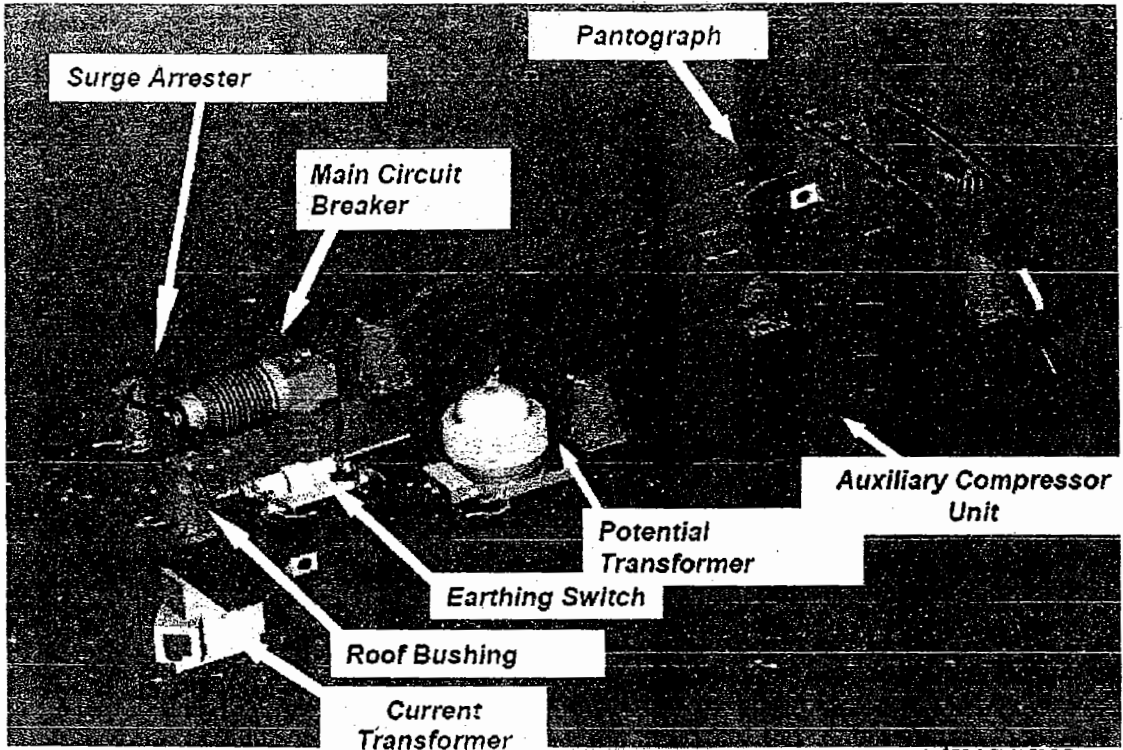
### Modular Traction System



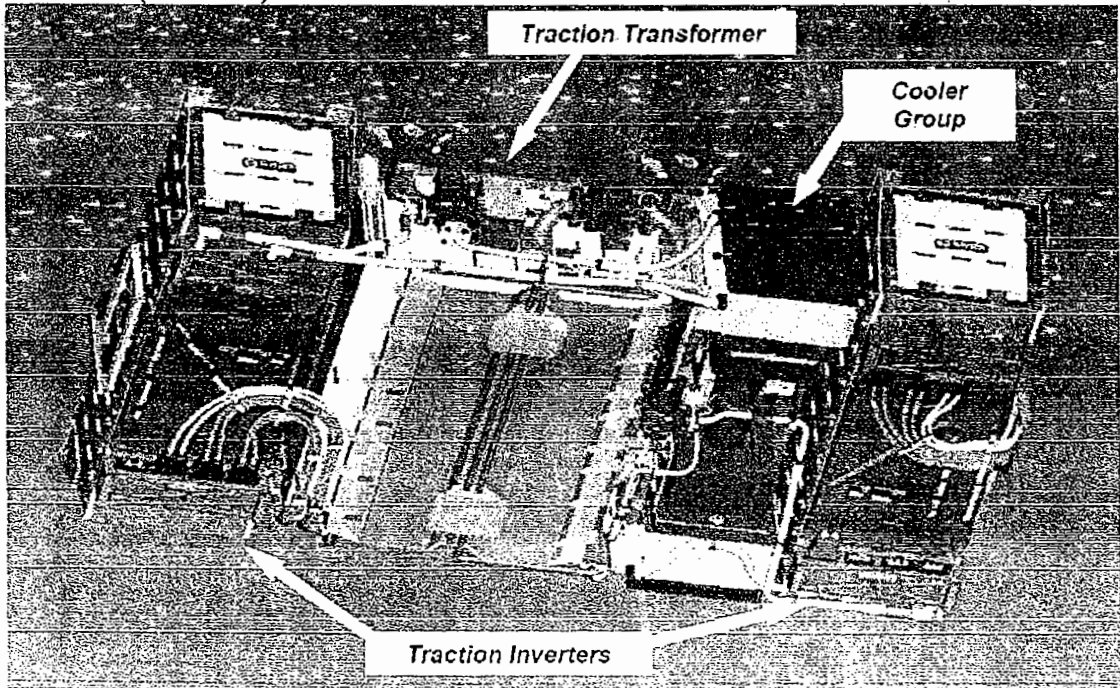
**Advantages of the modular Traction System are:**

- Fewer Interfaces
- Plug-Type cable connections
- Pre-Assembled and tested modules
- Increased quality
- Ease to maintenance

HIGH Voltage Module (Schematic)

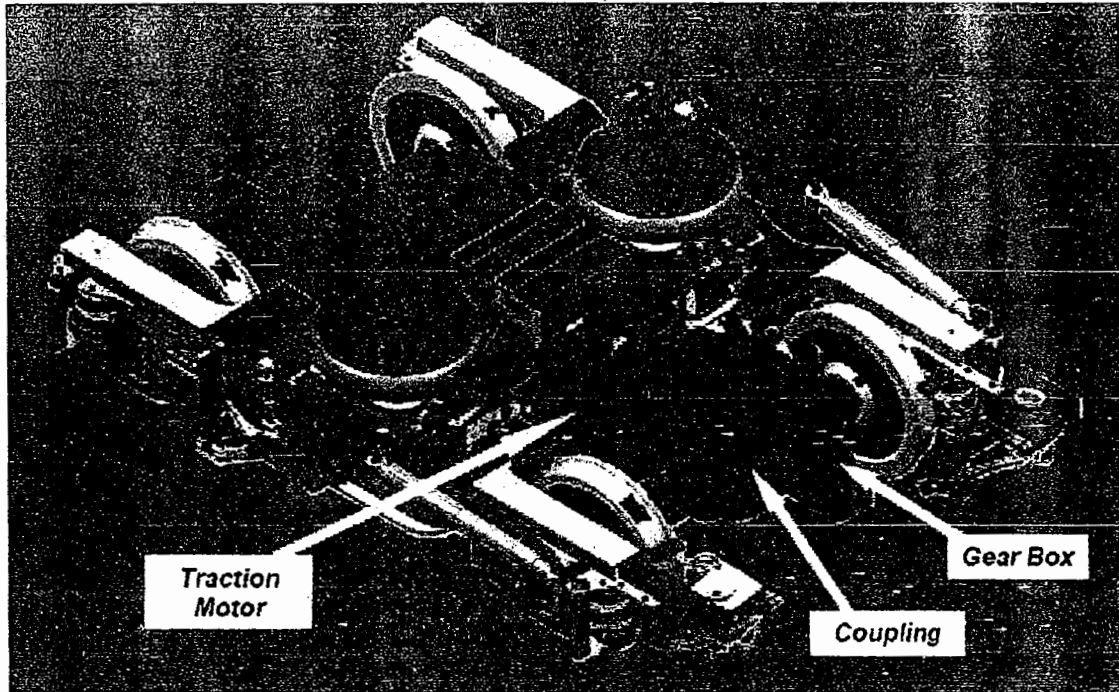


Power Unit (Schematic)

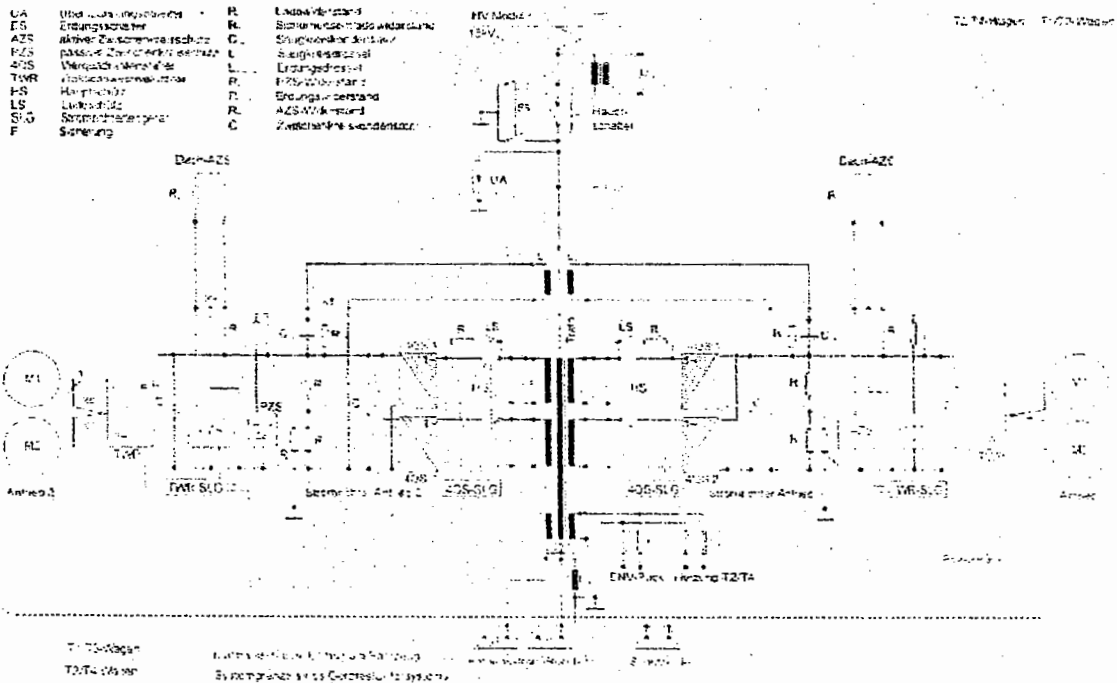




Principle arrangement of traction equipment in bogie



Schematic Diagram of Traction System in B1-Car (B2 without pantograph)



**Location of equipment:**

**B-Car:**

The pantograph mounted on B1 supplies the power-Units of B1 and B2 with High Voltage. Traction Transformer and one Traction Converter for each powered bogie are part of power unit. Break resistors for electric regenerative braking and cooler are mounted on the roof. Both bogies are equipped with traction motors, gear-box and coupling. CPU (ALG) in the LOW-Voltage cupboard in passenger room controls the traction motors and Converters. In 6-Car unit the 2-nd B1-Car has also a pantograph for redundant in case of fault in one High Voltage roof equipment.

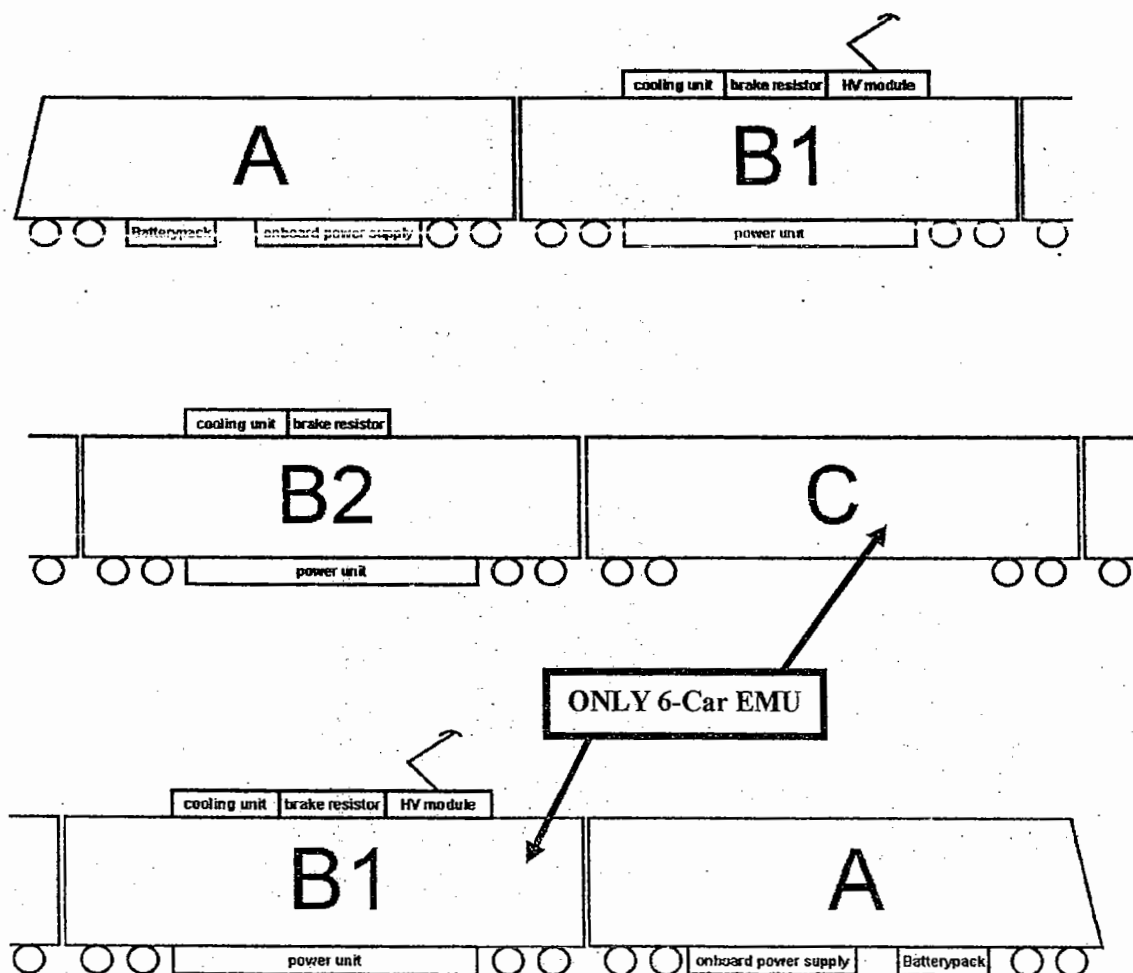
**A-Car:**

CPU (FLG) at drivers cap controls all functional Systems as:

- Signals from/to driver desk (Drive/Brake lever)
- Signals from/to Traction equipment in B-Car
- aso....

On-Board-Power Supply provides 110VDC, 240VAC and 415VAC three phases for Battery charging and all Electrical Systems on board.

**Schema of Traction Equipment arrangement in 4-Car and 6-Car Version:**



Detailed Traction system Specification  
 Main Circuit Schematic Diagram

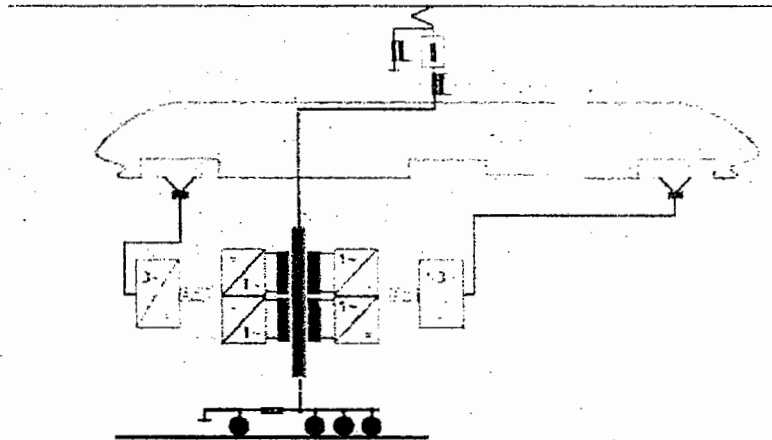


Fig.1 Example of Main Circuit, Every B1 and B2-Car has its own Main Circuit

Primary circuit – High voltage system

The traction transformer is supplied via the pantograph, the main circuit breaker and the primary current transformer. The return current path to the rails is via the vehicle body, the bogies, the earthing brushes and the wheel sets.

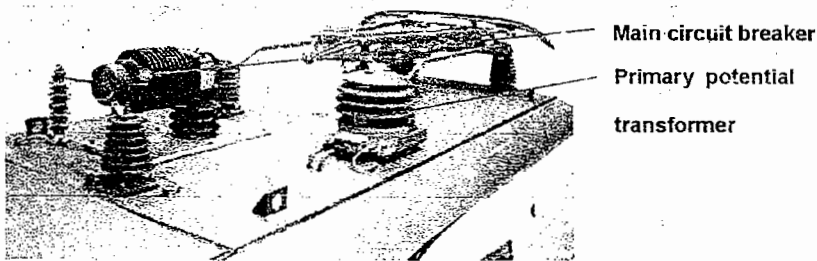


Fig 2: Main circuit breaker with pantograph, mounted on B1-Cars

Earthing switch

The primary winding of the transformer and the pantograph can be earthed by means of a two-pole earthing switch.



Fig.3 Earthing switch (in earthed position)

### Pantograph

The EMU's are equipped with a half-scissor pantograph, type VI-U, with compressed air bellows and pneumatic protection against collapsing .When the protection system has been activated it can only be reset from the roof of the vehicle.



Fig.4 Pantograph

### Main circuit breaker

The vacuum type main circuit breaker is actuated by compressed air. A spring is charged when the circuit breaker is closed .When the tripping circuit is opened the circuit breaker is the spring.

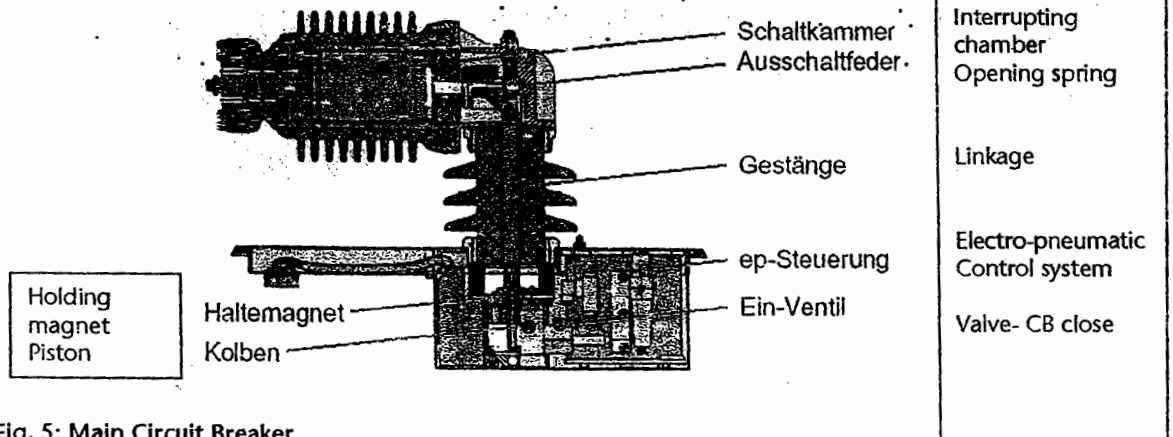


Fig. 5: Main Circuit Breaker

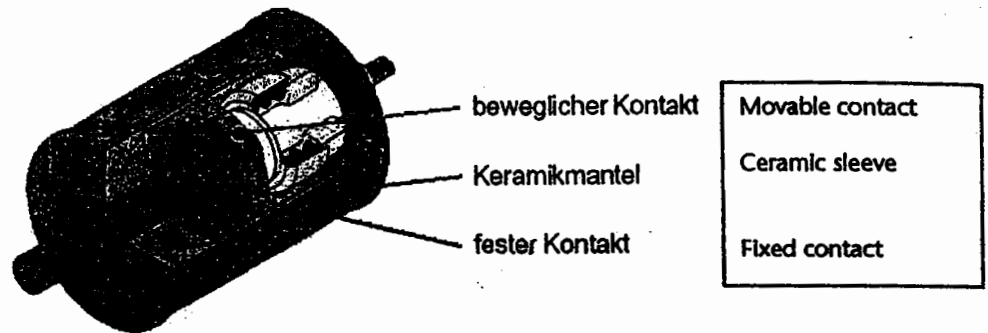


Fig. 6: Main circuit breaker –Vacuum Interrupter chamber

**Transformer**

The oil cooled transformer is installed in the underfloor mounted power pack. A safety valve ensures that oil and gas are discharged into an expansion vessel when gassing occurs, thus avoiding damage to the transformer.  
 Secondary windings:

Traction:	4 x 920 V	4 x 320kVA
On board power supply:	353 V	190 kVA

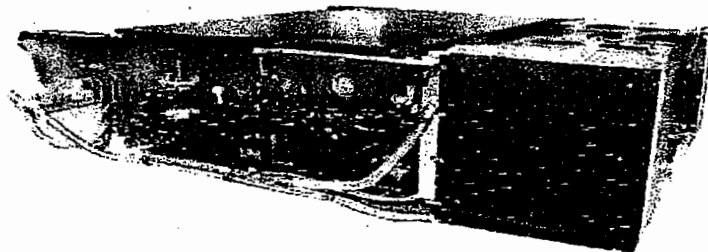


Fig. 7: Transformer with power pack cooler group

**Converters**

The converters are based on IGBT technology. One converter each supplies the traction motors in one powered bogie. It consists of :

- A traction system control unit (ALG) for the control and monitoring of the four-quadrant controllers and an inverter control unit (SLG) for the control and monitoring of the traction inverters.
- Two four-quadrant controllers, supplied from the traction windings of the transformer, which are switched electrically offset. The four-quadrant controllers convert the secondary voltage of the transformer into a direct current supply for the DC link:
  - This arrangement reduces the interference currents to a minimum and a filter choke is therefore not required.
  - The DC link capacitors are charged via a charging resistor and a charging contactor. When the appropriate DC link voltage has been reached the charging resistor is by-passed with the charging contactor. The smoothing of the DC voltage is carried out by means of capacitors and a smoothing choke.



- A traction motor inverter which converts the DC link voltage into a three-phase supply with variable frequency and variable voltage. Each traction motor inverter supplies two traction motors
  - An active DC link protection :
    - The purpose of the DC link protection is to dissipate fleeting voltage surges in the DC link caused by pantograph bounce during dynamic braking- in the roof mounted resistor AZS.
- The electro-dynamic braking force is limited to 70 kN, as the total braking force is distributed among the trailing and driving bogies.

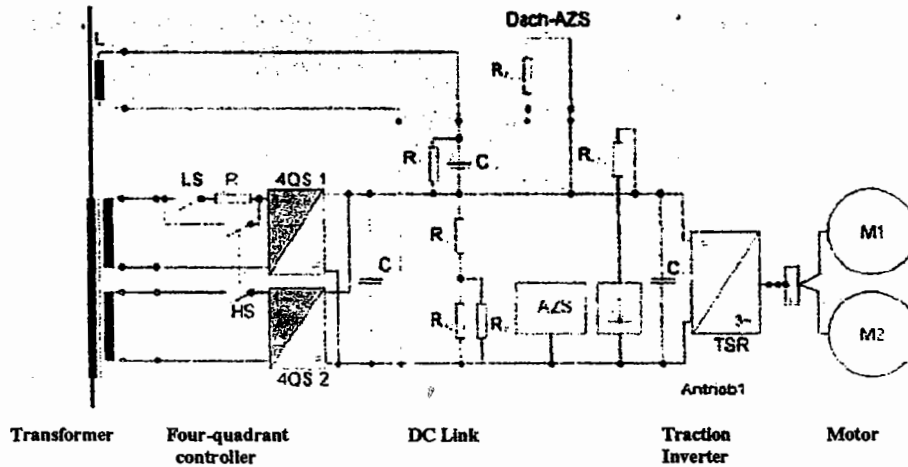


Fig.8: Converter Schematic

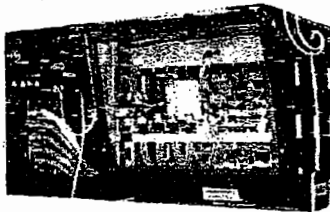


Fig. 9: Inverter.

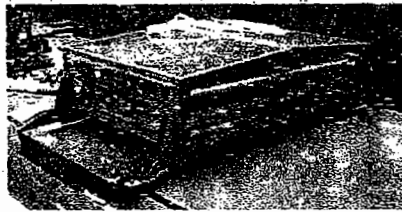


Fig10: Resistor AZS

### Traction Motor

The traction motors are four-pole, three-phase, asynchronous squirrel cage motors.

Rating :

- Continuous rating 340 kW
- Short time rating 380 kW (EMU Class 4024 with Warp Drive)

In the event that one traction motor becomes defective, the traction motor inverter is locked out by the traction system control unit ALG. This feature ensures that both traction motors of one bogie are no

longer available for traction in this event. The traction motors of one bogie cannot be uncoupled mechanically.



Fig.11: Traction motor

## Cooling

### Traction motor cooling

The cooling air for the traction motors is drawn in through an opening in the roof of the vehicle and ducted to the traction motors. The air ducts are located in the side wall panels of the vehicle. The traction motor blowers are radial blowers with a power supply of variable voltage and variable frequency.

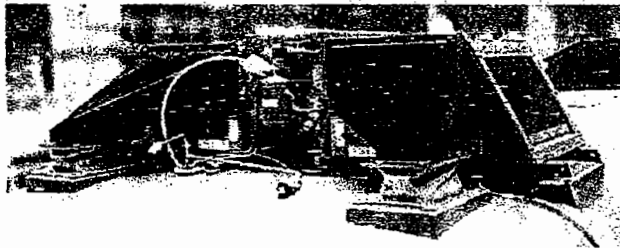


Fig.12: Traction motor blowers

Cooling of transformer and converters

The cooler group for the power pack is a compact unit bolted onto the transformer. The transformer is oil cooled whereas the converters are water cooled.

The core of the cooler group is a twin-circuit radiator for the cooling media water and transformer oil. The cooling air is drawn in at the side of the vehicle and the discharge air is exhausted downward towards the track bed. The air drawn in is filtered by means of a cyclone type filter to prevent the ingress of coarse dust, snow and water.

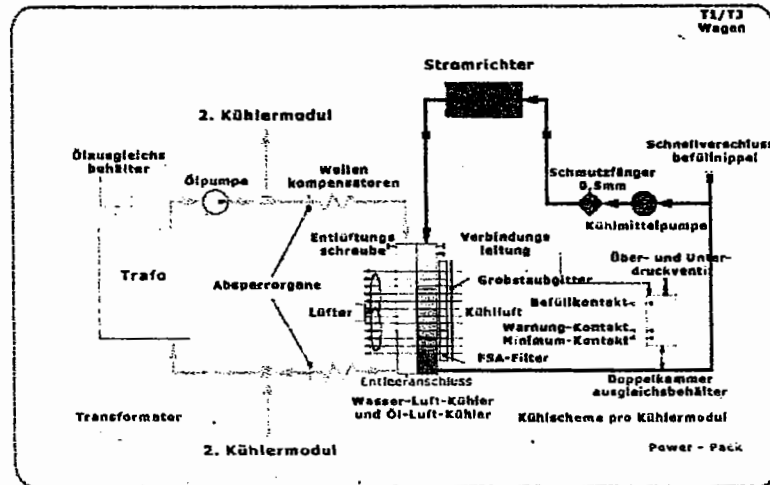


Fig. 13. Cooling circuit

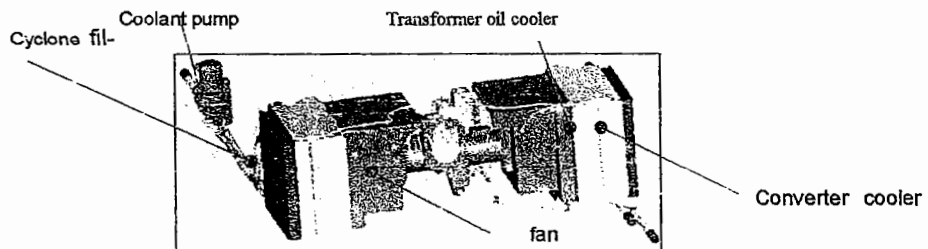


Fig. 14: Power Pack-cooling unit

19. AUXILIARY SYSTEMS

Compressed air supply

The brake Frame in each A-Car is equipped with electric powered double-chamber-compressors which generate the compressed air and supply the main air reservoir in each end car with compressed air of 7-9 bar with 850 l/min. The air supply system consists also of a regenerative, double chamber air drying unit with integrated oil separator, an air filter and an oil/water separator.



### Compressed air piping

The piping for the compressed air is made of VEBEO fittings. Seamless stainless steel pipes are used for the piping.

### Control of the compressed air supply

The compressed air supply system is equipped with pressure switch and safety relief valve protected against over pressure. The pressure in the main air reservoir can be monitored from the driver's cab and via the control system also via the system display.

### Air cleaning system

The compressed air is being cleaned from dirt and particles as well as of oil and water. Each compressor is equipped with regenerative, double chamber air dryer with integrated oil separator. The dryer consist essentially of two chambers with adsorptive desiccant material and integrated oil separator, control magnet valves, two check valves, one regeneration chock, three piston valves and exhaust silencers.

### Air reservoirs

The compressed air is stored in reservoirs from where it powers all the pneumatic consumers connected to the continuous main reservoir pipe.

### Drainage

Each compressed air tank is equipped with a drainage valve.

## 20. BATTERY SYSTEM

The battery system of the EMU consists of a set of batteries with its charging devices in every A-Car. The batteries supply the "vehicle plus" with energy to drive all 110V consumers like

- emergency illumination
- signal illumination
- inside lighting
- control system
- cab radio
- passenger information system
- fans to supply the passenger compartment with fresh air
- traction system
- aso.

The batteries charger is powered by auxilliary converter (in On-Board-Power-Supply). Charger is a 19" rack unit, mounted in the electrical cabinet inside the drivers cab. Each end car is equipped with a single charging device. If one device fails, the other device can load both ends.



## Batteries

The battery box is mounted in the underframe below driver's cab. Protection devices (fuses, overload switches, etc.) are located beside the boxes or in the electrical cabinet directly above. This way the necessary wiring from the auxiliary generator to the battery box and the cabinet will be short.

## Ventilation of battery boxes

The ventilation of the battery boxes is made by self-ventilation via openings in the battery boxes.

## Control of the battery system

The control of the batteries is done by the main control system, which monitors low voltage, charging current, warning of battery charging device, deep discharge and informs the driver via warning on Display and signal lamp.

## 21. CABLING

The cabling is made of halogen free material according to UIC Standards.

All lines and cables are chosen according the expected electric power requirements during operation. The installation is made in such a way that the expected vibrations and shocks occurring during the railway operation have no effect.

## 22. BRAKE SYSTEM

The brake system of the EMU comprises a model KBGM-P automatic, active direct, electro pneumatic brake with load correction and continuously variable control. It includes a purely pneumatic support level using the brake pipe and distributor valve.

The brake system is designed for the following applications:

Service braking	Provided primarily by the electric regenerative brake, blended with the EP brake, maximum deceleration approx. 1.2 m/s <sup>2</sup>
Emergency braking	Maximum brake forces; deceleration approx. 1.4 m/s <sup>2</sup> at 80 km/h. Only use of electro pneumatic brake via the distributor valve.
Parking brake	Spring-actuated cylinders mounted on the brake callipers in the motor bogie (MB)

### Brake control

Each cab contains a master controller to operate the brake system, a duplex pressure gauge to indicate MR and C pressure, an emergency stop button, a switch to operate the parking brake and a "parking brake applied" lamp.

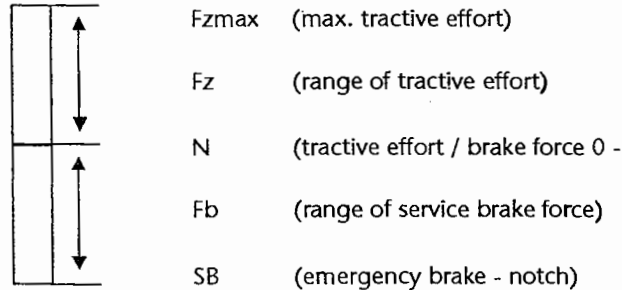


Each A-car and the C-car has a KBMG-P brake control unit. These brake control units operate quite independently and control the brake equipment of the own car and the next B-car.

### Master controller

The master controller or drive/brake controller, which is operated by the cab driver, produces the set-points representing the tractive effort and brake force. These set-points are transmitted to the vehicle controller and the KBGM-P central brake control unit.

The position-dependent master controller can be set as follows:



### Blending

The brake control unit provides for blending with the electric regenerative brake. The aim is to deliver as much of the required braking energy as possible by non-wearing means.

### Emergency braking concept

The EMU has an on-board emergency braking loop. When this loop is opened, the emergency brake contactor takes the brake control unit the non-emergency signal. The brake control unit builds up brake pressure via a second path, acting on the emergency application valves, mounted on the brake manifold panel.

The emergency brake loop can be opened by the driver (with the master controller or emergency stop button), by a passenger (with the emergency brake), or by the ATC or dead-man control.

### Parking brake

The spring parking brake is controlled electro pneumatically from a switch in the driver's cab. The spring-actuated cylinders are integrated in the brake calliper units on the motor bogie and are charged with compressed air to release the spring brake.

Each motor car has a pneumatic spring actuator module to control the spring actuators.



### Disk brakes

The EMU is equipped with state-of-the-art disk brakes. The brake disks are wheel-mounted at all axles. The brake callipers units are a modern, compact design.

The bogie has four gray cast iron brakes disks, each of which is combined with a compact brake calliper unit. Each axle of the motor bogie has a spring actuated parking brake cylinder integrated in a compact calliper unit. The brake shoes have a sept area and snap lock gates for fast pad replacement. The brake pads are the standard organic UIC.

### Wheel slide control

The wheel slide control systems helps optimise slip when wheel-to-rail adhesion is poor. It keeps the wheel sets turning and prevents skidding. The brake cylinder pressure is regulated by anti-skid valves. Each of the driven axles and trailing axles has an anti-skid valve providing wheel slide control on "per axle" basis.

Each of the axles has a single-channel speed sensor and a rotating gear. The axle bearing caps are modified to accommodate the speed sensors.

The electric signals from the speed sensors are processed by the brake control unit. The anti-skid valve will adjust the brake cylinder pressure accordingly if one or more of the wheel sets is found to be sliding. The working principle of the wheel slide control logic is similar to that of the UIC-approved MGS2 wheel slide controller.

### Air suspension

With help of the air suspension it is the aim to give the passengers an improved ride by minimising the dynamic influences. The air spring bellows carrying the car bodies over the bogies cushion the shocks caused by running on rails. The air suspension of the EMU has a "two-step-control".

Each car body has an overflow valve and an isolating cock carrying compressed air from the main reservoir to the suspension system. Each bogie has one levelling valve mounted on the car body. The working lever of these valves is joined to the bogie frame by linkage. The levelling valves control the pressure in the downstream air spring bellows and in the associated auxiliary volumes.

The pressure is regulated according to the load on the connected car body. When a car body is unloaded by passengers alighting, it is lifted because the pressure in the air spring bellows is still constant. When a car body is loaded by passengers boarding the process is reversed and the levelling valve charges the air spring bellows.

Damper between the bogie and car body and small air bores inside the levelling valves eliminate the influence of dynamic movements between the bogies and car body as the train travels along the track.

The pressure in the air spring bellows can be checked at the test fittings for repair and maintenance.



### 23. INTERIOR

The interior of the EMU is modular, design to prevent vandalism and for easy cleaning. Modern panelling materials are used.

Standing room in coach can accommodate at normal crush load 300 passengers (6pers/sqm) up to 375 passengers (8pers/sqm) at crush load. Lots of Handrails assure save condition to all standing Passengers in the coaches.

The Gangway with clear width of 1100mm allows rapid and save passenger flow from on coach to the next.

#### Floor

The floating wooden structure, on which the floor covering is applied, is elastically supported on the car body structure. Between the wooden frame and the car body structure glass wool is laid in for noise and thermal insulation.

For vibration reduction rubber pads are added between the wooden floor and steel structure of the car body and in the space between the seats dampers are added between the wooden floor and steel floor. The floor plate is of plywood with a layer of rubber filled between the two layers of the plywood. This improves the noise isolation of the floor of about 2 dB compared to common plywood. This kind of plywood also has the function of vibration reduction. The floor board is lapped at the joint without any seams for better noise isolation.

The floor covering is abrasion-resistant with anti-skid characteristics. The covering is furthermore wear-resistant, flame resistant, sulphide resistant and chemical resistant and its area-wide clotted. On the borders the floor covering runs out in a curvature to form a tub in order to avoid the leakage of water into the under frame.

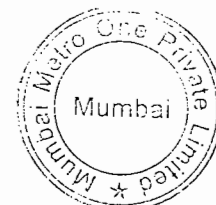
#### Interior decoration

The sidewalls will be built of aluminium honeycomb plates, which are weighted, not apt to deformation and easy to clean. The chosen material has also good noise isolation characteristics. The sidewalls are modular and if possible interchangeable between each other.

The ceiling will be of fibre glass reinforced plastics for both side ceiling and mid-ceiling plate. The invisible outlet port of the air conditioner is placed at the joint between the mid-ceiling plate and side ceiling plate. The flat ceiling plate will be of glass fibre reinforced plastics. The plate of the middle passage is removable and can be used as inspection door.

#### Internal wall

No internal wall is foreseen except for the dividing wall between driver's cab and the passenger compartment. As far as possible the dividing wall will be of safety glass with two layers.





### Seats

Each Coach is fitted with 6 longitudinal benches made out of Stainless Steel which can accommodate 42 seated passengers in a comfortable way.

### Hand holds / hand rails

There are 3 different kinds of handrails inside the car:

- Entrance room  
For entry and exit of passengers at regularly scheduled stops.
- Handhold for standing passengers  
on the roof of passenger compartment are lots of single handholds
- Handhold for standing passengers vertical  
adequate handholds for standing passengers are provided through vertical grab poles

The strength of hand rails meets the requirements of the UIC566 standard.

## 24. INTERIOR LIGHTING SYSTEM

The lighting of passenger compartment and vestibule uses 240 V fluorescent lamps powered by inverters which convert DC 110V supply into AC supply. Every lamp has an inverter.

The illumination of passenger compartment and driver's cab meets UIC 555.

For low energy consumption the lighting is cut in two lines which illuminate the compartment direct and indirect.

In entrance rooms separate fluorescent lamps support the general illumination.

There are three different modes of lighting: Full – Half - Emergency light

### Emergency Lighting

Emergency lights are DC 110V lamp.

As the fluorescent lamps will turn off automatically when the supply system has trouble, the emergency lamps will be powered directly by batteries for a certain time.

## 25. CONTROL SYSTEM

Each end A-vehicle is equipped with a Main-Control-Unit, each B-vehicle is equipped with a Traction-Control-Unit. All control units are connected via train-bus. The subsystems are connected to the Control-Units over Decentral-Controls or by hard wiring.

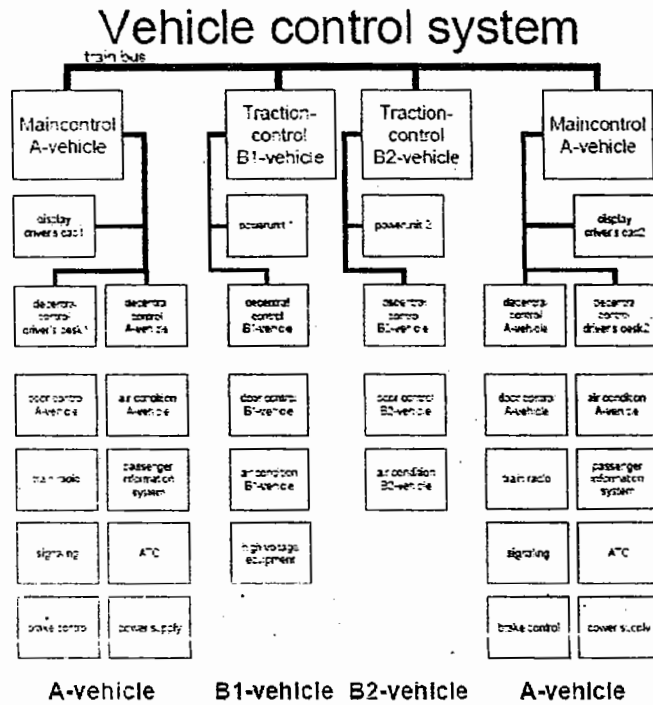
The diagnostic events of each vehicle in the train are displayed and stored on the Driver's Display.



The control system is qualified to realize applications up to SIL 3.

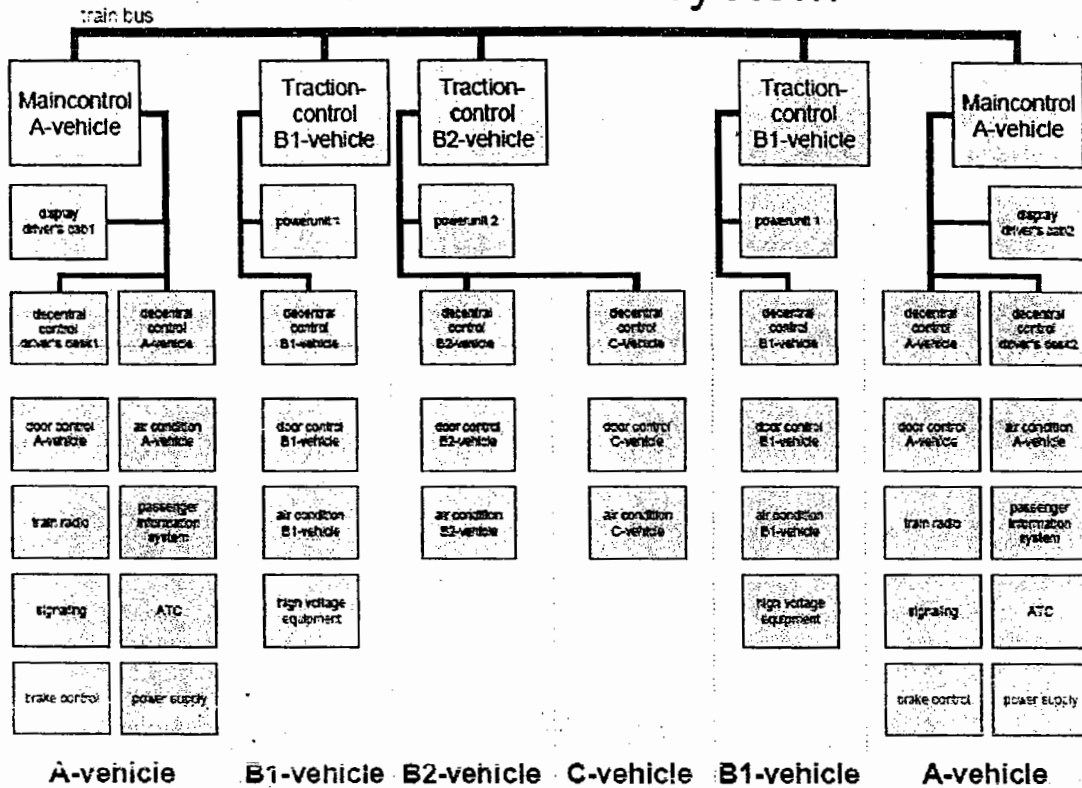
The application program is designed according to international quality and safety standards such as ISO 9001 rev 2000 and EN50128.

Proposed schematics of the Vehicle control system of a 4 car vehicle:



Proposed schematics of the Vehicle control system of a 6 car vehicle:

# Vehicle control system



The following chapters include a functional description of the main control of the EMU:

## Entering the vehicle

The driver or the train staffs are able to enter a deactivated vehicle through the passenger doors of the A-vehicle by using one of the key switches at the outside of the car.

## Vehicle activation and deactivation

By switching the activation switch the power supply of the control-system and the subsystems is turned on. If the temperature of the control system is within its specified temperature range it will start up automatically if not it is necessary to activate the automatic preheating.

The control system will stay active as long as the power supply or the Battery-Voltage is OK unless it is deactivated by switching the deactivation switch. The deactivation process is automated as well so that all subsystems can finish their proper power down procedure before the power supply is switched off.



### Operating mode

If the vehicle is activated and in the ready for operation mode the driver can put it in the operating mode by switching the key switch on the driver's desk he will use for operating the train. With this action all controls of this driver's desk are activated. On the other Driver's desk only specified controls such as emergency break or emergency turn off are activated, all the other controls are inactive as to avoid mis-operation.

### High voltage equipment

The pantograph of the B1-vehicle can be raised by pressing the "pantograph up button" on the activated driver's desk. If the catenary wire voltage is OK the power switch can be turned on by pressing the "power switch on button" on the activated driver's desk. If the primary current exceeds a certain limit or if the catenary wire voltage falls under a defined limit the power switch will open automatically as to prevent damage to the system. The high voltage supply is connected to the power units of B1- and B2-vehicle. If one of the emergency turn off switches of the train is pressed the power switch is turned off and the pantograph is lowered.

### Driving direction

The driving direction of the train is affected by the driving direction switch on the activated driver's desk. The driving direction can only be changed in standstill of the train. If the driver changes the driver's desk the driving direction stays stored until the other driver's desk is activated.

### Traction effort

The traction effort of the two power units in the train is controlled by the control lever on the activated driver's desk. The traction effort is turned off automatically if the braking pressure exceeds a certain level, the pressure of the main brake pipe falls under a certain level, a door is opened or a fatal error occurs. Traction effort can only be turned on again if the reason for turning it off is gone and the control lever is moved back to 0.

### Braking system

The braking system is controlled by its own control system. Only Fatal Errors, warnings and maintenance indications are submitted to the main control system. The pressure values of the air supply, the main brake pipe and the pressures of the brake cylinders are displayed on the driver's display. To reduce the wear of the brake disks the brake control uses the electric regenerative brake. This function is called blending.

The spring-operated brakes of the train can be set and released on the activated driver's desk. In Standstill all spring-operated brakes are set automatically if the driver's desk is deactivated.

### Door control

The vehicles are equipped with sliding doors.

The opening of the passenger doors is controlled by a rotary switch on the activated driver's desk. The driver can select left side open, right side open, both side open, non open. The enabled doors can only



be opened in standstill. With two push buttons the driver can force all selected doors to open and all doors to close. In Standstill the passengers can open an enabled door by pressing the door open switch mounted on the inside and the outside of the wing of the door. Open doors close automatically after a specified period of time.

The closing operation of each door is indicated by an acoustic device mounted near the door. In case of emergency even blocked doors can be opened by a mechanical emergency open handle mounted on the inside and the outside of the car body near each door. Doors with malfunctions can be mechanically locked. Traction effort can only be switched on if all doors of the train are closed and blocked or mechanically locked.

All Fatal Errors, warnings and maintenance indications are submitted to the main control system.

### Signal lighting

The signal lighting is switched automatically according to the chosen driving direction. The automatic signal lighting can be overruled manually by a rotary switch in each driver's cab.

### System Display

It shows all fatal errors, warnings and useful information to the driver.

Information on Display:

- Traction (Traction free or details information about the reason why the car is not allowed to drive)
- doors (open, closed, Error)
- Power units (coolant temp., Transformer temperature, traction effort)
- Transmission system
- speed
- Battery information (Voltage, charging, ...)
- Brake status

### Dead-man device

The installed dead-man system is designed according to UIC 641.

This device controls the driver when the train speed is more than 20 km/h and works on time base. (If required less than 20 km/h value can be set later).

If the driver doesn't press the push button or the footswitch for 2.5 seconds a signal lamp will appear and an acoustic signal reminds the driver.

After further 2.5 seconds tractive effort is shutdown and an automatic brake stops the train.

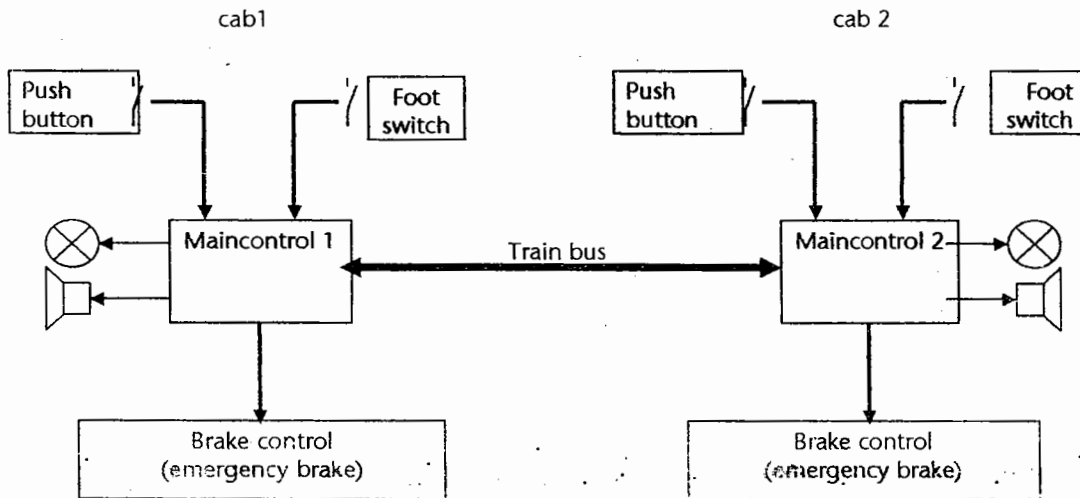
The same function will be applied if the driver presses the button longer than 30 sec.

When the driver operates one of the two controls the function will be reset.



The dead-man system consists of:

- Push button (operated by hand)
- Foot switch
- Light indicator (yellow)
- Loudspeaker
- Input and output signals of the main controller
- Input signals in the brake control system



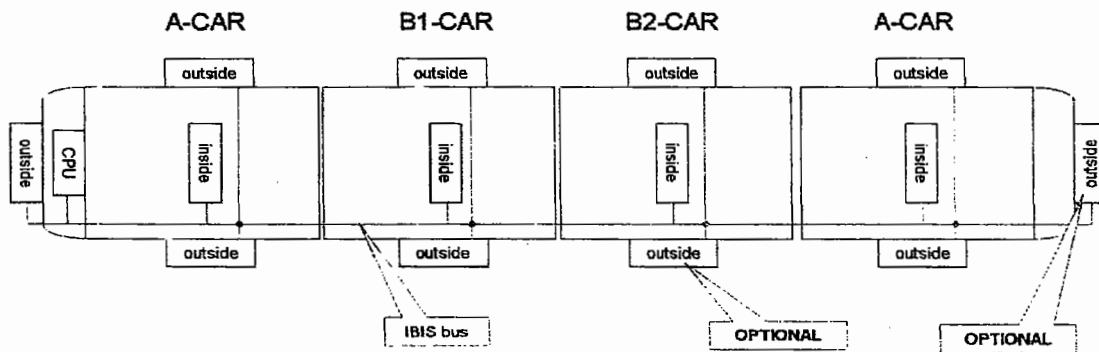


**Functional description**

The driver enters the train number in the respective window of the MMI so that the correct train destination and stops are indicated on the displays. In the memory of the CPU the information of every destination corresponding to the used train number are stored. The CPU transmits the destination information to the displays via the IBIS Bus. The text shown on the displays is free programmable according to the operators needs and requirements within the limits of the system. The displays have discrete addresses, so every display can show individual texts.

The CPU also starts the announcements of the ELA via an IBIS interface.

**Passenger Information Sytem (destination Displays)**



In... Inside LED Displays  
Out... Outside LED Displays

In 6-Car version: addition C-Car an B1-Car with the same equipment as in B-Cars.





## 28. TRAIN RADIO COMBINED WITH DRIVER-PASSENGER INTERCOM SYSTEM

The device provides the following functions:

- Train Radio
- Select switch Train-Radio <> Passenger Intercom
- Announcements driver – passengers outside
- Communication passenger – driver
- Cab-to-cab communication
- Option: Automatic announcements of the next train stop
- Option: Music broadcasting

The device consists of:

- Train Radio
- Loudspeaker in drivers cab
- Microphone in drivers cab
- Loudspeakers in the passenger compartment
- Loudspeakers at the doors outside the car at the doors
- Operating elements for the driver
- Two central units (one master and one Slave)

### Functional description

Microphone and monitor speaker in the cab are shared with the radio system and the mode changed to passenger intercom by the selecting switch.

The driver can activate the announcements and the cab-to-cab communication by push button.

If a passenger wants to talk to the driver he needs to activate the emergency call unit located in each entrance area. The call will be automatically transmitted on the cab loudspeaker. The driver has to push a button to answer the call. If another emergency call arrives, the first call has to be completed before the next call can be activated.

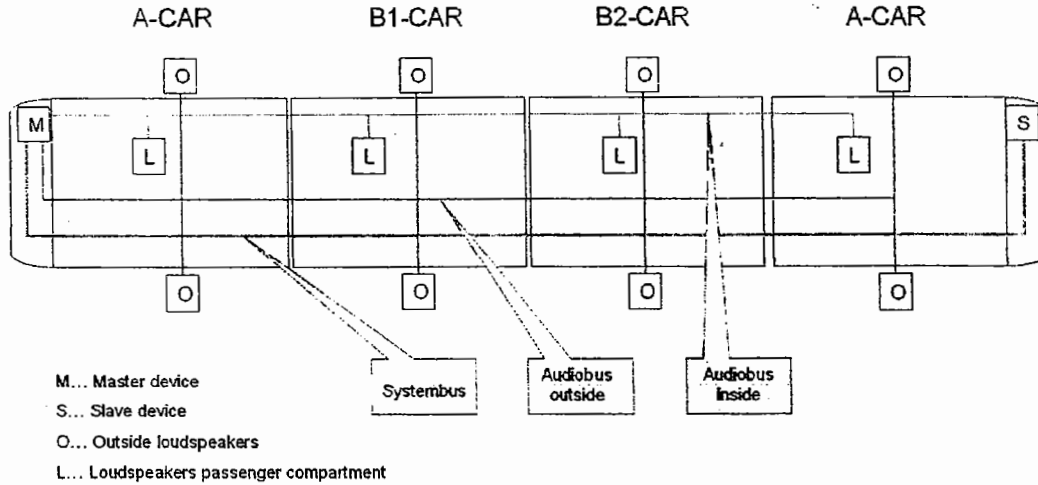
The master or the slave device (depending on the activated cab) activates the selected function. The driver has a microphone with an integrated push-to-talk button to make his announcements and to answer emergency calls.

The automatic train stop announcements are activated by the RBL system. The announcements will be started approximately 800 meters before the next stop.

The music can be entered in the system by an external CD-Player or radio (option).



# Passenger Information System (ELA)



In 6-Car version: addition C-Car and B1-Car with the same equipment as in B-Cars.

## 29. AIR CONDITION

Each coach is provided with two numbers of high performance air conditioning units of adequate cooling capacity each.

The temperature inside passenger compartment is controlled automatically by AC-Control unit inside the Low Voltage cupboard.

Under normal conditions the temperature will be 25°C. At external ambient temp. above 35°C a temperature differential of 10°C is maintained to prevent passengers experiencing "thermal shock"

In Case of an emergency without working Air condition suitably designed blowers provided enough fresh air for passengers. These blowers are powered direct by batteries.

## 30. FIRE PROTECTION

The rolling stock will be provided with all the fire prevention measures contained in the "Code of Practice for Prevention of Fires on EMU Stock" published by RDSO with latest amendments.

All cables and wirings will be of proven fire retardant, low smoke and halogen free type. All significant cable runs are protected by MCBs and Fuses. Inflammability and smoke parameters confirms to the specifications contained in relevant National / International standards.

The coach floor, walls including doors and both sides of any equipment areas within the coach body and the rear walls of the Drivers cab have adequate fire barriers of required duration as per the internationally accepted standards.

An adequate number of fire extinguishers is pasted inside passenger compartments an drivers cap.



# CHAPTER 1

## SERVICE REQUIREMENTS

### 1.1 Planned Train Services on the MRTS and Airport Line

- 1.1.1 The train service will initially operate from Versova to Ghatkopar. The service will start at Versova and continue to DN Nagar, Azad Nagar, Andheri, WEH, Chakala, Airport Road, Marol Naka, Sakinaka, Subhash Nagar, Asalpha Road and terminate at Ghatkopar. The Airport train service will be diverted from Airport Road and terminate at Sahar Airport. A bifurcated service will be operated from Airport Road to Ghatkopar eastwards and to Sahar Airport in the South. Depending on the passenger demand in 2011, every two to six trains will go to Ghatkopar with one train going to Sahar Airport. When the passenger demand to the Airport grows and the passenger demand going to both Ghatkopar and the Airport are nearly the same, alternate trains between Versova and Airport Road can be operated to Ghatkopar and Sahar Airport respectively.
- 1.1.2 At Andheri and Ghatkopar stations, covered sky walk of adequate length and width will be provided for dispersal of passengers between Andheri metro and Andheri suburban station as well as Ghatkopar station in consultation with railway authorities and MMRDA.
- 1.1.3 Integration with other modes of travel –
- So far as integration with other modes of transport at the above stations, adequate planning of the circulating area adjoining the stations, to provide facilities for bus depots, taxi stands, car parking and free movement of passengers will be planned in consultation with other authorities.
  - In this connection MMRDA may have to co-ordinate with other authorities to acquire adequate land and shifting/removal of existing structures at their own costs. Special lighting arrangements also have to be provided by these organizations for smooth operation of traffic during nighttime.

### 1.2 Journey Time

- 1.2.1 The precise end to end journey time will be determined when all alignment and rolling stock performance details are fixed. The target is to limit the journey time between Versova and Ghatkopar within 21 minutes including halt/dwell time. Average scheduled speed of trains on Versova – Andheri – Ghatkopar section with 10 intermediate stations will not be less than 33kmph.



### 1.3 Hours of Operation

- 1.3.1 The revenue service will last from 05:30 in the morning until 24:00 of the day, operating for a period of 19.5 hours each day. The expected peak hours are from 08:00 to 13:00 and 17:00 to 22:00 Hrs.

### 1.4 Service Level and Fleet Size

#### 1.4.1 Initial Service Level in 2011

The minimum train service headway from Versova will be 4 minutes during peak hours and 8 minutes during non-peak hours as required in the Technical and Performance Specifications. The train service to Sahar Airport will also operate at the same time if required resulting in a bifurcated service running from Airport Road to Ghatkopar and to Sahar Airport in the south. It is expected that the passengers demand to the Airport will be lower than the demand to Ghatkopar and every two to six trains will go to Ghatkopar with one train going to Sahar Airport. In order to achieve this service interval, 11 x 4-car trains for the peak hours are expected to be required for service with two spare 4-car trains bringing the total to 13 x 4-car trains.

#### 1.4.2 Ultimate Service Level in 2041

The ultimate passenger demand anticipated on the MRTS requires 3 minutes service headway with 6-car trains during peak hours. In order to achieve this service interval, 15 x 6-car trains for the peak period are expected to be required. A minimum of 2 x 6-car trains will be required as spares bring the total train fleet to 17 x 6-car trains for the service between Versova and Ghatkopar/ Sahar Airport.

#### 1.4.3 Summary of Service Level Forecast and Fleet Size Expansion

Year	Passengers per hour per direction	Headway in Peak Hour (minutes)	Total No. of Rakes (including spare trains)	Cars per Rake
2011	18600	4.0	13	4 - Cars
2021	23600	3.25	16	4 - Cars
2031	30500	3.5	14	6 - Cars

2041	39500	3.0	17	6 - Cars
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The detailed fleet size calculation is included in Chapter 10 – Rolling Stock. The exact timing of service level growth and upgrading from 4-car to 6-car trains will depend on the travel demand assessment.

## 1.5 Safety and Reliability

### 1.5.1 Safety

1.5.1.1 The design of MRTS will employ best design practices to minimise the potential for accidents to passengers on stations and in trains. The stations will be designed to minimise the risk of fire in accordance with N.B Code, NFPA norms and local fire safety guidelines / regulations. The layout of the station will be devised so that the passengers can be evacuated quickly and safely by an immediately obvious route including through AFC gates. For emergency evacuation of a train, provision will be made to clear the platform in 4 min.

1.5.1.2 In the event of a power outage, all train and station systems and services which are vital to safety must be provided with a back-up power supply, so that, if necessary, the passengers may be evacuated without their health or well-being being significantly impaired.

1.5.1.3 A set of emergency procedures will be formulated to deal with different emergency situations. These will be included in Disaster Management Manual.

### 1.5.2 Service Reliability and Availability

1.5.2.1 The equipment for the MRTS will be of a robust design. Every effort will be made to improve reliability of equipment where this can be done at reasonable cost. The target is that the overall availability of services will not be less than 97% during 1<sup>st</sup> year of operation. During 2<sup>nd</sup> and subsequent years, target service availability will be at least 99%. The MKBF will not be less than 100,000km.

1.5.2.2 Ventilation, air conditioning, fire fighting, fire alarm, electrical, lighting, water, plumbing, drainage and SCADA/BMS for the Stations, Depot, workshops, yard, substations, Administration Building and OCC will, as a minimum, be provided, in accordance with the requirement.

### 1.5.3 Restoration of Service

1.5.3.1 The system will be designed so that, where a fault occurs, a limited service can be provided within a few minutes by isolation of the affected area or equipment, to the extent possible.



1.5.3.2 Emergency cross-overs will be provided at suitable locations to cater for such requirements. The details will be elaborated in Chapter 3 – Alignment.

1.5.4 Bi-directional Signaling

1.5.4.1 Bi-directional signalling will be considered where appropriate to enhance the flexibility of train movement during incident recovery.



## CHAPTER - 2

### SITE VISIT REPORT

#### 2.1 Introduction

2.1.1 The entire section between Versova to Ghatkopar and Sahar Airport, as well as depot sites has been inspected by the study team. In general, there are a number of generic concerns on the alignment as proposed by MMRDA. They include (not exhaustive though):

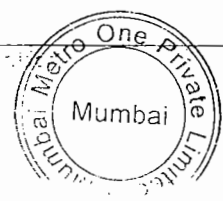
- The acquisition of land which has been designated for the MRTS and the time necessarily required for this process.
- The extent of the advance works required such as the widening of the roads to accommodate the track alignment.
- Provision of supporting portals to suit the proposed railway alignment.
- Locations requiring diversion of underground utility services.
- Transportation of rolling stock to depot site and lifting the same onto the elevated tracks.
- Erection of girders at road junction as well as the need of portal structures at very busy road junction together with the construction of station building at very congested site.
- The need to coordinate traffic flow, safety and environment issues during construction.

2.1.2 A number of critical locations along the alignment which can have significant effects during the construction stage have also been identified. They are shown in Figure 2.1 and briefly described as follow:

- The narrow width of the road and heavily congested commercial area between Navarang Cinema to Andheri Station on the west and up to M.V. Road on the east.



- The stipulation that the proposed alignment has to cross Western Express Highway (WEH) can only be achieved through the use of long span bridge (>60 metres) at high elevation over the existing Andheri fly-over. This will have significant impacts resulting in the increased height of approach piers.
- The construction of the elevated structure to cross the railway tracks at Andheri will require the approval from Western Railway Authorities on the structural design. The works to be undertaken will also be carried out under the technical supervision of the railway authority and that continuous coordination will be necessary.
- The provision of a bifurcation train service between Airport Road Station to Sahar Airport.
- The very hilly terrain and narrow roads together with the requirements of sharp curves along the proposed alignment in the vicinity of Asalpha Area.





## CHAPTER – 3

### ALIGNMENTS

#### 3.1 Alignments

3.1.1 The proposed alignments as indicated by MMRDA in their revised drawing, commences at Chainage W 3.732 from a point on the western edge of Seven Bungalow – Versova Road on the western side of Dadabhai Navroji Gardens and crosses through a large number of structures needing dismantling, till it joins J.P. Road at a distance of 200 meters from the commencement.

3.1.2 Thereafter the alignment extends along the centre-line of the J.P. Road for a distance of 0.6 KM up to Versova Station which is located at Chainage W 3.139 km. (0 Chainage is located at east side of Railway track at Andheri). The J.P. Road is being widened to 36 meters and the work is in progress.

3.1.3. The important road junctions crossed by the alignment on the J.P. Road are:

- a) Lokhandwala Junction, where the approach to D.N. Nagar platform is provided by having an elevated station at the intersection of Lokhandwala Road.
- b) The link road where the alignment will be crossed by the future MRTS north-south corridor.
- c) S.V. Road near approach of Western Railway tracks.

On all these road crossings, longer spans of 31 meters are proposed for the permanent structure.

3.1.4 The alignment crosses Western Railway tracks at Chainage W 30 with provision of 59 meters span. Adequate clearance of 6.5 meters over the railway tracks has been catered for.

3.1.5 Andheri station has been located at Chainage E 0.052 with approach to M.V. Road. The Andheri Station layout will be compatible with, and make provision for the planned MUIP Flyover at the same location. The conceptual layout which incorporates entrusted Works to



be performed by the Concessionaire, and for which compensation will be made, will be provided during the proposed meeting to discuss civil works.

- 3.1.6 The approach to existing Western Railway Andheri station from the proposed elevated Andheri Station would be via Mathurdas Vissanji Road (leading to Andheri Station) and the distance traveled would be around 300 meters. Thereafter the alignment extends along the M.V. Road up to the Western Express Highway with the crossing of 60 meters span at Chainage about 870. There after entering Western Express Highway station at Chainage E 995. After crossing Western Express Highway Station the alignment extends across the Cardinal Gracious Marg and Mahakali Gumpah Road with provision of 31 meters and 40 meters spans. The alignment there after extends to Chakala Road station at Chainage E 2.279 kms. On either end of the station, cross roads connecting the M.V.Road need little modification for diversion of traffic. After Chakala Station the alignment extends further towards east along the centre line of the M.V.Road to Airport Road station located at Chainage E 3.014 kms. After crossing Airport Road station a turnout is provided for diverting the alignment towards Sahar International Airport Station at Chainage E 3240.
- 3.1.7 The main alignment toward Ghatkopar is extended along the M.V.Road with station at Marol Naka at Chainage E 3.660. Marol Naka is an important location where all industrial activities for SEEPZ area and other offices and industries have been located. Thereafter the alignment extends towards Sakinaka by crossing the Saki Vihar Road with a span 40 meters. The Sakinaka Station has been located at Chainage E 4.696. Beyond Sakinaka Road station the alignment extends towards Ghatkopar via Asalpha village along Andheri-Ghatkopar Road.
- 3.1.8 Subhash Nagar station is located at Chainage E 6.047. Alignment involves a series of reverse curves on approaches of Asalpha Station at Chainage E 6.788 kms. Beyond Asalpha Station the alignment takes sharp curve of 100 meters radius at Chainage E 7.236 kms. near Sarvodaya Municipal Hospital and then crosses L.B.S.Marg at Chainage E 7.481 kms..
- 3.1.9 Thereafter alignment extends along Hirachand Desai Road crossing J.V.Road at Chainage E 7.770 with a span of 31 meters and terminates at Ghatkopar Station at Chainage E 7.786 kms.. The end of the station terminates at Chainage E 7.856 kms. adjoining road on the western side of Central Railway tracks at Ghatkopar Station on platform number 1.
- 3.1.10 The total length of the track on the western side from Chainage 0 at Andheri Station West to Chainage W 3.732 kms. towards Versova and the track length on the eastern site towards Ghatkopar Station extends up to Chainage E 7.856 kms. making the total track length of 11.588 kms. excluding the airport lines and the car shed lines.



3.1.11 The Airport Branch has been deferred. All references to the Airport Branch in the RFP are hereby omitted. However, the Airport Road Station Layout will provide for future extension to the airport for services from Versova end only.

3.1.12 Thus the total Corridor length is 11.588 kms.

3.1.13 The depot at D.N. Nagar will be elevated with entry / exit connections from Versova end. The area above and below the elevated depot will be utilized for service and offices and other facilities needed for operation and maintenance of the corridor. Control office and the administrative office required for the management of this corridor will be located at the upper floors above the elevated depot. The open area on the ground outside the elevated depot will be utilized for construction, infrastructure and mobilization, girder segments casting yard and storage yard etc. and on completion of the project the area will be utilized for permanent accommodation of the essential staff required for emergency operation and maintenance of the railway corridor.

3.1.14 The single line track length involved from entry to depot to main line connection towards Versova is 200 meters.

3.1.15 The alignment of the MRTS and the MUIP between Asapha Station and Ghatkopar station have been changed to incorporate compatible MUIP and MRTS layouts. For clarity, please confirm here that the elevated alignment of the way structure at Asapha would continue to be in the same vertical alignment as planned in Technical submission.

3.1.16 WEH Station - the current vertical height of WEH station shown on the RFP drawings appears excessive and escalators will be provided for downward movement of passengers. However, the vertical alignment can be optimized to best suit the operator's requirements.

3.1.17 Emergency cross-over will be provided in accordance with the submitted track schematic. That the turn round facilities will be provided in accordance with the submitted track schematic and will include provision for stabling a crippled train

## 3.2 Curves

3.2.1 The alignment will have curves of radius between 100 - 5000 meters and the curve length varies from 10 - 200 meters.

3.2.2.1 The transition length will be provided to all curves varying from length 10 to 80 meters on either side of the curve based on the following design criterion:



- Rate of change of cant (des max 37.5mm/s, abs max 55mm/s)
- Rate of change of cant deficiency (des max 37.5mm/s, abs max 55mm/s)
- cant gradient (max 1 in 440, min 1 in 1000)

3.2.3 Lists of curves along the alignments have been indicated in Table 3.1.

3.2.4 The maximum applied cant on circular curves will be limited to 150mm with maximum cant deficiency limited to 65mm.

### 3.3 Gradients

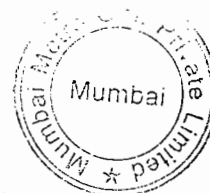
3.3.1 List of gradients along the alignments have been given Table 3.2 with the steepest gradient is 3.2% for a length of 375 metres.



TABLE 3.1

**List of Curves MRTS Corridor  
Versova – Andheri -Ghatkopar**

Curve No.	Start Ch	End Ch	Radius	Curve Length	Transition Curve Length	Shift Length
1	W3584	W3483	650	30.69	35	38.535
2	W3445	W3360	1168	35.07	25	0.008
3	W3360	W3194	150	55.66	55	68.024
4	W3136	W3020	1100	56.39	25	0.012
5	W3020	W2925	898	34.28	30	0.012
6	W1858	W1808	7000	29.85	10	115.504
7	W1692	W1540	457	42.13	55	0.009
8	W1540	W1404	425	26.53	55	25.073
9	W1379	W1319	3000	39.22	10	66.364
10	W1253	W1193	2500	29.98	15	83.167
11	W1100	W803	275	196.63	55	0.072
12	W803	W659	121	34.33	55	83.007
13	W576	W491	930	25.21	30	65.739
14	W425	W334	900	30.52	30	79.525
15	W225	W201	5000	34.4	10	186.547
16	W14	E61	2000	61.31	15	107.19
17	E184	E243	2700	29.2	15	151.128
18	E394	E487	2000	63.43	15	127.934
19	E657	E686	4000	50.31	10	382.981
20	E1069	E1321	400	142.38	55	59.504
21	E1380	E1603	500	143.31	40	29.638
22	E1633	E1731	750	38.04	30	137.56
23	E1868	E2029	500	80.14	40	128.357
24	E2157	E2213	3500	35.62	10	59.504
25	E2272	E2369	2500	67.19	15	174.637
26	E2544	E2599	2000	25.44	15	166.041
27	E2755	E2858	800	32.61	30	381.764
28	E3240	E3288	3000	27.78	10	442.578
29	E3730	E3871	270	31.07	55	73.53
30	E3945	E4250	300	195.82	55	78.334
31	E4329	E4381	4000	32.18	10	86.23
32	E4522	E4612	250	34.42	55	62.445
33	E4674	E4823	1000	98.41	25	66.581
34	E4889	E4980	800	30.65	30	74.539
35	E5054	E5204	300	38.98	55	525.776
36	E5406	E5692	400	125.73	55	355.549
37	E6040	E6122	2500	44.97	15	149.777
38	E6272	E6417	252	34.53	55	0.03
39	E6417	E6556	185.3	29.13	55	0.048
40	E6556	E6662	706	25.83	40	273.204
41	E6935	E7078	225	33.26	55	103.149
42	E7181	E7043	100	111.29	55	78.136
43	E7481	E7565	1500	44.51	20	193.731
44	E7559	E7813	5500	33.56	10	193.731



**TABLE 3.2**  
**Gradients between Andheri – Versova West Side**  
**Details of Gradients from Versova to Andheri**

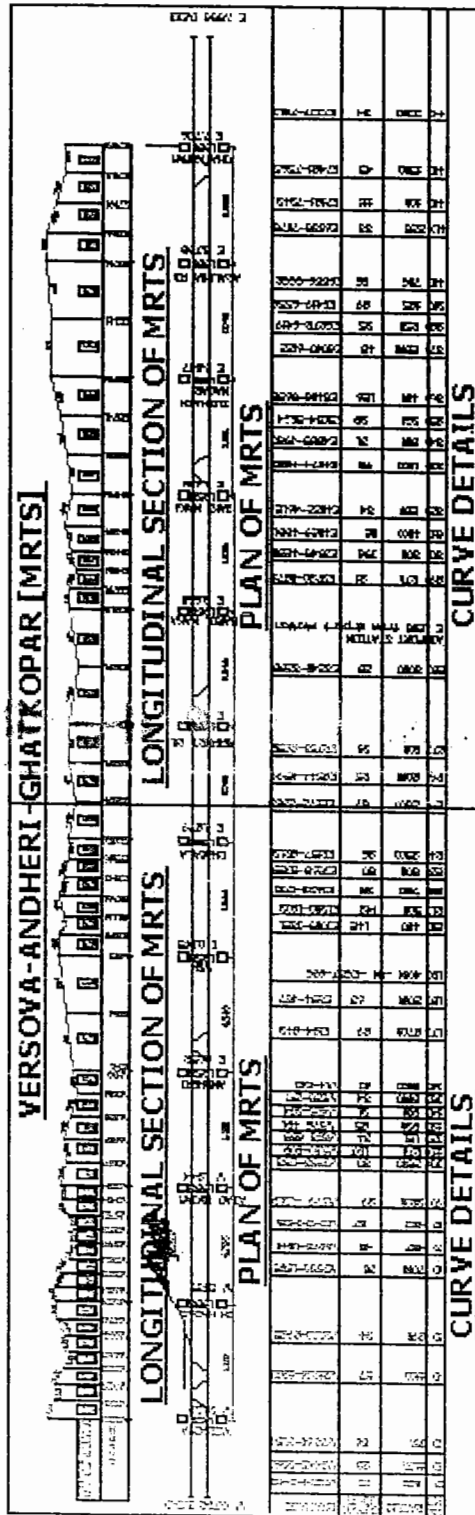
Sr. No.	FROM	TO	LENGTH	SLOPE	RISE/ FALL/LEVEL
1	3734	3284	450	1 in 1000	Fall
2	3284	3059	225	Level	Level
3	3059	2784	275	1 in 330	Fall
4	2780	2659	121	1 in 58	Fall
5	2659	2384	275	1 in 225	Rise
6	2384	2259	125	1 in 80	Rise
7	2259	2059	200	Level	Level
8	2059	2034	25	1 in 40	Rise
9	2034	2009	25	1 in 40	Fall
10	2009	1934	75	1 in 42	Fall
11	1934	1909	25	1 in 40	Fall
12	1909	1856	53	1 in 40	Rise
13	1859	1759	100	1 in 100	Rise
14	1759	1484	275	1 in 134	Rise
15	1484	1234	250	Level	Level
16	1234	1184	50	1 in 122	Fall
17	1189	609	580	1 in 122	Rise
18	609	459	150	1 in 500	Fall
19	459	334	125	1 in 840	Fall
20	1090	334	756	1 in 50	Rise
21	109 W	141E	250.00	Level	Level

**Gradients between Andheri – Ghatkopar East Side**  
**Details of Gradients from Andheri to Ghatkopar**

Sr. No.	FROM	TO	LENGTH	SLOPE	RISE/ FALL/LEVEL
1	141	516	375	1 in 100	Rise
2	516	891	375	1 in 32	Rise
3	891	1166	275	Level	Level
4	1166	1441	275	1 in 66	Fall
5	1441	1766	325	1 in 1000	Rise
6	1766	1941	175	1 in 36	Fall
7	1941	2166	225	1 in 98	Fall
8	2166	2366	200	Level	Level
9	2366	2616	250	1 in 50	Fall
10	2616	2891	275	1 in 83	Rise
11	2891	3091	200	Level	Level
12	3091	3291	200	1 in 66	Fall
13	3291	3541	250	1 in 333	Rise
14	3541	3791	250	Level	Level
15	3791	4016	225	1 in 66	Fall
16	4016	4416	400	1 in 333	Rise
17	4416	4616	200	1 in 91	Rise
18	4616	4616	0	Level	Level
19	4616	4966	350	1 in 66	Fall
20	4966	5391	425	1 in 83	Rise
21	5391	5741	350	1 in 66	Rise
22	5741	5966	225	1 in 38	Rise
23	5966	6141	175	Level	Level
24	6141	6716	575	1 in 200	Rise
25	6716	6866	150	Level	Level
26	6866	7091	225	1 in 200	Fall
27	7091	7641	550	1 in 33	Fall
28	7641	7850	209	Level	Level



A Schematic Sketch of the Alignment is shown below with detailed vertical and horizontal profile given in Figures 3.1 to 3.12



## CHAPTER - 4

### SURVEY WORK - METHODOLOGY

#### 4.1 Main Alignment

- 4.1.1 As MMRDA has specified the alignment fixed by them as obligatory, the triangulation points with respects to its coordinates, as already marked and given by MMRDA will be checked at site with respects to the correctness of its co-ordinates with the help of TOTAL Station / Auto Level (Prism and other accessories as required).
- 4.1.2 The points found disturbed shall be identified for its revised co-ordinates and the points made firm with its station numbers. For missing points new points with its coordinates would be identified and marked firm with the help of rod in masonry pillars by punch mark or nail. All points will be repainted and protected at site and got checked by MMRDA staff if required by them. All records of coordinates will be documented.
- 4.1.3 Based on the above, the alignment along with curves and transitions will be fixed at site and coordinates of the proposed piers and pile locations will be marked at site with TOTAL Station / Auto Levels, with all documentation and records. All such sites so fixed will be properly protected. Pier and Pile locations will be probed for any underground utility services falling within piles / pile caps locations by digging 2-meter deep pits manually.
- 4.1.4 Utilities coming in the way shall be identified and marked for relocations or redesign the locations. Existing temporary Benchmarks fixed by MMRDA will be checked with reference to GTS Benchmark and new Benchmarks will be established along the entire alignment and at 100-meter intervals or as required and converted into permanent benchmark for adoption during construction. For carrying out the above work equipment such as measuring steel tapes of Freeman's make as calibrated from authorized agency. Prisms target, Auto levels, Leveling staff, Total Stations with 1 second accuracy, Line thread, Line powder for marking, Wooden pegs, Nail points etc. Based on the above survey work detailed working plans of the alignment will be prepared (Scale 1:200) showing there on deviation from Central Verge and widening of the existing roads and relocation of the Central Verge and additional land to be acquired if any and dismantling of existing structures etc.





- 4.1.5 A longitudinal section of the alignment will also be made out for the entire length. Similarly location of pile foundations, of station building will be fixed along with alignment survey. The survey will also include the locations of an elevated Depot area near D.N.Nagar station with single line entry from Versova end or alternative site at Ghatkopar end at Godrej as proposed by MMRDA i.e. an elevated single line entry of 1.74 kms with depot at underground level with ballasted track on PSC Sleepers.
- 4.1.6 All survey work and its documentation will be carried out to the satisfaction of MMRDA or its nominated Consultant / engineers appointed for the project. After the survey work is complete the entire construction area will be barricaded in 8-meter width (outside to outside barricade) or as desired by MMRDA in consultation with the local traffic police authorities.
- 4.1.7 All staff / personnel working within the construction area will wear personal protection equipments (PPE) All employees will follow companies health and safety policy, environment policy, HSE plan of owners i.e. MMRDA's environment policy and plan if any. Quality Assurance and Quality Control of survey works will be as per the quality plan and corresponding inspection test plans.
- 4.1.8 The following documentation will be maintained:
- A. Inspection and Test plans.
  - B. Triangular points verification report
  - C. Field books.

#### 4.2 Alternative Depot Locations

- 4.2.1 At Ghatkopar end, the alternative depot site is also being considered involving an elevated corridor crossing the central railway tracks and terminating at ground level for the depot area. The additional length of 1.74 kms of single line track will be involved in the alternative depot location near Godrej Soap land.

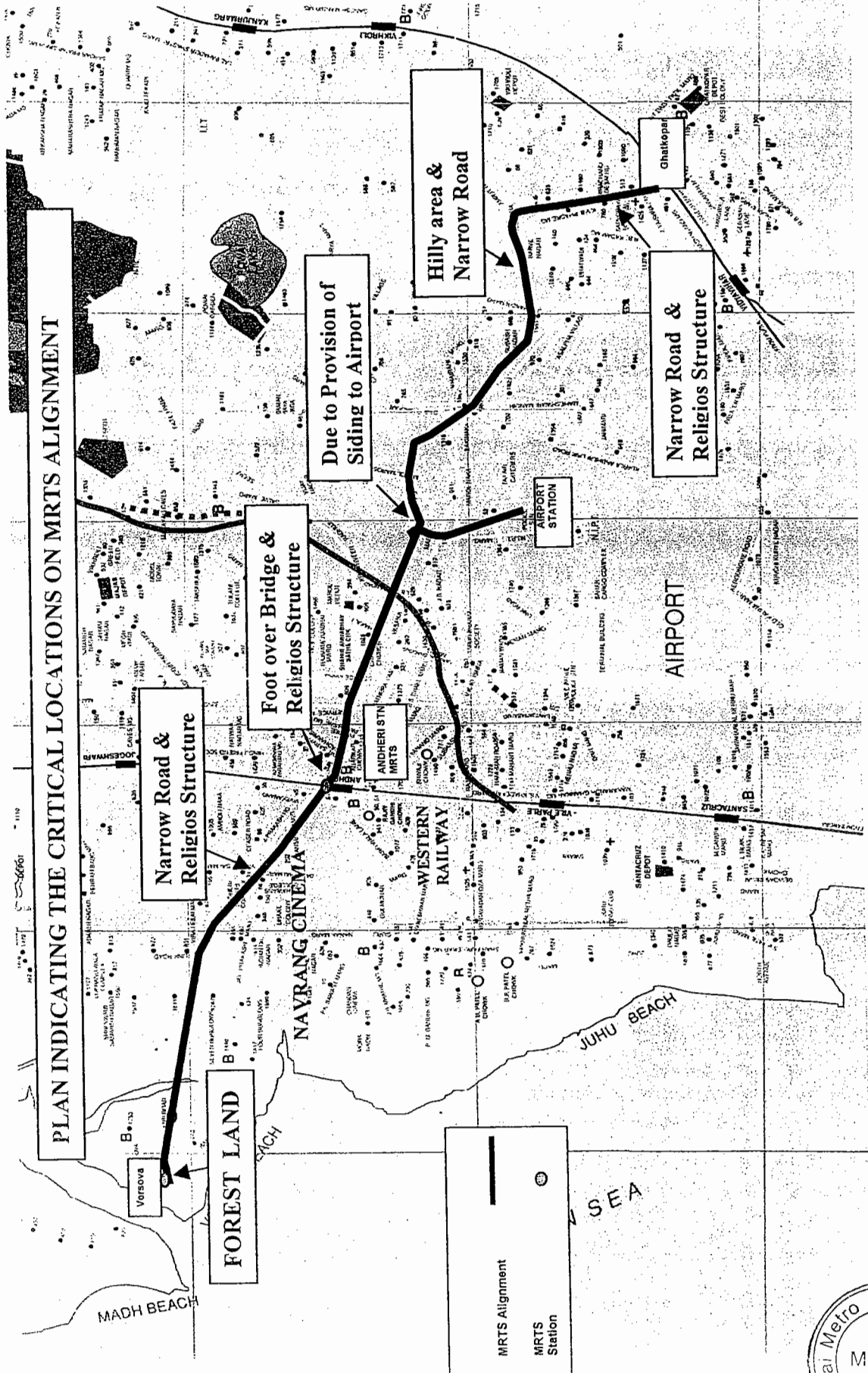


### 4.3 Critical Locations Along the Alignment

- 4.3.1 It will be seen from the above alignment that the critical locations from the construction point of view would be at Versova, Ghatkopar and Andheri Station and crossing of all railway tracks at Andheri, with the span of 60 meters and crossing of the Western Express Highway with span of 59 meters, crossing through congested area near Asalpa station towards Ghatkopar, crossing of all utility services along the alignment. Crossing of railway tracks will need coordination with concerned local authorities and Western and Central Railways necessitating co-operation and assistance from MMRDA to facilitate the construction work including approval of all proposals in time. Other critical location would be those requiring widening roads, acquisition of lands, dismantling of structure, permanent diversion of roads due to centerline of the railway alignment not coinciding with existing central verge of the road. Any minor changes need due to site conditions or as desired by MMRDA for alignments, stations, construction facilities etc. will be done in consultation and with prior approval of MMRDA.



# MRTS VERSOVA - ANDHERI - GHATKOPAR MAP



## CHAPTER - 5

### DIVERSION OF UTILITY SERVICES

All drawings especially underground water pipelines, sewer lines, gas lines and other utility services between Versova and Andheri Station made available by the respective utilities were closely examined. Our observations have been brought out in the following paragraphs.

#### 5.1 Water Pipelines

##### 5.1.1 From Chainage W 3400 to W 3720

From Chainage W 3720 to W 3550 no water pipelines are coming in the MRTS alignment. Water pipeline of 200mm dia may foul with foundation of pier no 10 to 17 between Chainage W3518 to W 3360. Similarly water pipeline of 450 dia may foul with foundation of pier no 11 to 15. These two pipelines will have to be shifted along with domestic connections from these pipe lines.

##### 5.1.2 From Chainage from W 2900 to W 3400

Water pipeline of 450mm dia has been observed along the alignment from Chainage W 3360 to W 2990 (pier no 17 to 24). Water pipeline of 450mm dia is coming in the way of pier no 25 to 28 between Chainage W3045 to W 2955 and also water pipeline of 200 dia is likely to foul with foundation of station area. All the three pipelines will have to be shifted along with domestic connections from these pipelines.

##### 5.1.3 From Chainage 2500 to 2900

Water pipeline of 200mm dia is coming in the way of pier no 28 to 44 from Chainage W2955 to W 2500. This will need shifting along with the domestic connections.

##### 5.1.4 From Chainage 2500 to 2200

Water pipeline of 200mm dia is coming in the way of pier no 44 to 60 located between Chainage W2500 to W 2200. Water pipeline will have to be shifted to other location along with domestic connections to these pipelines.



#### 5.1.4.1 From Chainage 2200 to 1500

Water pipeline of 200mm dia is coming in the way of pier no 44 to 60 between Chainage W 2200 to W 1500. Water pipelines are coming in the way of DN Nagar station area and also water pipeline of 200 dia is coming in the way of foundation of station area. All these pipelines will have to be shifted along with domestic connections from this pipeline.

#### 5.1.5 From Chainage 1500 to 1100

Between Chainage W 1500 to W 1100, water pipelines of 200mm dia are coming in the way of pier no 70 to 85. These pipelines will have to be shifted along with domestic connections from these pipe lines.

#### 5.1.6 From Chainage W 1100 to W 750

Between Chainage W 1100 to W 750, water pipeline of 200mm dia is coming in the way of pier no 97 to 112. This pipeline will have to be shifted along with domestic connections from this pipe line.

#### 5.1.7 From Chainage W 750 to W 300

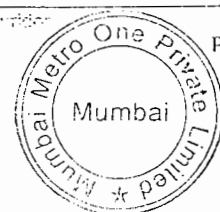
Between Chainage W 750 to W 300, water pipeline of 200mm dia is coming in the way of pier no 111 to 128. This pipeline will have to be shifted along with domestic connections from this pipelines.

#### 5.1.8 From Chainage E 100 to E400

Between Chainage W 120 to W 350, water pipeline of 250mm dia is coming in the way of Andheri station Area (pier no 128 to 134 and 136 to 139). This pipeline will have to be shifted to other location along with domestic connections from this pipeline.

#### 5.1.9 From Chainage E 0.920 to E 0.960

Between Chainage E 0.920 to E 0.960, a water pipeline is crossing the alignment. This pipeline may have to be shifted.



**5.1.10 From Chainage E 0.960 to E 1.000**

Between Chainage E 0.960 to E 1.000, a water pipeline is crossing the alignment. This pipeline may have to be shifted to other location.

**5.1.11 From Chainage E 1.440 to E 1.520**

Between Chainage E 1.440 to E 1.520, Water pipeline is running very close to the alignment and also crossing the alignment. This pipeline may have to be shifted to other location.

**From Chainage E 2.600 to E 2.640**

Between Chainage E 2.600 to E 2.640, (4 Nos) Water pipelines are crossing the alignment. These pipelines cannot be shifted since they are the trunk mains. As such the pier location may have to be modified to accommodate the crossings of the pipelines.

**5.1.12 From Chainage E 3.200 to E 3.240**

Between Chainage E 3.200 to E 3.240, a water pipeline is crossing the alignment. This pipeline may have to be shifted to other location along with domestic connections from this pipeline.

**5.1.13 From Chainage E 3.440 to E 3.480**

Between Chainage E 3.440 to E 3.480, water pipeline is crossing the alignment. This pipeline may have to be shifted to other location along with domestic connections from this pipeline.

**5.1.14 From Chainage E 4.240 to E 4.280**

Between Chainage E 4.240 to E 4.280, water pipeline is crossing the alignment. This pipeline will have to be shifted to other location along with domestic connections from this pipeline.

**5.2 Sewer Lines – Our Observations**

5.2.1 600mm dia sewer line is likely to foul with the foundation of pier no P7 & P9..

5.2.2 Sewer line of 600mm between Chainage W 3194 to W3107 at Versova station area.



- 5.2.3 Sewer line of 600mm at station area between Chainage W 1459 to W1100 at Azad Nagar station area.
- 5.2.4 Sewer line of 600mm between Chainage W 780 to W 810.
- 5.2.5 Sewer line crossing the alignment between Chainage E 0.920 to E 0.960.
- 5.2.6 Sewer line crossing the alignment between Chainage E 0.960 to E 1.000.
- 5.2.7 Sewer line crossing the alignment between Chainage E 1.000 to E 1.080.
- 5.2.8 Sewer line crossing the alignment between Chainage E 1.400 to E 1.440.
- 5.2.9 Sewer line crossing the alignment between Chainage E 1.520 to E 1.560.
- 5.2.10 Sewer line crossing the alignment between Chainage E 2.360 to E 2.400
- 5.2.11 Sewer line crossing the alignment between Chainage E 4.000 to E 4.040
- 5.2.12 Sewer line crossing the alignment between Chainage E 4.320 to E 4.600
- 5.2.14 Sewer line crossing the alignment between Chainage E 4.600 to E 4.640

Advance action for shifting of these lines is requested in order to avoid hassles during construction

### **5.3 Gas Pipeline – Our Observations**

- 5.3.1 2 No gas pipelines, of 150mm dia each are passing through the area between Chainage W 3194 to W 3107 which is located at the junction of S.V. Road and J.P.Road. It may be difficult to shift them as there are many domestic connections from these pipelines.
- 5.3.2 2 No gas pipelines of 150mm dia each are passing through the DN Nagar station area between Chainage W 2200 to W 1848. It may be difficult to shift them as there are many domestic connections from these pipelines.



- 5.3.3 2 No gas pipelines of 150mm dia each are passing through the Azad Nagar station area between Chainage W 1459 to W 1100. It may be difficult to shift them as there are many domestic connections from these pipelines.
- 5.3.4 2 No gas pipelines of 150mm dia each are passing through the Andheri station area between Chainage E 100 to E400 (pier no 150 to 190) It may be difficult to shift them as there are many domestic connections from these pipelines.
- 5.3.5 A gas pipeline with domestic connections is also running close to the alignment from Chainage E 1.600 to E 1720.
- 5.3.6 A gas pipeline is crossing the alignment between Chainage E 2.280 to E 2.320.
- 5.3.7 A gas pipeline is crossing the alignment between Chainage E 2.480 to E 2.520.
- 5.3.8 A gas pipeline is running close to the alignment from Chainage E 2.640 to E 3.120.
- 5.3.9 A gas pipeline is crossing the alignment between Chainage E 3.120 to E 3.160.
- 5.3.10 A gas pipeline is crossing the alignment between Chainage E 3.160 to E 3.200.
- 5.3.11 A gas pipeline is crossing the alignment from Chainage E 3.520 to E 3.560.
- 5.3.12 A gas pipeline is crossing the alignment from Chainage E 3.800 to E 3.840.
- 5.3.13 A gas pipeline is crossing the alignment from Chainage E 4.200 to E 4.240.
- 5.3.14 A gas pipeline is crossing the alignment from Chainage E 4.440 to E 4.840.
- 5.3.15 A gas pipeline crossing the alignment from Chainage E 4.560 to E 4.600.

All these lines are with domestic connections. Advance action for shifting these lines or any other alternative arrangement is requested so as to avoid hassles during construction.

#### 5.4 Electrical & Telecommunication Cables

- 5.4.1 REL and TPC electrical cables between Chainage W2200 to W1848 and W1459 to W1100. These cables might have been shifted during the widening of road, which is in progress. If in case the cables are not shifted they will be shifted by the concerned companies.





- 5.2.3 Sewer line of 600mm at station area between Chainage W 1459 to W1100 at Azad Nagar station area.
- 5.2.4 Sewer line of 600mm between Chainage W 780 to W 810.
- 5.2.5 Sewer line crossing the alignment between Chainage E 0.920 to E 0.960.
- 5.2.6 Sewer line crossing the alignment between Chainage E 0.960, to E 1.000.
- 5.2.7 Sewer line crossing the alignment between Chainage E 1.000 to E 1.080.
- 5.2.8 Sewer line crossing the alignment between Chainage E 1.400 to E 1.440.
- 5.2.9 Sewer line crossing the alignment between Chainage E 1.520 to E 1.560.
- 5.2.10 Sewer line crossing the alignment between Chainage E 2.360 to E 2.400
- 5.2.11 Sewer line crossing the alignment between Chainage E 4.000 to E 4.040
- 5.2.12 Sewer line crossing the alignment between Chainage E 4.320 to E 4.600
- 5.2.14 Sewer line crossing the alignment between Chainage E 4.600 to E 4.640

Advance action for shifting of these lines is requested in order to avoid hassles during construction

### 5.3 Gas Pipeline – Our Observations

- 5.3.1 2 No gas pipelines, of 150mm dia each are passing through the area between Chainage W 3194 to W 3107 which is located at the junction of S.V. Road and J.P.Road. It may be difficult to shift them as there are many domestic connections from these pipelines.
- 5.3.2 2 No gas pipelines of 150mm dia each are passing through the DN Nagar station area between Chainage W 2200 to W 1848. It may be difficult to shift them as there are many domestic connections from these pipelines.



- 5.3.3 2 No gas pipelines of 150mm dia each are passing through the Azad Nagar station area between Chainage W 1459 to W 1100. It may be difficult to shift them as there are many domestic connections from these pipelines.
- 5.3.4 2 No gas pipelines of 150mm dia each are passing through the Andheri station area between Chainage E 100 to E400 (pier no 150 to 190) It may be difficult to shift them as there are many domestic connections from these pipelines.
- 5.3.5 A gas pipeline with domestic connections is also running close to the alignment from Chainage E 1.600 to E 1720.
- 5.3.6 A gas pipeline is crossing the alignment between Chainage E 2.280 to E 2.320.
- 5.3.7 A gas pipeline is crossing the alignment between Chainage E 2.480 to E 2.520.
- 5.3.8 A gas pipeline is running close to the alignment from Chainage E 2.640 to E 3.120.
- 5.3.9 A gas pipeline is crossing the alignment between Chainage E 3.120 to E 3.160.
- 5.3.10 A gas pipeline is crossing the alignment between Chainage E 3.160 to E 3.200.
- 5.3.11 A gas pipeline is crossing the alignment from Chainage E 3.520 to E 3.560.
- 5.3.12 A gas pipeline is crossing the alignment from Chainage E 3.800 to E 3.840.
- 5.3.13 A gas pipeline is crossing the alignment from Chainage E 4.200 to E 4.240.
- 5.3.14 A gas pipeline is crossing the alignment from Chainage E 4.440 to E 4.840.
- 5.3.15 A gas pipeline crossing the alignment from Chainage E 4.560 to E 4.600.

All these lines are with domestic connections. Advance action for shifting these lines or any other alternative arrangement is requested so as to avoid hassles during construction.

#### 5.4 Electrical & Telecommunication Cables

- 5.4.1 REL and TPC electrical cables between Chainage W2200 to W1848 and W1459 to W1100. These cables might have been shifted during the widening of road, which is in progress. If in case the cables are not shifted they will be shifted by the concerned companies.



- 5.4.19 REL cable is crossing the alignment between Chainage E 2.440 to E 2.480.
- 5.4.20 11 KV cable is crossing the alignment between Chainage E 2.520 to E 2.560.
- 5.4.21 11 KV (3 nos) cable are crossing the alignment between Chainage E 2.560 to E 2.600.
- 5.4.22 11 KV (3 nos) cable are crossing the alignment between Chainage E 2.640 to E 2.680.
- 5.4.23 22 KV cable is crossing the alignment between Chainage E 2.760 to E 2.800.
- 5.4.24 11 KV cable is crossing the alignment between Chainage E 2.800 to E 2.840.
- 5.4.25 Tata cable crossing the alignment between Chainage E 3.000 to E 3.040.
- 5.4.26 22 KV cable is crossing the alignment between Chainage E 3.600 to E 3.640
- 5.4.27 22 KV cable is crossing the alignment between Chainage E 3.880 to E 3.920
- 5.4.28 11 KV cable is crossing the alignment between Chainage E 3.960 to E 4.000.
- 5.4.29 Telephone cable is crossing the alignment between Chainage E 4.040 to E 4.080.
- 5.4.30 REL cable is crossing the alignment between Chainage E 4.080 to E 4.120.
- 5.4.31 11 KV cable is crossing the alignment between Chainage E 4.120 to E 4.160.
- 5.4.32 Telephone cable is crossing the alignment between Chainage E 4.160 to E 4.200.
- 5.4.33 11 KV cable is crossing the alignment between Chainage E 4.160 to E 4.200.
- 5.4.34 22 KV cable is crossing the alignment between Chainage E 4.280 to E 4.320.
- 5.4.35 22 KV & 11 KV cables are crossing the alignment between Chainage E 4.320 to E 4.360.
- 5.4.36 22 KV cable is crossing the alignment between Chainage E 4.400 to E 4.440.
- 5.4.37 11 KV cable is crossing the alignment between Chainage E 4.480 to E 4.520.
- 5.4.38 REL cable is crossing the alignment between Chainage E 4.520 to E 4.560.



- 5.4.39 Tata Broadband Communication cable is crossing the alignment between Chainage E 4.560 to E 4.600.
- 5.4.40 22 KV (2 nos) cable are crossing the alignment between Chainage E 4.560 to E 4.600.

While shifting of REL power cables shall be coordinated by us internally, advance action is requested for shifting of other utility cables so as to facilitate hassle free construction.

## 5.5 Notes on Future Proposed Flyover

- 5.5.1 MMRDA have proposed two flyovers along the alignment; one at Saki Naka Junction and the other at Western Railway crossing. Both Flyovers are proposed parallel to the MRTS line and proposals are above the platform level. These flyover alignment are not affecting any MRTS alignment and suitable planning will be done while designing the structures in this areas.
- 5.5.2 Our team of Engineers in association with MTR Corporation, Hong Kong who are the consultants for formulation of the technical proposal have extensively carried out the survey for utility services and also collected the data regarding the utility services in the area from concerned organization. However, the list of utilities fouling with the alignment / station area is not exhaustive and cooperation is requested in case any more utilities are discovered during construction.



## CHAPTER 6

### LAND REQUIREMENT

#### 6.1 Land Requirement Outside Right of Way (ROW) for Permanent Acquisition by MMRDA (Pl. Ref. Table 6.1)

6.1.1 Our survey team carried out walk over survey along the MRTS corridor, from Versova (7 bungalow – Andheri) along JP road, MV Road (Andheri Kurla Road and Saki Naka, to Ghatkopar Via Asalpha. The survey team noticed and identified a number of critical locations where the problems are likely to arise during the construction of MRTS. These critical locations are:

6.1.2 MMRDA has made available the alignment (ROW) on a drawing. Although the road widening work along the alignment are in progress and ROW are marked at the sight by the road contractor, we have noticed that most of encroachment have not yet been removed thus hampering the progress of road work. In order to avoid such problems during construction, MMRDA are requested to initiate advance action to remove all such structures causing obstruction along the ROW before finalizing the award.

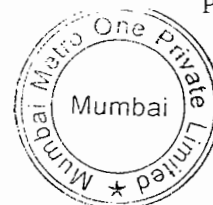
6.1.3 There are 13 stations along the Versova – Andheri – Ghatkopar and a few of which require additional land beyond the proposed ROW land. This additional land is indicated on the plan and the same needs to be acquired by MMRDA before finalizing the award.

#### 6.1.4 Versova station

6.1.4.1 For this station additional land is required. The part of the land belongs to forest department and part of the land belongs to private owners. Land acquisition for forestland requires more time and lot of formalities have to be carried out for acquiring the land. We therefore request to initiate the land acquisition for the forestland at the earliest. The area assumed for acquisition outside ROW is 1184 sqm. (Ref. Figure 6.1).

#### 6.1.5 Western Express Highway (WEH) station

In this part of the alignment, the height of columns will be much more than the normal height of the columns because of the Andheri Fly over. Also this part is crowded and narrow and Western Express Highway station is located at very high level than the normal station.



Hence, the time required for construction will be more. These locations will be critical for construction work. Hence MMRDA are requested to initiate the work of land acquisition at this place in advance.

## **6.2 Land Requirement within the Right of Way (ROW) for Permanent Acquisition by MMRDA (Pl. Ref. Table 6.2)**

### **6.2.1 Area between Navrang theater to Nagardas Road Andheri East**

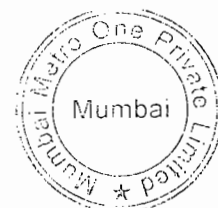
This part of the road is very narrow and having a lot of commercial and religious buildings. Also, it is required to cross Western Railway tracks through a crowded area. Since the main market is located in this area, lot of resistance in locating and relocating the structures affected in this area is expected. It is therefore earnestly requested to take up the land acquisition and resettlement activity at this place at the earliest.

### **6.2.2 Crossing Western Railway Track**

MRTS has to cross over the Western Railway tracks at Andheri. The length of crossing is approx. 100m. The existing 6 meter wide Foot Over Bridge across the railway tracks is coinciding with the MRTS alignment. This FOB may therefore have to be relocated before starting the construction works for which necessary permission is required from Western Railway. The designs and drawings of this section have also to be got approved from Western Railways. The construction works at this section will have to be carried out under supervision of Western Railway. All the above permissions require constant follow up with the WR and the time required for obtaining these permissions is very high. MMRDA are therefore requested to initiate activities to get the permission and also obtain ROW from Western Railways.

### **6.2.3 Area between Airport station, Marol Station and Saki Naka Station**

This area is most congested area in the alignment having lots of industrial estates and commercial complexes and hotels. There is very heavy traffic on this section and the traffic jam problem is all the time in this area. Hence it is requested to expedite the work of land acquisition within the ROW proposed.



#### 6.2.4 Saki Naka Asalpha and Ghatkopar

This area is mostly covered by hutments and temporary structures and religious structures and is having very steep gradients and sharp curves for which more time is required for construction. It is noted that MMRDA have not yet started the resettlement and rehabilitation works in this area. Also, there are a few permanent structure coming in the ROW. Hence it is requested to expedite the work of land acquisition within the ROW proposed.

### 6.3 Land Requirement for Temporary Works

6.3.1 There is large number of activities which has to be undertaken in various disciplines viz. Foundation, Wayside Structures, Station Buildings, Service Building, Track Laying, Electrical, and Signaling works etc. The land along the ROW of the alignment would not be sufficient for large number of integrated activities in various disciplines. Hence an additional land apart from ROW land would be required on temporary basis for carrying out following activity:

1. Casting yard for Girder casting.
2. Storage area for storing construction material.
3. Storage area for storing construction machinery.
4. Parking area for Heavy construction machinery.
5. Site offices for construction staff of various disciplines.

6.3.2 There will be two agencies out of which one will operate on east side of alignment and other on the west side of the alignment. The land shown in the drawing is proposed to accommodate two agencies and also other site offices of various disciplines.

6.3.3 The proposed alignment is passing by the Airport Authority of India's (AAI) land near Hotel Leela. It is proposed that 450m x 250m land on either side of the airport road be temporarily acquired. This location is in the centre of the alignment, is well connected by road, so this location is suitable for various centralized activities and also for Site Offices.

Figure 6.8 indicates the above location of the land to be temporarily acquired.



Table 6.1 - Details of Land Acquisition outside ROW by MMRDA

Sr No.	Chainage	Area outside ROW (Sqm)	Remarks
1	W3139	1184	Versova Stn L1
2	W2139	5000	D.N. Nagar Stn L2
3	W1344	740	Azad Nagar Stn L3
4	E 0.052	666	Andheri Stn L4
5	E 0.995	546	WEH Stn L5
6	E2279	126	Chakala Stn L6
7	E7786	632	Ghatkopar Stn L7
	<b>Total</b>	<b>8894</b>	

Table 6.2 - Details of Land Acquisition inside ROW by MMRDA

S. No.	Chainage	Area Inside ROW (Sqm)	Remarks
1	W3675	3411	Versova Garden
2	W2139	301	D.N. Nagar Stn
3	W900	179	Bhardawadi
4	W858	38	
5	W803	8	
6	W714	100	
7	W245 – W700	2008	Navrang to S.V. Road
8	W201 to 150	1116	Masjid Gully
9	W100	598	East of Rly Line
10	W14 – W80	457	
11	E0.061	63.6	M.V. Road
12	E1300	350	
13	E1380	83	WEH
14	E1770	156	
15	E2700 to E2858	373	Chakala
16	E3300	193	
17	E3600	373	Marol
18	E4467	334	
19	E4600	298	
20	E4696	466	Saki Naka
21	E4880 to E4798	1142	
22	E4950 to E5054	973	Saki Naka
23	E5184 to 5100	2214	
24	E5200 to E6047	4873	Asalpha
25	E6050 to E7700	50000	Complete Slum Area on the ROW
26	E7300	638	Building
	<b>Total</b>	<b>70746</b>	





# CHAPTER - 7

## CIVIL ENGINEERING

### 7.1 Design

7.1.1 The way structure has been designed for axle load of 18 tonnes. The train configuration consists of a maximum of 6 coaches per train. Other loads and forces considering the design are in accordance with the Bridge Rules of Indian Railways. As continuous welded rails are proposed with non ballasted track, the forces due to temperature variations have been catered for RCC and pre-stressed concrete work are in accordance with Indian Railways Concrete Bridge Code and Indian Railways Sub-structure and Foundation Code. Prestressed concrete girder has been adopted for super structure of the all spans with provision for sound barriers all along the corridor. The way structures have been designed to be supported on single column erected along medium of the road. At few places where it not possible to adopt the same portal frames supports have been adopted in lieu of single column. The depth of foundation proposed varies from 15 to 18 meters based the geological data along the alignment. The width of the Way structure has been proposed at 8.95 meters with track centers at 4.05 meters. The minimum clearance above road has been maintained at 5.5 meters location where alignment crosses railway tracks the minimum clearance has been kept at 6.55 meters as applicable for 25 kV AC traction. A passage of 700 mm wide has been provided all along the corridor 6.5 m either side to facilitate evacuation of commuters during emergency. Ducts for laying electrical signals and communication cables have been provided. Provision has been made for drainage with connections to the underground drainage with a crossfall of 2.5% on deck top. The provision for drainage has been on the annual rainfall of 2000 mm with a maximum rainfall intensity of 75 mm per hour. In view of the congested location of the alignment the structure has been designed for construction with the use of 3 meter pre-cast elements for the entire length. While designing the shape of the super structure and sub structure aesthetics has been kept in view. The spans of the way structure has been mainly at 25 meters with minor adjustments at critical locations by use of shorter spans and adoption of 28 and 31 and 40 spans for road crossing and with 60 meters span for crossing tracks at Andheri and the Western Express Highway. While planning the location care has been taken to ensure that no piers are located in front the religious sites. Plan showing location of columns along the alignment has been enclosed in the documents furnished. A statement of number of type of span with the design group is enclosed. Drawings of typical cross sections for 60 meter span, 40 meter spans, 31-25 meter span, 22 and below meter spans are enclosed (Figures 7.1 to 7.9). The super structure has been designed to cater for anti crash barriers in concrete and provision made for OHE mass and other ancillaries.



7.1.2 Structure - The proposal to use U beams throughout the viaduct and boxes in the stations will be reviewed as per design requirements.

## 7.2 Design Codes

### 7.2.1 Piles And Pile Cap

7.2.1.1 Design of Piles and pile cap is based on IS 2911 (part III), IRS/Concrete Bridge Codes and IS 456/2000. Durability criteria have been taken as per IRS Concrete Bridge Code (Correction slip 1) taken as severe condition. Environmental exposure has been catered for severe conditions as specified in the IRS Concrete Bridge Code. Earthquake effects on foundation and detailing have been checked as per Caltrans Codes (Post Loma Prieta) and Japanese code (Post Kobe) besides Indian Railways / BIS Codes.

### 7.2.2 Pier And Pier Cap

7.2.2.1 Designs are based on IRS Concrete Bridge Codes clause 15.6 and IS 456/2000 along with SP 16 of BIS. Earthquake effects of sub structures have been checked as per Caltrans Codes (Post Loma Prieta) and Japanese Code (Post Kobe).

### 7.2.3 Bearings

7.2.3.1 Two sliding and two-fixed bearings are to be attached with each simply supported girder. On each pier cap two fixed and two sliding bearings are to be rested. Bearing forces, displacement & rotations for each span category to be work out using SLS Combinations with added factor of safety, design bearing load, displacement & rotations are to be calculated as per IRC 83 part III and BS 5400 as no railway specification in this subject is available.

Proposed no. of bearing to be used – 1184 X 2 (1184 – Fixed & 1184 – Sliding)

### 7.2.4 Girders

7.2.4.1 Segmental construction technology has been proposed for designs, constructions and erections of prestressed concrete girders. The design incorporates IRS Concrete Bridge Codes Clause 16 and 17, ACI Codes, IS 14268/1995 and IS 13920/1999.

## 7.3 Assessment of Volume of Work in Way Structures, Station and Depot

7.3.1.1 The details of the number and type of spans including the quantities under various categories for the way structure have been tabulated below in tables A, B, C, D and E.



## (A) Main way structure including Station (Along Alignment) but Excluding Depot

I. SPANS							
1) No of Spans	2	3	372	92	58*	120	589*
2) No of Int. Segments	36	36	2662	496	-	480	3710
3) No of End Segments	4	6	744	184	-	240	1178
II. PILES							
1) No. of Piles	24	36	2226	364	232	480	3362
2) Qty. of m/35 in Piles	1380	1167	38316	6348	4002	8280	59493
3) Qty. Tor Steel in Piles	188	156	5208	856	540	1116	8064
III. PILE CAPS							
1) No of Pile Caps	4	6	371	91	58	120	650
2) Qty. of m/35 in Pile Cap	960	750	26040	2852	1800	3720	36122
3) Qty. of Tor Steel in Pile Cap	200	150	4836	575	363	750	6874
IV. PIERS							
1) No. of Piers	4	6	371	91	58	120	650
2) Qty. of m/40 in Piers	200	240	14136	3680	2320	4800	25376
3) Qty. of Tor Steel in Piers	120	132	7812	1748	1102	2280	13194
V. PIER CAPS							
1) No. of Pier Caps	4	6	371	91	58	120	650
2) Qty. of m/40 in Pier Caps (cum)	46	69	4252	1043	340	1375	7125
3) Qty. of Mt)	5	7	425	104	34	137	712
VI. BEARINGS							
1) No. of Bearings							
a) Fixed	8	12	742	182	-	240	1184
b) Sliding	8	12	742	182	-	240	1184
VII. GIRDERS							
1) No. of Girders	2	3	372	92	-	120	589
2) Qty. of Concrete (cum)	870	323	56472	1073	-	15240	83643
3) Qty. of Steel (Mt)	88	84	7184	1094	-	1560	10010
4) Strands 19/13 (Rm)	2040	1314	94740	1490	-	21120	134118**
5) Strands 12T/13(Rm)	600	264	28422	3726	-	5280	38292**

\*58 is not added in 589 being included in other spans.

\*\*Total high tensile steel = 2375 Mt.

## (B) Depot / Carshed Elevated

QTY. M 35 in m<sup>3</sup> & Fe 415 in Mt.

SPAN	No. of SPAN (in No.)	M 35 (in m <sup>3</sup> )	Fe 415 (in Mt.)
PILES	2452	42297	5701
PILE CAPS	613	19003	3831
PIERS	613	4414	526
BEAMS	2245	38794	3879



SLABS	-	24883	1990
TOTAL		129391	15929

## (C) Station Building Excluding Portals under Way Structure Alignment

**QTY. (Other than Way Structure) M 35 in m<sup>3</sup> & Fe 415 in Mt.**

SPAN	M 35 (m <sup>3</sup> )	Fe 415 (Mt)	Fe 415 (m <sup>3</sup> )
PILES	2496	706	96
PILE CAPS	624	2730	273
PIERS	624	5616	685
BEAMS	600	810	95
SHELL ELEMENTS	-	15725	1048
TOTAL		25587	2197

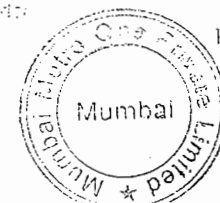
## (D) Station Roof Structure

**QTY. - Steel in Mt. & Fiber in m<sup>2</sup>**

	STEEL	FIBER
FRAME (Mt)	1616	-
CLADDING (Sqm)	-	75000
TOTAL	1616 Mt	75000 Sqm

## (E) Location of Pier Portal

Sr	Pier No.	No. of Portal	Chainage	Location
1	P3	1	Ch: W3700	Versova
2	P16, P17	2	Ch. W3360	Versova
3	P25, P26	2	Ch. W3085	Versova
4	P34 to P45	11	Ch. W2800 to W2550	D. N. Nagar C/S
5	P104 to P108	4	Ch. W900 to W 803	Navrang
6	P183 to P188	5	Ch. E1260 to E 1420	Chakala
7	P287 to P289	2	Ch. E4150 to E4250	Saki Naka
8	P299 to P302	3	Ch. E4425 to E4500	Saki Naka
9	P343 to P356	13	Ch. E5637 to E5900	Asalpha
10	P362 to P363	2	Ch. E 6200	Asalpha
11	P375 to P381	6	Ch. E6525 to E6662	Asalpha
12	P400	1	Ch. E7236	Asalpha
13	P425	1	Ch. E7300	Ghatkopar
14	P446	1	Ch. E7800	Ghatkopar
15	P449 to P450	2	Ch. E7900	Ghatkopar
	TOTAL	56		



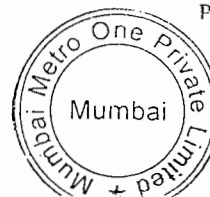
## 7.4 Construction

### 7.4.1 Quality Control Field Laboratory

7.4.1.1 An engineering laboratory will be set up to cater for the quality assurance testing of all civil engineering materials, soils, concretes, cubes etc. to be tested on MRTS project. The lab will be located at depot site area. It will have facilities for compression test for cubes, soil physical and chemical analysis etc. The productivity and quality of testing would be improved by computerization of the system with automatic data acquisitions and printout of results. The concrete tests will also be computerized for easy retrievals and analysis of results. Electronic mail systems will also be adopted for quick response and timely decisions. Quality assurance test on building materials will be carried out to ensure consistency of quality in the construction process. Tests will be carried in the selection of raw materials to be used in production of concrete and continued to site production, supervision and control. Any deficiency observed in quality of material would be taken up immediately with the supplier. All document for testing and analysis will be properly maintained for future references admixture of different types proposed to be used would be checked for their proportions like workability, retardation of setting time and water reduction. Each administrator will be checked for its performance requirements to BS 5075. The manufacturer will be asked to obtain test data from an independent laboratory as required. Routine quality control testing, dry material content, ash content, relative density and chloride Iron content will be determined. The chloride content in admixture shall generally less than 0.1%. The quality test on fine and coarse aggregates will be as per relevant IS Code or as decided by MMRDA and their consultants if any.

### 7.4.2 Pile Foundation (Cast-In Situ RC Bored Piles)

7.4.2.1 It is proposed to adopt 1.2 meter diameter piles for the major portion of the way structures up to 31 meters span and 1.5 meter diameter piles for 40 meter span and 2 meter diameter piles for 60 meter span. The total number of piles required for way structure for the entire alignment from Versova to Ghatkopar excluding depot and station buildings, including Airport line to Sahar Airport would be about 3200 numbers. The approximate quantity of concrete in piles is 90000 cubic meters and steel is around 12000 metric tones. It is expected that the piles would be 15 meters depth below the ground level and about 18 meter depth for 40 meter and above span. The piles will be anchored in to the hard rock 1.5 – 2.0 meters as necessary. The entire way works would be divided into 2 sections to be executed by two independent agencies. The average progress of the piling work for the entire section would be about 120 piles per month to be completed in a period of 30 months. It is proposed to complete 4 piles per day by using 4 rotary piling machines including accessories suitable for 1200 mm / 1500 mm / 2000 mm diameter bore (soil make 518 BG-15) piling equipments.

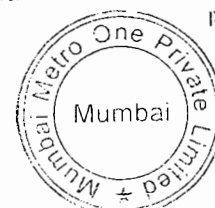


7.4.2.2 Additional piling equipments will be used for simultaneously working for the elevated depot at D.N. Nagar and separately for 13 station buildings to complete entire project within the time schedule of 5 years for commissioning. All piling work is being planned for completion within 36 months from commencement including 6 months for mobilization. The piling points shall be marked with reference to nearby control points by using Total Station. Manual excavation will be done to a depth of 2 meters to check obstruction of underground utility services. Adequate care will be taken to position the piling machine to ensure verticality of the bore without disturbing the already cast pile. Temporary casing will be driven in the borehole by attachment fixed to the piling machine and casing top level will be at least 300 mm above the ground level. The tilt and shift of casing shall not exceed 1.5% and 75 mm respectively. The muck removed during the boring operation shall be disposed off at approved dumping yard with cover-protected dumpers.

7.4.2.3 Bentonite method will be used for boring below temporary casing. Two MS tank of adequate capacity will be used within the barricaded place. Piling of 4 numbers of consecutive pier foundations will be done. Alternatively the above tanks will be kept at suitable location outside the barricaded space without hindrance to common public or kept at suitable location over trailers / trucks without obstruction to common public / traffic.

7.4.2.4 Bentonite solution will be pumped from the above tank into the bored hole and Bentonite coming out from the pile boreholes will be collected into a pit from where used Bentonite will be pumped in to excavated recycled Bentonite pit at pile cap location, where the sand and other material coming out of the bore will be allowed to set. The clear Bentonite will be pumped into steel tank to be re-used. Enough resources will be deployed to ensure that the reinforcement cages will be kept ready at the bar bending fabrication yard with spiral helix tac welded at the both end of the cage. Cover blocks will be provided at 3 meter center-to-center spacing all around the cage to provide uniform cover of 75 mm. The strength of concrete cover block shall be the same as that of the pile concrete. The reinforcement cage will be lowered into the pile bore by crane as one unit (or in segments and lap joints will welded or tied with binding wire to avoid slippage of segment lowered). It should be ensured that adequate length of reinforcement is available for pre embodiment into the pile cap.

7.4.2.5 The borehole will be cleaned before lowering the cage. Specific gravity of the water at the bottom before commencement should not exceed 1.2, Marsh Cone will be used to ensure viscosity of the water collected from the bottom of the borehole. M35 concrete with 10% extra cement will be used for the pile concrete and will be arranged by transit mixer from approved ready mixed batching plant such as L&T, ACC, GODREJ, TARMAC after checking their design mix at their plant. The slump of the concrete would be between 150 mm – 175 mm at site. The first charge of the concrete will be placed with the floating plug inside the tremmie and with a suitable charged plate at hopper mouth. It should be ensured that one tremmie (2.0 Mtr.) is embedded in concrete at all times to take care of accidental withdrawals. As concrete



progresses the tremmie will be dismantled and regular sounding will be taken to ensure extra concrete built up beyond the cut-off level is not less than 1000 mm. When concreting of the pile reached up to one meter of the cut-off level the top one meter detachable casing will be removed and concrete above the cut-off will be gently pushed into excavated pit and pile top shall be finished at the cut-off level.

7.4.2.6 Concrete cubes will be taken for testing compressive strength for concrete quality as per IS456-2000 and cylinders will be taken for permeability test. Number of cubes to be tested will be as per Indian Railways specifications. It should be ensure that concrete temperature does not exceed 40 degree centigrade.

#### 7.4.3 Load Testing Of Piles

7.4.3.1 The initial load test will be done for 2.5 times the designed load and test load may be increased up to 1.25 times the designed test load. The testing will be done by placing hydraulic jacks over the MS girders and plates and as per the procedures led down in IS code of pile testing.

#### 7.4.4 Pile Cap Casting – Methodology

7.4.4.1 The total number of pile caps would be approximately 540 nos. involving a total concrete of 60000 cubic meters and quantity of the steel would be 9000 metric tones, (excluding station buildings and depot). Different sizes of the pile caps will be adopted for different span and pile groups and diameters. It is proposed to complete the pile cap concreting work in a total period of 30 months. This will need an average progress of 18 pile caps per month. It is proposed to cast 1 pile cap per day on an average. This work will be taken up after 3 to 4 weeks of pile casting when sufficient number of pile caps would be available for continuous casting of the pile caps. It is proposed to engage two sets of agencies for the entire work one starting from Versova end towards Andheri station including and the other from Andheri station excluding to Ghatkopar station including.

7.4.4.2 Before commencement of excavation of the pile cap the area will be marked on the ground with reference to control points and center-line pillars. The pile locations will be checked with reference to control points for any shift and will be documented. After leveling to desired level of excavation to PCC M15 grade, 75 mm thick will laid on which the layout of the pile cap will be marked with reference to control points by total stations.

7.4.4.3 The reinforcement bars will be fixed in position with 75 mm cover blocks spaced at not more than 2 meters. It would be ensured that the reinforcement of the pile extends inside the pile cap depth and reinforcement of the pile cap also extent in the pier position as per the drawing. There after the shuttering duly oiled will be fixed with proper props for support. M35 concrete will



be poured in to the pile cap from transit mixer from the ready mixed concrete plant. The slump will be kept between 75 –150 mm admixtures will be used within limits specified as necessary to control workability. The shuttering will be removed after 24 hrs. of concreting. The concrete will be cured by pending method and the sides of the pile cap will be covered by Hessian cloth till back filling is done and kept moisturized with water. Back filling will be done in layers of 300 mm and compacted by plate vibrators. Concrete cubes will be taken for testing compressive strength for concrete quality as per IS456-2000 and cylinders will be taken for permeability test. Number of cubes to be tested will be as per Indian Railways specifications. It should be ensure that concrete temperature does not exceed 40 degree centigrade.

7.4.4.4 The following equipments will be used:

1. Excavator – JCB (0.5 Cubic meter capacity) x 2 Nos.
2. Dumpers – TATA / LEYLAND (6 Cubic meter capacity) x 4 Nos.
3. Welding Generators - 400 AMPS x 2 Nos.
4. Concrete Vibrators – Internal x 4 Nos.
5. Vibrating Needles – 60 mm x 8 Nos.

(Transit Mixers, Concrete Pumps, Batching plants will be from ready-mix concrete supplier.)

7.4.4.5 All safety procedures and barricading of the roads and caution signage to road users will be ensured at site as necessary. Additional staff will be engaged for traffic control to assist the Police department for the security and safety of Public.

#### 7.4.5 Pier Shafts – Methodology

7.4.5.1 The total number of piers along the alignment would be around 540 numbers excluding for stations and depot. The size of the piers for the majority of the spans between 25 – 31 meters would be 2 meter x 2.5 meters and for longer spans beyond 31 meters would be 2.5 x 2.5 meters. For spans lower than 25 meters the size of the column would be about 1.75 x 2.5 meters. The height of the piers from top of the pile cap to the bottom of the pier head is around 4 – 11 meters. The average height would be around 9 meters. The total quantity of concrete involved in piers would be approximately 25000 cu. meters and steel would be 4000 metric tones.

7.4.5.2 It is proposed to complete the pier work in 30 months by providing two sets of agencies. The average concrete per month would be 800 cubic meters i.e. approximately 30 cu. meters per day. We have planned to complete about 20 pier shafts per month i.e. average of 1 pier shaft per day. Pier locations and their layouts shall be rechecked with reference to points already established during survey of piles and piles cap.





7.4.5.3 In the reinforcement fabrication yard, advance manufacture of pier reinforcement cages would be taken to ensure that sufficient numbers are kept ready duly fabricated for placing in position so that work is not held up on this account. The vertical reinforcement and necessary transverse reinforcement would be placed in position prior to the concreting of the piles cap. Additional vertical bars if any required to reach concrete up to the pier cap would placed and fixed in position with concrete cover blocks of 50 mm thick for reinforcement cover. Steel formwork fabricated in the yard as per scheme and design up to the full height of the pier to be cast and assembled at site.

7.4.5.4 Formwork will be of standard height with few of non-standard size to cover the full height of the pier. The Formwork before use will be cleaned and applied with the shutter oil before fixing in position. M/45 – M/60 concrete will be used as per design and concrete procured from ready-mix batching plant in transit mixer. The slump will be kept between 75 – 150 mm. Re-dosing of admixtures within limits will be done in transit mixer. Concrete pump with flexible hose or bucket or tremmie will be used for placing concrete. The height of fall of concrete shall not be more that 2 meters. Needle type vibrators will be use for vibration. Cubes will be taken to check compressive strength. Curing will be done with Hessian cloth after removal of formwork and kept moist with water sprinklers.

7.4.5.5 The equipments proposed are:

1. Vibrator x 4 Nos.
2. Vibrator Needles 60 / 40 mm diameter x 6 Nos.

All safety and quality control procedure will be followed as specified in the manuals to be prepared during construction.

#### 7.4.6 Concrete Portals – Methodology

7.4.6.1 Total numbers of portals required along the alignment are 56 Nos. spread over 15 locations (Statement # 7.3(E)). These portals (Figure 7.10) will be cast along with casting of piers. The location points will be marked with reference to nearby control points using total stations. Center-line pillars will be installed for checking the position of the structure. All items

mentioned in the methodology of piles and piles cap and piers for way structure will be followed for casting of portals. All safety methods barricading quality control procedures will be followed. The diversion of road wherever necessary will be done in advance and land acquisition will be done prior to commencement of work at such locations. Minimum of 6.5 meter wide road ensured for temporary movement of traffic. On completion of top beam of



portal the centre-line will be marked on top surface in both directions with reference to control points to fix bearing pedestals locations (reflectors, blinkers, diversion boards, proper elimination, painting of barricades etc. will be provided for guiding road users and for their safety).

#### 7.4.7 Pier Caps – Methodology

7.4.7.1 The total number of pier caps to be cast for the way structure will be about 540 numbers excluding stations and depot area involving 15000 cu meter of concrete and 2500 metric tones of steel. The entire work will be planned for completion within 30 months by using two separate agencies as stated earlier. The work of pier caps will be taken up in 3 to 4 weeks after casting of columns. The average progress has been planned at 1 pier cap in 2 days i.e. an average of 1 pier per day per agency. Suitable staging will be erected from ground level to support the formwork. Space will be kept on staging beyond planned dimension of pier caps on all sides for used as a platform for fixing reinforcement, side formwork, concreting and vibrations. The cap length will be design for additional length for accommodating erection scheme for girders and will be used later for inspection facilities.

7.4.7.2 MS railing will be provided at the edge of the pier cap platform and MS railing will be fixed from ground level to climb up to top of the pier cap. The bar bending schedule for the pier cap will be prepared and reinforcement fabricated in the fabrication yard. Adequate numbers will be fabricated in advance and stacked properly so that they are not in contact with ground surface. The reinforcement cage will be transported in trucks and erected in position by crane / manually and fixed in positions providing adequate concrete cover by use of concrete cover blocks. After inspection and checks formwork will be fixed in position. The steel forma work will be fabricated in fabrication yards and will be suitably numbered for ease of assembling before transport to site. The steel formwork surface will be cleaned and oiled before fixing in position. Concrete of required strength M35 shall be poured by concrete pump and received in transit mixtures from ready-mix concrete plant and ensured for desire workability with suitable admixture (use within limit). The concrete will be vibrated suitably and slump test will be taken at site and slump will be between 75 – 150 mm. Concrete cubes will be taken for testing compressive strength for concrete used in the work. The quality of concrete will confirm to IS-456/2000. Permeability test will also be conducted by taking concrete cylinders

during concreting. After removal of formwork adequate curing will be done by watering by user of Hessian cloth storing water on top of pier cap.

7.4.7.3 Equipment such as cranes, concrete pumps, vibrators, will be used as required. The centre-line of the pier cap will be marked on the top surface of the pier cap in both directions from control reference points. Bearing central pedestal locations will be checked with reference to control



point before fixing formwork and concreting. Necessary safety procedure, quality control procedures will be followed during this operation and all records documented for future reference.

#### 7.4.8 Girder / Casting Of Segment – Methodology

##### 7.4.8.1 Segments

- The total numbers of spans for the corridor ways structure are 540 numbers with spans varying from 60 meters to 8 meters centre to centre excluding station areas and depots. A single 60-meter span each has been adopted for crossing of Western Express Highway and railway tracks at Andheri. 3 x 40 meters spans have been adopted at different locations for over-road crossing. A common structure arrangement for girders has been adopted for spans varying from 25 – 31 meters and separate structure adopted for spans less than 25 meters. At stations the span are of 15 meters and with beam and slab type arrangement. The concreting of these columns, beam and slabs will be taken up along with station building construction. It will be ensured that way structure station yard girder and slabs are completed ahead of the erection way structure span to provide continuity for erection of main span girder.
- A single span girder for both up and down tracks is to be adopted for all spans. A casting yard for girder segment is proposed to be located at depot site in the open ground area, outside the elevated depot structure. Approximate area required for casting and the storing of the segment would be around 35000 sq. meters. The second casting yard will be located near the Sahar International Airport requiring similar area of 35000 sq. meters.
- This is necessary as it proposed to adopt two separate agencies for the way structure to complete the project in time. Out of the total spans 60% of the spans are on straight and 40% are on curves. Each segment is proposed to be of 3.0 meter in length. It is proposed to pre-cast the segment on long line as well on short line base. Curved span segment will be essentially cast on long line beds. The segment of straight spans will be cast on long line as well as short lines beds.
- The total number of segments will be 4888 numbers x (Comprising of 1178 end segments and 3710 intermediate segments). The end segment cycle time will be around 4 – 5 days per segment. Intermediate segment cycle time will be around 1 day per segment. The time cycle for 31 meter span girder on long line method will be

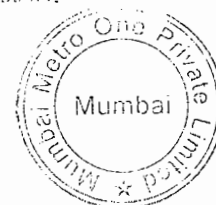


around 10 days. It has been assessed that about 6 beds per agency will be necessary. The area required for casting yard will cover that for casting beds, moulds, reinforcement fabrication and tying area, reinforcement jigs, stacking area for segments, area for pre-stressing material, other civil and mechanical items, water tanks, lavatory, office blocks, sand blasting pedestals, general inspection area, generator sheds, survey towers, access road, gantries (80 tone capacity x 2 nos. and 10 tone capacity x 2 nos. at each location).

- Approximate assessment of moulds and equipment in casting yard (both sides) are as under:
  1. Long line casting beds less than 25 meters x 2 Nos.
  2. Long line casting beds more than 25 – 31 meters x 6 Nos.
  3. Long line casting beds more than 31 meters x 2 Nos.
  4. Normal moulds x 16 Nos.
  5. Pier segment moulds independent x 4 Nos.
  6. Pier segment moulds for long lines x 8 Nos.
  7. Batching plants x 2 Nos. (Provisional)
  8. Transit Mixer x 6 Nos. (Provisional)
  9. Reinforcement Jigs x 20 Nos.
  10. Goliath Cranes 80 tone capacity 30 meter span x 4 Nos.
  11. Goliath Cranes 10 tone capacity 20 meter span x 12 Nos.
  12. Needle vibrators x 12 Nos.
  13. Concrete pumps x 2 Nos.
  14. Welding sets x 2 Nos.
  15. Total stations x 2 Nos.
  16. Auto levels x 2 Nos.
  17. Theodolite x 2 Nos.

#### 7.4.8.2 Moulds

The assessment of the number of moulds of different types has been based on an assumption of completing the castings of all segment in a period of 30 months. Further detailed assessment will be done at the time of execution to assess the numbers required of different types to complete the project in the stipulated period. Detailed drawings will be prepared for the moulds of different type and different spans including for bottom shuttering and site shuttering. A traveling gantry will be provided for the movement of side shuttering with provision to cast to intermediate segment simultaneously one from each end. A detail drawing of sequence of casting will be prepared before taking up casting operation. Detail assessment of time cycle for casting/curing/storing of end segments and intermediate segments will be made out during execution to the satisfaction of the nominated consultant if



any / MMRDA. It is assessed that the time cycle for each girder of say 31 meter span will be around 10 days. Details of typical casting sequence and time cycle for casting segments for 31 meter span are shown in the tables at Para 7.4.8.8 (A), (B), (C) & (D).

#### 7.4.8.3 Reinforcement Jig

This will be fabricated to provide a 40 mm clear cover for reinforcement with adequate spare jigs as stand bys. The reinforcement cage shall be cut and bend by using cutting and bending machines in the yard and checked through respective reinforcement jigs. Sheathing shall be fitted inside reinforcement cage at the required dimensions and approved tendon profile drawings and held in position by chairs and hooks. The cage will be lifted by 10 tone capacity EOT crane ensuring no distortion of the cage. M45 concrete / plastic semi circular cover blocks will be used to provide 40 mm cover.

#### 7.4.8.4 Concreting

The sequence of the concreting will be as follows:

1. Soffit Slab
2. Half height of web -1
3. Half height of web -2
4. Remaining half height of web -1
5. Remaining half height of web -2
6. Top flanges

M45 grade concrete based on the design with slump of 80 - 130 mm shall be used and transported by transit mixers. The concrete shall be vibrated by vibrators of various sizes of various diameters like 40 mm / 60 mm etc. cubes will be cast for respective parts for testing. For separation of matched cast segment a suitable bond breaking material (e.g. Concore, WB FOSROC will be used on the surface of previously cast surface). All fixtures of OHE mask bolts and drainage spouts etc. will be provided at specified locations as detailed in the drawing.

#### 7.4.8.5 Geometry Controls

Geometry Controls will be ensured by providing survey towers on one side and target pole on the opposite side of the casting bed. The centre line will be marked on a plate embedded in the segment with nails / bolts embedded at the center of each of top flanges for measurement of levels (wider space used on curved span). The bottom shuttering is fixed to the pedestals



as per actual profiles. During subsequent casting the matching of the centre line along the crown and top levels of top flanges are controlled.

#### 7.4.8.6 Curing Of Segments

Curing compound will be used for curing after casting of segment and application on all exposed surfaces after initial set and surface kept moist. Shuttering can be removed after concrete has achieved M15 crushing strength. The matched cast segment will be fitted with lifting frame in the lifting holes provided at the time of casting. The lifting will be done from Soffit shutter by 80 tone capacity EOT crane and place in stacking yard. The lifting of segment will be done after achieving the strength of M25.

#### 7.4.8.7 Pier Segments

Pier Segments need not be pre-stressed transverse at the time of match casting. It shall be pre-stressed before erection as per detail specification led down by the designer. Sand blasting of the concrete segment shall be done gently for 5 minutes so as to avoid any damage and remove any de-bonding agents, laitance, dirt, and foreign material before transportation. The sand blasting will be done by the combination of dry fine sand and compressed air through sand blaster equipment.

#### 7.4.8.8 Segment Castings – Activities and Time Cycle

##### (a) Activities for Casting of Each Intermediate Segment

S.No.	ACTIVITY	TIME (Hours)
1.	Demoulding of previous segment collapse of internal shuttering and sliding of the external formwork.	1.0
2.	Clean the bed for the next segment.	0.5
3.	Shift mould to next location and external shutters (cleaning & oiling done parallelly).	1.0
4.	Apply debonding agent.	0.5
5.	Place the rebar cage with the help of 10T Gantry.	1.0
6.	Fix the sheathing pipe including its connection to match cast segment.	1.0
7.	Inspection by client.	1.0
8.	Move the internal shutter and fix the same butting against match cast segment.	1.0
9.	Provide inserts, holes etc. for lifting and temporary pre-stressing.	1.0
10.	Fix end stopper.	1.0
11.	Inspection & approval from client for concreting.	1.0
12.	Concreting of the segment.	2.0
13.	Setting time for concrete.	12.0
	<b>Total</b>	<b>24.0</b>



## (b) Time Cycle for Casting Pier Segment S1 on Long Line Bed

S.No.	ACTIVITY	TIME (Hours)
1.	Clean the bed.	0.5
2.	Fix the external formwork including cleaning and oiling.	1.5
3.	Install special shuttering plates at bearing locations.	0.5
4.	Fix the anchorages.	2.0
5.	Lower the rebar cage and move inside by 10T Gantry.	1.0
6.	Attach the sheathing pipe to the trumpet.	1.0
7.	Inspection by client.	1.0
8.	Fix end stopper from one side.	1.0
9.	Provide inserts, holes etc. for lifting and temporary pre-stressing.	1.0
10.	Fix and shutter toward span side and close the formwork including fixing of internal shuttering to both sides and stoppers.	1.0
11.	Inspection and approval from client for concreting.	1.0
12.	Concreting of the segment.	3.0
13.	Setting to time fro concrete & waiting period for stressing.	72
14.	Demoulding.	1.5
15.	Stressing.	2
	<b>Total</b>	<b>80</b>

## (c) Time Cycle for casting of 31 M span on long line

Sr. No.	Operation	Total Time
1	Cast S1 and place S11 and make ready for match casting.	0 – 2 days
2	Cast S2, S10	2 – 3 days
3	Cast S3, S9 / Lift S1, S11.	3 – 4 days
4	Cast S4, S8 / Lift S2, S10.	4 – 5 days
5	Cast S5, S7 / Lift S3, S9.	5 – 6 days
6	Cast S6 / Lift S4, S8.	6 – 7 days
7	Lift S5, S7	7 – 8 days
8	Lift S6.	8 – 9 days

7.4.9 Girder Erection – Methodology

- 1) The main components of the launching girder are:
  - a) Main Box Girder
  - b) Front, Middle and Rear Support
  - c) Rear Trolley and Slider Beam
  - d) Moving Trolley
  - e) Counter Weight
  - f) Fixed Mounted Hoist
- 2) Stages of erection includes:
  - a) Transportation of segments from casting yard to bridge site.
  - b) Lifting of Segments
  - c) Dry matching, gluing and temporary pre-stressing of segments.
  - d) Post Tensioning works
  - e) Erection Sequence for pre-cast segments
  - f) Auto launching of launching girder
  - g) Erection Cycles



- 3) Launching Erection Works will be handled by two agencies. Each agency will have approximately 270 – 300 girders to be launched. The segments will be cast at the yard at D.N.Nagar depot and the other at the Airport yard at Sahar.
- 4) Configuration of Bridge and Launching Girder
  - a) Maximum span length 31 meters.
  - b) Minimum span length 17 meters.
  - c) Maximum steepest gradient 2.5%
  - d) Maximum weight of the segment 80 tones.
  - e) Maximum length of the segment 3 meters
  - f) Minimum horizontal radius 100 meters
  - g) Total height of intermediate segment 2 meters
  - h) Total end segment 3 meters
  - i) Segment glued or dry jointed Epoxy Glue
  - j) Loading of Segments from ground
- 5) Staff required – Each launcher would need 2 x Engineers, 2 x Foremen, 30 x Workers, Servers and Erection Manager.
- 6) Steps Involved in Operations at Site
  - a. Transportation and Unloading of segments at site
  - b) Span Erection
  - c) Epoxy Gluing
  - d) Temporary pre-stressing works
  - e) Post Tensioning
  - f) Lowering on Temporary Bearings
  - g) Permanent Bearings / Vertical Bearing and Shear Key Installations.
  - h) Hand Drilling
  - i) Expansion Joints.
- 7) Launching Works
  - a) The transverse stressing and grouting of pier segments will be done at the storage yard and sand blasting of the joining surfaces before transportation to site (see Photo 7.1).

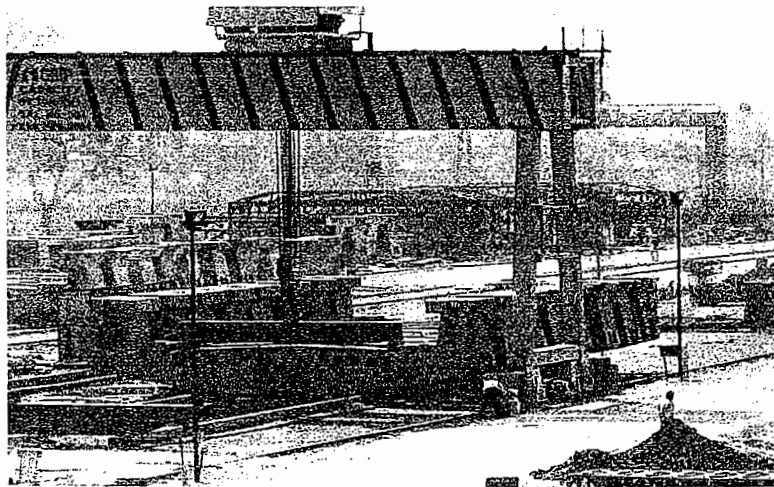
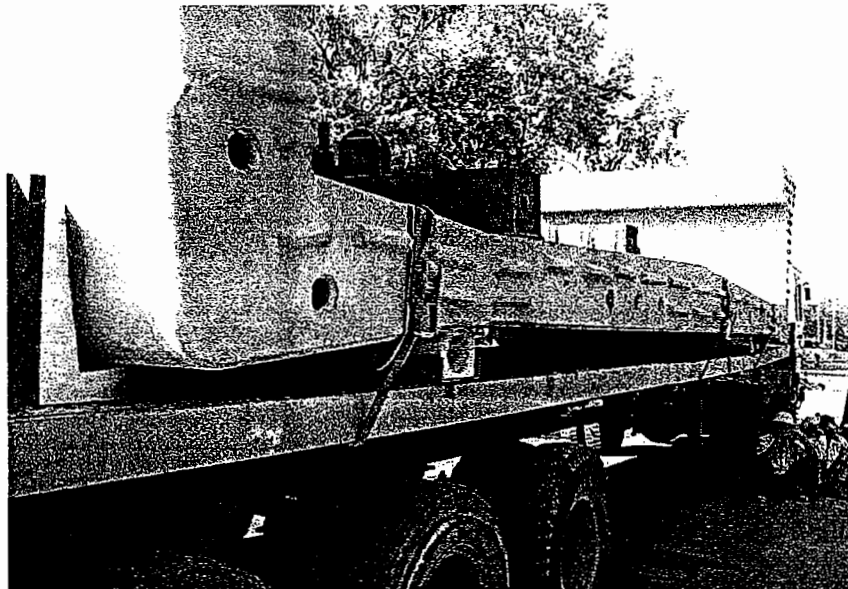


Photo 7.1 - Storage yard

- b) Segments will be loaded on trailer by 80 tones capacity Gantry crane in sequence with adequate packing and tie with slings / ropes and trailer transported to the site (see Photo 7.2).





**Photo 7.2**

- c) Transport of segments will be done at night and about 6 trailers will be required at each site for erection works. The segments will be unloaded from the trailer in sequence by using 80 tone hoist of the launcher. Segments will be lifted to the launcher and hung on to the suspender bars one at a time.
- 8) **Span Erection**
- a) For erection of segment the launcher have to be erected over the pillars.
- b) For the first span launcher will be erected on temporary structure consisting of cribs (designed to suit the span length)
- c) The main components of the launching girder are:
- Box Girder
  - Front, Middle and Rear support
  - Rear Trolley Support
  - Slider Beam
  - Counter Weights
  - Fixed Mounted Hoists
- d) The main box girder consists of 7 box type steel structures of length 9.25 meter each, spliced together by 24 diameter HSFG bolts.



9) Launching Girder

- a) The launching girder main box structure rests on 4 supports viz. Front Support, Middle support, Rear Support and Rear Trolley. Front support consists of Top Beam, Bottom beam, Top Vertical legs and Telescopic Legs with built-in height adjustments. Telescopic leg moves on top of the vertical leg and can be locked using 100 mm diameter pins. Where entire support rest on concrete pedestals on the front pier and is secured to the pier cap by 4 numbers, 32 mm diameter anchor bolts (Photo 7.3). Vertical adjustment of support is done by 2 hydraulic jacks of 150 tonnes capacity. Side shifting of front support with reference to launching girder is not possible. Middle support is located at rear pier segment of the span. During erection the weight of the whole launcher is supported by front support and middle support and level adjusted by using 4 numbers of single acting hydraulic jacks of 200 ton capacity. Longitudinal pushing and breaking device is clamped to the top beam of the middle support with attachment to a monorail underneath the launching girder. This assembly ensures forward movement of launching girder with 40 tonnes double acting jacks for its operations and connecting it to monorail is done by 40 mm diameter pins. The rear support is similar to middle support without the pushing device assembly but has a breaking device assembly. Four numbers of 100 tones jacks are used in the assembly to withstand the load of the launcher during auto launching operations. The rear support consists of pair of A – Type truss support connected to 4 wheels on each truss moving on a pair 90 lbs rails at distance of 4.7 meters distance c/c laid on completed span. The truss will be connected to each other by a pin connection to the top beam to facilitate vertical rotation movement during auto launching. The launching girder can be locked with respect to this support by 4 sets of Macalloy bars passing through brackets in launching girder and movable brackets consisting of 2 ISMC 200 and bolted at top and bottom.

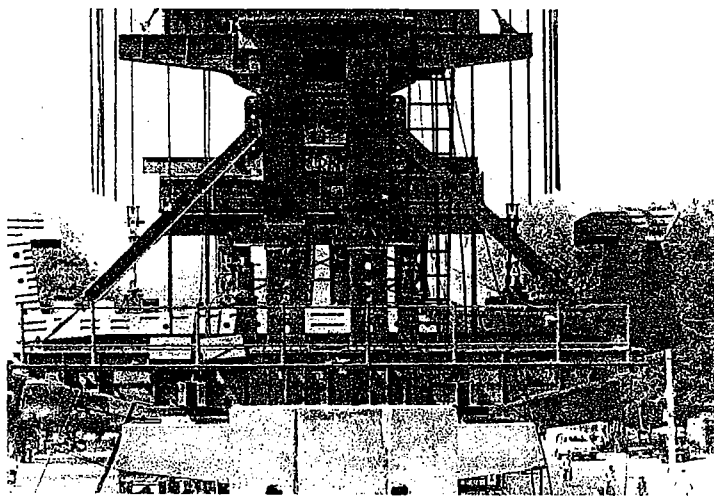


Photo 7.3



(b) Sliding Beam

Consists of assembly of 2 numbers of build up I section connected by stiffeners. The sliding beam rest on 70mm x 40mm plates with 3 mm stainless steel plate fitted on top of the launching girder's main box. Each sliding beam will have one number of suspender bars on each end. The slider beam will have 2 suspended bars at each end which move 500 mm on either sides in transverse direction while maintaining constant distance of 5.8 meters among themselves. The suspended bars and the assembly will then be connected to the temporary pre-stressed beam, which has been fixed to the segment. Longitudinal movement of the segment will be done by using high tensile wires attached to the sliding beam and pulled by mono jacks from one end of the launcher.

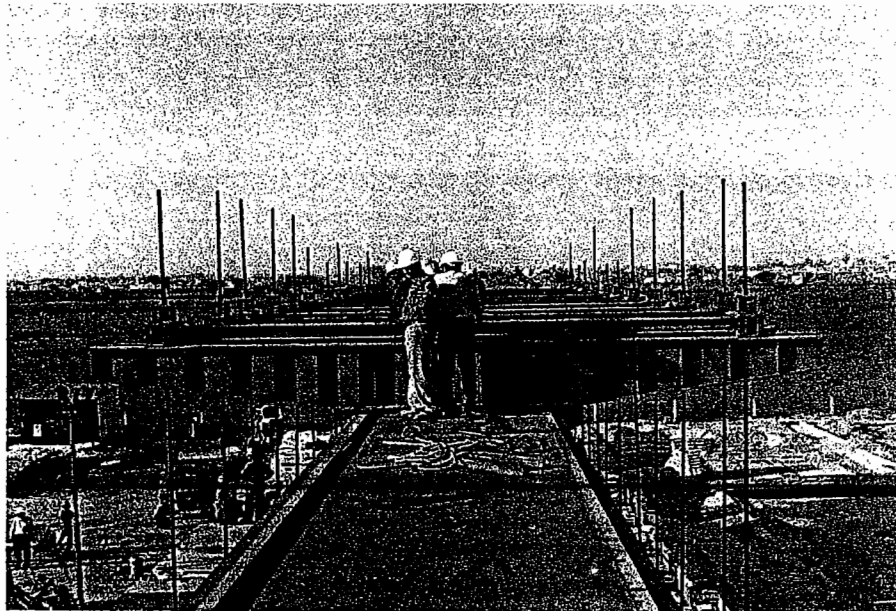


Photo 7.4

(c) Moving Trolley

- Moving Trolley is an independent device consisting of 2 tools resting on a platform mounted on 4 wheels and is mainly used for forward movement of middle support and rear support. Moving trolley is also useful for temporary supporting the rear support and middle support for minor repairs and maintenance of the support jacks.

(d) Counter Weight

- Counter weight is provided in the form of pre-cast concrete segments, which will remain fixed at rear end of the launching girder during the entire launching process. This counter weight balances the launcher during auto launching of the launching girder.



e) Fixed Mounted Hoist

- An electrically operated device fixed over a bracket at a distance of 13.4 meters from the front end of the launching girder. Lifting capacity of Hoist is 80 tonnes and is used for lifting segments during erection stages. (Photo 7.5).

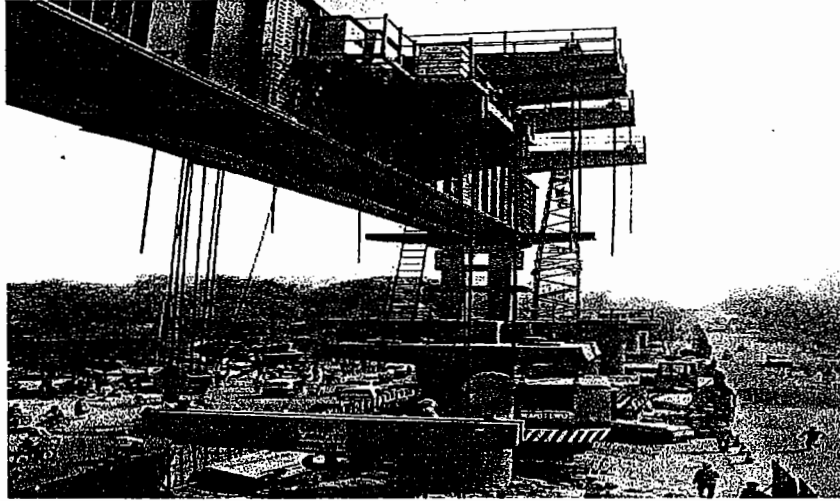
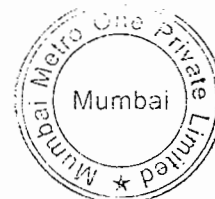


Photo 7.5

f) First Span Erection

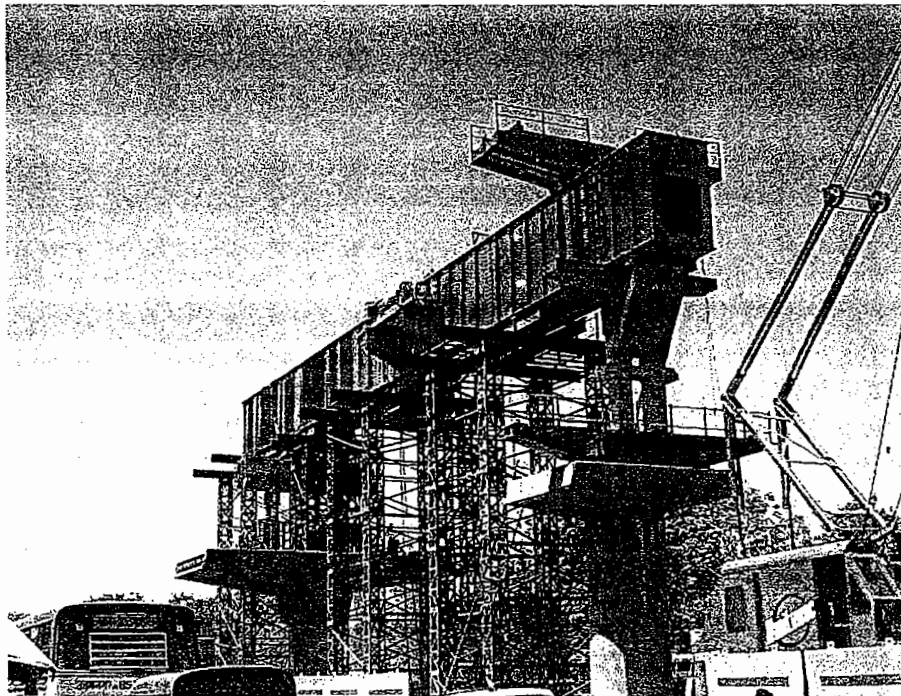
- A temporary support is required to support the launcher by erection of trestles TR1, TR2, TR3.
- Erect stool over the pier and erect front support over the next pier.
- Erect box S1 and connect it to the front support so that the box S1 will sit on the front support while the other will sit on the trestle TR1.
- Box S2 are connect to box S1 by splicing plate and 24mm  $\phi$  HSFG bolts. This box S2 will rest on trestle TR1 at one end and TR2 at the other end (Photo 7.6)
- Erect box S3 and connect it to box S2 so that box S3 will rest on trestles TR2 and TR3.
- Erect middle support over stool -1 on the first pier.
- Erect box S4 and connect it box S3. Thus the S4 will rest on trestle TR3 at one end and middle support at the other (Photo 7.7).
- Remove trestle TR1 & TR2 but maintain TR3.
- Erect TR1 and TR2 behind the pier.
- Erect box S5 and connect it to box S4. Thus the S5 will rest on TR1 and TR2.
- Remove trestle TR3 from front of the pier and erect it behind TR2.
- Erect box S6 and connect it to box S5. Thus box S6 will rest on TR2 and TR3.
- Erect Crab Hoist, brackets for mono-jacks and sliding beams on the launcher at box S1 and S2.
- Erect temporary trestle over the pier and counter weight over the trestle.



- Erect extra two numbers of sliding beams on the launcher and hang counter weights to these extra sliding beams. Slide the counter weights to box S6.
- Remove temporary trestles from the pier and the span is ready for the erection of segments.

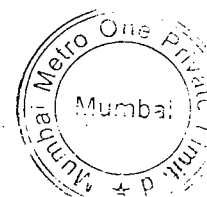


Photo 7.6



**Photo 7.7****(g) Erection of Segments (Procedure for 31.0 meter Span)**

- Move all the slider towards the span to be erected and install 250-ton flat-jacks, two numbers of each side of the pier cap to received pier segments of S1 and S11.
- Position the trailer under 80 ton hoist and attached lifting beams hanging from the hoist to temporary pre-stressing beam attached to the segment at the soffit level and lift and rotate the segment to the required direction and height.
- Attached suspender bar assembly of first sliding beam to the temporary pre-stressed beam and slightly lift the suspender bars by a mono jack and thereafter detached and remove the lifting beam together with the suspended segment to position (**Photo 7.8**).
- Repeat procedure for segments S1, S2, S3, S4, S5 & S6 and move the remaining segment beams towards segment 6.
- Lift pier segment S11 and position it as near as possible to the shear key of the front pier.
- Lift segment S10 and park it over segment S11.
- Lift segment S9, S8 & S7 and position them at their respective location (**Photo 7.9**).
- Arrange the segment by adjusting the level and alignments of pier segments S1& secure it against any movement similarly adjust segment S2 to match it to segment S1 (Dry match) and then detach it from segment S1.
- Apply Epoxy Glue to the matched surface of segment S1 & S2 with a thin 1mm thick layer to manufacturers recommendations and match the surface of segments S1 & S2 together.
- Carry out temporary pre-stressing of segments S1 & S2 Macalloy Bars.
- Repeat the process to the rest of the segments



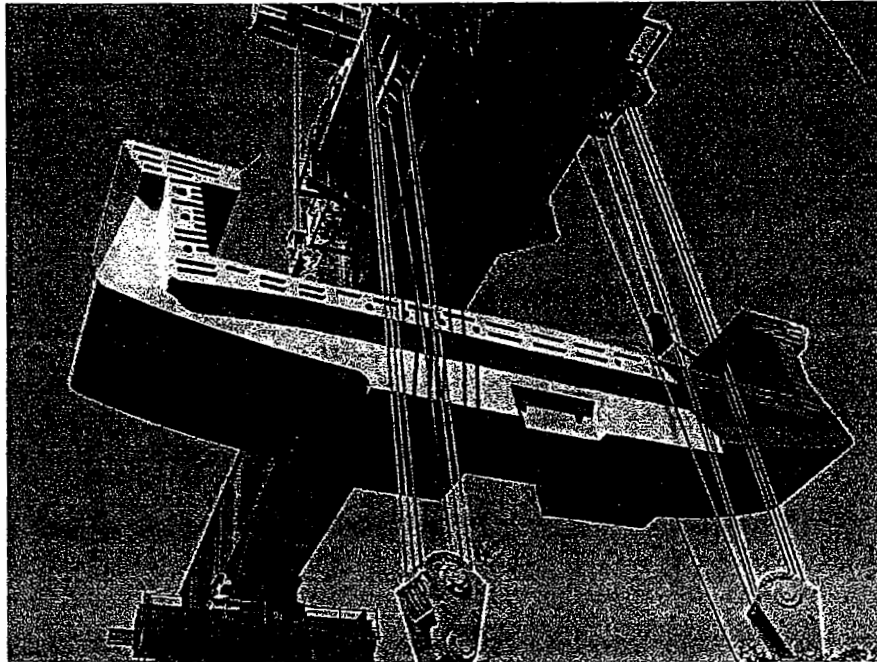


Photo 7.8

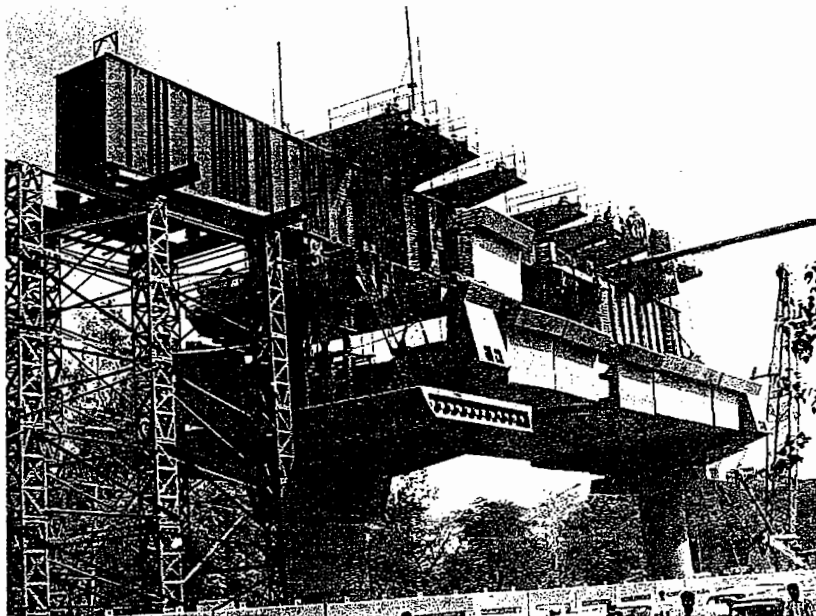


Photo 7.9



**(h) Post Tensioning Works**

- Insert pre-stressing tendons and carry out longitudinal pre-stressing of the entire span.
- After pre-stressing the load is transferred on to temporary bearings. There after release the suspenders and remove the temporary pre-stressing beams and move the sliding beams towards the counter weight side.
- Launching girder is ready for auto launching.
- 

**(i) Auto Launching**

- Auto launching involves forward movement of launching girder from the previously erected span to the span to be erected.
- All safety precautions will have to be taken for auto launching as specified in working drawings to be prepared during project execution.
- Bring the slider beam backwards so as to rise at 4.45 M from the end of the launching girder (near Rear Trolley) and all other slider beams rests in succession at spacing of 0.9M.
- Erect rail over the span and the rear support of segment S1 on the completed spans and jack it up to take a load of min 10 tons of launcher.
- Transfer the load to the rear support and remove the middle support and stool 1 from pier.
- Erect middle support on segment S11 on completed span and jack the middle support to take a min of 10-ton load of the launcher.
- Slide all sliding beams and counter to box S2 & S3 of the launcher and close the leg of the front support.
- Open the jacks of the middle support and the rear support by 100mm and release trestles TR1, TR2 & TR3 from vertical and horizontal roads.
- Slide the launcher forward by 4M using pushing and breaking device.
- Push the launcher forward to the optimum stroke.
- Lock the pin of the breaking device to the monorail and thereafter free the jack from the monorail.
- Lock the pin of the pushing device and release the pin of the breaking device of the monorail and the launcher is ready for the next round of movement forward. This process is repeated until the launcher reaches the required position. It should ensure that one of the pins must always be slotted in all times to avoid accidents.
- Move the sliding beam and the counter weight and slide the launcher girder another 5M.





- Slide the sliding beam and counter weight to box S5 & S4 after erecting box S7 over trestles TR2 & TR3 and connecting by splicing.
- After realizing all the trestle free of load slide the launcher forward by another 10M and the sliding beams and counter weights over box S7 & S6 at a distance of 7M from the end of the launcher.
- Slide the launcher forward by another 9.5 M and remove trestles TR1, TR2 & TR3.
- After opening the front support leg and anchoring it to pier cap slide all the sliding beams and counter weights to box S1, S2 & S3.
- Slide the rear support from segment S1 to Segment S9. Erect rear trolley support at segment S2 slide all sliding beams and counter weights to box S5 & S6 and lowered down the middle support jacks so that the soffit of the launcher touches the top of the rear trolley support.
- Lock the rear trolley support to the launcher and slide the counter weights to the final position of box S7.
- Remove the two extra sliding beams and slide all the sliding beams to box S7 & S6.
- Slide the launcher forward to the final position anchor the jacks of the front support to the pier cap and the jacks of the rear support should just touch the soffit of the launcher without taking any load.
- Then the launcher is ready for the next span erection.

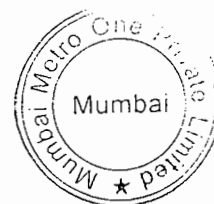
j) Erection Cycle

- In the initial stages the erection cycle may be as long as 10 days per span initially but this will get reduced to optimum cycle of 3 days per span.

**SUMMARY OF ERECTION CYCLE TIME FRAME**

ITEM	ACTIVITY	DURATION	
		(MINUTES)	(HOUR)
A1	Preparation works	120	2.00
A2	Erection works with 11 segments	385	6.20
A3	Total time rearrange the segments (11nos.)	550	9.17
A4	Total stressing time	1140	19.00
A5	Auto Launching Works	1665	27.27
	<b>TOTAL LAUNCHING CYCLE =</b>	<b>3860</b>	<b>64.33</b>

$$= 64.33/24 = 2.68 = 3 \text{ Days}$$



## (k) Other Works

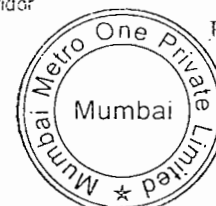
- Other works will start as soon as the launcher moves from the completed span. This is done so as to interfere with the launching works.
- These works include:
  - a) Span adjustment.
  - b) Remove temporary bearing.
  - c) Permanent bearing installation.
  - d) Grouting of tendons.
  - e) Installation of Shear key.
  - f) Installation of Vertical bearings.
  - g) Cable Trough.
  - h) Hand Railing.
  - i) Expansion joints.

## 7.5 Details of Hydraulic Equipments / Miscellaneous Items

S.No.	Item Description	Unit	Qty.
<b>1</b>	<b>Jacks and Power Pack</b>		
<b>1.1</b>	<b>Front Support</b>		
(a)	Hydraulic Jack 150 T capacity Stroke 250mm Single Acting with threaded ram, lock nut and base plate of size 300mm x 300mm x 25mm.	Nos	2
(b)	Power Pack to operate the above jacks simultaneously.	Nos	1
<b>1.2</b>	<b>Middle Support</b>		
(a)	Hydraulic Jacks 200 T capacity 300mm strike single acting with threaded ram & lock nut plate of size 400mm x 400mm x 25mm.	Nos	4
(b)	Power Pack to operate the above four jacks simultaneously.	Nos	1
(c)	Longitudinal launching jacks 40 t capacity, Double acting with a stroke of 1200mm including over valve.	Nos	1
(d)	Power Pack to operate above jacks.	Nos	1
<b>1.3</b>	<b>Rear Support</b>		
(a)	Hydraulic Jack 100 T capacity Stroke 300mm Single Acting with threaded ram, lock nut and base plate of size 300mm x 300mm x 25mm.	Nos	4
(b)	Power Pack to operate the above jacks simultaneously.	Nos	
<b>1.4</b>	<b>Rear Trolley</b>		
(a)	Hydraulic Jacks 100 T capacity 300mm strike single acting with threaded ram & lock nut plate of size 300mm x 300mm x 25mm.	Nos	2
(b)	Power Pack to operate the above 2 jacks simultaneously.	Nos	1
(c)	Central Hole jack for pulling 26.5mm Mac alloy bar with stroke of 200mm.	Nos	1
<b>1.5</b>	<b>Slider Beams</b>		
(a)	Hydraulic Jack with Central hole capacity 60T and stroke 200mm for moving suspenders of 40mm dia	Nos	2

	Mac alloy bars.		
(b)	Hydraulic jacks for transverse movement of slider beam capacity 20T, Double Acting, stroke 600mm.	Nos	2
1.6	Jacks for Supporting and Lowering the span after launching capacity 200T single Acting with lock nut maximum height 250mm.	Nos	4

<b>2</b>	<b>Macalloy Bars</b>		
(a)	40mm dia Macalloy bars as suspended each of length 6.5m.	Nos	22
(b)	Nut of dia 51mm to suit 40mm dia suspenders.	Nos	44
(c)	26.5mm dia Mac alloy bar for side shifting over rear trolley.	M	11.8
<b>3</b>	<b>Hoist / Winches</b>		
(a)	80 T capacity hoists resting over brackets of launching girder for fitting of segments.	Nos	1
(b)	Mono jacks for pulling slider beams capacity 10 T.	Nos	2
(c)	10 T Hoist for shifting supports operating on monorail attached to bottom of L.G.	Nos	1
<b>4</b>	<b>Wire Ropes</b>		
(a)	20mm dia wire rope for pulling sliders beams.	M	60
(b)	40mm dia rope assembly for lifting segments.	M	100
(c)	Thimble for 40mm dia wire rope assembly.	Nos	44
(d)	Aluminum grip foil for 40mm dia wire rope assembly.	Nos	88
<b>5</b>	<b>Miscellaneous</b>		
5.1	Bolts for Launching Girder splices 24mm dia. HSFG bolts	Nos	2100



## CHAPTER - 8

### TRACK - METHODOLOGY

#### 8.1 Construction Method

8.1.1 Track for the entire alignment including depot and Airport line will be elevated except for the portion for alternative depot site at Ghatkopar where it will be at ground level. It is, therefore, proposed to provide non-ballast track for the entire elevated portion including depot and a ballasted track for the ground level portion for the alternative depot site at Ghatkopar.

8.1.2 Considerations shall be given to the design of the trackform with derailment protection in mind. The principle of derailment protection shall be to contain a derailed train to within the trackform in order to:

- minimize risk to passenger safety
- minimize damage to surrounding structure
- minimize damage to the track
- minimize damage to the rolling stock

8.1.3 The work of providing concrete blocks for the non-ballast tracks will commence on completion of viaduct deck construction and progress will be maintained. The pre-cast RCC Blocks will be provided as per the design standards and the specifications of the Ballast less track for standard Gauge. After adequate curing of blocks, track fittings installation and track laying will commence. The track will be laid by using 10 rails / 3 rail panels made from 60 Kg/m rail section conforming to IRS / UIC specifications to form CWR / LWR track with joints by A.T. welding as per Indian Railways specifications. The track fittings will include Rubber pad on Steel shims, Pre-cast track bolts, CI bearings, Pandrol clips/ Vossloh fittings & Grooved Rubber Pads.

8.1.4 The total route kilometers are as under:

- (a) Versova to Ghatkopar – 11.588
- (b) Air Port side – 1.265 12.853 D/L
- (c) D N Nagar- Depot Entry S/L 0.37 km
- (d) Alternative Car Depot at Ghatkopar end – S/L 1.74 Km
- (e) Car Shed – S/L 5.0 Km
  
- (f) No of Turn Outs in yard at D N Nagar - 1 in 9 & 1 in 6



- i) No of Turn Outs in Main Line 1 in 9 27 Nos.
- ii) In the Car Depot – 1 in 6 25 Nos.
- (g) Total track length 60 Kg – 26.076 Km & 52 Turnouts/ 49 Kg – 5.370 Km
- (h) The types of turnouts used shall be kept to a minimum. As a general rule, diamond crossovers are not be used.

**Making a total track length of- 31.446Km, of which 60 Kg is 26.076 and 52 Turnouts/ 49 Kg is 5.370**

- 8.1.5 It is proposed to complete the entire track work including welding and destressing etc in a total period of 26 months. The total track length involved including yards is around 32Kms and the monthly progress therefore has been planned at the rate of 2Kms per month engaging two agencies the average progress per agency will be 1Km per month. The destressing welding etc will be done in the remaining period of 10 months. The track tolerances will be as per the International Standards of Standard Gauge.
- 8.1.6 The rail expansion joints for continuous welded track will be designed to suit the rail temperature ranging from 10 deg to 60 deg C. The ballasted track will be laid on 250mm thick ballast bed at sleeper density of 1540 PSC sleepers per kilometer. PSC sleepers to standard gauge designs for yard lines and turnouts of proven design will be provided.
- 8.1.7 Buffer stops will be provided to standard designs at Ghatkopar and Versova and Sahara station and in yards. The numbers of Buffer Stops are 26.
- 8.2 **Summary of Track Components**

**Summary of the track materials required for the entire track work is given below:**

Sr. No.	ITEM	Unit	Quantity
1	RAILS 60Kg	MT	3200
2	RAIL 52 Kg for Yard (OR 49 Kg)	MT	600
3	CHECK RAILS	MT	600
4	CONCRETE BLOCKS	Nos	1,00000
5	RUBBER PADS	Nos	1,00000
6	GROOVED RUBBER PADS	Nos	1,00000
7	ERC CLIPS	Nos	2,00000
8	PANDROL CLIPS	Nos	2,00000
9	S.E.J	Nos	12
10	BUFFERS STOP	Nos	26
11	WELDING JOINTS	Nos	2500
12	49/52 Kg, 1:6 Turnouts with fittings and PSC Sleepers.	Nos	25
13	60 Kg, 1:6 Turnouts with fittings and PSC Sleepers	Nos	27



**P-way Works at D.N. Nagar Car shed**

Sr. No	Description of items	Unit	Quantity
1	Supplying 52/49 kg (T18) Rails (Plain track and check rail)	MT	520
2	Laying charges for plain track	Km	5000
3	Fishplates for 52 kg/49 kg rails	Pair	600
4	Fish plates Bolts & nuts 52 / 49 kgs	Nos	2400
5	SKV welding 60kg rails	Nos	200
6	Supplying Concrete Block sleepers for 52 kg rails	Nos	12000
7	Supplying GR rubber pad	Nos	11000
8	Supplying ERC clips	Nos	22000
9	Supplying Pandrol Clips	Nos	22000
10	Supply of MS Plates	Nos	12000
11	Rubber Pad	Nos	12000
12	Pandrol Clip Assembly Block	Nos	12000
13	Supplying and fixing the buffer stop in correct position.	Nos	25
14	Laying charges for check rails	Km	1000
15	Special block for check rail	Nos	1000

**P-way Works at Alternative Car shed at Ghatkopar  
(By the side Eastern Express Highway)**

Sr. No	Description of items	Unit	Quantity
1	Supplying 52/49 kg (T18) Rails (Plain track and check rail)	MT	520
2	Laying charges for plain track	Km	5000
3	Fishplates for 52 kg/49 kg rails	Pair	600
4	Fish plates Bolts & nuts 52 / 49 kgs	Nos	2400
5	SKV welding 60kg rails	Nos	200
6	Supplying MBC sleepers for 52 kg rails	Nos	6000
7	Supplying GR rubber pad	Nos	11000
8	Supplying ERC clips	Nos	22000
9	Supplying Pandrol Clips	Nos	22000
10	Supplying ballast	Cum	10000
11	Laying of ballast	Cum	8000
12	Supplying and fixing the buffer stop in correct position.	Nos	25
13	Laying charges for check rails	Km	1000
14	Special block for check rail	Nos	1000

**P-way Works for main line**

Sr. No	Description of items	Unit	Quantity
1	Supplying 60 kg rails	MT	3200
2	Supplying 52 kg rails	MT	600
3	Check rail	MT	600
4	Concrete block	Nos	100000
5	MS plate	Nos	100000
6	Rubber pad	Nos	100000
7	Pandrol Clip Assembly Block	Nos	100000
8	Grooved rubber pad	Nos	200000
9	ERC clip	Nos	200000
10	Pandrol Clip	Nos	200000
11	Switch expansion joint	Nos	12
12	Buffer stops	Nos	26
13	SKV welding 60kg rails	Nos	2500
14	Turnout 52 / 49 Kg 1 in 6 with fitting and sleeper	Nos	25
15	Turnout 52 / 49 Kg 1 in 9 with fitting and sleeper	Nos	27



## CHAPTER - 9

### STATIONS - PLANNING AND ARCHITECTURE

#### 9.1 Introduction

##### 9.1.1 Elevated Stations

9.1.1.1 Elevated stations are gaining prominence world wide and have been acknowledged as a progressive solution by urban transit planners to relieve traffic congestion caused by increasing number of cars over the years, along with trucks, lorries, buses, motorcycles etc. Therefore, elevated stations are also expected to get appreciated in India as it can separate rail traffic with the road traffic as an alternative to the traditional at-grade rail system.

9.1.1.2 The design of the Station roof will conform to the submitted drawing. Ghatkopar station will be located in accordance with the drawings. The designs will take cognizance of the impact of the MUIP.

##### 9.1.2 Location Of Elevated Stations

9.1.2.1 The locations of the stations are recommended by MMRDA, considering space, route and existing development of the area.

##### 9.1.3 Inter-Station Distances

From	To	Distance in Km
Versova	D.N. Nagar	1.00
D.N. Nagar	Azad Nagar	0.80
Azad Nagar	Andheri – MRTS	1.40
Andheri – MRTS	Western Exp. Highway	0.94
Western Exp. Highway	Chakala	1.28
Chakala	Airport Road	0.74
Airport Road	Marol	0.65
Marol	Saki Naka	1.04
Saki Naka	Subhas Nagar	1.35
Subhas Nagar	Asalpha	0.74
Asalpha	Ghatkopar – MRTS	1.00



## 9.2 Planning Principles

The station serves two groups of users and they are the PASSENGERS and the OPERATORS.

### 9.2.1 Passengers

- The design of the station fulfils the primary concern of passengers, which is to move through the station as quickly and efficiently as possible.
- The station is user friendly and fully accessible to the physically challenged people.
- Lifts, escalators, staircases are designed at each level at appropriate position so that there is no confusion.
- Clear and direct pathways to and from the platform with adequate queuing areas.
- Visible fare vending machines & other facilities like toilets, refreshments, are also designed in appropriate areas. All these reduce congestions and speeds up passenger flow.

### 9.2.2 Operators

- Station buildings have been provided with separate area for operators, which is the "Operational Area".
- The heart of the "Operational Area" is the "Station Control Room".
- Staff efficiency is achieved by making access points, all concourse and other public areas visible from the Station Control Room.
- Visibility is required for the security surveillance of the station public spaces, monitoring of passenger flow at escalators and crown control at Platform Level.

## 9.3 Design Flow

Keeping the passengers and operators in mind the station is designed as follows:

### 9.3.1 Passengers Area

- The passenger area is divided into two parts:
  - The NON-PAID AREA i.e TICKETING AREA
  - The PAID AREA





- Escalators, staircases, lifts are designed on both sides of the road so that Passengers can come to the NON-PAID or TICKETING AREA at the Concourse Level.
- After buying the tickets, they go to the PAID AREA from which there is another set of staircases, escalators and lifts on both sides which lead the passengers to the Platform Level.
- The NON-PAID AREA has ticketing counters with proper queuing facilities, kiosks, ATM etc.

### 9.3.2 Operational Area

- Operational area is only for the staff so it is placed on one side of the concourse Level.
- Both PAID as well as NON-PAID areas are visible from the Operational Area.
- Vantage points of Operational Area are Station Control Room and Signaling Room.

## 9.4 The Station in the Community

9.4.1 The overall design ought to send a message to the regional economic and political establishment that WE live in a modern society.

9.4.2 The station buildings will be new and predictable concentrations of people who are the economic and social resource in the community, fostering both Commerce & Communication. Therefore existing community patterns and land use are studied and the station design give due consideration of:

- The pedestrian flow.
- Existing buildings in the vicinity of the proposed stations.

## 9.5 Aesthetics

9.5.1 FORM follows FUNCTION whilst at the same time it should be aesthetically appealing. Thus the whole building must be both functionally and appearance Wise so that it becomes the "LANDMARK OF THAT PARTICULAR PLACE".



## 9.6 Architectural Finishes

### 9.6.1 Materials and finishes proposed must satisfy the following criteria:

- Satisfy Safety requirements
- Fire resistant
- Floors are non-slip.
- At the same time low maintenance
- Suffice Acoustics.
- Materials also suffice the ambience requirements

## 9.7 Graphics and Signage

Graphics and Signage are proposed in the design for the smooth passenger flow in order to minimise chaos and confusion.

## 9.8 The Final Product

The final product achieved is a functional design with a unique aesthetics in totality.

## 9.9 Salient Features of Design

### 9.9.1 Flow Wise

Planning is in 3 levels:

- 1) Road level,
- 2) Concourse level,
- 3) Platform level.

#### 9.9.1.1 Road level

- There are two sets of covered staircase & up & down escalators on both sides of roads on footpath leading to the NON-PAID AREA at concourse level.
- Lift has also provided to go to the concourse level.
- Staircase width proposed is 4m & each escalator width is 1.75m. to cater the Crowd at peak hour.



### 9.9.1.2 Concourse level

- The Entrance lobby area at concourse level is large enough to suffice huge crowd.
- Passengers reach the NON-PAID AREA, take tickets & come to PAID AREA where there are again 2 sets of staircase, up and down escalators as well as lifts on both sides to go to platform level.
- The other part of concourse level is the operational area.
- The size of concourse area in main station is approximately 85m by 30m.

### 9.9.1.3 Platform level

- The tracks are in the center and side platforms are proposed.
- The side platforms result in greater traveling comfort and help in the uniform distribution of pedestrian flow.
- Each platform measures approximately 135m in length and of appropriate width as required.
- Platforms are covered from top and open from sides giving sense of openness, at the same time protecting sunlight and rains.
- In all type of plans passenger flow remains the same.
- Openness in planning incorporated since it fosters security and a sense of comfort.

## 9.9.2 Aesthetic Wise

### 9.9.2.1 Type 1 (refer to Figures 9.1 to 9.5)

- **MODERN DESIGN** – A tensile structure with trusses etc. reflecting a modern & confident society.

### 9.9.2.2 Type 2 (refer to Figures 9.6 to 9.10)

- This is the combination of traditional Indian Architecture blended with Modern Architecture.
- In both types the design aesthetically satisfies the technical & functional needs.

## 9.10 **Materials & Finishes**

- Stainless Steel antirust for tensile parts.
- Granite slabs 25 mm thick, 600 X 600 flame finish for floors making them non-slippery.



- Acoustic panels on walls, ceiling for clarity of public system.
- Purpose made glass fiber reinforced concrete.
- Artworks, Murals inside to enhance Station Architecture.
- Lighting, A.C's, Electrical services etc. are proposed to have good control over the overall architectural ambience.

## 9.11 Conclusions

Finally, over all, ELEVATED STATION BUILDINGS, come out as a dynamic system having far reaching impact on the lives & well being of the people providing them with an efficient system to support the daily & business activities.

## 9.12 Design and Construction Methodology

9.12.1 Station area of approximately 135x40m will be used to support concourse and platform structure. The whole structure will be designed as elevated framed structure comprising of columns, beams, slabs, pile caps and piles. Tentative size of column is 600x600mm and total no. of columns in a typical station is 52 approximately. Tentative size of beam are 450x600mm and slab thickness is 200mm. Tentative size of piles is  $\square$ 600mm and 4 no. of piles underneath each pile cap supporting individual columns in a typical station. Piles are to be socketted in the hard rock not less than 900mm which is nearly 15m deep below the ground level. Piles will be designed as per IS: 2911 (part 3) and National Building codes. Apart from dead load, superimposed dead load, a live load of 5kN/m<sup>2</sup> will be taken into the design. Roof and its supporting assembly may be designed separately mainly for wind load and gust effect because of its geometry, light weight and inaccessibility. The reaction from roof and its supporting assembly may be applied in the main column, beam and slab grid. The whole station building during erection and service is to be checked for seismic forces as per IS: 1893-2002. (Part 1) for zone 3 and ductile detailing of reinforcement will as per IS: 13920-1999. Other codes used in designing of station building are given in code list.

9.12.2 Alignment and proposed stations are located in a busy district of suburban Mumbai, it is therefore proposed ready mix concrete (RMC) for all cast in situ construction and bored piles. During construction, proper barricades and other protective measures are to be taken so as to ensure a safe flow of traffic and construction activity with close coordination and cooperation of concerned authorities. RMC quality and workability will be constantly monitored by regular cube test and slump test in laboratory. Cube test will also be done for assessment of strength of concrete.



9.12.3 Three groups of construction agencies will be arranged with 4 to 5 sets of station building to each group. This will ensure the timely completion of this activity (approximately 3 years). The construction of station building is a parallel activity with way structure construction. However way structure construction will be given due priority. It will be ensure the in detail planning that the erection of main girder of the way structure is not effected by the progress of station building.

9.12.4 During detail designing, composite construction may also be considered on the basis of economic, ease, and other considerations.



9.13 Examples

Typical arrangements of station layout and other associated facilities are shown in the following figures.

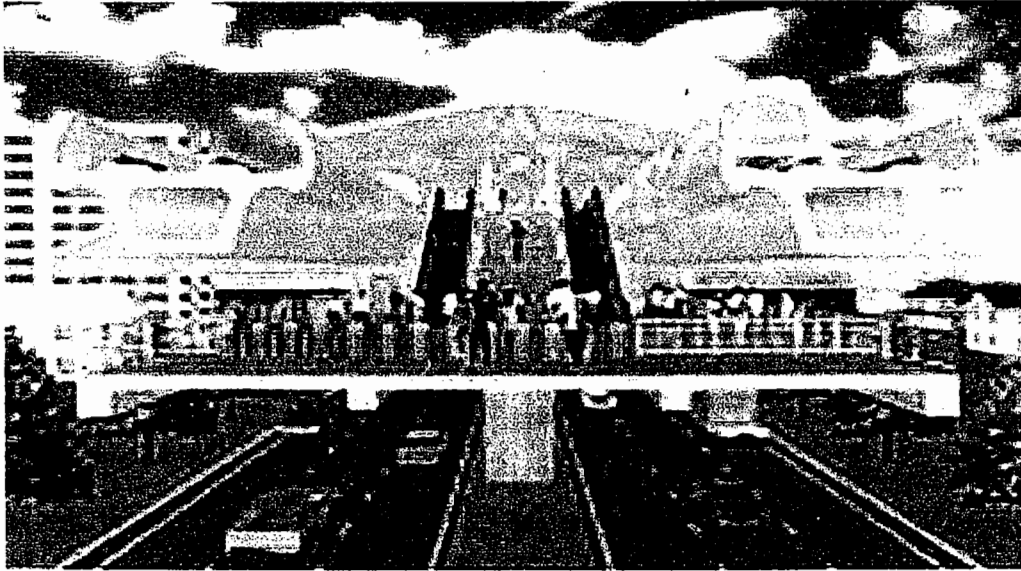


FIGURE 9.11

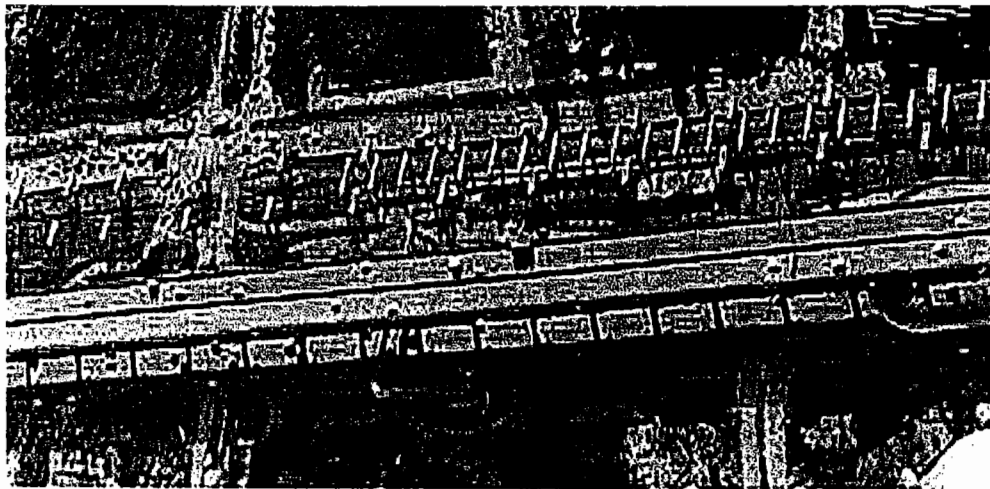


FIGURE 9.12



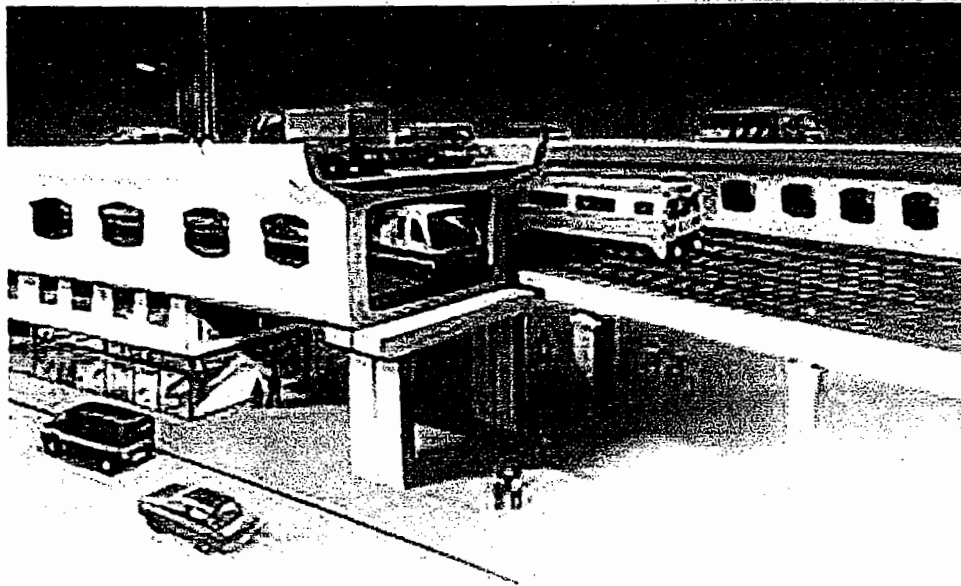


FIGURE 9.13

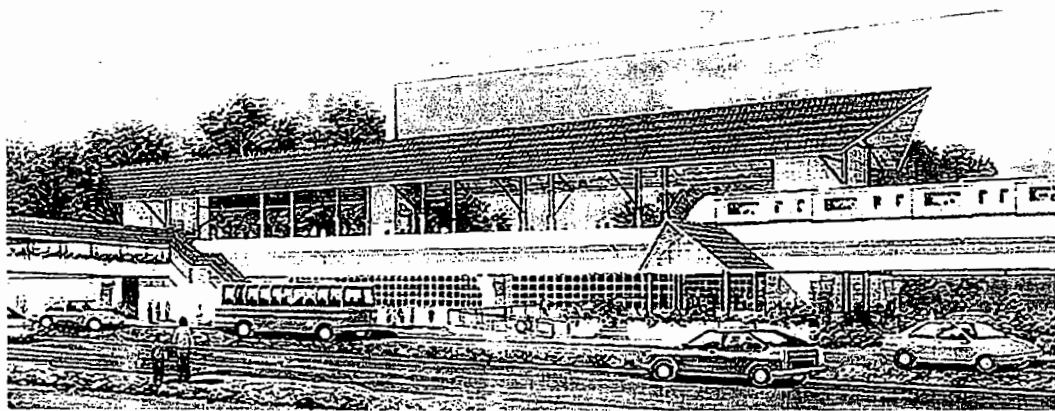


FIGURE 9.14



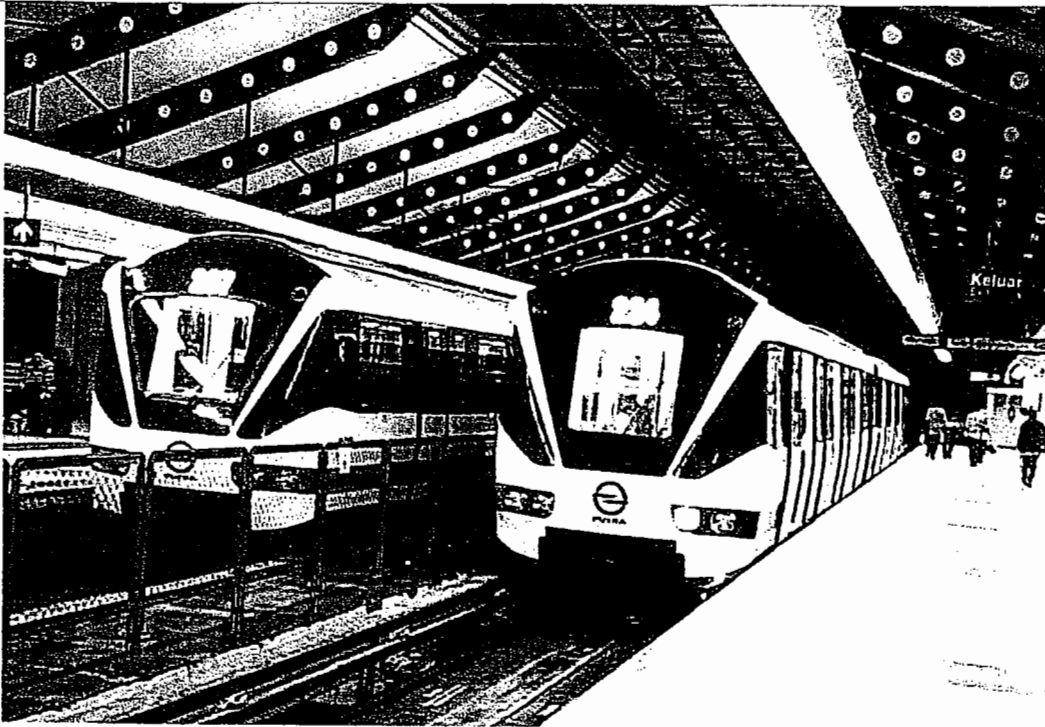


FIGURE 9.15

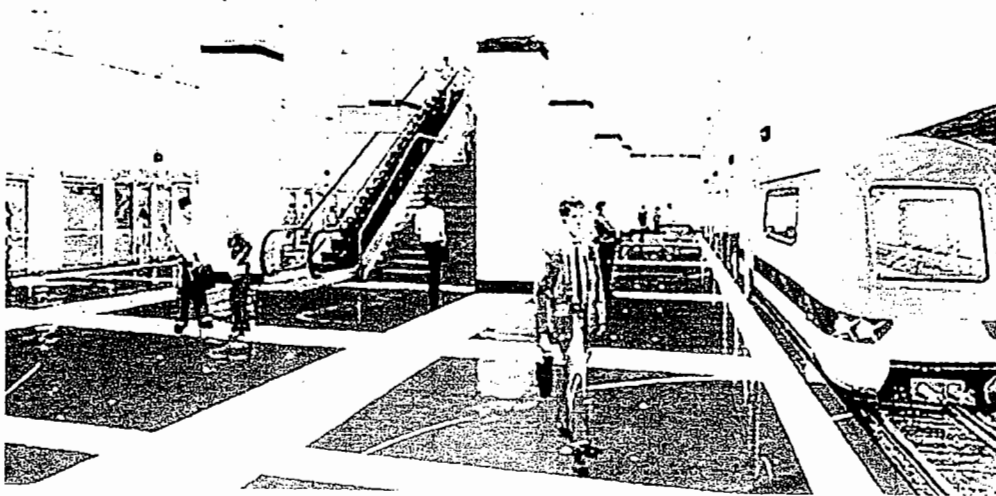


FIGURE 9.16





FIGURE 9.17

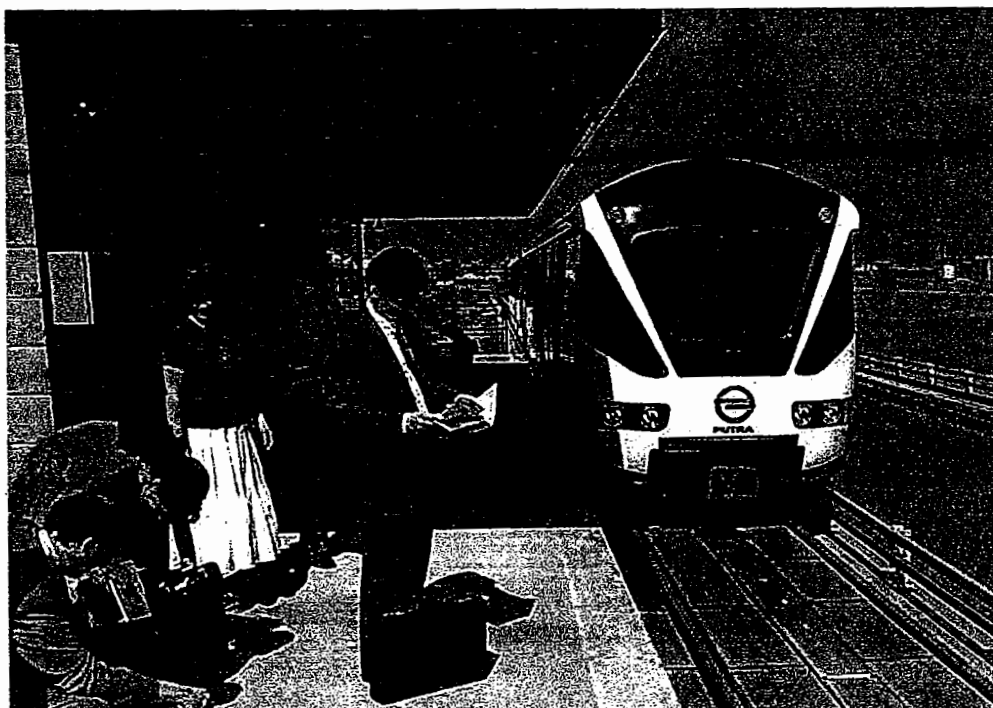
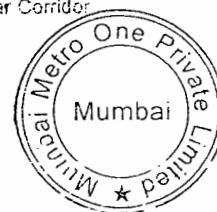


FIGURE 9.18



## CHAPTER 10

### ROLLING STOCK

#### 10.1 Introduction

10.1.1 Our offer for the Rolling Stock (Electrical Multiple Unit Stock) for the MMRDA's most prestigious Mass Rapid Transit System along Versova-Andheri-Ghatkopar Corridor is going to be advanced, modern and with the latest State of the Art Technology.

10.1.2 The proposed design of the EMU stock will FULLY MEET the required parameters of the MMRDA as contained in their BID document.

10.1.3 The Rolling Stock and their components will be in conformity with one or more of the following specifications:

- Bureau of Indian Standards (BIS)
- Indian Railway Standards (IRS)
- Research, Design & Standards Organization Specification (RDSO-spec)
- British Standards Specifications (BS)
- UIC, ASTM, IEEE, IEC

10.1.4 The special features of the proposed EMU coaches are described in the following sections.

#### 10.2 Train Set

10.2.1 The trains can be configured to a train set which consists of 4 coaches or of 6 coaches.

10.2.2 Considering the severe service conditions (Steep Grade and Sharp Curves) under which train sets are required to operate, necessitated by the high availability (97%), need to minimize the maintenance down time and to meet the stringent operating parameters (High Acceleration, Heavier Load, Optimum Running Time and Higher Deceleration), it is proposed to have at least half of axles motored either for the 4-car train or the 6-car train.

10.2.3 Subject to detailed design, the train formation for the 4-car train will be:

DT-M-M-DT

and the train formation for the 6-car train will be:

DT-M-M-M-M-DT    or  
DT-M-M-T-M-DT

where    DT – Driving Trailer

M – Motor Coach  
T – Trailer Coach

10.2.4 Each coach will be approximately 22 meters in length (buffer to buffer), 3.2 meters in width and 3.6 meters in height. The overall train length will be less than 135 meters.

10.2.5 The 6-car train set will comprise two 3-car units equipped with wide interior gangways automatic couplers at each end and with intermediate couplers of the semi permanent type in-between coaches to allow flexibility for cut out. Hostler control will be provided at the unit end of the non-driving coach.



10.2.6 During the initial stages of MRTS operation period when the traffic demand does not warrant 6-car train sets, the system can be operated with 4-car train set consisting of two motor coaches and two driving trailer coaches as a measure of economy. The 4-car train set will be expanded to form 6-car train set when traffic demand requires.

**10.3 Coach Body**

10.3.1 The Coach Body will be made out of Stainless Steel, which will ensure lightweight construction.

10.3.2 The Coach Body will have 4 doorways along each side ensuring equal spacing along the entire train length. The ends of the Roof structure shall be recessed to accommodate the Roof mounted AC package units.

10.3.3 The structural design will cater to the maximum vertical loading of about 20 % higher than the maximum envisaged service loading of 22,500 Kg (375 passengers) and the vertical deflection at the body centre will be limited to the acceptable international standards.

10.3.4 The Coach body will be capable of resisting the designed static end load applied through the coupler and draft gear centre line.

10.3.5 The headstocks of the coaches shall have anti-climber protection of appropriate design to absorb the permitted vertical shear loads restricting the damages to the couplers and anti-climb devices.

10.3.6 The under frame will be strengthened in such a way to provide for direct suspension of underframe equipment.

10.3.7 The coach profile will be designed to ensure near verticality of the sides for easy washing through mechanized washing machines. The nose end of the Driving Trailer coaches shall also be designed to offer least aerodynamic resistance at a reasonable cost.

10.3.8 For heavier roof mounted air conditioning units it will be necessary to provide additional structure to further distribute loads applied to the floor structure.

10.3.9 The Coach floor assembly and the side wall assembly will be provided with an effective fire barrier protection and heat barrier protection. The detailed design will ensure the required anti-noise measures.

10.3.10 The Coach body shell structural design will be checked by the use of F.E.M computer analysis and will be verified by the static load testing of the prototype.

10.3.11 Each coach shall be provided with two numbers of high performance air conditioning units of adequate cooling capacity each. Suitably designed blowers will be provided for emergency.

10.3.12 The on board power supply for the high performance A/C units would be provided by means of static inverters featuring IGBT technology.

10.3.13 Each Coach will be fitted with 6 to 8 longitudinal benches made out of Stainless Steel / Glass Reinforced Plastic (GRP) which can accommodate 42 to 48 seated passengers.

10.3.14 Standing room in coach will be ample with a normal crush load of 300 passengers (6 persons per sq. meter) and a maximum of 375 persons at dense crush load (8 persons per sq. meter).

10.3.15 On each side of the coach, four pairs of double leaf pocket sliding doors will be provided with 1400 mm clear width and 1900 mm clear height when opened. This clear opening of 1400mm door ways will also provide easy access for physically challenged persons and carriage of Wheel chairs in to the compartment with passengers of impaired mobility.

10.3.16 Gang ways of minimum 1400 mm clear width and 1900 mm clear height will be provided on the non cab end of the driving trailer coach and on either end of the motor coaches which will allow an



optimal passenger flow of upto about 2250 passengers per train equal to about 135 tonnes of payload.

- 10.3.17 The interior of the coaches will be provided with modern panelling materials, which will give aesthetically pleasant look and comfortable feeling to the passengers. The external profile, colour and finishes of the car body should give an attractive appearance.
- 10.3.18 All coach windows will be of tinted and double-glazed to reduce radiant heat transmission into the coaches in view of Mumbai's sunny tropical climate.
- 10.3.19 Body side thermal and acoustic insulation shall be of compressed fibre glass wool to satisfy specified heat and noise transmission criteria to create a comfortable and quiet environment for passengers.
- 10.3.20 Appropriate design of hopper windows will be provided to ensure adequate ventilation into the compartment during emergency. The operation of the hopper windows will be made user friendly for easy operation by the commuters.
- 10.3.21 Adequate handholds for standing passengers shall be provided through vertical grab poles suitable for passengers of varying heights.

#### 10.4 Bogies

- 10.4.1 Each motor bogie will carry two Frame mounted AC Traction Motors connected to Axle mounted gear units by flexible couplings.
- 10.4.2 Wheel arrangement for motor coach will be of Bo-Bo type.
- 10.4.3 Bogie frames are of bolster less H configuration fabricated from steel plates.
- 10.4.4 The Axle box primary suspension will be of conical bonded rubber springs or coil springs. If rubber springs are used, they will be of high hysteretic self damping type obviating the need for separate dampers. If coil springs are used, the coil springs will have vertical absorbers according to the wheelset guide principle.
- 10.4.5 The secondary suspension will be of single convolution Air Springs. The air springs connect directly between bogie frame and under frame bolster without a separate bogie bolster. These springs will be mounted in series with circular section, bonded rubber / steel sandwich springs providing emergency support for safe operation of the coach in the event of an air spring failure and for ensuring adequate rotational freedom to avoid undue twisting of air spring when negotiating curved tracks.
- 10.4.6 The secondary suspension will be provided with viscous dampers in both vertical and horizontal planes.
- 10.4.7 The air springs will be controlled by one central leveling valve at each bogie and this system will also provide reference signals to the load weighing of Traction and Brake performance.
- 10.4.8 Each bogie set of air springs will be transversely interconnected to ensure that in the event of failure including a burst air spring, both springs on the affected bogie deflate simultaneously.
- 10.4.9 Wheel sets are equipped with monoblock wheels and cast aluminum Axle boxes with spherical roller bearings. Single pusher tread brake units are provided at each wheel and will be fitted with brake blocks of high friction composition type.
- 10.4.10 Bogie frames and associated equipments are generally identical for motor and trailer coach application as far as practical.



- 10.4.11 The primary suspension system shall have suitable arrangement to provide requisite packing to maintain the Buffer heights (Bogie heights) within the specified limits under varying Wheel wears.
- 10.4.12 The average noise level along the length of the interior of each car measured at a height of 1.5 metres above the floor at the car centre line shall not exceed the following levels with all equipment operating and the vehicle running on the MRTS alignment with new level tangent track conditions and with all windows and doors closed: a) At 80 km/h - 74 dB (A) (b) With car stationary 69 dB (A) The average noise levels shall exclude measurements taken in the inter-car connecting gangway.

## 10.5 Brake System

- 10.5.1 MRTS train sets will be equipped with the following brake system:

An electro pneumatic friction service brake.  
An electric regenerative service brake.  
A pneumatic friction emergency brake.  
An automatic spring applied air release parking brake.

- 10.5.2 The brake system can be made to operate through encoder units under Automatic Train Operation System (ATO) if provided or through manually controlled cab equipment. The brake demand will be proportional between driving trailers and motor coaches to maximize electric brake effort on motor coaches upto limit of Wheel / Rail adhesion. Brake blending normally ensures priority for electric brake with pneumatic brake being utilized for topping-up and low speed braking. In the event of an electric brake failure, the pneumatic brake will provide a full-time rated service brake.

- 10.5.3 The pneumatic brake system will be fed by a suitable electric motor driven air compressor mounted at driving trailer / motor coach.

- 10.5.4 The emergency brake will use many components common to the pneumatic service brakes but operates as a fully independent high integrity friction brake. Emergency braking will be initiated variously by operation of the master controller, emergency valve with handle in the cab, loss of low voltage control supply, release of the Deadman's handle, interruption of train line due to separation of couplings (train parting), loss of main reservoir pressure or by the Automatic Train Protection (ATP) system.

## 10.6 Auxiliary Equipments and Systems

- 10.6.1 Each motor coach will be provided with a static converter / inverter (IGBT) for the auxiliary power supply system providing 110 V DC, 240V AC and 415V AC three phase, 50 Hz from the pantograph.

- 10.6.2 Two independent, roof mounted and self contained type Air Conditioners will be provided in each coach with redundancy and adequate cooling capacity.

- 10.6.3 An additional smaller capacity roof mounted and self contained type Air Conditioner will be provided for the driving cab.

- 10.6.4 The EMU will be equipped with headlight, signal lighting and internal lighting.

- 10.6.4 A battery bank of adequate capacity on driving trailer will be provided for the essential and emergency electrical loads of a three-car unit including emergency lighting and emergency ventilation.

## 10.7 Doors

- 10.7.1 Four sets of outside hung doors with exterior door sills will be provided on each side of the coaches which when opened will provide 1400mm clear width and 1900mm clear height. The door



operating mechanism will be housed above the doorway within the coach and will be mounted on a rigid frame, which can be removed as a unit for ease of maintenance.

10.7.2 The door operating mechanism will have provision for:

- Pushback mechanism allowing door leaves to be opened by about 100 mm permitting withdrawal of trapped objects.
- A cutout cock for pneumatic isolation of individual pairs to enable manual opening and closing.
- A device to latch defective doors in the closed position.

10.7.3 Each cab will be provided with manually operated pocket type sliding/hinged doors.

## 10.8 CAB

10.8.1 A full width cab will be provided at each end of the train on the driving trailer coaches. The driving console and fully adjustable operator's seat will be located on the left hand side of the cab, with the equipments and console being designed ergonomically for one man operation.

10.8.2 The driving console comprises the control desk and the dashboard. The control desk houses Fore and Apt type master controller for manual operation with the mode selector. Mounted on the console desk are also push buttons for door control, train start and emergency stop. A foot-operated horn will be provided for whistling. During normal station stop the train operator remains in the cab for control of passenger doors and monitor's platform conditions on the CCTV screen. The radio communication system is provided in the console desk. The dashboard will be provided with the speedometer indicating the target speeds, duplex air pressure gauges and variety of indicators.

10.8.3 The train-borne ATP equipment will be housed within the cabinet in the non driving side of the cab with the partition wall behind driver's seat housing fault / status indicators, miniature circuit breakers (MCBs) and auxiliary push buttons.

10.8.4 Two hinged door leaves will be located at each cab/coach partition wall, which can be opened in emergencies for the passengers to move toward coach cab and for evacuation.

10.8.5 Emergency detrain doors will be located as the centre of coach cab end. These will have two functions

- Folding down to provide a ramp to track level.
- Sliding aside to give access to the cab of a coupled train.

10.8.6 Under emergency condition passengers can be detrained to the track by first releasing the door, pushing it over vertically and then unfolding it to form a sloping ramp to track level with the assistance of train staff.

10.8.7 Alternatively passengers can be detrained to a coupled train with the doors pushed out and slid aside to provide wide exit passage. Passengers will be detrained under staff supervision by the use of detrain plates normally will be kept in the emergency equipment cabinet under the adjacent seats.

10.8.8 Station signages, destination boards and route maps will be displayed appropriately.

## 10.9 Fire Prevention Requirement

10.9.1 The rolling stock will be provided with all the fire prevention measures contained in the "Code of Practice for Prevention of Fires on EMU Stock" published by RDSO with latest amendments.



10.9.2 All cables and wirings shall be of fire retardant, low smoke and halogen free type. All significant cable runs shall be protected by MCBs and Fuses. Inflammability and smoke parameters shall confirm to the specifications contained in relevant National / International standards.

10.9.3 The coach floor, walls including doors and both sides of any equipment areas within the coach body and the rear walls of the Drivers cab shall have adequate fire barriers of at least 30min duration as per BS476 or equivalent internationally accepted standards.

## 10.10 Train Communication

10.10.1 The train communication system will have following primary functions:

- Operation centre to train driver communication and vice versa.
- Cab to Cab Communication
- Emergency Calls
- Public address system.

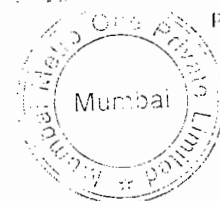
10.10.2 The micro phone and the monitor speakers in the cab will be shared with the radio system and the mode changed by the selected switch. This will be normally positioned for radio use and will require switching to use the train communication system. Passengers can communicate with the train driver by means of micro phones that will be provided at door pillars in the coaches. Communications will be initiated by the operation of the adjacent passenger alarm buttons.

10.10.3 Train passenger information display system will be provided to allow the train crew at the front cab to make predefined visual message to passenger on train.

10.10.4 Details of train radio and train-borne communication systems should be referred to Chapter 15.

## 10.11 Summary of Various Indicative Parameters of the Proposed Rolling Stock for the MRTS on Versova-Andheri-Ghatkopar Corridor

01	Track Gauge	1435 mm
02	Minimum curve radius	100 m
03	Maximum gradient	4%
04	Length of Coach – Buffer to Buffer	22 m
05	Width of Coach – outer to outer	3.2 m
06	Height of Coach from Rail level to Top most part under tare	3.6 m
07	Height of platform rail level	1 m
08	Height from Rail level to floor level of Coach under tare with a new wheel	1.1 m
09	Type of Traction	25 kV Single phase, 50 Hz.
10	Type of current collection	Through Pantograph
11	Train Configuration	4-car train will be: DT-M-M-DT  6-car train will be: DT-M-M-M-M-DT or DT-M-M-T-M-DT
12	Length of train	Maximum 135 m
13	Coach tare weight (Approx)	DT – 35 ton, M – 40 ton , T – 35 ton
14	Passenger capacity per coach	Normal: Seated - 48 Standing - 252 Total = 300 Maximum: Seated - 48



		Standing - 327 Total = 375
15	Number of Passenger Doorways	8/coach (4/coach side)
16	Additional Doorways	2/DT
17	Size of Passenger Doorway	1400 mm width. 1900 mm Height
18	Gangways	1 on non-driving end of DT, 2 on each side of M and T
19	Size of Gangways	1400 mm W, 1900mm H
20	Vestibules Per Train	5 Nos. ( 2 Nos. between DT & M, and 3 Nos. between M & T or between motor cars)
21	Length of Coaches over body	21300 mm
22	Distance between Bogie centers	15000 mm
23	Wheel Base	2400 mm
24	Maximum axle load and wheel load	18 Tonnes (axle load), 9 Tonnes (wheel load)
25	Wheel Diameter	860 mm New, 820 mm Half Worn 780 mm Full Worn
26	Speed Control System	Speed through VVVF inverter blended with regenerative braking.
27	Brake System	Dynamic Regenerative Brake. Electro Pneumatic Tread Brake. Emergency Mechanical Tread Brake. Parking Brake.
28	Traction Motor	4 poles, self ventilated Asynchronous Squirrel Cage Type. 3 Phase A.C. Induction Motor. No. of Motors per MC =4. No. of Motors per Train = 16. Continuous Rating: shall be suitably rated to meet the operating parameters
29	Converter / Inverter	Voltage Source PWM Inverter based on IGBT technology
30	Pantograph	Single Arm, Air Operated, Direct Air Type.
31	Main Air Compressor	3 Phase, 415 V A.C., 50 Hz, Induction Motor of suitable capacity.
32	Auxiliary Air Compressor	110 v DC, 10 minutes rating.
33	Auxiliary Power Supply	Type = IGBT Converter, IGBT Inverter. Natural Cooling, Input Voltage- 470 v AC at 25 kv Link Voltage - 825 DC Output AC 415 V, 3 Phase, AC 230 V Single Phase DC 110 V
34	Air Conditioning	Roof Mounted, Self Ccontained type of suitable capacity. Passenger Area temperature = 25 degree C at 60% Humidity
35	Cab Air Conditioning	Roof mounted and self-contained of suitable Capacity.
36	Train PIDS	Central Unit (CU) Local Unit (LU)

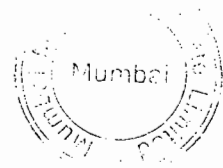
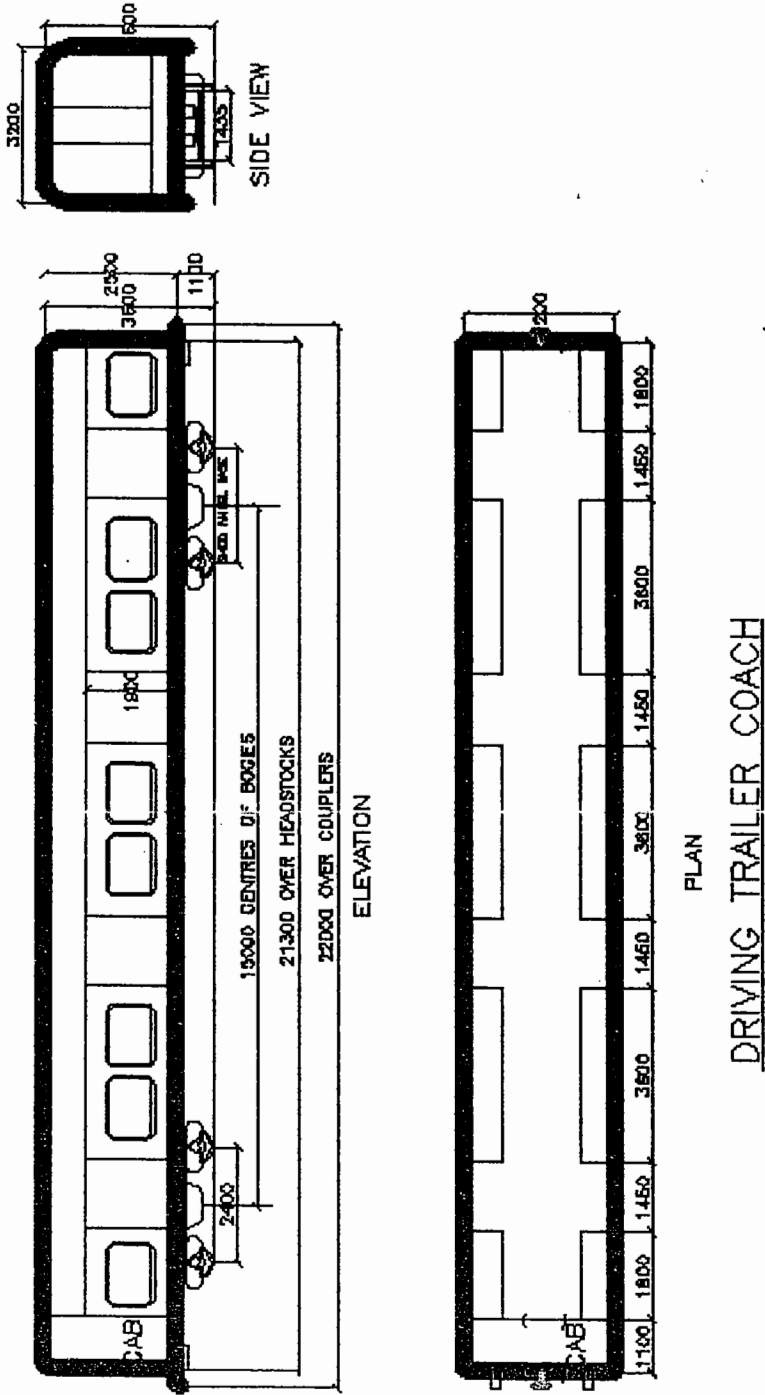


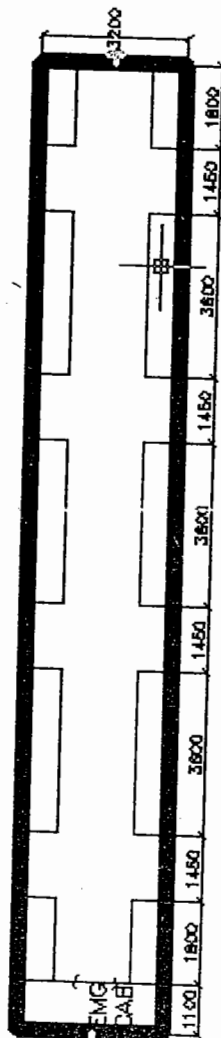
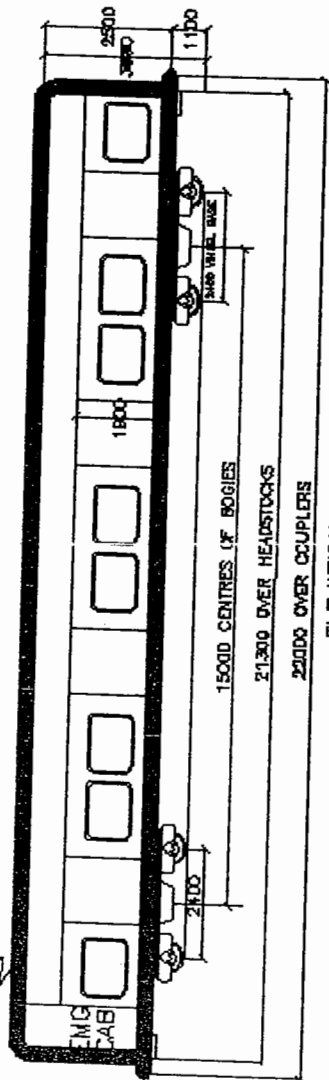
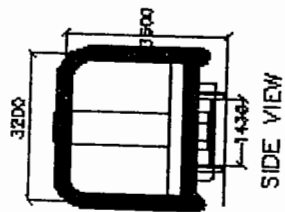


		Video Display Unit (VDU) Display Controller (DC)
37	Battery	Type – Nickel Cadmium Alkaline Battery, 110V DC of suitable capacity.
38	Noise level	Pass-by noise at maximum speed not exceeding 80dB(A), measured at a distance of 25m from centerline of track and 3.5m above top of rail Internal noise at passenger areas not exceeding 70dB(A)
39	Train Performance Parameters	Maximum Operating Speed = 80 kmph. Maximum Design Speed = 90 kmph. Maximum Acceleration = 1.1 m / Sec / Sec Maximum Deceleration = 1.2 m / Sec / Sec Jerk Rate = 0.8 m / Sec / Sec / Sec Round Trip Schedule Speed With 30 Sec / Halt and 8 % coasting (Excluding terminal station turn around time) with fully loaded train with 10 intermediate halts – 33 kmph Maximum Journey time between Versova and Ghatkopar, including station dwell time = 21 Minutes.



10.11.1 The proposed general arrangement of the Driving Trailer coach and motor coach is shown in figure attached.





MOTOR COACH



## 10.12 Projected Requirement of Rolling Stock

10.12.1 The Rolling stock requirement on holding basis has been worked out based on:

- Normally, an enhanced service than the minimum train service requirement will be operated during the peak hour due to:
  - Peak of the peak passenger distribution within the 1-hour period
  - Uneven train loading
- Dense crush load capacity of 2250 passengers per 6 coach train, 1500 for 4 coach train.

It is confirmed that -

- Minimum gangway width of 1400 mm will be provided
- The required level of interior lighting will be provided
- Under worst conditions the wheel load will not exceed the specified 9.35 tonnes
- Provision will be made for wheelchairs within the saloon
- Acceptable brake blending will be possible
- The design of the bogies will take into account the need to operate over a minimum radius of 100m.
- Brake resistors will not be provided on the roof of the motor car
- The lighting provided in the vehicles will conform to the Specification
- The parking brake will be capable of holding a fully loaded train on the steepest gradient with a factor of safety of at least one point five
- The "pushback" feature for the door allows limited pushback for releasing a trapped arm etc
- Electric door operation will be considered during detailed design
- Made for wheelchairs the saloon
- Integrated ventilation will be provided for traction motors
- A wheel diameter of 80mm has been considered

10.12.2 On the above basis, the minimum EMU stock requirement will be as follows:

Sr.No	Particulars	For the Traffic level of Years			
		2011	2021	2031	2041
1	Year of Operation				
2	Projected Traffic peak hour per direction.	18600	23600	30500	39500
3	Frequency of peak hour trains per direction in minutes.	4	3.25	3.5	3
4	No. of Coach in a Train	4	4	6	6
5	Minimum no. of trains required in operation	11	14	12	15
6	Minimum no. of spare trains required for standby and maintenance	2	2	2	2
7	Minimum no. of Rakes Required in Total	13	16	14	17
8	Minimum no. of Coaches Required in Total:	52	64	84	102



**10.13 Transportation and Commissioning of the Rolling Stock**

10.13.1 The EMU coaches may be imported in a fully assembled condition or in a completely knocked down condition. Or the coaches may be got manufactured indigenously through technical collaboration with foreign manufactures for the Electrics. The coaches can be transported by road over special trailers in a knock down condition or can be transported by rails over special railway wagons on the Broad Gauge system of the Indian Railways. As MMRDA has desired adoption of SG coaches, the same will have to be either imported or got manufactured from one of the existing coach factories, within the country. For imported coaches, the same will be brought at the Mumbai Port and loaded in trailers of adequate length, of around 23 mtrs, with the help of cranes. Local specialised agencies would be hired for transportation of these trailers by road transported during lean traffic condition at night to DN Nagar depot. Co-ordination will be done with the traffic police Authorities for taking traffic blocks at special road junctions for transportation of such over size consignments. Prior to the actual transportation of these coaches, trials will be conducted in consultation with the traffic police for the route to be selected for transportation from Mumbai Port to DN Nagar depot. To decide the feasibility of such transportation, the availability of adequate width of the road and the turning area at road junctions would be considered along with other safety measures, required to be adopted during transportation along with assessment of total time required for such transportation. Necessary notification will be issued prior to such transportation operations, to the press, for giving wide publicity to the public.

10.13.2 The coaches on arrival at the DN Nagar car depot have to be unloaded by special cranes installed or hired. Since the coach maintenance depot being at the elevated floor, the coaches, bogies and other equipments will be lifted and placed on the track at the elevated floor through EOT cranes of the carshed or by special cranes hired. After reaching the DN Nagar station these coaches will be lifted by a pair of cranes and placed on to the pre-assemble track on the elevated depot already constructed with all facilities. There after there will be no problem of further movement of rolling stock along the route after due checks at the depot. The procurement of this rolling stock will be so timed that the elevated track at depot is completed

10.13.3 Each coach will be fully assembled at the elevated carshed floor and taken for pre-commissioning, inspection and test. After each coaches is tested then 3-car unit will be formed and tested unit wise. Thereafter two 3-car units will be coupled to form a 6-car train set. All the tests and sequence of operations will be carried out over the test track provided for this purpose at the car depot.

10.13.4 In case the SG rolling stock is manufactured at one of the manufacturing units in India, the coaches and the wheel sets would be separated and loaded on special BFR's and transported by rail from the manufacturing units and brought to Western Railway Andheri yard from where, in a night block, the same will be lifted by cranes and placed on the trailers placed on the elevated metro track and from there they will be moved on rail on already linked track along the alignment to DN Nagar depot. If alternative BG coaches are also accepted the transportation problem will be eased and become more economical as they can be transported along the existing BG Railway tracks upto Andheri yard, from where they will be lifted in the night block on to the bridge and then moved further to DN Nagar depot. However to decide the actual transportation methodology, it is proposed to conduct logistics studies through a logistics expert agency after the award.

**10.14 Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC)**

10.14.1 All equipment and systems provided will be electromagnetically compatible with each other and with all existing external systems. Liaison with the appropriate authorities will be carried out to agree the standards to be adopted and any custom specifications to supplement these standards. Failure of any electromagnetic suppression components fitted to safety critical systems shall not cause that equipment to fail and cause an unsafe condition on the railway, when it is subjected to interference that is within the bounds of the adopted standards.

10.14.2 A typical rolling stock electromagnetic compatibility standard for a recent Hong Kong MTR project is attached in **Appendix A** as reference. MTR will develop the relevant electromagnetic interference and electromagnetic compatibility requirements for MRTS during the detailed design



based on the intensive EMC experience. This will ensure the system to be protected from electromagnetic interference from both elements of the system and external elements that might affect it.

**10.15 Sample Design Specification**

10.15.1 A sample design specification which can meet the proposed technical requirements is attached in **Appendix B** as reference. The design features shown are indicative only.

**10.16 Reliability of Rolling Stock**

10.16.1 The reliability figures for the rolling stock and its major components depend on the selected international/local suppliers during project implementation and would be advised to MMRDA during detailed design.



## CHAPTER 11

### CAR DEPOT

#### 11.1 General

11.1.1 The car depot for the Versova – Andheri – Ghatkopar corridor will be located at DN Nagar (or alternatively at Ghatkopar). Due to space constraints the car depot track layout will have to be at the elevated floor at the level of the main line track layout. The proposed car depot is going to deal with the running maintenance activities and the Depot activities of the Rolling Stock.

11.1.2 At the DN Nagar Car Depot (Figures 11.1 to 11.3), the following facilities will be located:

- a) Depot and Workshop for Rolling Stock
- b) Depot for Fixed Installations
- c) Depot for General services
- d) Administration and Training facilities
- e) Operational control centre
- f) Depot Remote control centre

11.1.3 Therefore, the DN Nagar Car Depot will be a multipurpose plant area. It will serve not only for maintenance and repairs of MRTS Trains, but also will include cleaning facilities, stabling sidings, administration buildings, training facilities, stores, test track, emergency vehicles and control centre.

11.1.4 The depot design will cater for 6-car train with the provision for expansion to cover ultimate fleet size requirement to meet passenger demand.

11.1.5 Depot electrical services, depot signaling and depot communication details should be referred to Chapter 13, 14 and 15 respectively.

11.1.6 The depot layout will be such that a 30-meter wide 'greenbelt' be provided around the depot. This is to comply with a recent notification issued by the Government of Maharashtra.

11.1.7 Rake Transfer Facilities - Provisions will be made to allow for train transfers to/from the depot and the envisaged north-south line will be included. Arrangement shall be made within the Car Depot limits for receiving similar trains as plying in the V-A-G Corridor from North South line.



## 11.2 Planning of Maintenance Activities

11.2.1 Proper maintenance planning and supply of spare parts of the rolling stock should be organized in such a way to ensure the reliable functioning of the MRTS. Based on the technical specification for all essential components of MRTS maintenance and overhaul program for all system parts will have to be established. In addition, technical specifications for components, general system requirements must also be taken into consideration.

11.2.2 Further, the requirements resulting from operational concepts are especially important and have a major influence on the layout and planning of the car Depot. The important aspects are:

11.2.2.1 The number of coaches/Rakes required for daily peak hour service and number of coaches/Rakes available for maintenance attention during different hours of the day.

11.2.2.2 Starting and stabling schedules for incoming and outgoing rakes to and from the main line.

11.2.2.3 The numbers of system components and estimated number of hours required for inspection and repairs are the main input for determining the necessary capacities for each Depot. These can be broadly summarized as below:

- a) Spares requirements.
- b) Personnel requirement for the Depot
- c) Requirements for equipments and tools.

11.2.2.4 The proposed space provided for train washing, maintenance, repairs, inspection, storage, spare parts and handling must be accommodated within the available space taking into consideration the topography, maneuverability and alignment.

11.2.3 Details of rolling stock maintenance planning should be referred to Chapter 19.

## 11.3 Activity Wise Areas to Cater for

11.3.1 The Car Depot should provide for work areas for various equipment of the rolling stock and other functional and non functional assets of the MRTS. The area / earmarked places for different equipment should cover broadly the following:

11.3.1.1 Rolling stock components lifting of coaches for replacement/ removal of bogies/ wheel sets/ traction motors/ other major equipments and components.

- a) Repair of coach bodies.





b) Painting of coaches

c) Repairs and testing of:

- Bogies
- Wheels
- Traction motors
- Transformers
- Inverter / Convertors
- Auxiliary machines
- Air conditioners
- Pantographs
- Brake equipments
- Cab equipment
- Sheet metal, welding, construction of jigs and fixtures
- Cab Signaling equipment.

11.3.1.2 Non rolling stock components are:

- Permanent way equipments
- Drainage pumps
- Station escalators
- Passenger platform sliding doors
- General Services Electrical equipment
- Sub-station and OHE equipments.
- Signaling & Telecommunication system
- Fare collection system
- Machinery and tools of the Depots
- Auxiliary vehicles and road cars
- Structures
- Fire frightening equipments
- ART and Brake down equipments
- Operation control centre
- MRT traction substation
- General services substation
- Depot remote control centre
- Rest room for running staff (Running room)
- Rest room and lobbies for running staff



## 11.4 Storage Facilities

11.4.1 Storage facilities are required to be provided for:

- Main store for receipt and issue of new parts
- Stores for main components where motors, bogies and wheel sets will be stored after overall and final inspection and also new ones under unit exchange system
- Unit exchange spares for smaller components such as compressors, door switches, air conditioners etc. will be kept after overall and testing
- Sub store for consumable items such as bolts, nuts, washers, etc
- Store for special items, which must be kept under cover
- Open-air storage specially for Pway, structural and OHE emergency mast and components
- Storage for OHE and substation items
- Tool room and tool cribs.
- Emergency generators and UPS system will be provided within the Depot
- Hazardous Material Store and a Paint Shop will be provided

## 11.5 Administration and Social Facilities

11.5.1 The following facilities should be provided in the administrative office and the adjunct:

- Medical centre
- Canteen
- Lockers room and washing accommodation
- Cab simulator
- Training room (basic training centre & motor man training centre)
- Model room
- Cash handling facilities
- Technical Office
- Administrative office
- Library
- Visitors room
- Conference room

### 11.5.2 Watch Towers

2 Nos of Watch Tower For vigilance of depot activity will be provided.



11.5.3 Check Post

2 Nos. of Check Post will be provided for security check for incoming/ outgoing staff, material and coaches.

11.5.4 The design of the Depot will allow for expansion of some facilities, e.g. the stabling area and the same will be finalized in consultation with MMRDA.

11.5.5 Roads and car parks will be provided in accordance with the submitted drawing

11.5.6 PA, CCTV, telephone and a clock system will be provided within the Depot

11.5.7 Limited speed test track with signaling will be provided within the Depot if possible

11.5.8 The proposed yard lighting, will be sufficient to allow the effective working of the Depot and that a minimum of 80 Lux will be provided.

11.5.9 The Rolling Stock will be moved into workshops that do not have an overhead electric supply by a combination of a battery/diesel vehicle and winches.

### 11.6 Activity Wise Minimum Area Requirement

11.6.1 Considering difference schedule for the rolling stock storage requirement and other functional activities of the MRTS, the approximate space required for different activities in the car depot shall be as follows:

Sr. No.	ACTIVITY	Area in sq m
1	Heavy repair Bay for lifting of coaches, painting, bogie, traction motor and other equipment replacement – with 2 nos of 25 T EOT cranes, 15m*150m	2250
2	Medium repair Bay for bogies, wheels, traction motor and transformers – with 2 nos 15T EOT cranes, 15m*150m.	2250
3	Light repair Bay for Auxillary machines, Air conditioners, sheet metal works, welding etc with 1 no. 10T crane, 15m*150m	2250
4	Inspection shed covered PIT/ SUNKEN FLOOR minimum 4 track 30m*50m Sun shed roof for 11 rakes of 6 cars each	9600
5	Lean to shed for brake equipments, batteries, pantograph, electronic components etc, 10m*150m	1500
6	Under floor wheel lathe shed 15m*30m	450
7	Area for depot staff (lockers, toilets and bathrooms 10m*30m	300
8	Supervisor and Administrative staff offices 15m*100m	1500
9	Automatic Train wash facilities for inside and outside cleaning	300



	10m*30m	
10	Washing apron 140m * 6.5m	910
11	Stabling siding for 11 rakes, 4.5m*15m*150m	10125
12	Stores for depot and Pway material and OHE material	2000
13	Electrical substation	550
14	General service sub station 20m*30m	600
15	Telephone Exchange and S&T maintenance 10m*30m	300
16	OCC & Remote control centre (SCADA)	1500
17	Canteen, time office, health unit, recreation and firefighting 10m*100 m	1000
18	Basic training centre, motor man training centre and simulator 30m*150m	4500
19	ART & Tower wagon stabling 30m*100m	3000
20	DCOS Stores & Offices including Ramp	2025
21	Check Post (2Nos)	20
22	Watch Tower (2 Nos)	10
23	Underground Tank (5,00,000 Ltrs.)	1 Nos
24	O.H. raw water tank (1,00,000 Ltrs.)	1 Nos
25	Pump house and Bore well (200 mm)	100
26	Workshop Manager office	600
27	ATP & ATO Room	20
28	Waste water treatment plant	80
29	Compressor room 1 No	80
30	Traction substation	750
31	Running room	100
32	Yard master Office	20
33	Cycle & Scooters Stand	150
34	Blow down plant	450
35	P. Way office & stores	1600
36	Security office & Time office	120
37	Garages	50
38	OHE workshop & Stores	1500
39	Electrical General Services	1500
40	Signal & Telecom workshop	2000
41	Training Centre	500
	<b>Total</b>	<b>56560</b>

## 11.7 Provisional List of Major Machinery and Plants for the Car Depot

### 11.7.1 The following will be the major machinery and plants for the car depot:

1.	25T EOT cranes (Cab Operated)	2 Nos	
2.	15T EOT cranes (Floor operated)	2 Nos	
3.	10T EOT cranes (Floor operated)	2 Nos	
4.	15T Whiting jack with synchronized control	8	
5.	Jib Crane		1
6.	PIT wheel lathe		1
7.	Surface wheel lathe		1
8.	Wheel turning and Burnishing machine		1
9.	Vertical Boring machine	1	
10.	Horizontal Boring machine	1	
11.	Wheel Press		1
12.	Centre Lathes		2
13.	Bogie testing fixtures		1 Set
14.	Bogie lifting vehicle		1
15.	Bogie Squaring fixture	2 Sets	
16.	Wheel sets transporter	1 Nos	
17.	Traction Motors Test Bed	1 Set	
18.	Bogie turn table		1 Set



19. Transformer Oil purification plant		1 Nos
20. Slotting machine		1
21. Shaping machine		1
22. Electronic component testing kits		3 sets
23. Compressor testing bed	1	
24. Brake equipment test panel	1	
25. Speedometer testing and calibration panel	1	
26. Instruments testing and calibration panel		1
27. Spring testing machine	1	
28. Grit blasting plant		1
29. Coach painting booth		1
30. Equipment painting booth	1	
31. Bogie cleaning plant		1
32. Portable cleaning equipment for under frame and Air conditioners		2 Sets
33. Automatic coach washing plant		1 set
34. Jigs and fixtures		L/s
35. Measurement and testing equipments		5 Sets
36. Material handling equipments		1 Set
37. Battery Charger		1 Set
38. AC equipment test plant	1	
39. Tower wagon (self propelled)		1 Nos
40. Auxiliary Relief Train (self propelled)		1 set
41. Fork lift Tractor		4 Nos
42. Work lift platform		1
43. Pallet Trucks		4
44. Mobile Lifting Table		1
45. Mobile safety steps		2
46. Motor trucks		4
47. Commercial light vehicles.		4
48. Synchronised pit jacks for two car lifting consisting of 8 jack system with Mobile lifting jacks – 12& 15T.		2 Sets
49. Diesel Shunting Engine	1	
50. Electric bogie tractor for pulling cars and bogies inside workshop		1
51. Mobile portal type A,B & Jib crane, mobilejib crane (overhang type)		1
52. Car body stands		2
53. Underframe & Bogie blowing plant	1	
54. Vertical carousel storage system		1
55. Rail fed Bogie wash plant		1
56. Ultrasonic machine for cleaning electronic equipments		2
57. Electric and pneumatic tools	2 Sets	
58. Floor cleaning machine	2	
59. EMU battery charger		2 Nos
60. High pressure washing pump for front and rear end cleaning of cars.		2
61. Storage racks.		6
62. Industrial furniture		10 Sets
63. Bearing puller & press		4 Sets

## 11.8 Water Supplies, Drainage and Sewerage

### 11.8.1 Water Supplies

Internal water supply system within the carshed area will be designed by the water supply consultant and got approved from the Mumbai Municipal Corporation and MMRDA and same



works will be carried out by the contractor as per the specification under the supervision incharge. Application for the requirement of water supply will be made to Mumbai Municipal Corporation and after sanctioning of the connection the Mumbai Municipal Corporation will provide water connection from its water main. The Municipal water will be stored through the new pipeline in the underground tanks and subsequently pumped to the water supply system of the carshed.

#### 11.8.2 Drainage and Sewerage

Internal Drainage and Sewerage within the car shed area will be designed by the Drainage and Sewerage consultant and same will be got approved from the Mumbai Municipal

Corporation. The works recommended by the consultant will be carried out by the contractor under the supervision of the Engineer in-charge. The final disposal of Drainage and Sewerage will be connected to the Mumbai Municipal Corporation Drainage and Sewerage system.

#### 11.9 **Alternative Car Shed at Ghatkopar (see Figure 11.4)**

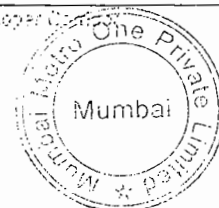
11.9.1 General Alignment: The car shed alignment will take off from the Pier No. P398 and turns towards the left side of alignment passed through hutment area upto LBS Marg (P420 to P445 are located between takeoff point and LBS Marg. From LBS Marg up to Ghatkopar ROB it runs parallel with the existing road leading to Eastern Express Highway. (P445 to P 458) are located

between LBS Marg and ROB crossing Central Railway line. From P458 to P475 Ramp with Gradient of 1 in 40 will be provided [REW] for entering in the Ghatkopar Car Shed. One Constraint in this work is that there is no access road between LBS Marg and take off point. Additional activity for construction of the alternative Car shed are as under:

1. Number of Piles = 232
2. Number of Pile Caps = 58
3. Number of Piers = 58
4. Number of Girders = 57

11.9.2 For crossing the Central Railway line lot of formalities including Design, Co-ordination, permission for Right of Way is required is be obtained from Railway Authorities for which additional manpower and time would be required. The Railway portion of the work has to be carried out under the supervision of Railway Authorities.

#### 11.9.3 General Design Methodology



From take of point near Sarvodaya Hospital upto Central Railway crossing, the track will be elevated and having 25 to 40m spans. Ramp will be designed as Reinforced Earth Wall taking Earth pressure, Live load, Surcharge Load, Dead Load and Super Imposed Dead Load. In carshed, repair platform office and workshop will be designed as RCC Structure taking Dead Load, SIDL and Live Load. Ramp and Car shed structure is to be checked for seismic forces as per IS: 1893:2002 for zone III. Track structure will be ballasted track from the take off point and will be designed accordingly. All these activities require additional time.

11.9.4 Summary of the Track Materials Required for the Alternative Car Shed Depot Near Extern Express Highway Ghatkopar Work is Given Below:

**P-way Works at Alternative Car shed at Ghatkopar**  
**(By the side Eastern Express Highway)**

Sr. No	Description of items	Unit	Quantity
1	Supplying 52/49 kg (T18) Rails (Plain track and check rail)	MT	520
2	Laying charges for plain track	Km	5000
3	Fishplates for 52 kg/49 kg rails	Pair	600
4	Fish plates Bolts & nuts 52 / 49 kgs	Nos	2400
5	SKV welding 60kg rails	Nos	200
6	Supplying MBC sleepers for 52 kg rails	Nos	6000
7	Supplying GR rubber pad	Nos	11000
8	Supplying ERC clips	Nos	22000
9	Supplying Pandrol Clips	Nos	22000
10	Supplying ballast	Cum	10000
11	Laying of ballast	Cum	8000
12	Supplying and fixing the buffer stop in correct position.	Nos	25
13	Laying charges for check rails	Km	1000
14	Special block for check rail	Nos	1000

Elevated single line structure and Ramp total length - 1.65 Kms

**Track material for 1.65 Kms**

Sr. No	Description of items	Unit	Quantity
1	Supplying 52/49 kg (T18) Rails (Plain track and check rail)	MT	172
2	Laying charges for plain track	Km	1.650
3	Fishplates for 52 kg/49 kg rails	Pair	60
4	Fish plates Bolts & nuts 52 / 49 kgs	Nos	240
5	SKV welding 60kg rails	Nos	100
6	Supplying MBC sleepers for 52 kg rails	Nos	2200
7	Supplying GR rubber pad	Nos	4400
8	Supplying ERC clips	Nos	8800
9	Supplying Pandrol Clips	Nos	8800
10	Supplying ballast	Cum	3500
11	Laying of ballast	Cum	3500
12	Laying charges for check rails	Km	0.250
13	Special block for check rail	Nos	80



## CHAPTER 12

### TRACTION POWER SUPPLY AND SCADA

#### 12.1 Power Supply for Traction System

##### 12.1.1 Source of Power Supply

- 12.1.1.1 As envisaged in the technical specifications, Power Supply for traction load will be arranged from Reliance Energy / Tata Power from their Switching Stations.
- 12.1.1.2 Actual locations of switching stations and the cable run etc. will be finalized during detail Survey Stage.
- 12.1.1.3 Because of Space Constraint for locating equipments either on the ground level or on elevated locations, it is preferable to obtain power supply from the supplying authority at 25 kV AC Single Phase with variations +/- 10% . All other insulated switchgears for feeding and sectioning will be located on the elevated corridor. However this subject will also be discussed with power supply authority during detail designing.
- 12.1.1.4 Lightning protection system will be provided for the Overhead Catenary System and Traction Sub Stations
- 12.1.1.5 The maintenance equipment to be supplied will include an OHL recording car and a tower wagon
- 12.1.1.6 Three phase power will be supplied to the MRTS from two separate sources at 33kV or above
- 12.1.1.7 Power will be supplied and distributed for general services, including Stations, the Depot and the Administration Building by means of a ring main from the supply points
- 12.1.1.8 Design will recognise the need to deal with stray currents and earthing issues and take into account that the alignment is adjacent to and passes through 1500 v DC traction areas, which may still be in place when the system opens.





12.1.1.9 The Switchgear & CB's can be operated at 3 levels; OCC, Sub Station and component.

12.1.1.10 The Transformer capacities are to be rated for six cars at two minute headway

12.1.1.11 Trip Stations are not required with the proposed system

12.1.1.12 The OHE will be deactivated whilst trains are passing through the wash plant

12.1.2 Line Capacity and Energy Consumption

12.1.2.1 In order to plan capacity of sub-stations for feeding power to traction over head lines; it is essential to know the maximum number of trains operating in the section. Therefore line capacity is number of cars, which can be operated over the period of heaviest traffic.

12.1.2.2 Line capacity depends upon scheduled speed, Rate of acceleration of cars; Rate of braking, Length of train etc. Line capacity bears direct relation with Energy Consumption, which determines the capacity of Sub-Stations for determining size of Transformers.

12.1.3 Planned Capacity

12.1.3.1 Versova-Andheri-Ghatkopar Corridor is presently planned to run six car EMU, that is two sets of motor coach, trailer coach and driving coach at 3 minutes interval. The number of passengers to be carried is estimated to be 375 persons per car. Therefore capacity of Sub-Stations is being planned considering future growth.

12.1.4 Energy Consumption / Power Demand

12.1.4.1 The specific Energy Consumption of trains operating at a given schedule speed is influenced by the following factors:

- i) Distance between stops.
- ii) The acceleration
- iii) The retardation
- iv) The maximum speed
- v) The type of train and equipments
- vi) The configuration of tracks



12.1.4.2 Specific Energy Consumption is expressed in Watt-hours per tonne kilometer.

12.1.4.3 For the Versova-Andheri-Ghatkopar Corridor, maximum demand is calculated on the basis of following figures:

- i) No. of passengers to be carried in each car is 375 nos.
- ii) Maximum speed is 80 kmph.
- iii) Average weight of each passenger is 60 Kgs.
- iv) Headway between trains is 3 minutes.
- v) Weight of empty train is 230 T.
- vi) Specific Energy Consumption assumed as 100 watt / tonne km.
- vii) Route length is 18 km.

Maximum Demand =	7.2 x Length of Section x Weight of Train x Specific Energy Consumption	
	Headway between Trains in sec.	

Therefore Maximum Demand =	7.2 x 18 x 365 x 100	= 26280 KVA
	180	

Which works out to be around 26 MVA.

12.1.4.4 Power Demand for Auxiliary Services at station buildings and Car Depot Machinery will be another 20 MVA.

12.1.4.5 Extra power system capacity for traction and station power loads will be allowed to cater for future traffic growth up to two minutes headway with 6 car train operation.

12.1.4.6 Therefore Total Power Demand for about 50 to 60 MW is required to be planned.

12.1.4.7 Demand for traction load will be distributed in two feeding posts with two transformers in each feeding post.

12.1.4.8 One transformer will cater for normal load and the other Stand-by transformer will be brought into operation when the demand increases and also for extending feed from one feeding post incase the other feeding post is out.



12.1.7.2 According to the station layout it is seen that emergency cross-overs are planned only at 5 stations.

12.1.7.3 However to facilitate easy maintenance and outage of small sections, it is planned to have motor operated isolators (off load) at each station and controlled through SCADA System and as well local operation.

#### 12.1.8 Yard Lines and Car Depot

12.1.8.1 Yard Lines and Car Depot OHE will be supplied through separate circuit breaker and can be isolated from main lines without affecting services on main lines. Since car depot needs to be isolated from the main line for emergency operation; group of lines will be controlled separately through independent circuit breaker. Individual lines such as washing lines, inspection pits etc will also have independent control isolators control circuit breaker for car depot lines will be controlled through SCADA and as well from Local Control operator.

#### 12.1.9 Type of Equipment

12.1.9.1 Insulated switchgears such as vacuum circuit breakers / gas insulated switchgear will be installed according to the space availability while detail designing.

#### 12.1.10 Safety Precautions

12.1.10.1 Mumbai area is known for thunder and lightning during monsoon. Therefore safety of equipments and personnel will be considered by providing lightning arresters and proper earthing and bonding of Electrical Equipments. All high voltage exposed circuits will be fenced and will be away from traveling public at least 2.0 meters distance.

### 12.2 OVER HEAD TRACTION EQUIPMENT (OHE)

#### 12.2.1 Over Head Traction Operation

12.2.1.1 The Versova-Andheri-Ghatkopar Corridor section will be operated on 25 kV AC, Single Phase, 50 Cycles. Since this is elevated corridor and running through busy and developed locality; all precautions will have to be taken for traveling public and also surrounding residents about coming in close proximity of high voltage traction lines.



12.2.2 Design Standards

12.2.2.1 25 kV AC Single Phase traction introduced on Indian Railways since 1759 is equipped on Broad Gauge and Meter Gauge. Standard Gauge (1.435m) will be introduced for the first time in India on Versova-Andheri-Ghatkopar Corridor.

12.2.2.2 There are no standard schedule of dimensions framed by Indian Railways for Standard Gauge (1.435m) track overhead electrification.

12.2.2.3 Standard Gauge track overhead electrification on 25 kV AC Single Phase is in operation in some other countries. Therefore reference will be taken for guidance for the practices followed by Railways in other countries for similar situations.

12.2.2.4 However all Electrical Operations including on Railways have to confirm with Indian Electricity Act 1910 and Indian Railway Act 1890 and Rules made thereafter.

12.2.2.5 Therefore clearances to be maintained from high voltage for public safety have to be according to the Indian Railways manual of A.C. Traction.

a) Maximum vertical distance between OHE and Fixed Structure.

- Long duration 320 mm
- Short duration 270 mm

b) Maximum lateral distance – between OHE and Fixed Structure

- Long duration 320 mm
- Short duration 220 mm

c) 25 kV AC OHE to adjacent buildings, structure 2.0 m

Other equipments and fittings will be according to International Standards and their equivalent IS Specifications.

12.2.2.6 Preliminary list of standards are shown in the following:.



a) Traction Power System

IEC 60044	Current Transformers
IEC 60076	Power Transformers
IEC 60186	Voltage Transformers
IEC 60296	Specification for unused and reclaimed Mineral Insulating Oils for Transformers and Switchgear
IEC 60137	Insulated Bushing for Alternating Voltages above 1000V
IEC 60529	Degree of Protection provided by Enclosures
IEC 60056	High Voltage Alternating Current Circuit Breakers
IEC 60060	High Voltage Test Techniques
IEC 60071	Insulation Co-ordination
IEC 60129	Alternating Current Disconnectors and Earthing Switches
IEC 60255	Electrical Relays
IEC 60265	High Voltage Switches
IEC 60298	High Voltage A.C. Metal-Enclosed Switchgear
IEC 60376	Specification and Acceptance of Sulphur Hexafluoride
IEC 60688	Electrical Measuring Transducers
IEC 60694	Common Specification for High Voltage Switchgear and Controgear
IEC 61634	Use and Handling of SF6 in HV Switchgear
IEC 60502	Power Cables with Extruded Insulation and their Accessories for Rated Voltage from 1kV up to 30kV
IEEE Std. 80	IEEE Guide for Safety in AC Substation Grounding
EN 50122-1	Protective Provisions Relating to Electrical Safety and Earthing

b) Overhead Line

## i) General

IEC 60050-812	Electric Traction
IEC 60913	Electric traction Overhead Lines
IEC 60099-4	Metal Oxide Surge Arresters

## ii) OHL Wires

BS 23	Specification for Copper and Copper-Cadmium Trolley and Contact Wire for Electric Traction
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BS 7884	Specification for Copper and Copper Cadmium Stranded Conductors for Overhead Electric Traction and Power
DIN 43148	Flexible Cables for Overhead Equipment and Return Current
DIN 48201 Part 1	Copper Stranded Conductors
DIN 48201 Part 2	Bronze Stranded Conductors
EN 50149	Copper and Copper Alloy Grooved Contact Wire
IEC 60494	Rules for Pantograph of Electric Rolling Stock
UIC 606-1	Application of Kinematic Gauges to Contact Lines
UIC 606-2	Installation of 25kV Contact Lines

## iii) Insulator

IEC 60060	High Voltage Test Techniques
IEC 60071	Insulation Co-ordination
IEC 60305	Insulators for Overhead Lines with a Nominal Voltage above 1000V- Ceramic or Glass Insulator Units for a.c. System
IEC 60383	Insulators of Overhead Lines with a Nominal Voltage above 1000V
IEC 60433	Characteristics of String Insulator Units of Long Rod Type
IEC/TR 60797	Residual Strength of String Insulator Units of Glass or Ceramic Material for Overhead Lines
IEC 60672	Ceramic and Glass insulating Materials
IEC 60815	Guide for the Selection of Insulators in respect of Polluted Conditions

## iv) Isolator

IEC 60129	Alternating Current Disconnectors and Earthing Switches.
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## v) Mast

BS 4	Structural Steel Sections – Specification for Hot Rolled Sections
BS 449	Specification for use of Structural Steel in Building
BS 729	Specification for Hot Dip Galvanized Coatings on Iron and Steel Articles
BS 4848	Specification for Hot Rolled Structural Steel Sections
BS 5493	Code of Practice for Protective Coating of Iron and Steel Structures against Corrosion



### 12.2.3 Other Clearances

12.2.3.1 Based on the Car dimensions and Pantograph Coach dimensions, Vertical distance of OHE from Rail level and lateral distance of OHE Structures from track centres will be designed. These dimensions will be designed taking into consideration of tangent track, tracks on curvature and sighting of signal indications for motor-man.

12.2.3.2 However this corridor is only for passenger operation, therefore dimensions will be designed for only passenger traffic.

12.2.3.3 Future conversion of the section to Broad Gauge will also be kept in view for moving dimensions.

### 12.2.4 Configuration of OHE

12.2.4.1 The Design of OHE will be Simple Catenary and Contact Wire with fully Regulated type. An earth wire is required to be provided for earthing and bonding of OHE Structures.

### 12.2.5 Size of Conductors

12.2.5.1 Considering 600 Amp. Current required and safe current density of 4 amp / sq.mm; conductor size will be 150 sq.mm. Therefore Standard Cadmium Copper Catenary of 65 sq.mm and Contact wire of 107 sq.mm is suitable. All standard 25 kV AC OHE fittings and equipments already designed and developed will be used.

### 12.2.6 Height of Contact Wire From Rail Level

12.2.6.1 It is of primary importance to design the height of contact wire from Rail level to decide the structure height for supporting O.H.E.

12.2.6.2 According to the MMRDA specifications, the height from rail level to the topmost part of the empty car is 3.60 m.

12.6.2.3 With the mounting of Pantograph over the motor coach, the top most height will be about 4.0 m considering other allowances such as Track maintenance tolerance, Vertical Oscillation



and short time electrical clearance the minimum height of Contact Wire works out to  $4000 + 20 + 270 = 4290$  mm. Since No ODC is contemplated to run in the section, the minimum height of contact wire will be 4.50 m from Rail level.

## 12.2.7 Design of Foundations and Structure

12.2.7.1 The elevated columns will be located at intervals ranging from 18.0m to 60.0m. Therefore it is proposed to locate OHE structures on the concrete parapet on either side. Foundation bolts will be provided along with RCC construction.

12.2.7.2 OHE structures will be steel galvanized with bolted base arrangement.

12.2.7.3 This will be well co-ordinated work along with RCC elevated structure as anchor masts will also be required for termination of OHE conductors.

## 12.2.8 Cantilever Assembly

12.2.8.1 Standard Cantilever assembly, already in use on Indian Railways for 25 kV AC will be used. However any new design required for non-standard spans, which is not covered in employment schedule will be worked out and adopted.

## 12.2.9 Wires and Conductors

12.2.9.1 The wires and conductors will be of standard specifications and will be insulated whenever coming in close proximity to other fixed structures if the physical clearance is less.

## 12.2.10 Quality of Work

12.2.10.1 Erection of overhead equipments and its bringing into operation will be arranged in such a manner that it is entirely safe for operation without causing any Electrical Sparks and fully safe for commuters.

## 12.2.11 Operation and Maintenance Depot

12.2.11.1 Operation and Maintenance Depots will be established at D.N. Nagar, Airport and Ghatkopar with fully equipped Road Vehicle so that instantly they can rush and attend to any failure in the least possible time.





12.2.11.2 The Maintenance Staff will be trained just like fire brigade staff to attend to any failure. Maintenance Vehicles will be equipped with emergency spares to attend to faults.

12.2.12 Stores Depot

12.2.12.1 Main Stores will be located at D.N. Nagar or Ghatkopar and will be equipped with Stores Material of OHE and Switching Stations. As already explained, OHE masts with base plate arrangement will be kept in the main Depot and as well at few intermediate stations.

12.2.13 Training of Men

12.2.13.1 Required man power will be recruited at the time of commencement of work and will be trained for Construction, Operation and Maintenance of Power Supply, OHE and Operation in Indian Railway zonal training schools.

12.2.14 Maintenance Schedule

12.2.14.1 Maintenance Schedule for all the erected equipments will be made and will be strictly followed and monitored to ensure trouble free service of commuters.

12.3 **Earthing and Bonding**

12.3.1 Earthing and bonding will be provided for the traction power system, station auxiliaries power system and the OHE system to ensure safety from electric shock for operating personnel and the general public and protection against interference between electrical systems. The earthing and bonding system will be designed according to international standards.

12.3.2 Multiple earth electrodes forming an earth mat with an overall resistance not exceeding 1 ohm will be provided for each substation, switching station, passenger station and depot where traction power equipment and station auxiliary power equipment are installed. Earth electrodes will also be provided at each OHE isolator and surge arrester location.

12.3.3 An overhead continuous bare conductor will be installed as an earth wire along the track for the OHE system. All the metallic OHE structures including the masts, supports and enclosure for the isolator will be bonded to the earth wire.



12.3.4 The control of stray current leaking from the rails will be achieved by bonding the traction return rails at regular interval and in turn bonded to the earth wire of the OHE system. The exact bonding arrangement will further be developed in the detailed design.

## 12.4 SCADA

12.4.1 Supervisory control and data acquisition (SCADA) provides facilities for supervision and control of Electrical and mechanical equipments located at passenger stations, sub-systems are processed by the remote terminal units (RTU) and sent to the central computer system.

12.4.2 The primary objective of providing SCADA is to assist the Railway operation staff in maintaining the passenger carrying capacity as high as possible while ensuring the best conditions for safety and comfort.

12.4.3 SCADA will enable the operation to control and monitor the remotely located electrical and mechanical equipments to know the status, alarm, analog values, metering values, running time of equipments and will be logged, printed or displaced on the colour VDU.

12.4.4 Peak load supervision and local shedding will be provided.

12.4.5 The programme helps to ensure that the user does not pay unnecessary charges for the power consumption during non peak loads. The programme monitors the power consumption and forecasts whether the maximum demand level will be exceeded. Entire monitoring of the power control will be done for safe operation.

12.4.6 Apart from SCADA control, switchgear will have the following provisions for local control:

- controlled locally at switchboard
- controlled at local control panel at substation

12.4.7 The SCADA for ECS will include monitoring and alarm for ECS for critical rooms such as signaling, relay, CER, and UPS

12.4.8 The design and provision of the SCADA system will allow for future expansion

12.4.9 SCADA will interface with signalling to provide the overhead line equipment energisation status





#### 12.5.4 Basic Designs

12.5.4.1 As already stated certain basic designs have to be made for designing traction overhead equipments to suit electrification or Standard Gauge Tracks (1.435m) which is for the first time to be introduced in India. These standards will be based on basic dimension adopted in other cities of the world and modification to be done to suit local conditions.

12.5.4.2 Basic drawings and designs already in existence in India for 25 kV AC. Traction where modification is not required will be adopted.

12.5.4.3 Working Drawings will be taken up for switching, stations, sub-stations, station building and OHE.

#### 12.5.5 Mobilization

12.5.5.1 The organization has qualified engineers and supervisors who have long experience in Railway working for construction, operation and maintenance.

12.5.5.2 Additional manpower required as Engineers, Technical Assistants, skilled and unskilled staff will be recruited and trained in a short period. Sufficient manpower will be recruited so that work can be taken up at difficult locations simultaneously. This will reduce the construction time and complete the project in shortest duration.

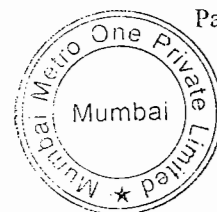
#### 12.5.6 Construction Depot

12.5.6.1 A construction depot will be established at suitable locations where arrangement will be made to store construction equipment.

12.5.6.2 Other activities such as cutting, welding, assembly etc will be carried out.

#### 12.5.7 Power Requirement finalization

12.5.7.1 As soon as working drawings are ready power requirement will be finalized with the power supply. Authority and the locations of feeding points will be fixed. This process will also include fixing tariff for power supply and agreement with power supply authority.





Galvanized small port steel work will also be commenced when OHE structures are erected for about 3 / 4 km. Cantilever erection will also be taken up simultaneously which will be fabricated in the depot and carried to the site.

#### 12.5.9.4 OHE conductors

As soon as a portion of the section is ready with track laying, stringing of OHE conductors will be taken up. Special motor operated vehicle suitable for Standard Gauge track (1.435m) will be procured along with a trailer on which conductor drums will be mounted for stringing operation.

#### 12.5.9.5 Insulation / adjustment

Insulation of OHE, jumpering, adjustment of height and stagger, earthing, bonding also will be completed in time.

#### 12.5.9.6 Sub-stations

Power supply stations with all equipments will also be erected simultaneously so as to match the OHE works and are ready well in time before OHE works are completed.

#### 12.5.10 Station buildings

12.5.10.1 Electrical works at station buildings with lighting, ventilation and operation of escalators and lifts will be completed and tested for safe operations.

#### 12.5.11 Inspection and testing

12.5.11.1 All inspection and testing of electrical equipments including OHE will be tested and kept ready for commissioning. Operation of the OHE by means of SCADA operation will also be tested for commissioning the system.

#### 12.5.12 Service operation

12.5.12.1 Required man power for operation of the service with full knowledge of their duties and responsibilities will be posted at suitable places for the service operation and operation of electrical services at station building will be manned 24 hours in shift duties.



12.5.13 Safety precaution

12.5.13.1 Caution plates and danger boards will be displayed at prominent places at all the stations and at entrance places to the traveling commuters regarding danger from high voltage overhead traction conductors.



## CHAPTER 13

### ELECTRICAL – GENERAL SERVICES

#### 13.1 Power Supply Requirement for MRTS

13.1.1 Power supply for MRTS is required for overhead Traction at high voltage 25 K.V. AC and also at low voltage 440/240 A.C. for general lighting. Traction power supply is dealt in O.H.E. / Switching stations separately.

13.1.2 Power supply for station and depot buildings is required to meet the following demands.

- Internal building lighting.
- External lighting of platforms and concourse.
- Yard lighting for depot.
- Ventilation and air-conditioning of enclosed area and open space on platforms.
- Power supply for signaling and communication equipment.
- Power supply for escalators, lift, water cooler and other equipments.
- Carshed maintenance Depot Machinery.
- SCADA operation.

13.1.3 Extra station power demand capacity will be allowed to cater for the future traffic growth.

#### 13.2 Source of Power Supply

13.2.1 At present C. Rly. and W.Rly. are getting power supply for traction and general lighting from M/S Tata Power, M.S.E.B. and Reliance Power Energy.

#### 13.3 Reliability and Safety

13.3.1 Proposed MRTS is totally elevated system and therefore safety of commuters in case of power failure and unforeseen accidents is being considered of foremost importance.





**13.4 Design Features of Lighting and Ventilation**

13.4.1 Metro Stations in important cities of the world have been planned to have good and aesthetic view. Illumination and lighting therefore has to be computable to beautify the surrounding.

13.4.2 Climatic Condition

13.4.2.1 The Mumbai city is essential having a tropical climate. The conditions of temperature and humidity are generally very severe even in the outside. Therefore Design of lighting and ventilation should be such as to give maximum comfort to commuters.

13.4.2.2 Prolonged periods of high humidity coupled with high ambient temperatures are the factors to be considered for giving maximum comfort to the traveling public and also to the passengers on the platforms.

13.4.2.3 There are elevated station buildings on Harbour branch line of Mumbai Division, which have been constructed long ago.

13.4.2.4 The modern design should consider the design adopted for metros constructed in other important cities of the world under similar situation.

13.4.2.5 For comparison sake a statement showing summer External design conditions in some cities are given below.

Location	Summer Dry Bulb temp. OF.	Wet bulb temp. OF.	Relative Humidity
Hong Kong	92.0	85.0	75
San Paulo	96.0	81.0	52
Buenos Aires	97.0	79.0	45
Osaka	95.0	80.0	51
New York	96.0	76.0	40
Toronto	91.0	72.0	40
Montreal	89.0	70.0	39
Mexico City	82.0	66.0	44
Calcutta (May)	96.0	82.0	68
(Aug)	89.0	81.0	75
Mumbai (May)	91.0	80.0	63
(Aug)	85.0	79.0	77



13.3.2 It is therefore planned to have suitable size of Diesel Generator set and uninterrupted power supply battery set to maintain essential services. The important characteristics of stand-by power supply from the generator and UPS system are described in the following.

### 13.3.3 Standby Generators

13.3.3.1 Standby generator with suitable capacity will be provided at the stations to provide emergency low voltage power supply to the station essential loads that can maintain the station operation in a safe environment in the event of the failure of the normal station power supply. The station non-essential loads will be shed before the generator takes up the loads.

13.3.3.2 The station essential loads include lighting, essential ventilation equipment and other safety related services equipment. The classification of station essential loads and non-essential loads will be determined in the design phase.

13.3.3.3 Facilities will be provided for auto and local start. When the normal station power supply fails, station loads will be disconnected from the normal station power supply. Standby generator will start and takes up the station essential loads automatically under auto start mode. An interlock will be provided to ensure that standby generator and station normal power supply will not be in parallel operation.

### 13.3.4 Uninterruptible Power Supply System (UPS)

13.3.4.1 Uninterruptible power supply will be provided at the stations to supply continuous electrical power to the following critical systems:

- Signaling System
- Automatic Fare Collection System
- SCADA System
- Communication Systems including CCTV, Data Transmission, Radio, Telephone and Public Address System
- Passenger Information System
- Emergency Lighting

13.3.4.2 The UPS will be provided with batteries that have sufficient capacity to back-up the above systems in the event of the failure of normal station power supply until the standby generator can take over.



13.6.2.5 Based on the above observations, escalators are planned at all the stations for upward direction movements of suitable capacity.

### 13.7 Lifts

13.7.1 Since MRTS service is a totally elevated system, it is not possible for disabled people to use escalators. Therefore it is also planned to install lifts of suitable capacity at each station to meet the need of handicapped passengers.

### 13.8 Earthing and Bonding

13.8.1 An earthing system will be provided for each station building to ensure safety from electric shock for operating personnel and the general public.

13.8.2 The earthing system will mainly comprise the following:

- multiple earth electrodes forming an earth mat with an overall resistance of not less than 1 ohm
- earthing network inside the building for earthing all electrical equipment

13.8.3 Equipotential bonding will be provided for all extraneous metal objects including metallic services pipes, ventilation ductwork, cable supporting system, window frames and handrails, etc.



