Mass Urban Transport Projects
8th BIMSTEC Training Course on Design and Maintenance of Passenger Coaches
Railway Staff College, Vadodara

Presentation on

Latest Developments in EMUs

(Specific to Mumbai Suburban System)

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2nd September 2008

Yesterday's Memories

Today's Lifeline

Tomorrow's Technology

Mumbai Railway Vikas Corporation

Mumbai Urban Transport Project (Rail Component)

MUMBAI SUBURBAN RAILWAY SYSTEM

- Mumbai has been the commercial capital of India since pre-independence days
- Due to its peninsular geography, the city has grown linearly
- Britishers realized that only an efficient suburban railway system can become the prime mover of growth for the city
- Suburban railway system set up in 1925
- Latest technologies of 1500v DC traction and DC Electric Multiple Units available at that time used.

Mumbai Suburban Railway System
An Overview

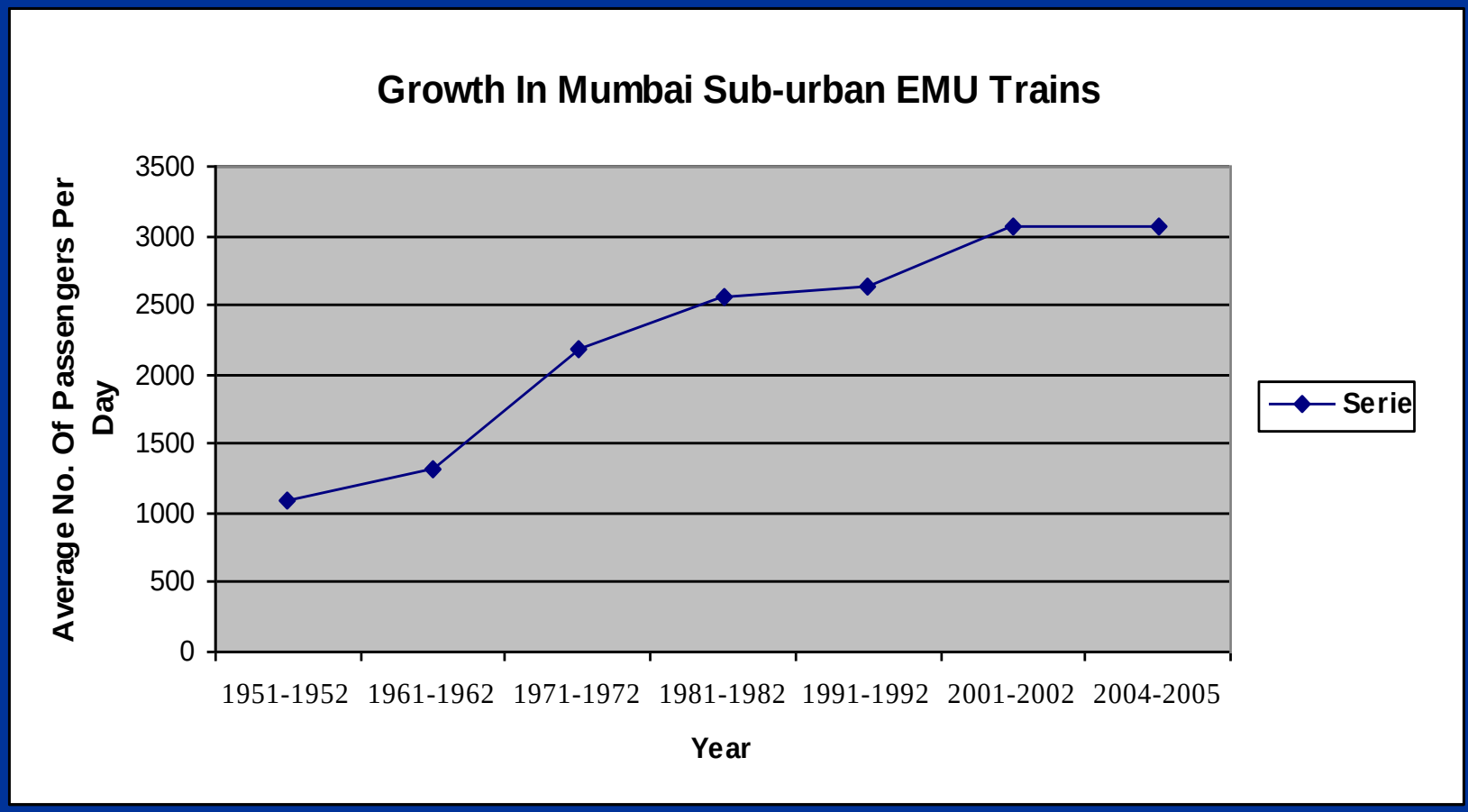
- 319 route Kms.
- 876 Track Kms (including 52 Kms already added in MUTP).
- 6.3 million passengers per day.
- 2385 trains per day
- Fleet of 227 rakes (9 car eq.) which are run in 9 and 12 car compositions.
- Mumbai Suburban Railway System is a part of Indian Railways which is a department of the Central government.

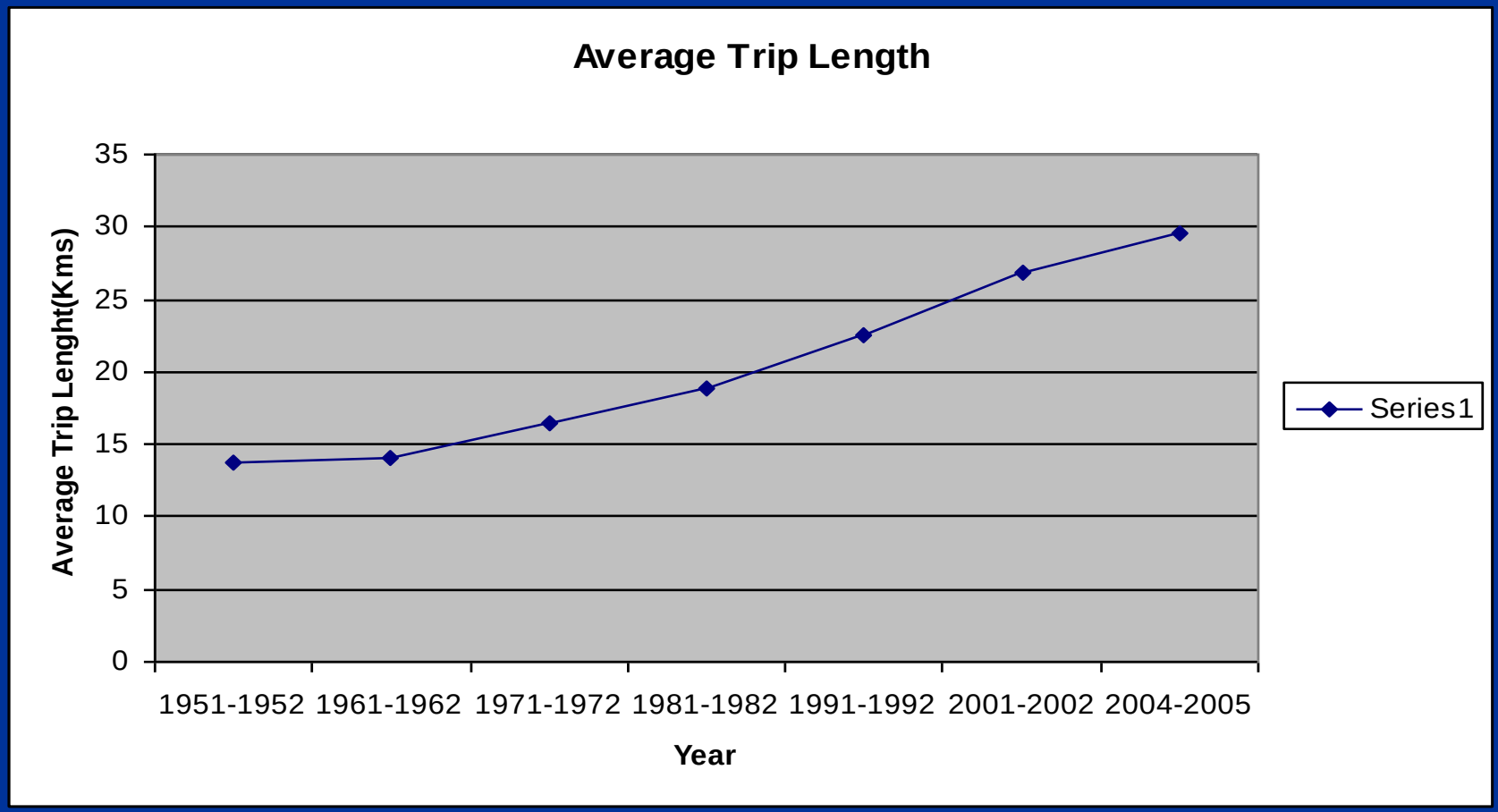
Suburban Traffic Growth

	Units	1951/ 52	1960/ 61	1970/ 71	1980/ 81	1990/ 91	2000/ 01	2004/ 05
Passenger carried	Million	292	454	915	1459	1795	2275	2314
	% Annual Compounded Growth Rate		5.0	7.3	4.8	2.1	2.4	0.43
Passenger KMs	Million	4031	6365	15123	27392	40462	61195	68362
	% Annual Compounded Growth Rate		5.2	9.0	6.1	4.0	4.2	2.8
Average trip length	Km	13.8	14.0	16.5	18.8	22.5	26.9	29.54
	% Annual Compounded Growth Rate		0.2	1.7	1.3	1.9	1.8	2.37

Lack of Investment

- The traffic demand was mainly due to phenomenal growth of population in the northern suburbs whereas the main business district continued to be in south Mumbai
- Development/Property tax used for roads & other infrastructure but not for suburban railway system
- Indian Railways also unable to provide funds for expansion as suburban system is loss making.


Growth In Mumbai Sub-urban EMU Trains
Average No. Of Passengers Per Day
3500
3000
2500
2000
1500
1000
500
0
1951-1952
1961-1962
1971-1972
1981-1982
1991-1992
2001-2002
2004-2005
Year
Serie


Average Trip Length
Average Trip Lenght(Kms)
35
30
25
20
15
10
5
0
1951-1952
1961-1962
1971-1972
1981-1982
1991-1992
2001-2002
2004-2005
Year
Series1

Mumbai Urban Transport Project (Rail Component)

- Rail projects were identified in 1998 through the project preparatory studies with the objective of:
  - Bring down the crowding in peak hour peak direction 9-car train to 3000 passengers as against existing around 5000.
  - Segregate the suburban train operation from the main line passenger and freight services.

Mumbai Urban Transport Project (Rail Component)

- Completion over a time frame of ten to twelve years.
- Total cost in excess of Rs. 10,000 crores
- MUTP (Rail Component) bifurcated in phases for the purpose of World Bank funding.

Institutional Arrangement for Rail Component of MUTP

- Ministry of Railways & Government of Maharashtra have set up **Mumbai Railway Vikas Corporation Ltd**. to undertake rail related works of MUTP for:
  - **Better coordination between GOM & MOR**
  - **Cutting down the bureaucratic delays**

OBJECTIVES OF MRVC

- Implement the rail infrastructure projects in Mumbai suburban sections.
- Commercial development of railway land and airspace in Mumbai area to raise funds for suburban railway development.
- Resettlement & Rehabilitation of Project Affected Households.

MUTP Phase I
(Rail Component)

- Phase I includes Works required to bring down the peak hour loading from 5000 to 3600 & to be completed by June 2009.

MUTP Phase I (Rail Component)

New Lines:	
Quadrupling of Borivali-Virar section	416.0 cr.
WR 5th line Santacruz-Mahim	59.0 cr.
Kurla Thane Additional pair of lines	166.0 cr.
Sub-Total (New Lines)	**641.0 cr.**
EMU procurement & manufacture:	**1359.2 cr.**
DC to AC Conversion	**380.4 cr.**
Resettlement & Rehabilitation:	**290.0 cr.**
Optimisation & Other Works:	
Optimisation of Western Railway	50.1 cr.
Optimisation of Central Railway	99.5 cr.
Optimisation of Harbour line	19.7 cr
Virar Car Shed	93.0 cr
Maintenance facilities for EMUs	64.3 cr.
Stabling lines for EMUs	48.5 cr.
Track Machines	31.3 cr.
Institutional strengthening & studies	48.2 cr.
Sub-Total	**454.6 cr.**
Grand Total	**3125.2 cr**

EMU PROCUREMENT

EMU Procurement:

- Total No. of rakes - 174, 9 Car.
  - MRVC Contract - 101, 9 Car.
  - GP-194 - 56, 9 Car.
  - GP-194 (30%) - 17, 9 Car.

Progress

1st Rake	12th Nov. 2007 (W.R.)
2nd Rake	17 Dec. 2007 (W.R.)
3rd Rake	13th Jan. 2008 (W.R.)
4th Rake	21st Feb. 2008 (C.R)
5th Rake	7th April 2008 (C.R)
6th Rake	13th May 2008 (CR)
7th Rake	26th May 2008 (CR)
8th Rake	13th June 2008 (CR)
9th Rake	4th July 2008 (CR)
10th Rake	31st July 2008 (CR)

Progress

11th Rake	8th Aug. 2008 (C.R.)
12th Rake	17th Aug. 2008 (C.R.)
13th Rake	23rd Aug. 2008 (C.R.)
14th Rake	Under commissioning (C.R.)
15th Rake	Received on 26th Aug. 2008

With the introduction of new rakes

- 126 additional services (74,12 car & 52, 9-car)
- 123 services earlier running with 9-car have been converted to 12-car

Hon'ble Chief Minister inspecting the New EMU Rake

New Rake in Public Service

New Rake in Public Service

MRVC

Improved Features of MRVC EMU Rake

MRVC

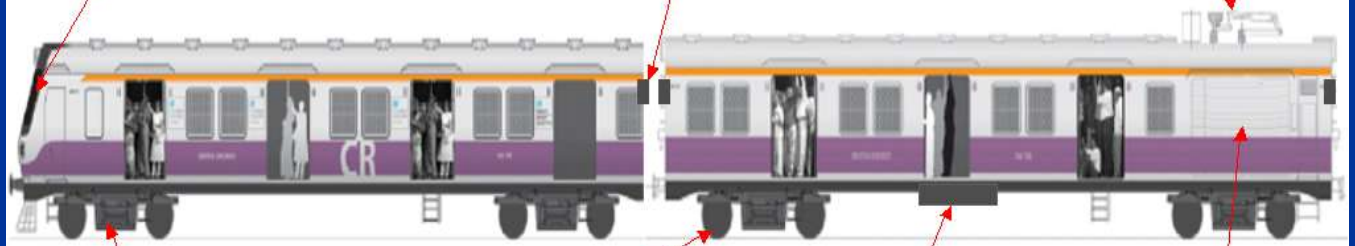
Technical Features

Details of Equipments

▪ Driver's Desk

▪ Ventilation Blower

▪ Pantograph



▪ Air Spring

▪ Traction Motor

▪ Traction Transformer

▪ Traction Converter

System Requirement

- Max. Axle load ⇒ 20.32 tones
- Typical Run ⇒ 1.5 km on level tangent track in less than 113 sec
- Acceleration (average ⇒ 0.54 m/s^2 with SDCL. Jerk: 0.75 m/s^3 from 0 to 40 Km/h)
- Deceleration ⇒ 0.76 m/s^2 (100 to 50 kmph) 0.84 m/s^2 (50 kmph to Stand still)
- Traction voltage ⇒ 1500 volt DC and 25 kv AC (Dual Voltage)
- Bogie suspension ⇒ Metallic springs in Primary, Air springs in Secondary.
- Brakes ⇒ Blending of Regenerative and Frictional brakes
- Main / Aux. Converter ⇒ IGBT based
- SEC (KWH /1000 GTKm) ⇒ 29
- Life ⇒ 25 year

Improved Performance Features of MRVC EMUs

Features	MRVC EMUs	Existing EMUs
• Acceleration with super dense crush loading	0.54 m/s^2	0.36 m/s^2
• Decelaration	0.76 m/s^2 (100 to 50 kmph) 0.84 m/s^2 (50 to stand stilll)	0.6 m/s^2
•Max Service Speed	100 kmph	80 kmph
• Specific Energy Consumption	27 units per Thousand Gross Ton Km	40 KWH/100 GTKM

Improved Performance Features of MRVC EMUs

• Traction Motor Power Rating	240 kW	187 kW
• Traction Control	Microprocessor based control & Fault Diagnostics	Resistance Control
• Auxiliary Power Supply Capacity	70 kW	12 kW
•Passenger Information System	Menu Driven Digital Audio –Visual system in each coach	Normal PA System

Commuters will get information like which is the next halting station & on which side platform will be there, on speakers as well as on LED display panels.

Main Transformer

Traction Transformer	
Continuous KVA rating	1250 KVA
Continuous Secondary Voltage (at 25KV primary)	2 X 950 V
No. of secondary windings	2
Type of cooling	ODAF
Type of coolant	Mineral oil
Weight	App. 3100 Kg
Efficiency	App. 96%

Power converter-inverter

Traction Converter	
Nominal Input voltage	2 x 950 V AC (AC Mode) 1500 V DC (DC Mode)
Nominal DC link voltage	1800 V DC (AC Mode) 1500 V DC (DC Mode)
No. of 4 quadrant choppers (4QC)	2 (IGBT based)
No. of pulse with modulated inverters (PWMI)	2 (IGBT based)
Continuous rating per 4QC	620 KW
Continuous rating per PWMI	535 KW
Output voltage	1217 (line to line, fundamental value)
Control	Microprocessor control
Cooling	Force air cooled
Weight	App. 2200 Kg

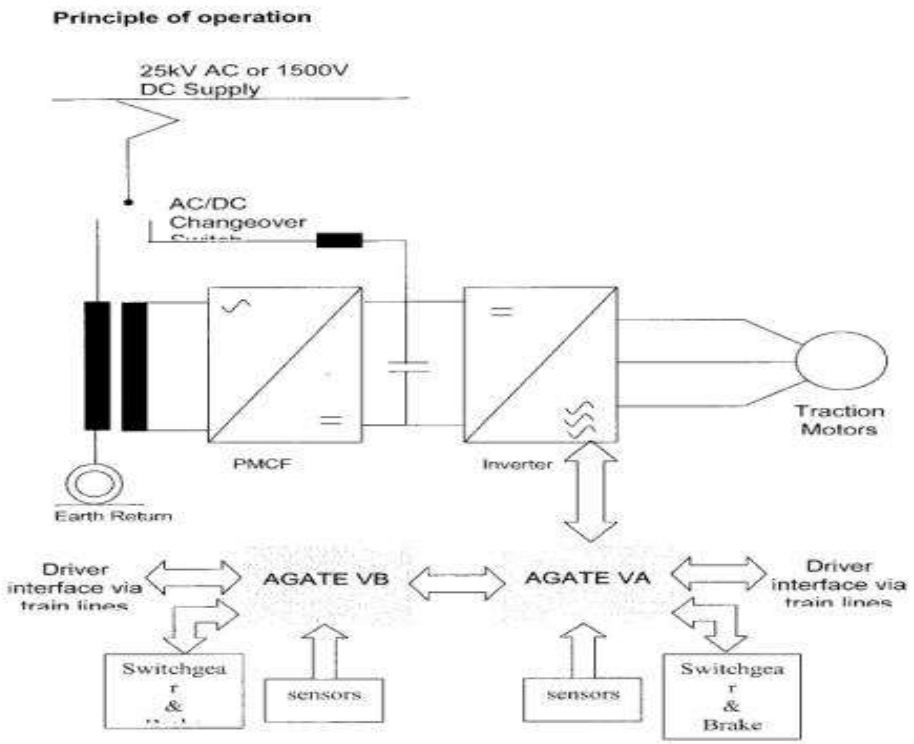
Traction Motor

Traction Motor & Gear	
Type	3 phase AC asynchronous traction motor Axle hung nose suspended
Continuous rating	240 KW (at 2000 rpm)
One hour rating	270 KW (at 2000 rpm)
Gear ratio	5.71
Design speed	3452 rpm (fully wom wheel, 100 kmph)
Insulation system	MICALASTIC T, 2.3 KV, Class 200
Cooling	Force air cooled
Weight	App. 1734 Kg
Efficiency	App. 94%
Weight	App. 2200 Kg

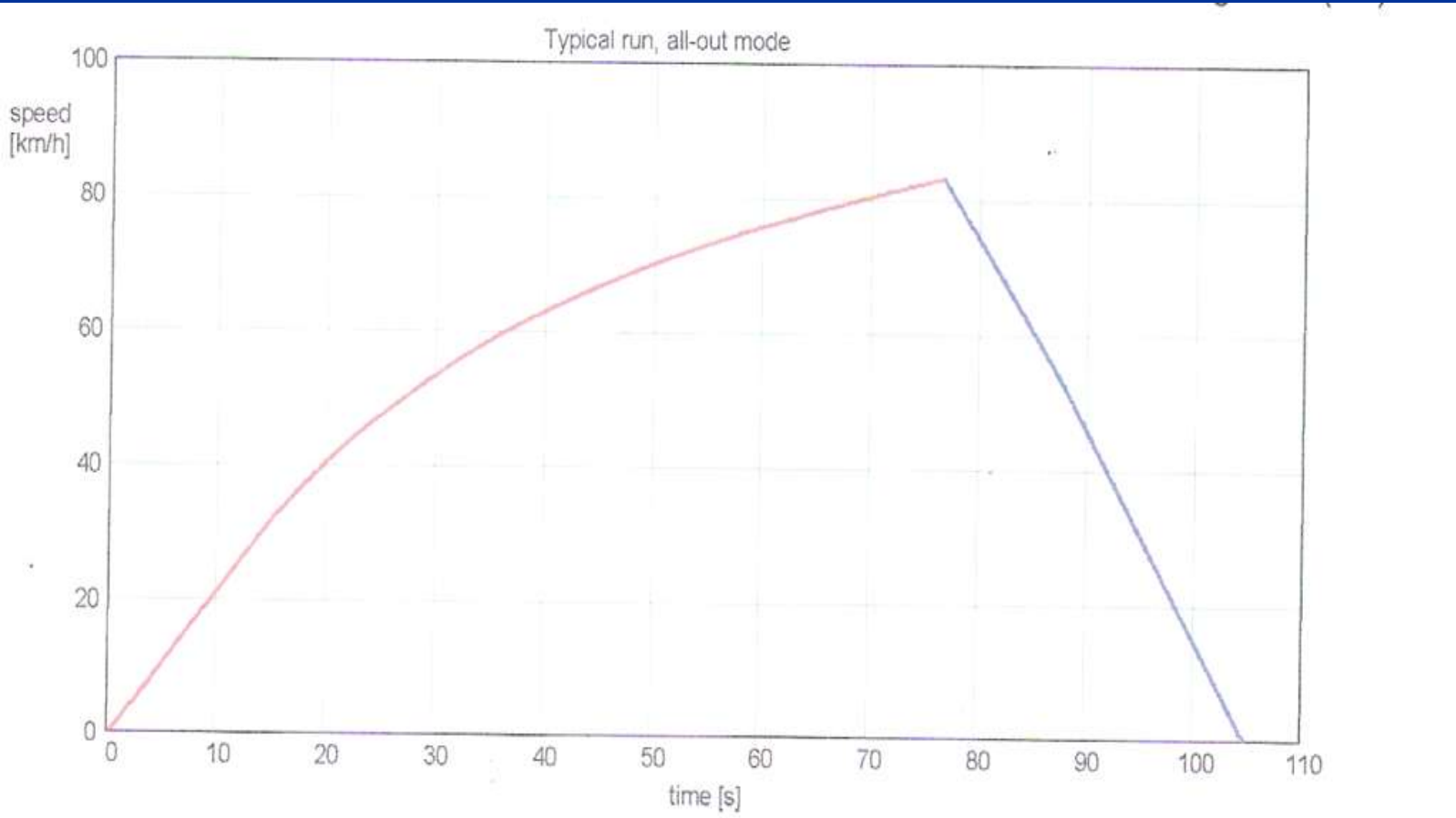
Auxiliary Systems

Auxiliary Converter & Battery Charger	
Nominal input voltage	1500 V DC
Nominal output voltages	415, 3 ph. AC, 50 Hz 110V, 1 ph AC, 50 Hz 110 V DC
Ratings	415, 3 ph. AC, 87 Hz 110V, 1 ph AC, 20 Hz 110 V DC – 9 KW
Semiconductor device	IGBT based
Control	Microprocessor control
Cooling	Force air cooled
Weight	App. 1200 Kg
Efficiency	> 90%

Power circuit



Typical run in a Mumbai suburban system



Passenger Friendly Features

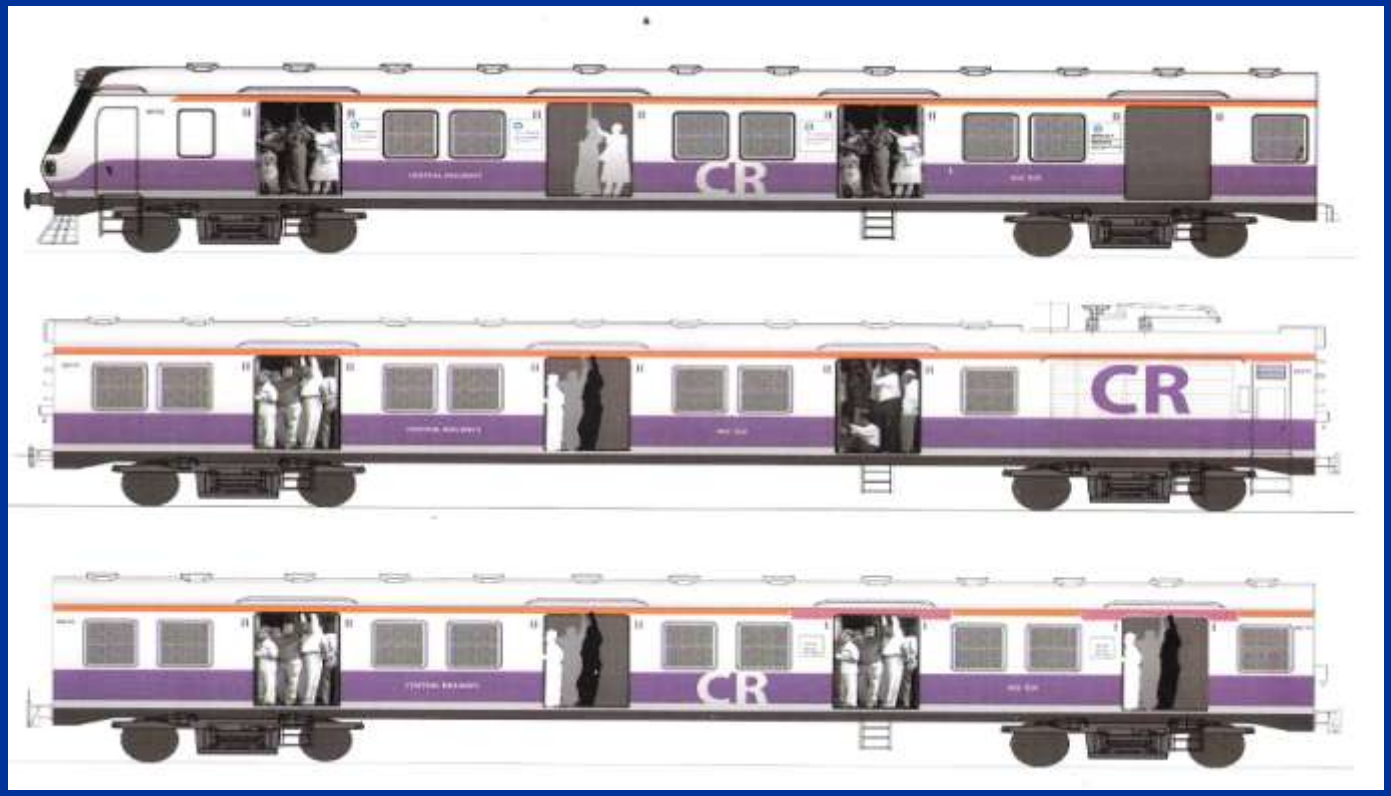
Improved Features

1. **Exterior colour scheme**: *Designed by National Institute of Design (NID), Ahmedabad.*
2. **Window:** *Lift-up window with fixed polycarbonate lower AT TOP with Tinted Glass.*
3. *Polycarbonate seat with stainless steel frame for second class.*
4. *PU cushion seat with stainless steel frame for first class.*
5. **Grab rails:** *Addition of one extra rail.*
6. **Handholds:** *Improved design to reduce dangling and material changed to stainless steel.*
7. **Grab poles:** *3 grab poles provided at door as against 1 in existing design.*
8. **Inside roof paneling:** *Stainless steel canvass finish roof paneling provided.*
9. **Trough floor and flooring:** *To reduce corrosion, stainless steel trough floor and flooring provided.*
10. **Doorway and compartment partitioning:** *Improved design stainless steel partition provided.*

Improved Features

11. **Coach door:** *Powder coated aluminum door with polycarbonate window provided.*
12. **Luggage rack:** *Stainless steel rack provided.*
13. **Ventilation:** *Forced air ventilation system provided.*
14. **Sidewall and end wall panel:** *FRP panels used for better aesthetics and long life.*
15. **Head code:** *LED type head code provided.*
16. **Secondary suspension:** *Pneumatic spring used to improve comfort and safety.*
17. **Signage:** *NID design signage with stickers.*
18. **Improvement in coach insulation:** *Recron thermal wadding used.*
19. **Rainwater gutter:** *Stainless steel water gutter provided.*
20. *Passenger information system*

1. Exterior colour scheme: *Designed by National Institute of Design (NID), Ahmedabad.*



Exterior Colour Scheme

2. Window: *Lift-up window with fixed polycarbonate lower AT TOP with Tinted Glass.*

Windows and Protective Window screen

Existing EMU

3. *Polycarbonate seat with stainless steel frame for second class.*

4. *PU cushion seat with stainless steel frame for first class.*

Seats of Existing Rakes

5. Handholds & Grab rails : *Improved design to reduce dangling and material changed to stainless steel.*

7. Grab poles: *3 grab poles provided at door as against 1 in existing design.*

8. Inside roof paneling: *Stainless steel canvass finish roof paneling provided.*

9. Trough floor and flooring: *To reduce corrosion, stainless steel trough floor and flooring provided.*

Trough Floor and flooring

10. Doorway and compartment partitioning: *Improved design stainless steel partition provided.*

11. Coach door: *Powder coated aluminum door with polycarbonate window provided.*

12. **Luggage rack:** *Stainless steel rack provided.*

13. **Ventilation:** *Forced air ventilation system*

14. Sidewall and end wall panel: *FRP panels used for better aesthetics and long life.*

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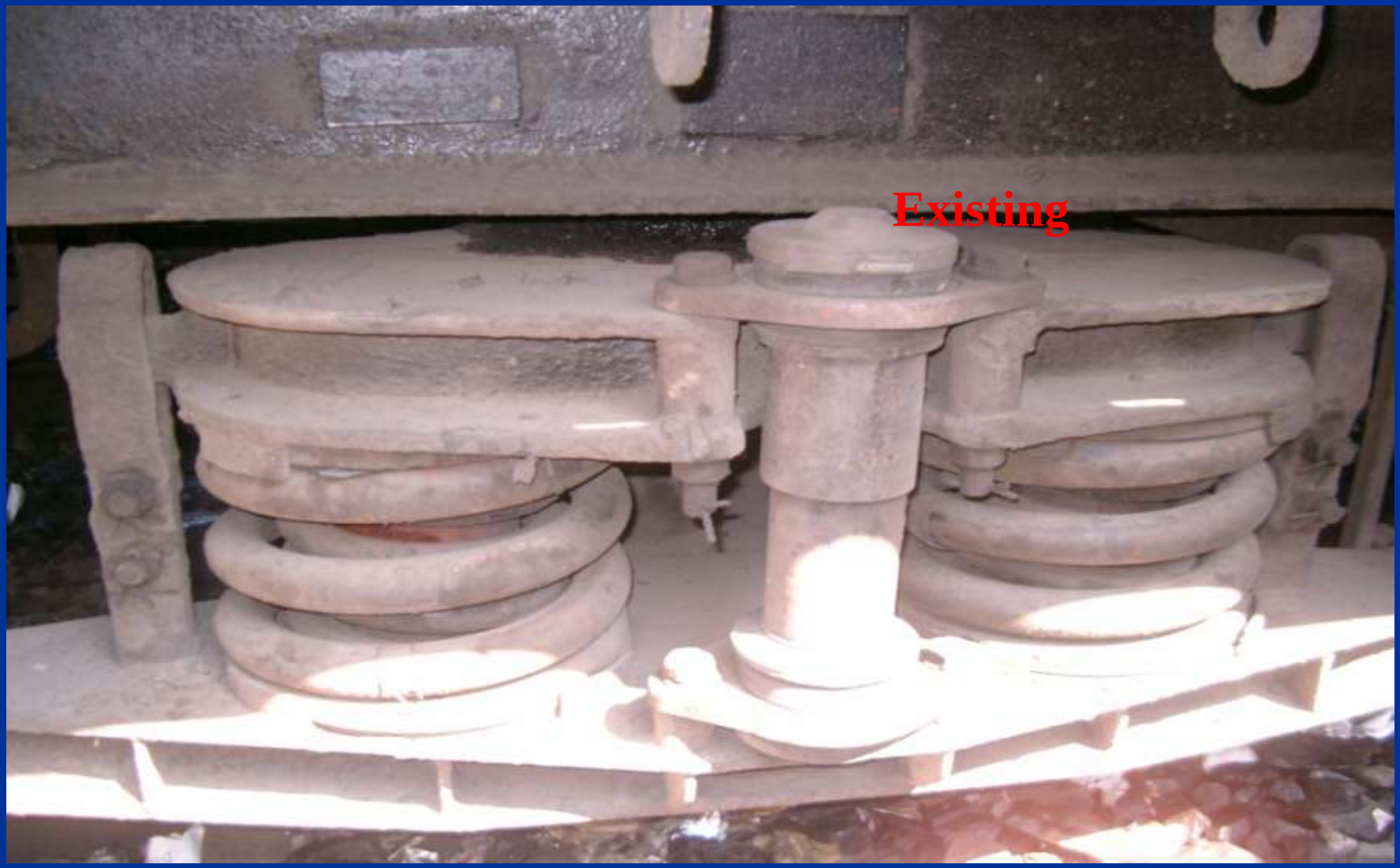
16. **Secondary suspension:** *Pneumatic spring used to improve comfort and safety.*

Secondary suspension



17. **Signage:** *NID design signage with stickers.*

18. **Improvement in coach insulation:** *Recron thermal wadding used.*

Improved Lighting : *illumination levels increased to 300 lux.*

19. Rainwater gutter: *Stainless steel water gutter provided.*

20. Passenger information system

Details of Cost

Cost 20 Crores

Cost of Imported Rake 60 crores

Ventilation System

VENTILATION Problem:

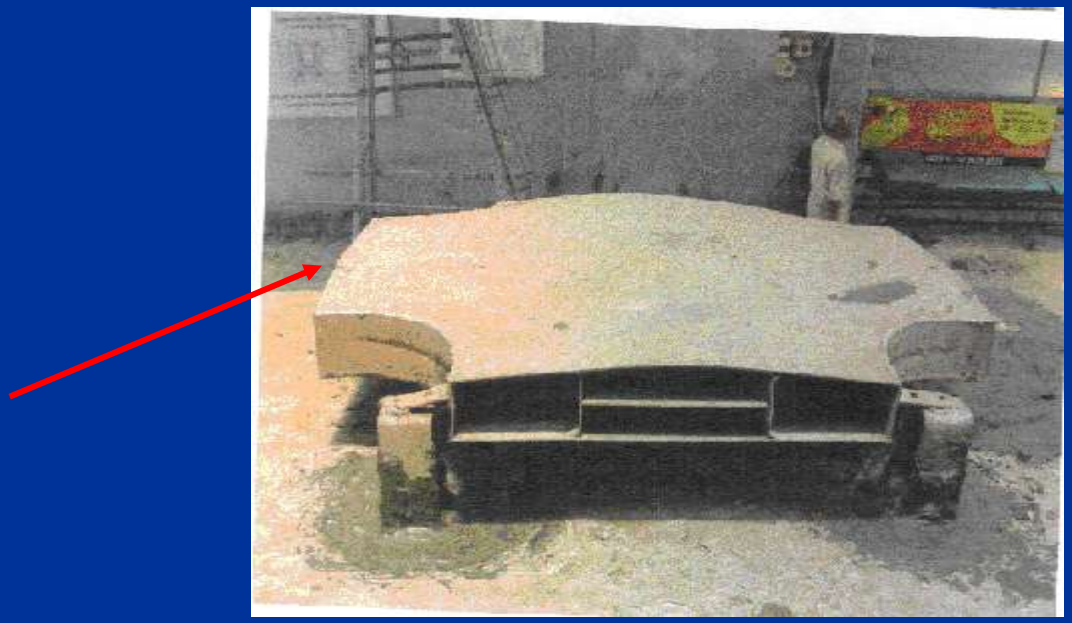
Age old Ventilation Arrangement on D.C. EMUs and its problems

- Natural Air Roof Ventilators
- Electric Ceiling Fans

Sr. No.	Coach Type	No. of Fans / Coach	Watt / Fan	Capacity of Each Fan in m^3/hr.	Total Wattage of Fans	Total Capacity of Fans in m^3/hr.
1.	D.T.C.	26	38 Watt	50 m^3/hr.	988	1300 m^3/hr.
2.	M.C.	22	38 Watt	50 m^3/hr.	936	1100 m^3/hr.
3.	T.C.	26	38 Watt	50 m^3/hr.	988	1300 m^3/hr.

Efforts made in past to Improve Ventilation

- Year 1970, High Capacity Ceiling Fans(80 m3/hr)
- Year 1984, Roof Ventilation Design with large opening



- Year 1996, Provision of louvers in sidewall of coaches alongwith exhaust fans in the ceiling to increase entry of fresh air

- Provision of openings in Coach Floor to permit entry of Fresh Air

- Year 2003, Electric Blowers for Ventilation

Improved Ventilation System in MRVC Racks

Ventilation system

- MRVC procured a portable carbon dioxide meter and measured the CO_2 levels inside the running trains.
- The CO_2 levels in the existing SDCL condition was 2500 ppm.

Ventilation system

- Detailed study was carried out referring ANSI/ASHRAE standard to modify the RDSO specification.
- ANSI/ASHRAE standard 62-2001 recommends that the maximum indoor CO2 concentration should be less than 700 ppm above the outdoor air concentration

Ventilation system
Fresh Air Requirement

- Passenger Loading per coach:
  - Seating Capacity 90 passengers
  - Normal standing for peak 90 passengers
  - Total passengers traveling in SDCL 570 passengers

Ventilation system
Fresh Air Requirement

- CO_2 Generated per Coach:
  - CO_2 generated per passenger — .018 m^3/hr
  - CO_2 generated by 570 passengers in SDCL — 10 m^3/hr
- Calculation of Fresh Air Requirement:
  - Fresh Air Required = $\frac{\text{Total } CO_2 \text{ generated}}{\text{Permissible PPM}}$

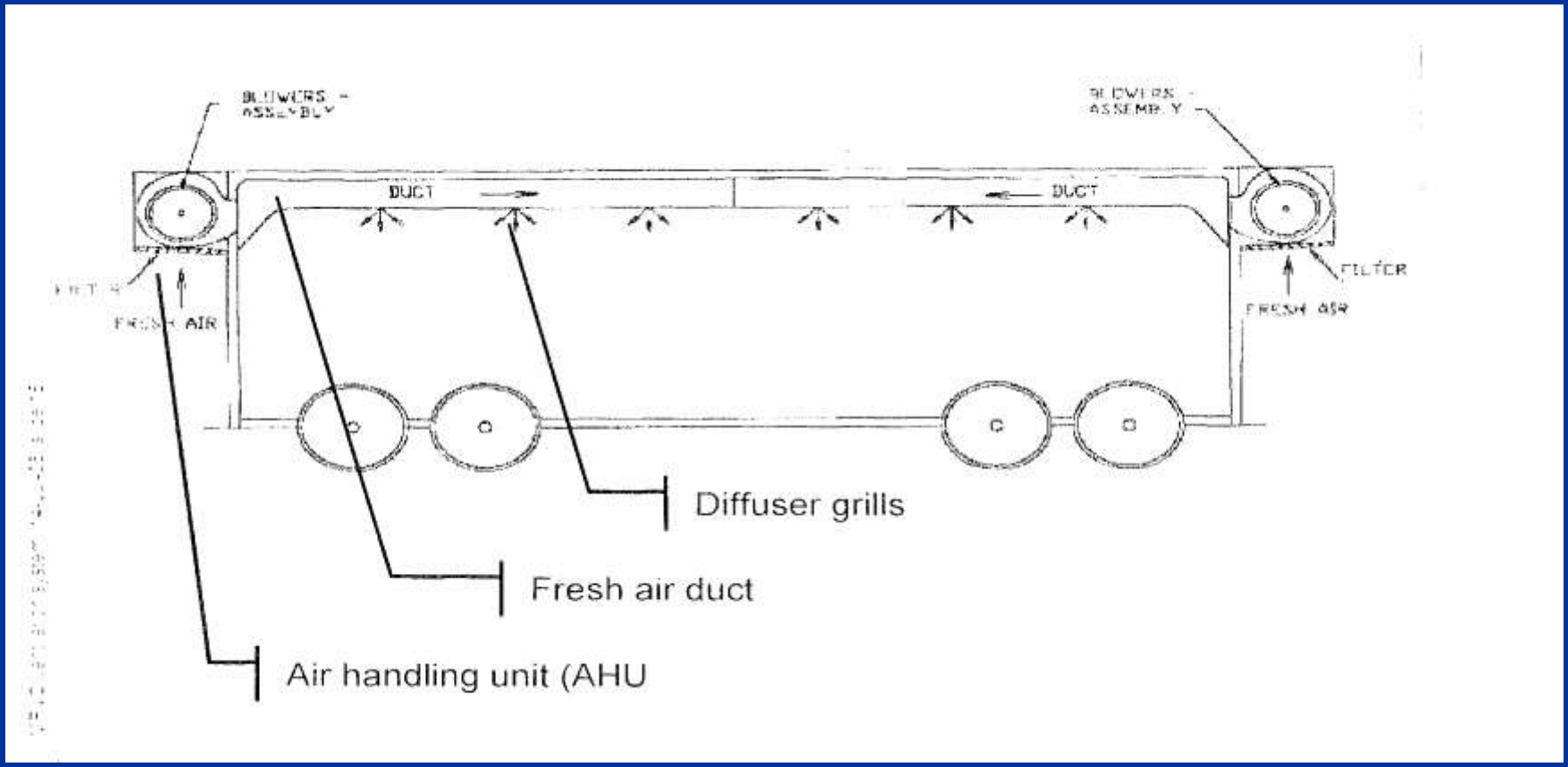
$$= \frac{10 \text{ m3/hr}}{700 \text{ X } 10^{-6}}$$

$$= \mathbf{15000\ m^3/hr}$$

ADDITIONAL FRESH AIR REQUIRED = 15000 m^3/h

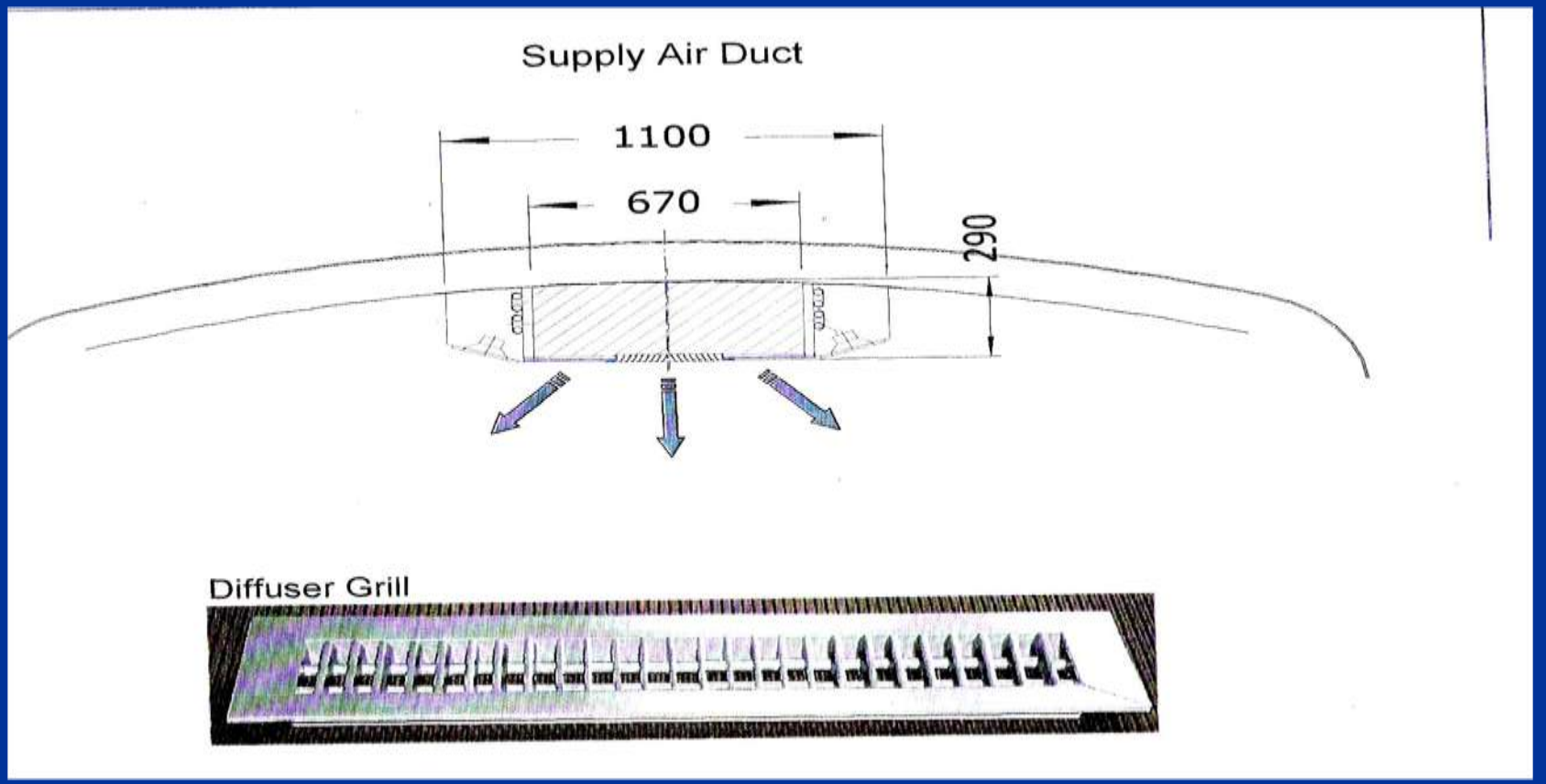
VENTILATION SYSTEM

The Design Concept :

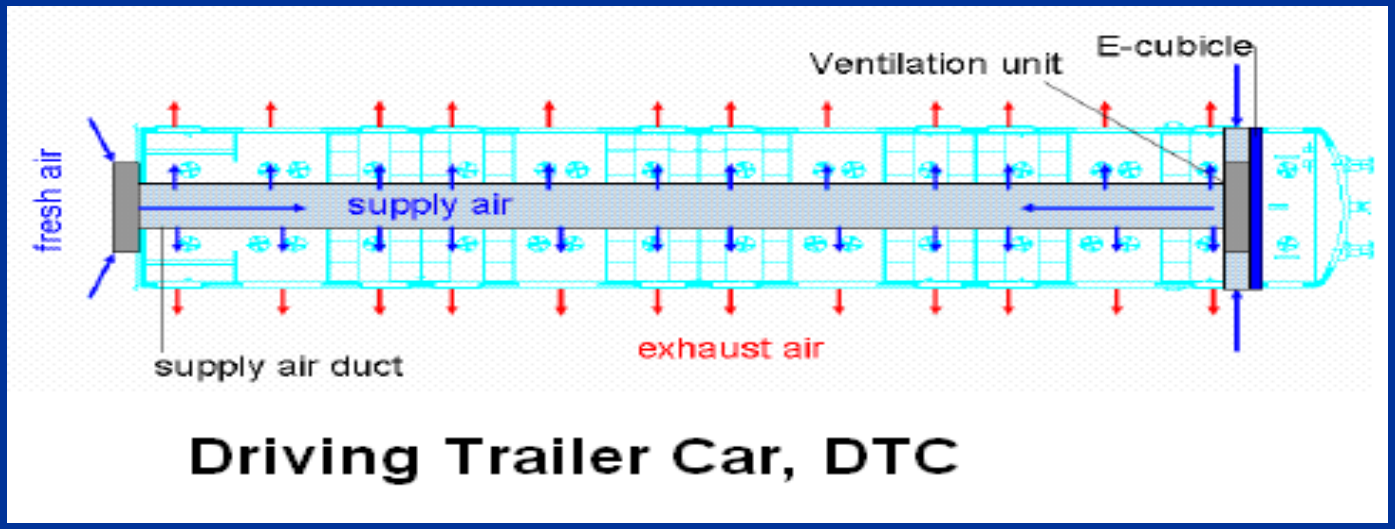


VENTILATION SYSTEM

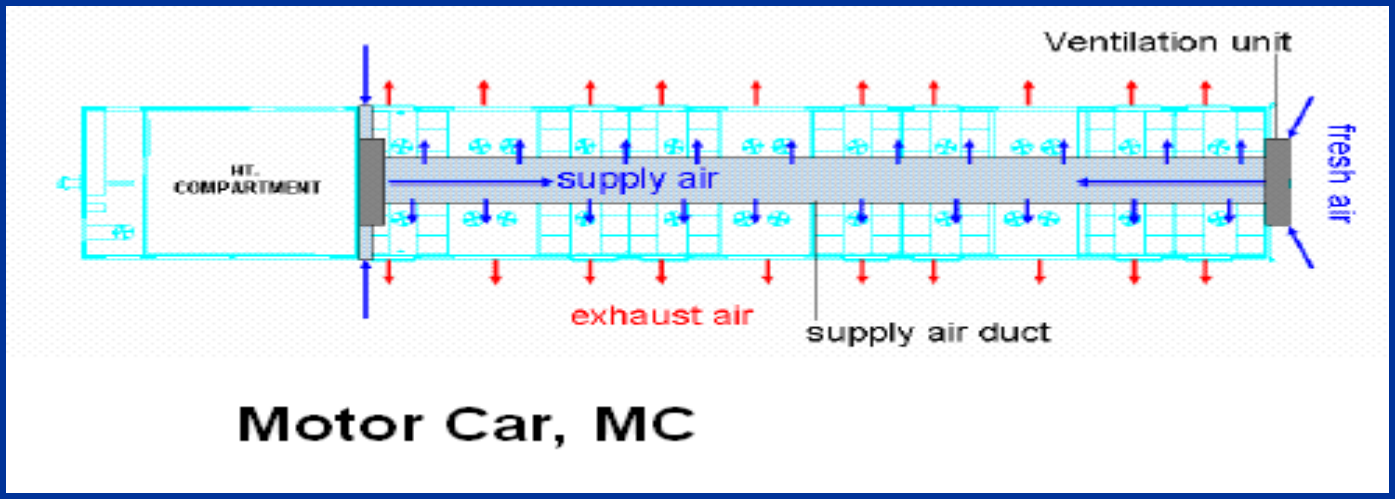
The Design Concept :



Basic Design:



Driving Trailer Car, DTC



Motor Car, MC

- Mounting arrangement
- Supply Air duct
- Electric Blower

Two three-phase induction motors are provided in each Air Handling Unit.

- 415 V, 50 Hz , 1,1 kW/ 4 poles
- IP56
- Frame size 90L
- Insulation class H
- Ambient temperature 65 °C
- Capability to withstand shock and vibration loads
- Blowers: The blower wheels are directly coupled on the motor shaft.
- Blower and blower housing made from stainless steel 304
- Blower wheel is made from galvanized steel

- Electrical requirements
- Ventilation Control Mechanism with respect to Load and Temperature variations under normal conditions

Percentage Occupancy	Temperature	AHU Control (No. of running AHU/car)
Load weight signal	Temperature sensor signal from TCC	
%	°C	
if	and if	then
<20	<15	0
<20	>15	0
>20	<15	1
>20	>15	1
>50	<15	1
>50	>15	2

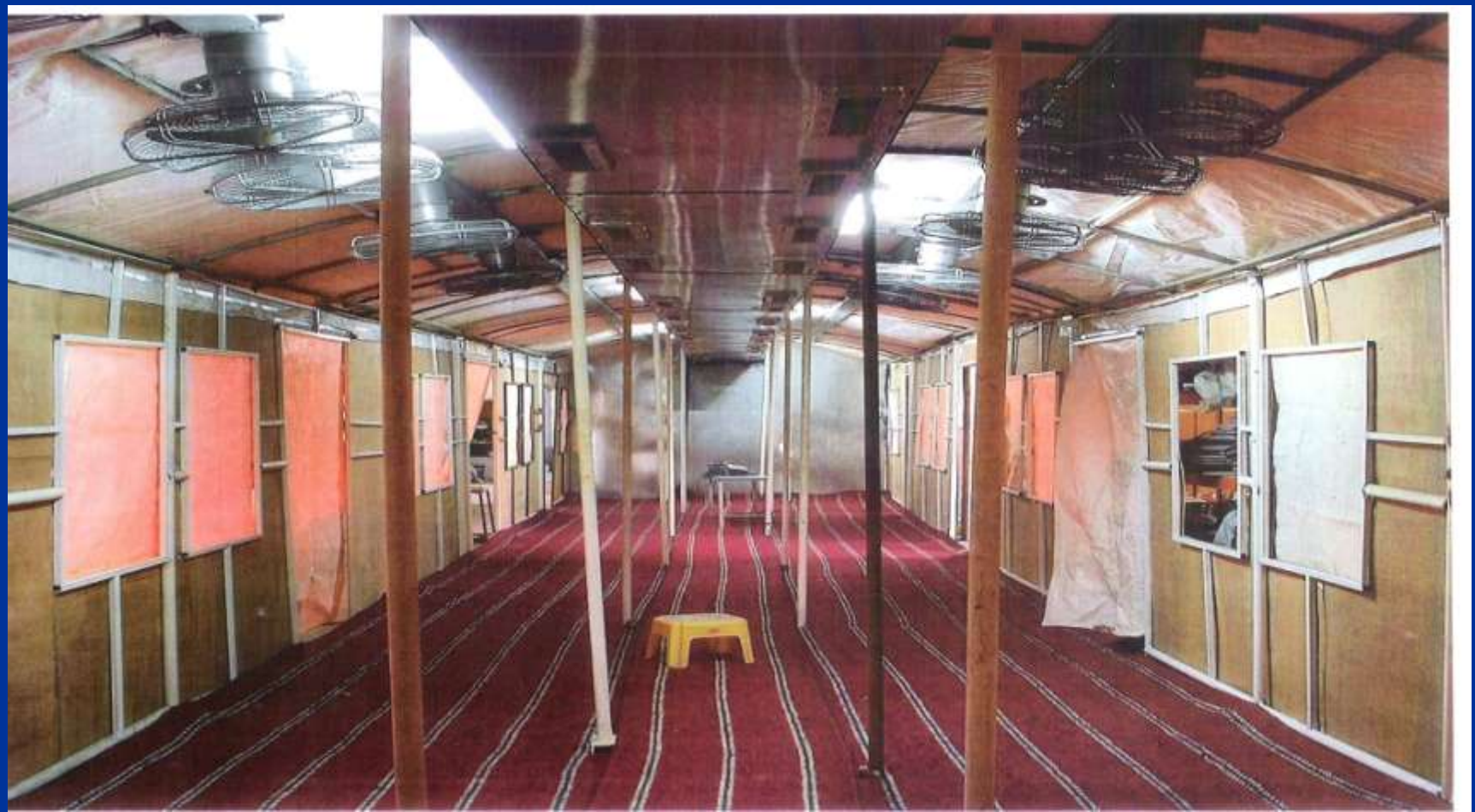
VENTILATION SYSTEM

- **Ventilation:** *Forced air ventilation system provided.*

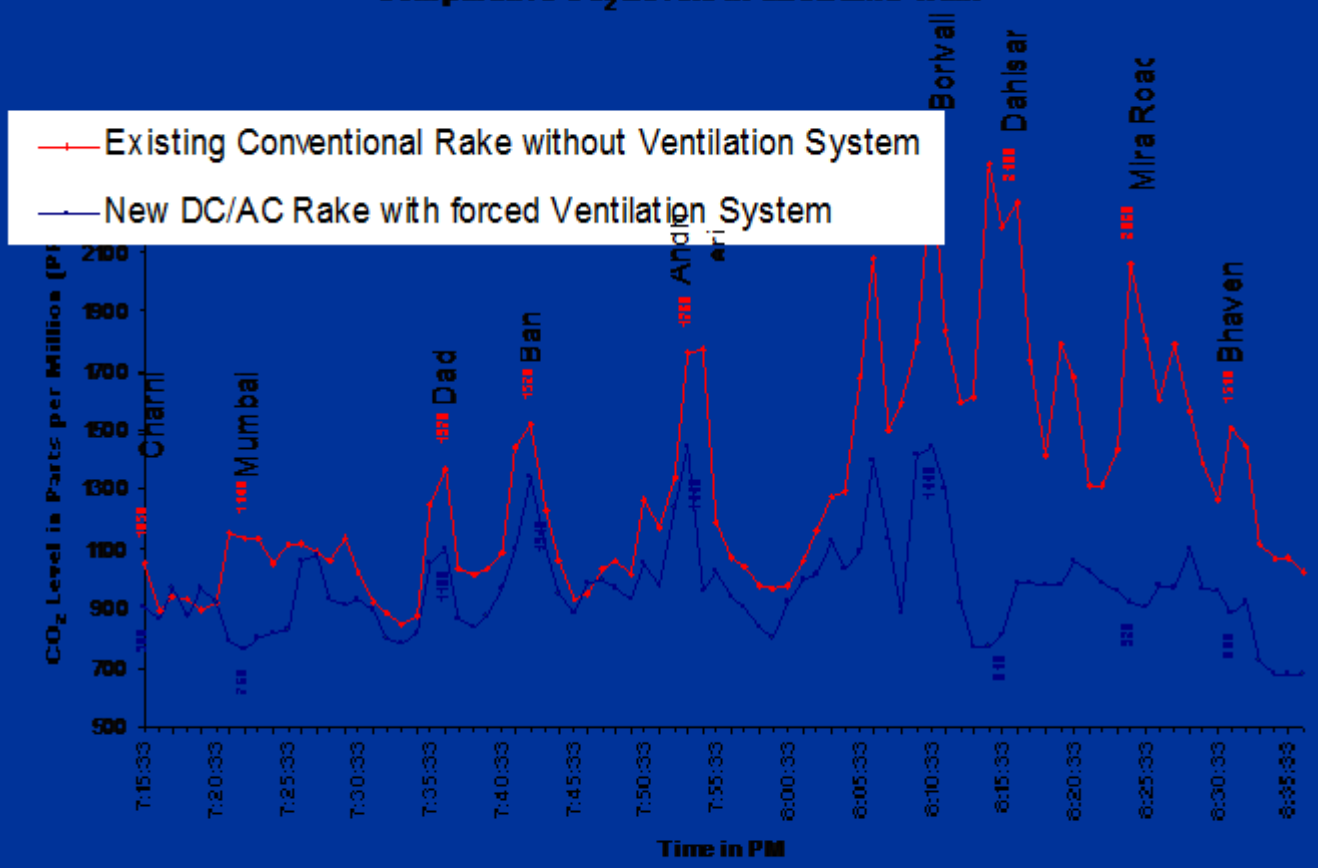
External Air Blowers for forced ventilation

VENTILATION SYSTEM

Photograph of Mock-Up



Comparative CO_2 Levels In SDCL EMU Train



* Above Comparative Graph Shows an appreciable reduction in CO_2 level in the EMU Train fitted with Forced Ventilation System

The ventilation provided in Mumbai Sub-Urban Coaches was a non standard and with such a large numbers traveling in each coach, was a difficult problem to solve. In the new EMU coaches procured under MUTP project this problem was technically approached by using following-

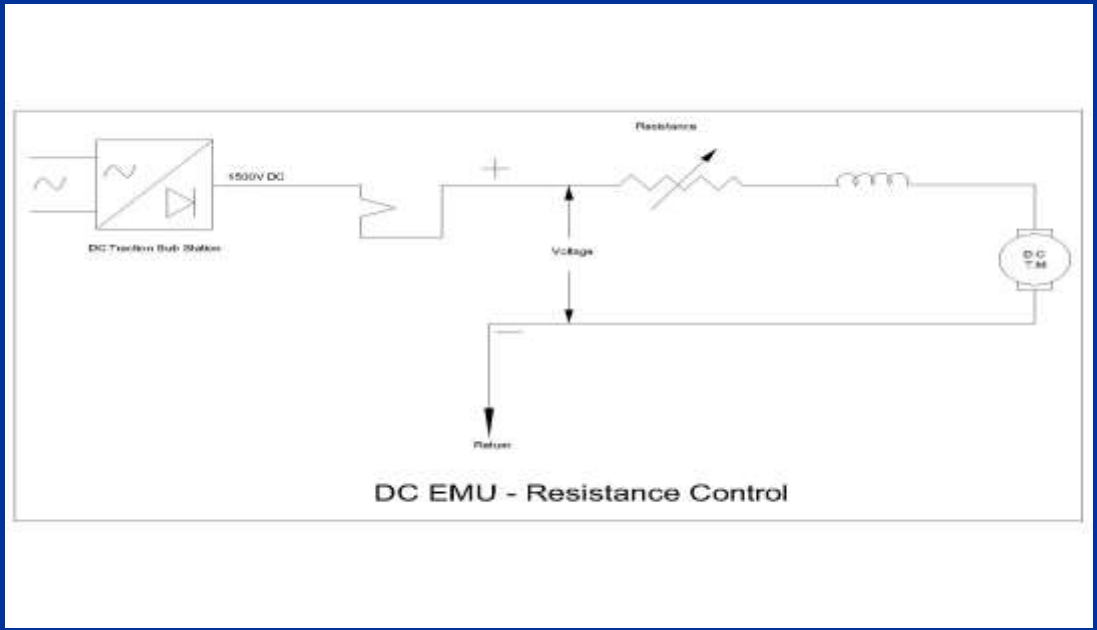
(a) Correct Standard Applicable
(b) Collection of accurate data
(c) Correct calculations of requirements
(d) Development of Mock-up to prove the design
(e) Manufacture of Ventilation units using reliable sub-systems.
(f) Extensive field Trials

Contribution to prevention of global warming due to saving of Electric energy

Existing DC EMUs design details of power circuit and brake system

- **Power circuit**

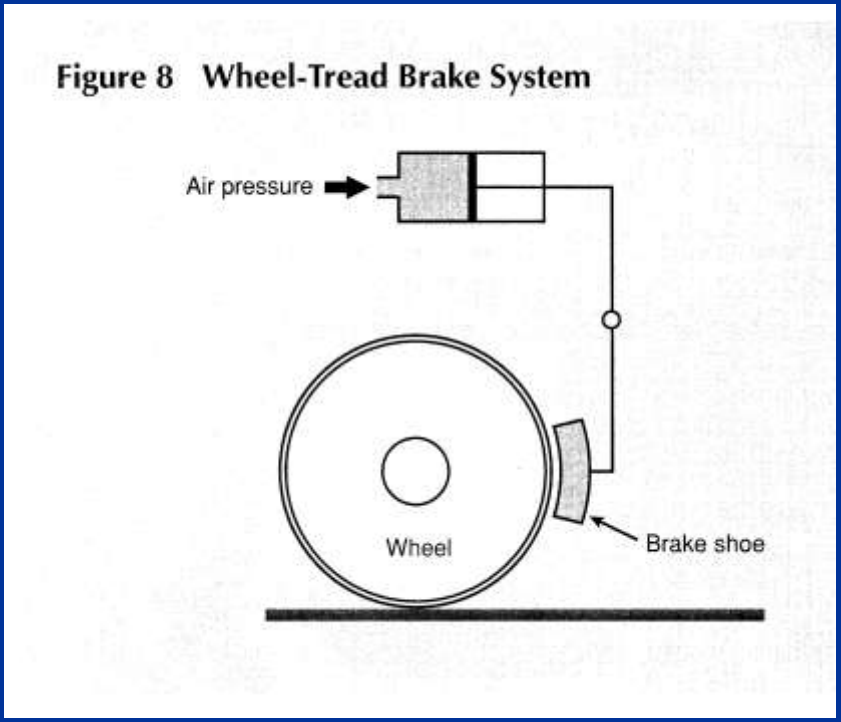
  The present design of EMU rakes draws electrical power from OHE at 1500V DC, which is fed to four DC traction motors of 210 kW capacity. The control of speed of traction motors is through resistance control, i.e. current is reduced or increased by resistances.



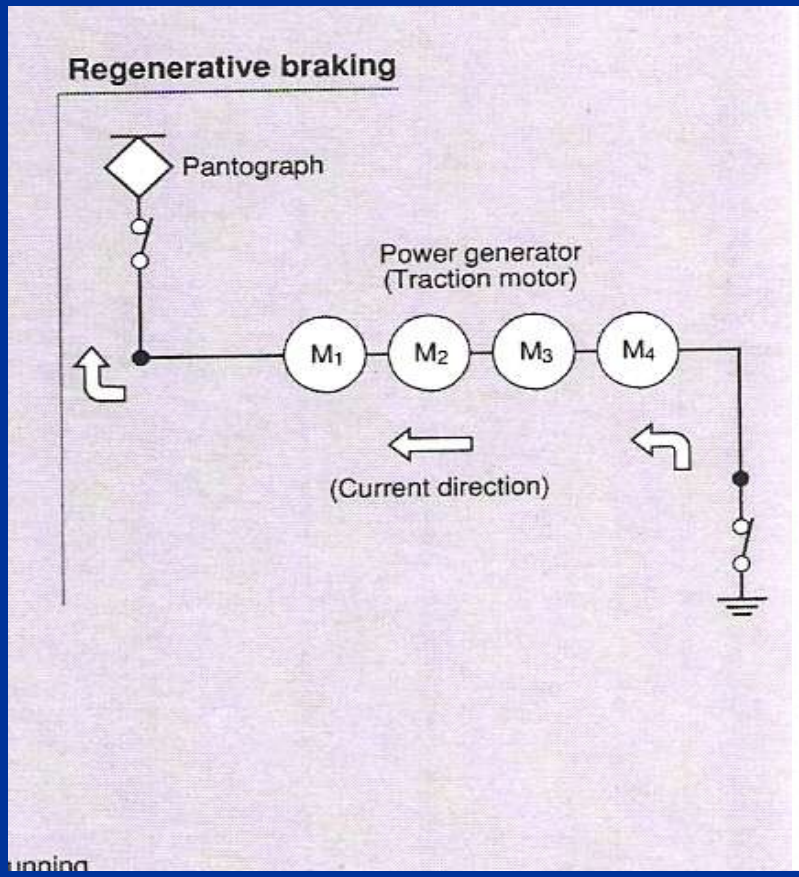
DC EMU - Resistance Control

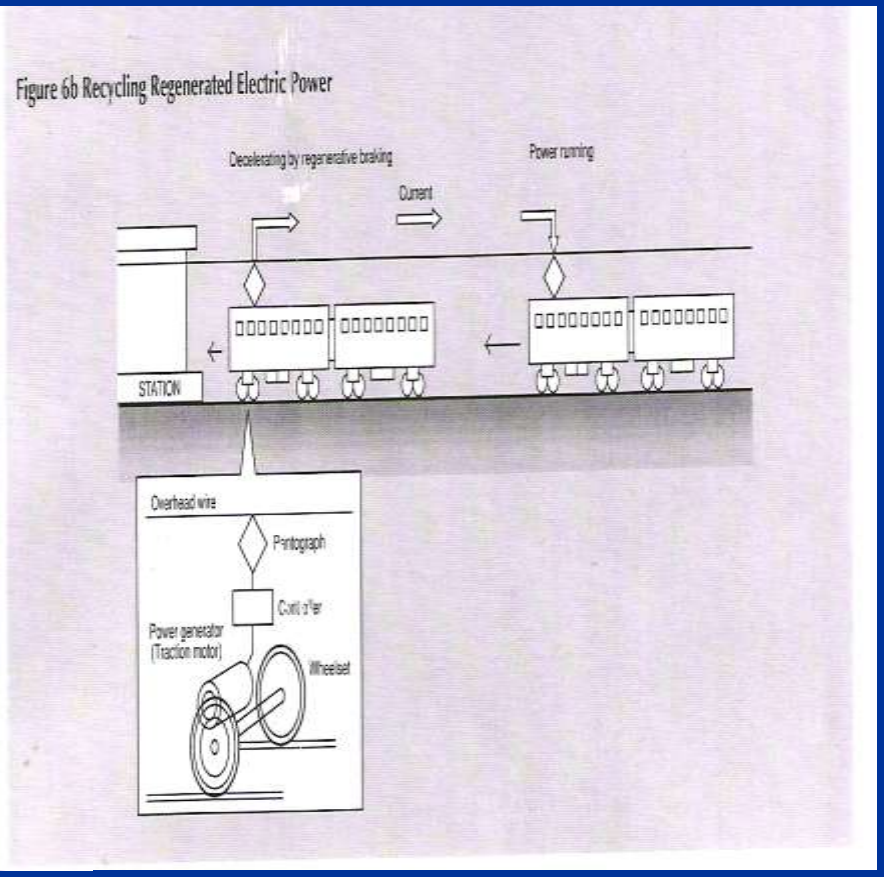
- **Present Brake System**

  The braking of rakes is through friction braking using tread brake system in the existing EMU's.



New EMU: Regenerative Braking





Improving Energy Efficiency

(a) DC EMU System (present)

(i)	Holding of rakes	:	
	Central Railway	:	132.6 (9 car)
	Western Railway	:	94.6 (9car)
	Total	:	227.3 (9-car) (190 DC EMU + 37.3 AC/DC EMU rakes)
(ii)	Energy consumption per DC 9 car rake per year is 2716406 Kwh		

Improving Energy Efficiency

(b) **Result of extensive trials for energy saving in AC/DC EMU rakes**

Corridor	Type of Service	% of Energy saving over DC EMU
Churchgate-Virar	Fast stopping at few stations	41.23%
Churchgate-Virar	Slow stopping at all stations	49.32%
Virar-Churchgate	Fast stopping at few stations	41.82%
Virar-Churchgate	Slow stopping at al stations	31.53%

Improving Energy Efficiency

(C) AC/DC new technology EMU rakes

- As mentioned above, with the use of regenerative braking there will be a saving of 40% of electrical energy. By the end of first phase of MUTP, 190 new technology EMU rakes would be available in Mumbai Suburban Railway System.

- Conventional DC EMU rake consumes 2.7 million units of energy every year/rake and new technology EMU rake consumes 1.6 million units of energy every year/rake for providing the same services. Thus with 190 EMU rakes after MUTP Phase I, there would be a saving of 209 million electrical units of energy per year.

- After MUTP Ph – II the holding of rakes would be 346, 9 car and total saving would be 380.6 Million units of Electrical Energy.

- With per unit cost @ Rs. 4, the financial savings would be INR 836 million per year after MUTP – I and INR 1522.4 Million per year after MUTP Ph - II. Even if a conservative estimate of 30% saving in Energy is considered, it will result in INR 1141 Million savings per year.

Benefits

(a) Reduction in fuel consumption / year (Depending upon Power Plant are anticipated as follows):-

Coal	⇨	4.6×10^8 Kg.
LPG	⇨	14.26×10^8 Ltr.
Crude Oil	⇨	21.46×10^8 Ltr.
Natural Gas	⇨	21.6×10^8 m^3.

(b) Reductions in Pollution:- By saving 20 Cr. units of power following will be reduction in pollution per year (for Coal based Power Plants).

CO2	⇨	2.092×10^8 Kg.
SO2	⇨	18×10^8 gm.
SPM	⇨	5×10^8 gm
Soot Carbon	⇨	0.2×10^8 gm
NO	⇨	20×10^8 gm

Reduction of CO_2 according to KYOTO Protocol is our commitment.

- Mumbai will receive 3 phase new technology EMU rakes with regenerative braking.
- Introduction of this technology would save about 20 crore units of energy every year
- For each unit of energy produced in a thermal power plant, 1 kg of carbon dioxide is produced.
- Thus, on account of this project there would be a reduction of approximately 2 lakh tones of carbon dioxide emission every year.
- This will qualify for Carbon Credits

Carbon Credits

- A project has been undertaken with World Bank to obtain Carbon Credits on account of this huge reduction in emission.
- The Project Idea Note for this project has already been approved by the World Bank and detailed work will start shortly.
- World Bank has approved and registered this project.
- This is a first project registered for transport sector.

Other environment friendly features of New technology rakes

- DC traction motor is replaced by 3 phase AC traction motor.
  - Carbon brushes used in DC traction motors and DC fans. Total 4 lakh carbon brushes per year will not be required.
- 110V DC carbon type fans have been replaced by 110V AC fans.
  - Mica used in commutator of DC traction motor and DC fans.
- Oil lubricated suspension bearings have been replaced by axle mounted roller bearings.
  - Mineral oil based lubricants for suspension bearing of DC traction motors. Total 85,000 litre of oil per year will not be required.
- By introducing electrical regenerative braking use of asbestos brake block for mechanical brakes reduced to 90%.
  - Ferro asbestos brake blocks. Total 1.25 lakh brake blocks per year will not be required.

It is seen that 380.6 Million units of Electrical energy will be saved per year by EMU's and 62.6 Million units of Electrical Power will be saved per year due to 1500 V DC to 25kV AC conversion. On suburban section alone 443 Million units will be saved on completion of MUTP Ph-II. In monetary terms it will be INR 1772 Million (@ Rs 4/unit) per year. In addition, saving on account of deploying energy efficient High Power rated Electric locomotive vice D.C. Electric Locomotive on main line upto Pune and Igatpuri on C.Rly. and Virar on W.Rly. will also be considerable.

THANK YOU

Website:www.mrvc.indianrail.gov.in